Agilent Technologies

Advanced Design System 2011.01

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DTV Design Library

Acknowledgments

Errata The ADS product may contain references to "HP" or "HPEESOF" such as in file names and directory names. The business entity formerly known as "HP EEsof" is now part of Agilent Technologies and is known as "Agilent EEsof". To avoid broken functionality and to maintain backward compatibility for our customers, we did not change all the names and labels that contain "HP" or "HPEESOF" references.

About DTV Design Library

The Agilent EEsof DTV Design Library includes the current Japanese, and European HDTV standards for the Advanced Design System platform. This design library focuses on the transmission layer of the HDTV system and is intended to be a baseline system for designers to get an idea of what a nominal or ideal system performance would be. They also provide determination of degraded system performance due to system impairments that may include nonideal component performance.

ISDB-T System

The ISDB-T system has been designed to have the flexibility to send television or sound programs as digital signals while offering multimedia services in which a variety of digital information (video, sound, text and computer programs) can be integrated. It aims to make use of the advantages provided by terrestrial radio waves so that stable reception can be provided by compact, light and inexpensive mobile receivers in addition to integrated receivers used at home by using a BST(band segmented transmission)-OFDM scheme (see Reference [1]).

Two transmission bandwidths are prescribed (5.6 MHz and 432 kHz), each oriented to particular types of broadcasting services. The 5.6-MHz bandwidth is primarily for digital broadcasting of television programs; the 432-kHz bandwidth is primarily for audio programs. These two modes share all other parameters such as encoding format, multiplexing format, and OFDM carrier interval and frame configuration.

Terrestrial ISDB provides hierarchical transmission features using different carrier modulation schemes (DQPSK, QPSK, 16-QAM, 64-QAM) and internal encoding rates (1/2, 2/3, 3/4, 5/6, 7/8). This enables part of the band to be allocated to signals for stationary reception and the rest to signals for mobile reception; this means audio and data broadcasts for automobile and portable receivers can be performed simultaneously with television broadcasts for home use. Each hierarchical level can be set for each BST segment having a bandwidth of 432 kHz. Such information can be sent to receivers by TMCC (transmission and multiplexing configuration control) signal allocated to part of the OFDM carrier.

Because the wide and narrow bandwidths in terrestrial ISDB share the same OFDM parameters, the 5.6-MHz wide band can directly include the 432-kHz narrow band. Consequently, a 432-kHz receiver can receive some 5.6-MHz services, and a 5.6-MHz receiver can receive all services broadcast at 432 kHz.

Based on the system configuration, this design library may include three sub-libraries, transmission, receiving and channel coding sub-libraries.

DVB-T System

The DVB-T system was designed with the flexibility to adapt to all channels including clear channels and interleaved planning, and co-channel operation for the same program by different transmitters (single-frequency networks).

It also permits service flexibility, with the possibility of reception by roof-top antennae and portable reception, if necessary. Mobile reception is possible for QPSK and for higher modulation orders, as proven by extensive laboratory measurements and field trials under different channel conditions.

The system was also designed to be robust against interference from delayed signals, either echoes from terrain or buildings or signals from distant transmitters in a single frequency network, a new tool which it brings to TV service planning to improve spectrum efficiency which is necessary in the case of particularly crowded spectrum as it is the case in Europe.

The DVB-T compliant signals can also be carried over cables. However, the DVB-T specification is part of a family of specifications covering also satellite (DVB-S) and cable (DVB-C) operation. All use MPEG-2 coding for video and audio and MPEG-2 type of multiplexing. They have common features in the error protection strategy to be used. The main difference is the modulation method that is specific to the relevant bearer (satellite, cable, or terrestrial). The available data capacity is also different, as higher bit rates are offered on cable and satellite. However, transferring programs from one bearer to another is possible provided that the bit rate is available.

The DVB-T system features a number of selectable parameters so it can accommodate a large range of carrier-to-noise ratio and channel behavior, enabling fixed, portable, or mobile reception, with a trade-off in the usable bit rate. The range of parameters lets broadcasters select a mode appropriate to the application. For example, a very robust mode (with correspondingly lower payload) is needed to ensure portable reception. A moderately robust mode with a higher payload could be used where the service planning uses interleaved channels. The less robust modes with the highest payloads can be used if a clear channel is available for digital TV broadcasting.

The DVB-T system also provides additional features to support handheld terminals transmitting DVB-H services.

OFDM Technique

Multi-carrier, or orthogonal frequency-division multiplexing (OFDM), systems have gained in interest during the last years. It is used in the European digital broadcast radio system, and its use in wireless applications such as digital broadcast television and mobile communication systems is currently being investigated. By the name of discrete multi-tone (DMT) modulation, OFDM is also being examined for broadband digital communication on existing copper networks. The OFDM technique has been proposed for high bit-rate digital subscriber lines (HDSL) and for asymmetric digital subscriber lines (ADSL).

The OFDM concept is based on spreading the data to be transmitted over a large number of carriers, each being modulated at a low bit rate. The multiplex of carriers can be conveniently generated digitally using the inverse fast-Fourier-transform (FFT) process.

Preferred implementations of the FFT tend to be based on radix 2 or radix 4 algorithms, or some combination of radix 2 and 4. Example systems are based on 2048 (2k) carriers and 8192 (8k) carriers. However, the number of actual carriers transmitted is always smaller than the maximum number possible, as some carriers at either edge of the channel are not used. These unused carriers make a frequency guard band for practical IF filtering. The active carriers carry data or synchronization information. Any digital modulation scheme can be used to modulate the active carriers, for example, QPSK, n-QAM, where n is commonly 16 or 64.

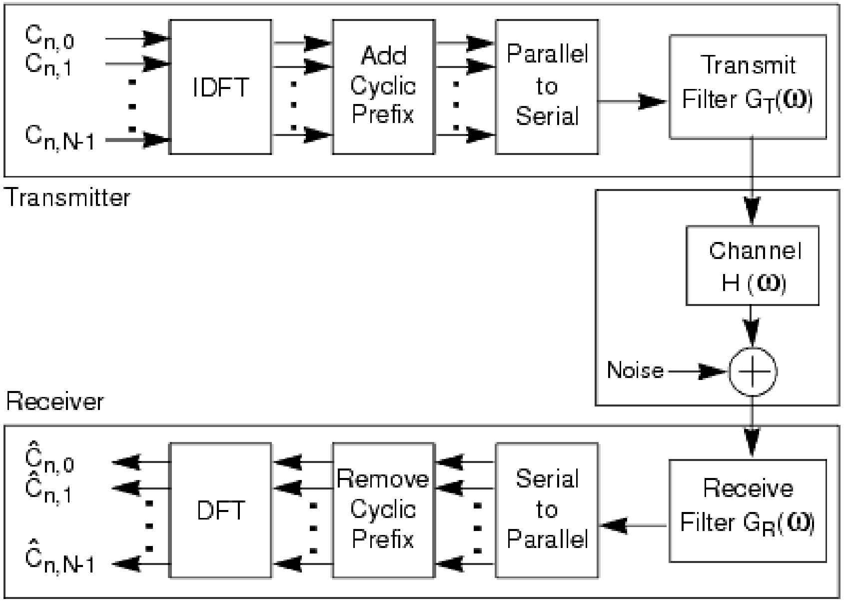
OFDM, due to its multi-carrier nature, exhibits relatively long symbol periods. This long symbol period provides a degree of protection against inter-symbol interference caused by multi-path propagation. However, this protection can be greatly enhanced by use of the guard interval. The guard interval is a cyclic extension of the symbol, in simplistic terms a section of the start of the symbol is simply added to the end of the symbol.

OFDM, when coupled with appropriate channel coding (error correction coding), can achieve a high level of immunity against multi-path propagation and against co-channel interference, for example, NTSC, PAL, SECAM. OFDM systems also offer the broadcaster great flexibility as bit rates can be traded against level of protection depending on the nature of the service. For example, mobile reception of the OFDM signal may be possible given due consideration to factors including vehicle speed, carrier spacing, data rate and modulation scheme; whereas, for a service with fixed reception, high order modulation schemes and consequently high data rates could be used.

OFDM signals also allow the possibility of single-frequency network (SFN) operation. This is due to OFDM multi-path immunity. SFN operation is possible when exactly the same signal, in time and frequency, is radiated from multiple transmitters. In this case at any reception point in the coverage overlap between transmitters, the weakest received signals will act as post- or pre-echoes to the strongest signal. However, if the transmitters are far apart the time delay between the received signals will be large and the system will need a large guard interval.

While the use of the guard interval (or cyclic prefix) removes the effects of inter-symbol interference under multi-path conditions, it cannot remove the effects of frequency selective fading. Under these conditions the amplitude and phase of each subcarrier is distorted. If the OFDM receiver is to coherently demodulate the signal it must equalize the phase and amplitude of each carrier; this can be done after the FFT using a simple equalizer. This process is known as *channel estimation and equalization*. The basic OFDM system block diagram is shown below.

Basic OFDM Communication System



Glossary of Terms

AC	Auxiliary channel
ACI	Adjacent channel interference
ACPR	Adjacent channel power ratio
ADSL	Asymmetric digital subscriber lines
AFC	Automatic frequency control
ARIB	Association of Radio Industries and Business
AWGN	Additive white gaussian noise
BCH	Bose-Chaudhuri-Hocquenghem code
BER	Bit error rate
CP	Continual pilot
CDSC	Complete differential set code
DBPSK	Differential binary phase shift keying
DQPSK	Differential quadrature phase shift keying
DFT	Discrete Fourier transform
DVB	Digital video broadcasting
DVB-H	DVB-Handheld
DVB-T	DVB-Terrestrial
EDTV	Enhanced definition television
ETS	European Telecommunication Standard
EVM	Error vector magnitude
FEC	Forward error correction
FFT	Fast Fourier transform
FIFO	First-in, First-out shift register
HDSL	High bit-rate digital subscriber lines
HDTV	High definition television
HP	High-priority bit stream
IFFT	Inverse fast Fourier transform
ISDB-T	Terrestrial integrated services digital broadcasting
LP	Low-priority bit stream
MER	Modulation error ratio
MPEG	Moving Picture Experts Group
NTSC	National Television System Committee
OFDM	Orthogonal frequency-division multiplexing
PAL	Phase alternating line
QAM	Quadrature amplitude modulation
QPSK	Quadrature phase shift keying
RS	Reed-Solomon
SFN	Single frequency network
SP	Scattered pilot
TSP	Transport stream packet
TS	Transport stream
TMCC	Transmission and multiplexing configuration control
TPS	Transmission parameter signalling
UHF	Ultra high frequency
VHF	Very high frequency

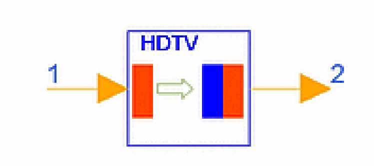
References

1. J. J. van de Beek, M. Sandell and P. O. Borjesson, "On Synchronization in OFDM Systems Using the Cyclic Prefix" In Proceedings of Radio Vetenskaplig Konferens (REVK'96), pp.663-667, Lulea, Sweden, June 1996.
2. M.Sandell, J.J. van de Beek and P.O.Borjesson, "Timing and Frequency Synchronization in OFDM Systems Using the Cyclic Prefix" In Proceedings of International Symmposium on Synchronization, pp.16-19, Essen, Germany, December 1995.
3. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); Specification of Channel Coding, Framing Structure and Modulation, Sept.1998.
4. ETSI, Digital Video Broadcasting (DVB); Framing structure, channel coding and modulation for digital terrestrial television. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.
5. ETSI, Digital Video Broadcasting (DVB); Framing structure, channel coding and modulation for digital terrestrial television. EN300 744 v1.5.1, European Telecommunication Standard, November 2004.

Channel Coding Components for DTV Design Library

- *DTV BCHCoder* (dtv)
- *DTV BCHDecoder* (dtv)
- *DTV ConvCoder* (dtv)
- *DTV ConvCoder1 2* (dtv)
- *DTV ConvDecoder* (dtv)
- *DTV ConvDecoder1 2* (dtv)
- *DTV Delay* (dtv)
- *DTV Demapper* (dtv)
- *DTV DQPSKCoder* (dtv)
- *DTV DQPSKDecoder* (dtv)
- *DTV InnerDecoder* (dtv)
- *DTV InterlvFloat* (dtv)
- *DTV InterlvInt* (dtv)
- *DTV ISDBChCoder* (dtv)
- *DTV ISDBChDecoder* (dtv)
- *DTV ISDBDerandomize* (dtv)
- *DTV ISDBRandomize* (dtv)
- *DTV Mapper* (dtv)
- *DTV PNreset* (dtv)
- *DTV PuncCoder* (dtv)
- *DTV PuncConvCoder* (dtv)
- *DTV PuncConvDecoder* (dtv)
- *DTV PuncDecoder* (dtv)
- *DTV QAM16Coder* (dtv)
- *DTV QAM16Decoder* (dtv)
- *DTV QAM64Coder* (dtv)
- *DTV QAM64Decoder* (dtv)
- *DTV QPSKCoder* (dtv)
- *DTV QPSKDecoder* (dtv)
- *DTV RSCoder* (dtv)
- *DTV RSDecoder* (dtv)
- *DTV ScrambleByte* (dtv)

DTV_BCHCoder



Description: BCH coder
Library: DTV, Channel Coding
Class: SDFDTV_BCHCoder

Parameters

Name	Description	Default	Symbol	Unit	Type	Range
FieldOrder	order of Galois field	7	M		int	[3, 12]
InfoLength	information bit data length	113	K		int	[1, N)†
BlockLength	length of block code	127	N		int	[2**(M-1), 2**M)
ErrorNum	error protection capability	2			int	(0, 7]

† InfoLength value depends on ErrorNum and BlockLength.

Pin Inputs

Pin	Name	Description	Signal Type
1	input	input signal	int

Pin Outputs

Pin	Name	Description	Signal Type
2	output	error protected output signal	int

Notes/Equations

1. This model performs shortened BCH error correcting encoding over the input signal. Each firing, K tokens are consumed at the input pin and *N* tokens are produced; $N - K$ parity bits are generated and appended to the input signal to form the output.
2. Implementation
   - Add 0 bit to make the output signal block length up to $2^M - 1$.
   - If the output signal block length is different with (2***M* - 1), the input signal block is added (2***M* − 1 − *N*) bits which are set to zero, and consists of a new BCH code length $2^M - 1$.
   - Calculate the output BCH code by field generator polynomial *g(x)*.
   - Calculate the coefficients of redundancy polynomial *b(x)*. The redundancy polynomial *b(x)* is the remainder after dividing ($x^{N-K} \times data(x)$) by the generator polynomial *g(x)*.
   - The output BCH ($2^M - 1$, $2^M - 1 - N + K$) code polynomial is
     $A(x) = x^{N - k} \times data(x) + b(x)$
     where
     data(x) denotes information bits data polynomial

A(x) denotes the output data polynomial
b(x) denotes redundancy polynomial

- The added 0 bits are deleted from the BCH ($2^M - 1$, $2^M - 1 - N + K$) and the output shortened BCH(*N,K*) code is determined.

3. DVB-T Primitive and Generation Polynomials
For DVB-T, the shortened BCH(67,53) is derived from BCH(127,113). The shortened BCH code is implemented by adding 60 bits, all set to zero, before the information bits input of a BCH(127,113, t = 2) encoder. After BCH encoding, these null bits are discarded, leading to a BCH code word of 67 bits.

For the primitive polynomial
$P(x) = x^7 + x^3 + 1$
For the generation polynomial
$g(x) = x^{14} + x^9 + x^8 + x^6 + x^5 + x^4 + x^2 + x + 1$
The primitive polynomials of BCH codes based on FieldOrder values are given in the table below.

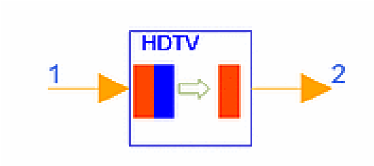
Primitive Polynomial of BCH Coding

FieldOrder	Primitive Polynomial
3	$P(x) = x^3 + x + 1$
4	$P(x) = x^4 + x + 1$
5	$P(x) = x^5 + x^2 + 1$
6	$P(x) = x^6 + x + 1$
7	$P(x) = x^7 + x^3 + 1$
8	$P(x) = x^8 + x^6 + x^5 + x^4 + 1$
9	$P(x) = x^9 + x^4 + 1$
10	$P(x) = x^{10} + x^3 + 1$
11	$P(x) = x^{11} + x^2 + 1$
12	$P(x) = x^{12} + x^7 + x^4 + x^3 + 1$

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.

DTV_BCHDecoder



Description: BCH decoder
Library: DTV, Channel Coding
Class: SDFDTV_BCHDecoder

Parameters

Name	Description	Default	Symbol	Unit	Type	Range
FieldOrder	order of Galois field	7	M		int	[3, 12]
InfoLength	information bit data length	113	K		int	[1, N) †
BlockLength	length of block code	127	N		int	[2**(M-1), 2**M)
ErrorNum	error protection capability	2			int	(0, 7]

† InfoLength value depends on ErrorNum and BlockLength.

Pin Inputs

Pin	Name	Description	Signal Type
1	input	input signal	int

Pin Outputs

Pin	Name	Description	Signal Type
2	output	decoded signal	int

Notes/Equations

1. This model performs BCH error correcting decoding over the input signal. After decoding, N tokens are consumed at the input pin and K tokens are produced each firing.
2. Implementation
When input data is shortened BCH code at the start of decoding, the input signal block is added (2***M*-1-*N* bits) and consists of BCH (2***M*-1, 2***M*-1-*N*+*K*) code. After decoding, the padded bits are discarded.
Syndrome Concept
How can a receiver know the occurrence of one or more errors during transmission/storage of an encoded block, given only the generator polynomial g(D) and the received code word y represented by its polynomial (D)?
The answer is to become familiar with *syndromes*, which indicate an erroneous situation. Suppose code word *x(D)* is transmitted and we receive *y(D)*. We can write *y(D) = X(D) + e(D)* where *e(D)* represents the polynomial corresponding to the error that occurred during transmission.
Now we have a simple procedure for checking the occurrence of errors at the receiver:

transform the received code word y into its polynomial representation *y(D)*;

calculate $S(i) = y(\alpha^i) = e(\alpha^i)$ for $i = 1, \ldots, 2t$;

if one or more *S(i)* values are not equal to zero, one or more symbol errors have occurred in the block.
Now we know if there are errors in the received block, but we do not know how many bits are affected, or the position of the errors. The location of symbol errors in a block is determined by the construction of another polynomial, the *error locator A(D)*. Given the 2t syndromes *S(i)*, the decoding algorithm will try to synthesize a polynomial of which the coefficient values indicate the error positions. This is done as follows. Let *n* errors occur in locations *j1, j2, ... , jn* of a block, where $0 \le j0 < j1 < \ldots < jn < N$. Then the error polynomial *e(D)* is:

$$e(D) = D^{jn} + D^{jn-1} + \ldots + D^{j1}$$

Define the error locator *X(l)* by $X_l = \alpha^{jl}$ $l = 1, 2, \ldots, n$
Then the syndromes can be expressed in terms of these error locators:

$$S(i) = e(\alpha^i) = X_n^{\,i} + X_{n-1}^{\,i} + \ldots + X_1^{\,i} \quad i = 1, \ldots, 2t$$

We now construct the error locator polynomial *A(D)* as follows:

$$\begin{aligned} A(D) &= (1+X_1D)(1+X_2D)\ldots(1+X_nD) \\ &= A_0 + A_1D + A_2D^2 + \ldots + A_nD^n \end{aligned}$$

This polynomial is the *error locator polynomial* since the inverses of its roots, *X(l) (l = 1, ... , n)*, yield the error locations.
To construct *A(D)*, this model uses the Massey-Berlekamp algorithm, which forms the key to decoding BCH code. The algorithm is more generally applicable for synthesizing linear shift feedback registers generating a predefined output sequence. For the Massey-Berlekamp Algorithm an iterative table is filled as shown in the table below.

Berlekamp Iterative Table

μ	$A^{(\mu)}(D)$	d_μ	l_μ	$\mu - l_\mu$
-1	1	1	0	-1
0	1	S_1	0	0
1				
2				
...				
2t				

where μ is the iterative step number, *d* μ is the μth step iterative difference, *l* μ is the order of $A^{(\mu)}(D)$.
If *d* μ = 0, then

$$A_\mu^{(\mu+1)}(D) = A_\mu^{(\mu)}(D)$$

and

$l_{\mu+1} = l_{\mu}$

If $d_{\mu} \neq 0$, search for lines in the table to find step ρ in which $d_{\rho} \neq 0$ and the value of $\rho - l_{\rho}$ is the maximum, then

$A^{(\mu+1)}(D) = A(D) - d_{\mu}d_{\rho}^{-1}D^{(\mu-\rho)}\Omega^{(\rho)}(D)$

and

$l_{\mu+1} = max(l_{\mu}, l_{\rho} + \mu - \rho)$

For the two conditions

$d_{\mu+1} = s_{\mu+2} + A_1^{(\mu+1)}s_{\mu+1} + \ldots + A_{l_{\mu}+1}^{(\mu+1)}s_{\mu+2-l_{\mu+1}}$

Iterate until the last line of the table $A^{(2t)}(D)$ is determined. If the order of the polynomial is greater than *t*, which means the received code word block has more than *t* errors, the errors cannot be corrected.

To decode binary BCH code, it is sufficient to know the position of bit errors in a block and make the bit value inverse.

3. DVB-T Primitive and Generation Polynomials

   For DVB-T, the shortened BCH(67,53) is derived from BCH(127,113). The shortened BCH code is implemented by adding 60 bits, all set to zero, before the information bits input of a BCH(127,113, *t* = 2) encoder. After BCH encoding, these null bits are discarded, leading to a BCH code word of 67 bits.

   For the primitive polynomial

   $P(x) = x^7 + x^3 + 1$

   For the generation polynomial

   $g(x) = x^{14} + x^9 + x^8 + x^6 + x^5 + x^4 + x^2 + x + 1$

   The primitive polynomials of BCH codes based on FieldOrder values are listed in the table below.

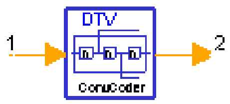
Primitive Polynomials of BCH Coding

FieldOrder	Primitive Polynomial
2	$P(x) = x^2 + x + 1$
3	$P(x) = x^3 + x + 1$
4	$P(x) = x^4 + x + 1$
5	$P(x) = x^5 + x^2 + 1$
6	$P(x) = x^6 + x + 1$
7	$P(x) = x^7 + x^3 + 1$
8	$P(x) = x^8 + x^6 + x^5 + x^4 + 1$
9	$P(x) = x^9 + x^4 + 1$
10	$P(x) = x^{10} + x^3 + 1$
11	$P(x) = x^{11} + x^2 + 1$
12	$P(x) = x^{12} + x^7 + x^4 + x^3 + 1$
13	$P(x) = x^{13} + x^4 + x^3 + x + 1$
14	$P(x) = x^{14} + x^{12} + x^{11} + x + 1$
15	$P(x) = x^{15} + x + 1$
16	$P(x) = x^{16} + x^5 + x^3 + x^2 + 1$
17	$P(x) = x^{17} + x^3 + x$
18	$P(x) = x^{18} + x^7 + x$
19	$P(x) = x^{19} + x^6 + x^5 + x + 1$
20	$P(x) = x^{20} + x^3 + 1$

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.

DTV_ConvCoder



Description: Convolutional coding the input bits
Library: DTV, Channel Coding
Class: SDFDTV_ConvCoder

Pin Inputs

Pin	Name	Description	Signal Type
1	input	bits to be coded	int

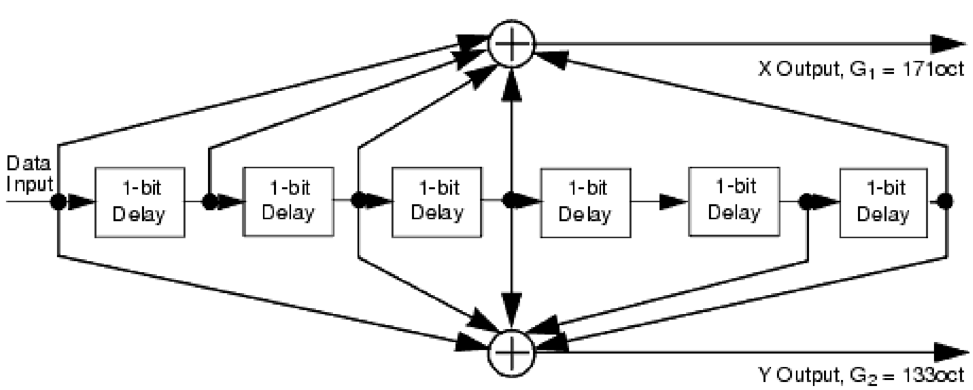
Pin Outputs

Pin	Name	Description	Signal Type
2	output	coded bits	int

Notes/Equations

1. This model performs normal convolutional encoding of data rate 1/2 over the input signal.
   Each firing, 1 token is consumed at the input and 2 tokens are produced.
   The encoder is shown below.

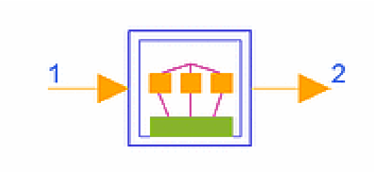
Convolutional Code Rate 1/2 (Constraint Length=7)



References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.

DTV_ConvCoder1_2



Description: DTV convolutional encoder for 1/2 rate
Library: DTV, Channel Coding
Class: SDFDTV_ConvCoder1_2

Pin Inputs

Pin	Name	Description	Signal Type
1	input	signal to be encoded	int

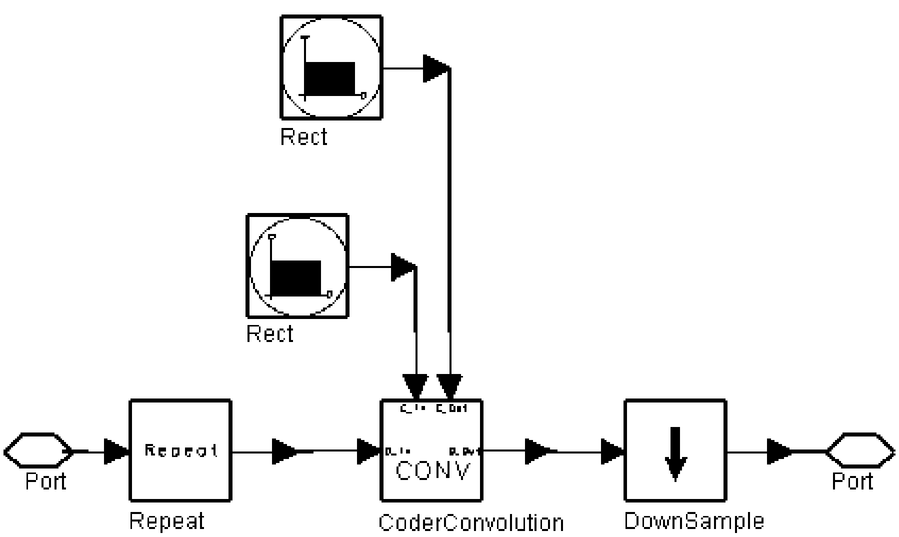
Pin Outputs

Pin	Name	Description	Signal Type
2	output	encoded signal	int

Notes/Equations

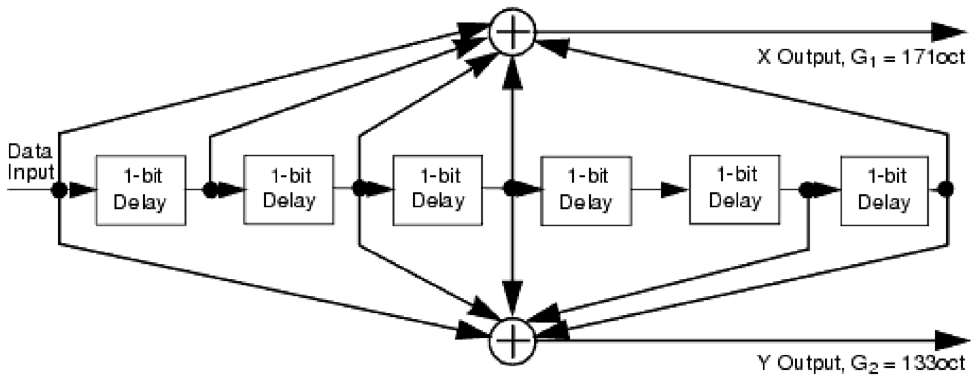
1. This subnetwork model performs normal convolutional encoding of data rate 1/2 over the input signal. Each firing, 1 token is consumed at the input and 2 tokens are produced. The schematic for this subnetwork is shown below.

DTV_ConvCoder1_2 Subnetwork



2. This subnetwork uses a general convolutional coding model to encode the input data into mother convolutional code of data rate 1/2. The encoder is shown below.

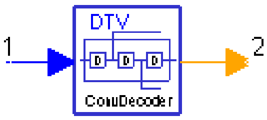
Mother Convolutional Code of Rate 1/2 (Constraint Length=7)



References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept. 1998.
2. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.

DTV_ConvDecoder



Description: Bit by bit viterbi decoder for DTV convolutional code
Library: DTV, Channel Coding
Class: SDFDTV_ConvDecoder
Derived From: DTV_ConvDecoder_base

Parameters

Name	Description	Default	Unit	Type	Range
TrunLen	path memory truncation length (bytes)	10		int	[5, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	input	The code words to be viterbi-decoded.	real

Pin Outputs

Pin	Name	Description	Signal Type
2	output	the decoded bits.	int

Notes/Equations

1. This model Viterbi-decodes the input code words. CC(2,1,7) and *g1 171 g2 133* is decoded. The delay is equal to the convolutional code memory. Padding bits detect the end of the code words.
   One output token is produced when 2 input tokens are consumed.
2. The following algorithm is used, with CC(2,1,7) as an example. The generator functions of the code are g1 (which equals 171 (octal)), and g2 (which equals 133 (octal)).
   Because the constraint length is 7, there are 64 possible states in the encoder. In the Viterbi decoder all states are represented by a single column of nodes in the trellis at each symbol instant. At each node in the trellis, there are 2 merging paths; the path with the shortest distance is selected as the survivor.
   The long encoded packets in DTV systems make it impractical to store the entire length of the surviving sequences before determining the information sequence when decoding delay and memory is concerned. Instead, only the most recent L information bits in each surviving sequence are stored. Once the path with the shortest distance is identified, the symbol associated with path L periods ago is conveyed to the output as a decoded information symbol. Generally, parameter L is sufficiently large (normally $L \geq 5K$) for the present symbol of the surviving sequences to have a minimum effect on the decoding of the L th previous symbol. In DTV systems, $L = 8 \times$ TrunLen.
   The following is the Viterbi algorithm for decoding a CC(n,k,K) code, where K is the

constraint length of convolutional code. In our components, the convolutional code is processed with k = 1.

Branch Metric Calculation

Branch metric $m(\alpha)_j$, at the J th instant of the α path through the trellis is defined as the logarithm of the joint probability of the received n-bit symbol $r_{j1}, r_{j2}, \ldots, r_{jn}$ conditioned on the estimated transmitted n-bit symbol

$c_{j1}^{(\alpha)}, c_{j2}^{(\alpha)}, \ldots, c_{jn}^{(\alpha)}$ for the α path. That is

$$m_j^{(\alpha)} = \ln\left(\prod_{i=1}^{n} P(r_{ji}|c_{ji}^{(\alpha)})\right)$$

$$= \sum^{n} \ln P(r_{ji}|c_{ji}^{(\alpha)})$$

If the receiver is regarded as part of the channel, for the Viterbi decoder the channel can be considered as an AWGN channel. Therefore

$$m_j^{(\alpha)} = \sum_{i=1}^{n} r_{ji}c_{ji}$$

Path Metric Calculation

The path metric $M^{(\alpha)}$ for the α path at the J th instant is the sum of the branch metrics belonging to the α path from the first to the J th instant. Therefore

$$M^{(\alpha)} = \sum_{j=1}^{J} m_j^{(\alpha)}$$

Information Sequence Update

There are 2^k merging paths at each node in the trellis and the decoder selects the one (known as the survivor) with the largest metric from paths $\alpha_1, \alpha_2, \ldots, \alpha_2$; namely

$$max(M^{(\alpha_1)}, M^{(\alpha_2)}, \ldots, M^{(\alpha_{2^k})})$$

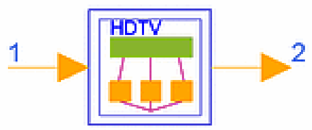
Decoder Output

When the two survivors are determined at the J th instant, the decoder outputs the (J-L)th information symbol from its memory of the survivor with the largest metric.

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.
2. S. Lin and D. J. Costello, Jr., *Error Control Coding Fundamentals and Applications*, Prentice Hall, Englewood Cliffs NJ, 1983.

DTV_ConvDecoder1_2



Description: DTV convolutional decoder for 1/2 rate
Library: DTV, Channel Coding
Class: SDFDTV_ConvDecoder1_2

Parameters

Name	Description	Default	Unit	Type	Range
NumBits	number of soft decision bits	4		int	[1, ∞)
SymbolLen	path memory truncation length	8		int	[1, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	input	signal to be decoded	int

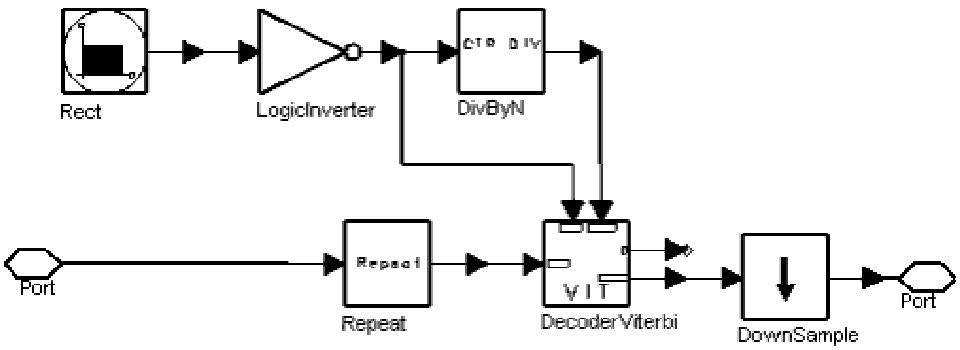
Pin Outputs

Pin	Name	Description	Signal Type
2	output	decoded signal	int

Notes/Equations

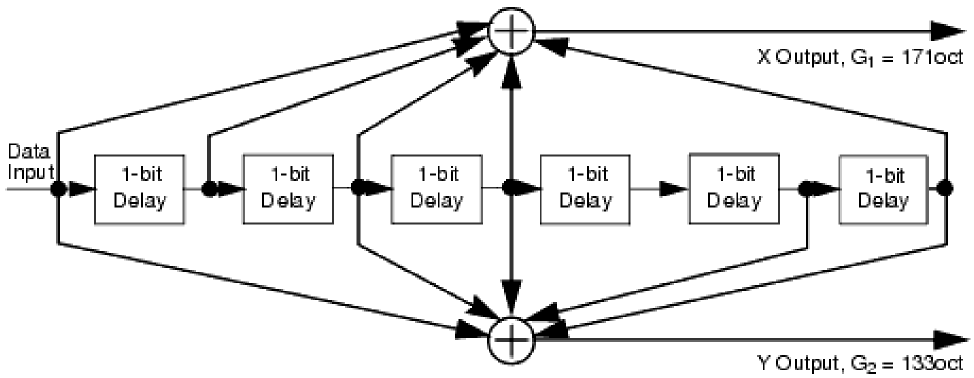
1. This subnetwork model Viterbi decodes a convolutional code that has a mother convolutional code of data rate 1/2 over the input signal. The schematic for this subnetwork is shown below.

DTV_ConvDecoder1_2 Subnetwork



2. A general Viterbi convolutional decoding model decodes the convolutional encoded input data. The encoder is shown below.

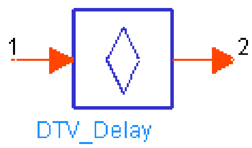
Mother Convolutional Code of Rate 1/2 (Constraint Length=7)



References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.
2. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.

DTV_Delay



Description: Delay including random initialization value
Library: DTV, Channel Coding
Class: SDFDTV_Delay

Parameters

Name	Description	Default	Unit	Type	Range
N	delay depth	0		int	[0, ∞)
InitialType	initial value type: Zero, NonZero	Zero		enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	input	input data to be delayed	anytype

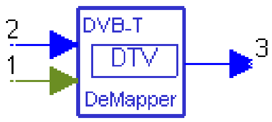
Pin Outputs

Pin	Name	Description	Signal Type
2	output	output data been delayed	anytype

Notes/Equations

1. This model adds a delay to the input data.
2. If InitialType is set to Zero, the initial N output tokens will be all zeros; if set to NonZero, the initial N output tokens will be the same as the N input samples.

DTV_Demapper



Description: Soft demapper for uniform and non-uniform QPSK, 16QAM and 64QAM
Library: DTV, Channel Coding
Class: SDFDTV_Demapper

Parameters

Name	Description	Default	Unit	Type	Range
MappingMode	signal constellations and mapping: QPSK, QAM-16, QAM-64	QAM-16		enum	
Alpha	non-uniform factor for DVB-T.	1		int	[1, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	input	signal to be demodulated	complex
2	CSI	channel state information	real

Pin Outputs

Pin	Name	Description	Signal Type
3	output	soft metric information	real

Notes/Equations

1. This model de-maps uniform and non-uniform QPSK, 16QAM, and 64QAM to determine the soft-bit information that is used by Viterbi decoding.
   Each firing, the CSI and input pins consume 1 token each; 2 tokens for QPSK, 4 tokens for 16QAM, or 6 tokens for 64QAM are generated.
2. MappingMode specifies the signal constellation and mapping mode: QPSK, QAM-16 or QAM-64.
   While the constellation point is sent to the input port before demapping, the point is scaled up by a factor that is determined by Alpha and MappingMode given in the table below.

De-Normalization Factors for Data Symbols

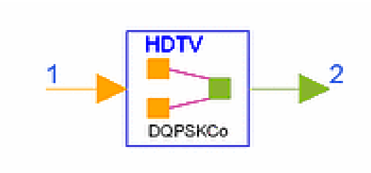
Modulation Scheme	Normalization Factor
QPSK	$c = z \times (\sqrt{2})$
16-QAM: Alpha=1	$c = z \times (\sqrt{10})$
16-QAM: Alpha=2	$c = z \times (\sqrt{20})$
16-QAM: Alpha=4	$c = z \times (\sqrt{52})$
64-QAM: Alpha=1	$c = z \times (\sqrt{42})$
64-QAM: Alpha=2	$c = z \times (\sqrt{60})$
64-QAM: Alpha=4	$c = z \times (\sqrt{108})$

3. The soft bits are determined by the decision equations.
   I is the real part of product and Q is the imaginary part.
   The final soft bit information b is the product of soft bits calculated by the following equations and the CSI input.
   - 64QAM decision equations are:
     b0 = I
     b1 = Q
     b2 = 4 - |b0|
     b3 = 4 - |b1|
     b4 = 2 - |b2|
     b5 = 2 - |b3|
   - 16QAM decision equations are:
     b0 = I
     b1 = Q
     b2 = 2 - |b0|
     b3 = 2 - |b1|
   - QPSK decision equations are:
     b0 = I
     b1 = Q

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.
2. M. R. G. Butler, S. Armour, P.N. Fletcher, A.R. Nix, D.R. Bull, *"Viterbi Decoding Strategies for 5 GHz Wireless LAN Systems"* Vehicular Technology Conference, 2001. VTC 2001 Fall. IEEE VTS 54th, Volume: 1, 2001.

DTV_DQPSKCoder



Description: DQPSK baseband modulator
Library: DTV, Channel Coding
Class: SDFDTV_DQPSKCoder

Parameters

Name	Description	Default	Unit	Type	Range
Delay	delay of feedback (as length of register)	384		int	[1, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	input	input data bits	int

Pin Outputs

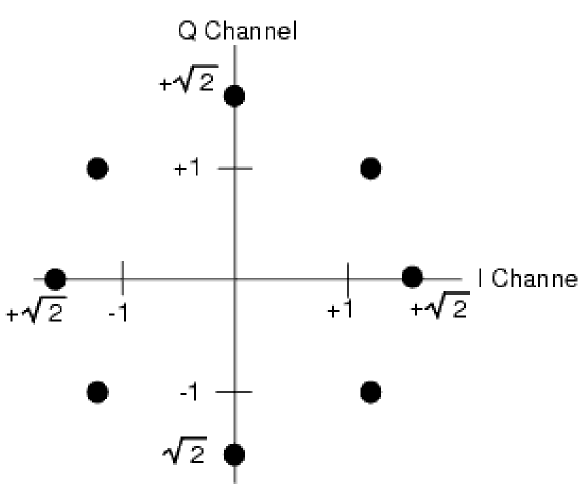
Pin	Name	Description	Signal Type
2	output	signal after constellation mapping	complex

Notes/Equations

1. This model performs Π/4 shift DQPSK constellation mapping and modulation. Each firing, two bits of input data are consumed to produce the complex data output.
2. Phase calculation and mapping is shown below.

Phase Calculation and Π/4 Shift DQPSK Constellation Mapping

Input b0′, b1′	Output θ_j
0, 0	$\pi / 4$
0, 1	$-\pi / 4$
1, 0	$3\pi / 4$
1, 1	$-3\pi / 4$



Complex data is calculated by,

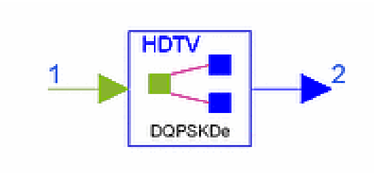
$$\begin{pmatrix} I_j \\ Q_j \end{pmatrix} = \begin{bmatrix} \cos\theta_j & -\sin\theta_j \\ \sin\theta_j & \cos\theta_j \end{bmatrix} \begin{pmatrix} I_{j-1} \\ Q_{j-1} \end{pmatrix}$$

where (I_j, Q_j) denotes complex data of the *j* th symbol and *d* denotes the number of symbols between (I_j, Q_j) and (I_{j-1}, Q_{j-1}).

References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.

DTV_DQPSKDecoder



Description: DQPSK decoder with soft decision
Library: DTV, Channel Coding
Class: SDFDTV_DQPSKDecoder

Parameters

Name	Description	Default	Unit	Type	Range
Delay	delay of feedback (as length of register)	384		int	[1, ∞)
Renorm	option to re-normalize reference phase (set to the nearest symbol point): NO , YES	NO		enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	input	signal to be demodulated	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	output	signal after demodulation	real

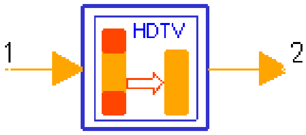
Notes/Equations

1. This model performs π/4 shift DQPSK demodulation; it is the reverse of the process for DTV_DQPSKCoder.
   It decodes the complex DQPSK signal to floating-point data to be Viterbi convolutional decoded.

References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.

DTV_InnerDecoder



Description: Punctured convolutional decoder
Library: DTV, Channel Coding
Class: SDFDTV_InnerDecoder

Parameters

Name	Description	Default	Unit	Type	Range
PuncConvType	punctured convolutional code type: DTV_1_2, DTV_2_3, DTV_3_4, DTV_5_6, DTV_7_8	DTV_1_2		enum	
TrunLen	path memory truncation length (bytes)	10		int	[5, ∞)
DelayByte	number of bytes to delay for delay adjustment	0		int	[-∞, 204 - TrunLen]

Pin Inputs

Pin	Name	Description	Signal Type
1	input	signal to be decoded	real

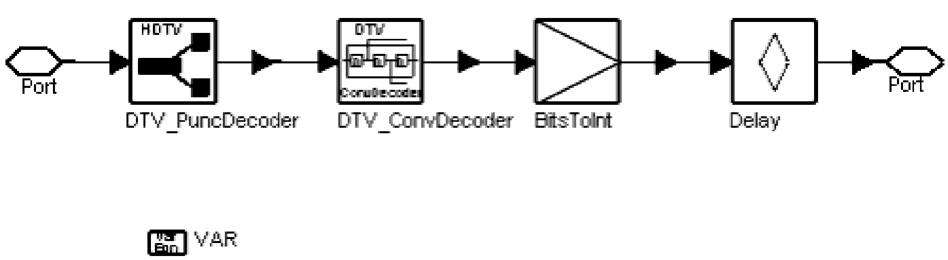
Pin Outputs

Pin	Name	Description	Signal Type
2	output	decoded signal	int

Notes/Equations

1. This subnetwork model performs punctured convolutional decoding over the input signal.
   The schematic for this subnetwork is shown below.

   DTV_InnerDecoder Schematic

2. At the receiver side, DTV_PuncDecoder calculates the puncturing pattern and inserts null (zero) at the position where a bit is punctured. A Viterbi decoder is then used to

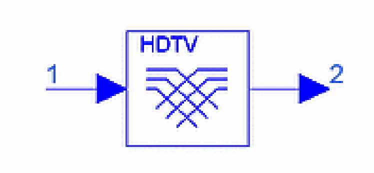
further decode the recovered code bit stream. By replacing the punctured bits with nulls, the punctured bits do not contribute to decoding performance.
The data rate of the mother convolutional code is 1/2.

3. The generator polynomial is $G_1 = 171_{oct}$ and $G_2 = 133_{oct}$.

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.

DTV_InterlvFloat



Description: Interleaver and de-interleaver for float
Library: DTV, Channel Coding
Class: SDFDTV_InterlvFloat

Parameters

Name	Description	Default	Unit	Type	Range
Delays	delay of each branch	0 1 2 3		int array	[0, ∞)
Initial_value	initial value in interleaver delay FIFOs	0.0		real	[0, ∞)
Multiplier	multiple branch number	1		int	[1, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	input	signal to be interleaved	real

Pin Outputs

Pin	Name	Description	Signal Type
2	output	interleaved signal	real

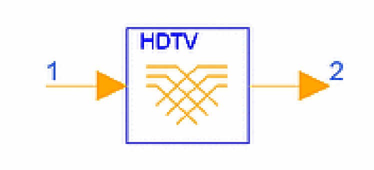
Notes/Equations

1. This model performs floating-point symbol interleaving or de-interleaving over the input signal. It performs de-interleaving of the floating-point symbol after QAM, QPSK or DQPSK decoding.
   A general interleaver is used for floating-point data. It is composed of a number of FIFO delay branches as specified by the Delays array in which the delay can be specified individually. Multiplier can be used to implement multiple isomorphic interleavers.
   The structure of this interleaver is the same as that of DTV_InterlvInt, except this model handles floating-point data.

References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.
2. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.

DTV_InterlvInt



Description: Interleaver and de-interleaver for integer
Library: DTV, Channel Coding
Class: SDFDTV_InterlvInt

Parameters

Name	Description	Default	Unit	Type	Range
Delays	delay of each branch	0 1 2		int array	[0, ∞)
Initial_value	initial value in interleaver delay FIFOs	0		int	[0, ∞)
Multiplier	multiple branch number	1		int	[1, ∞)
InitialType	interleaver delay FIFOs initial value type: Const, Random	Const		enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	input	signal to be interleaved	int

Pin Outputs

Pin	Name	Description	Signal Type
2	output	interleaved signal	int

Notes/Equations

1. This model performs interleaving or de-interleaving over the input signal.
   A general interleaver is used for integer data. It is composed of a number of FIFO delay branches as specified by the Delays array in which the delay can be specified individually. Multiplier can be used to implement multiple isomorphic interleavers. The InitialType parameter specifies the initialization values for the interleaver buffers. The table below shows the relationships of InitialType, Initial_value, and initial buffer values.

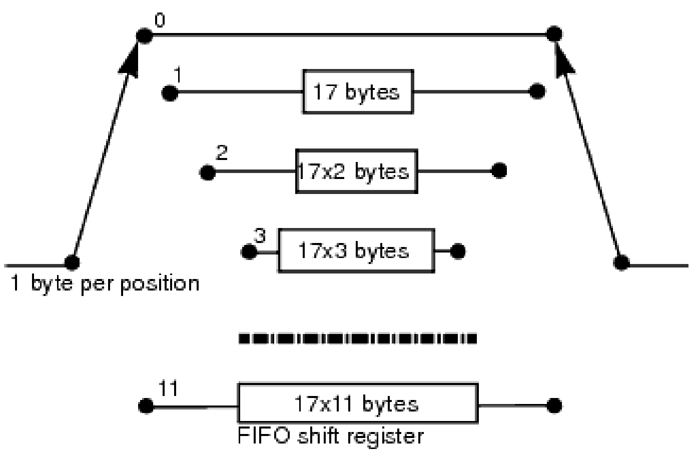
   ### Initial Buffer Values

InitialType	Initial_value	Initial Buffer Value
Const	i (integer)	i
Random	1<=i<=32	i-bit random integer
" "	i<=0 or i>32	8-bit random integer

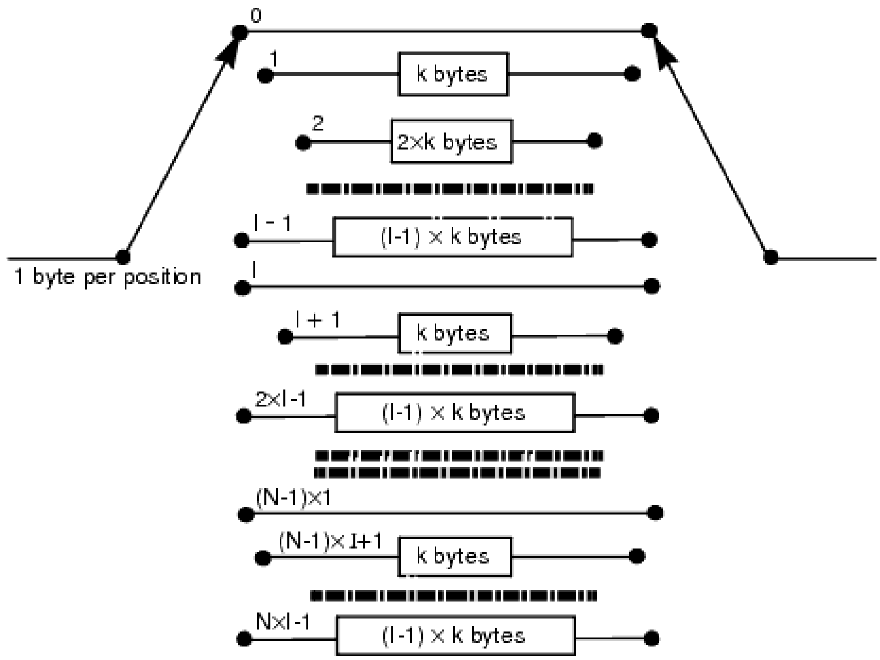
2. The conceptual structure of the interleaver used in ISDB-T is described here. Following the conceptual scheme in ISDB-T Interleaver, convolutional byte-wise

interleaving with length of I = 12 is applied to the 204-byte packets. For synchronization, the bytes following SYNC bytes will be routed in branch 0 of the interleaver (corresponding to a null delay).
The interleaver can be composed of I = 12 branches, cyclically connected to the input byte-stream by the input switch. Each branch j must be a first-in, first-out (FIFO) shift register, with length of $j \times 17$ bytes. The cells of the FIFO must contain 1 byte, and the input and output switches must be synchronized.
The de-interleaver, in principle, is the same as the interleaver, but the branch indices are reversed.
I corresponds to the size of Delay array. The size of every branch, ($j \times 17$ in ISDB-T Interleaver), corresponds to the element of Delay array. Multiplier is the number of FIFO register in the interleaver, its value is 1 in ISDB-T Interleaver.
The conceptual interleaver structure with Multiplier = N and Delay array = (0, $1 \times K$, $2 \times K$, ... , (I -1) × K) is shown in Interleaver with Multiplier = N and Delay Array = (0, 1 × K, 2 × K, ... , (I-1) × K).

ISDB-T Interleaver



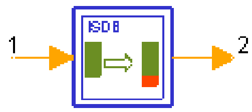
Interleaver with Multiplier = N and Delay Array = (0, 1 × *K*, 2 × *K*, ... , (*I* -1) × *K*)



References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.
2. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.

DTV_ISDBChCoder



Description: Channel coder of ISDB-T
Library: DTV, Channel Coding
Class: SDFDTV_ISDBChCoder

Parameters

Name	Description	Default	Unit	Type	Range
Mode	transmission mode: Mode 1, Mode 2, Mode 3	Mode 1		enum	
MappingMode	signal constellations and mapping: DQPSK, QPSK, QAM-16, QAM-64	DQPSK		enum	
CodeRate	convolutional code rate: DTV 1/2, DTV 2/3, DTV 3/4, DTV 5/6, DTV 7/8	DTV 1/2		enum	
Segments	number of segments per layer	13		int	[1, 13]

Pin Inputs

Pin	Name	Description	Signal Type
1	In	input data	int

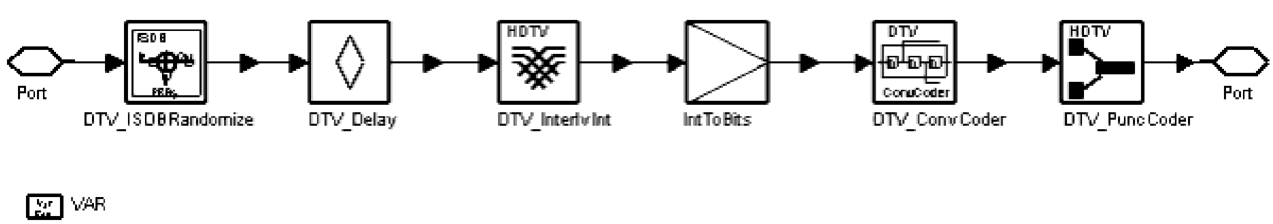
Pin Outputs

Pin	Name	Description	Signal Type
2	Out	output	int

Notes/Equations

1. This subnetwork model performs channel coding except RS-coding in an ISDB-T signal generator. Functions include bit-wise randomization (energy dispersal), delay adjustment for byte-wise interleaving and deinterleaving, and punctured convolutional encoding.
   The schematic for this subnetwork is shown below.

   DTV_ISDBChCoder Schematic

2. Input of the subnetwork starts with the synchronization byte of the first frame. DTV_ISDBRandomize randomizes RS-coded bytes with a block size of 204 bytes.

3.
4. DTV_Delay, with DTV_InterlvInt, adjusts the delay between the transmitter and the receiver to provide an identical transmission and reception delay of one frame length for all hierarchical layers. The number of bytes to be delayed in each hierarchical layer is:

$$Delay = (MapRate \times 96^{Mode} \times CodeRate)/8 - 204 \times 11$$

where

MapRate equals 2, 2, 4, or 6 for DQPSK, QPSK, 16QAM, or 64QAM, respectively

Mode equals 0, 1, or 2 for Mode 1, Mode 2, or Mode 3, respectively

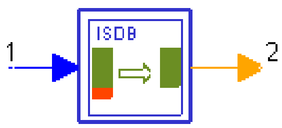
CodeRate represents the inner code rate 1/2, 2/3, 3/4, 5/6, or 7/8

204 × 11 is the delay derived from byte interleaver and deinterleaver

References

1. ARIB STD-B31 Version 1.5, *Transmission System for Digital Terrestrial Television Broadcasting*, July 29, 2003.

DTV_ISDBChDecoder



Description: Channel decoder of ISDB-T
Library: DTV, Channel Coding
Class: SDFDTV_ISDBChDecoder

Parameters

Name	Description	Default	Unit	Type	Range
Mode	transmission mode: Mode 1, Mode 2, Mode 3	Mode 1		enum	
MappingMode	signal constellations and mapping: DQPSK, QPSK, QAM-16, QAM-64	DQPSK		enum	
CodeRate	convolutional code rate: DTV 1/2, DTV 2/3, DTV 3/4, DTV 5/6, DTV 7/8	DTV 1/2		enum	
Segments	number of segments per layer	13		int	[1, 13]
TrunLen	path memory truncation length (bytes)	10		int	[5, ∞)
DelayByte	number of bytes to delay for delay adjustment	8		int	[0, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	In	input data	real

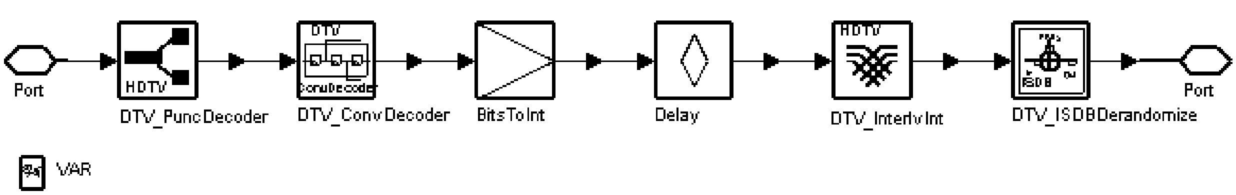
Pin Outputs

Pin	Name	Description	Signal Type
2	Out	output	int

Notes/Equations

1. This subnetwork model performs convolutional decoding, delay adjustment, byte-wise deinterleaving, and energy distribution.
   The schematic for this subnetwork is shown below.

   DTV_ISDBChDecoder Schematic

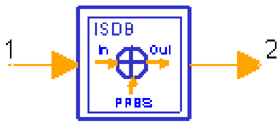
2. The DelayByte parameter includes all delay bytes before and after convolutional decoding.

3. The Delay component adjusts the block size to 204 bytes after convolutional decoding.

References

1. ARIB STD-B31 Version 1.5, *Transmission System for Digital Terrestrial Television Broadcasting*, July 29, 2003.

DTV_ISDBDerandomize



Description: ISDB-T energy derandomization of tansmission stream packages
Library: DTV, Channel Coding
Class: SDFDTV_ISDBDerandomize

Parameters

Name	Description	Default	Unit	Type	Range
Mode	transmission mode: Mode 1, Mode 2, Mode 3	Mode 1		enum	
CodeRate	convolutional code rate: DTV 1/2, DTV 2/3, DTV 3/4, DTV 5/6, DTV 7/8	DTV 1/2		enum	
MappingMode	signal constellations and mapping: DQPSK, QPSK, QAM-16, QAM-64	DQPSK		enum	
Segments	number of segments per layer	13		int	[1, 13]
Delay	equivalent delay in bits between randomizer and de-randomizer	0		int	[0, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	In	input	int

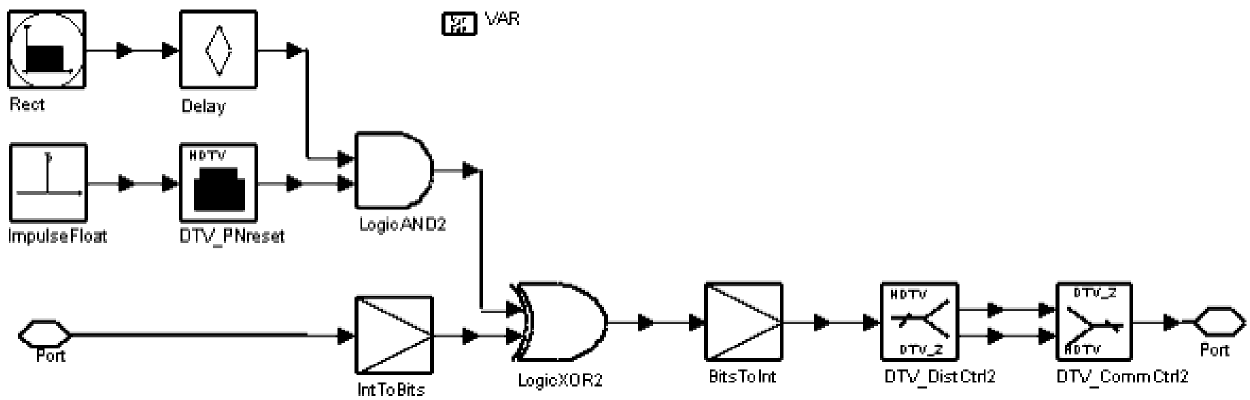
Pin Outputs

Pin	Name	Description	Signal Type
2	Out	output	int

Notes/Equations

1. This subnetwork model derandomizes the signal after byte deinterleaving. The schematic for this subnetwork is shown below.

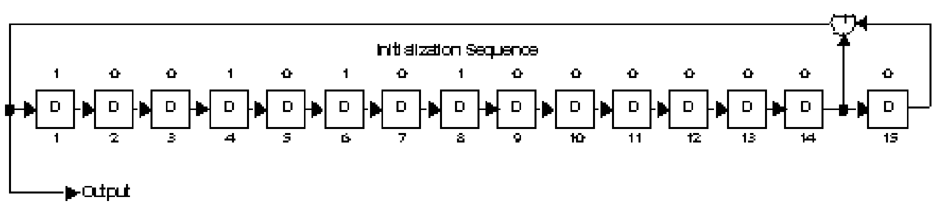
DTV_ISDBDerandomize Schematic



2. Derandomization is conducted using a PRBS shown below.

PRBS Generating Polynomial and Circuit

$$G(x) = x^{15} + x^{14} + 1$$

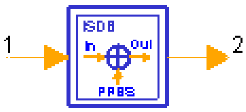


3. All signals except the synchronization bytes in each TSP are XORed bit-by-bit using PRBSs, MSB (most significant bit) first. The PRBS-generator is initialized at the beginning of each OFDM frame with 100101010000000 (D1, D2, ... , D15 in PRBS Generating Polynomial and Circuit). In each frame, the first PRBS bit is applied to the MSB of the byte next to the TSP synchronization byte (the second byte of the frame). Note that the shift register also performs shifting when the TSP synchronization byte arrives.
4. The Delay parameter includes all delay bits before derandomization.

References

1. ARIB STD-B31 Version 1.5, *Transmission System for Digital Terrestrial Television Broadcasting*, July 29, 2003.

DTV_ISDBRandomize



Description: ISDB-T energy randomization of tansmission stream packages
Library: DTV, Channel Coding
Class: SDFDTV_ISDBRandomize

Parameters

Name	Description	Default	Unit	Type	Range
Mode	transmission mode: Mode 1, Mode 2, Mode 3	Mode 1		enum	
CodeRate	convolutional code rate: DTV 1/2, DTV 2/3, DTV 3/4, DTV 5/6, DTV 7/8	DTV 1/2		enum	
MappingMode	signal constellations and mapping: DQPSK, QPSK, QAM-16, QAM-64	DQPSK		enum	
Segments	number of segments per layer	13		int	[1, 13]

Pin Inputs

Pin	Name	Description	Signal Type
1	In	input	int

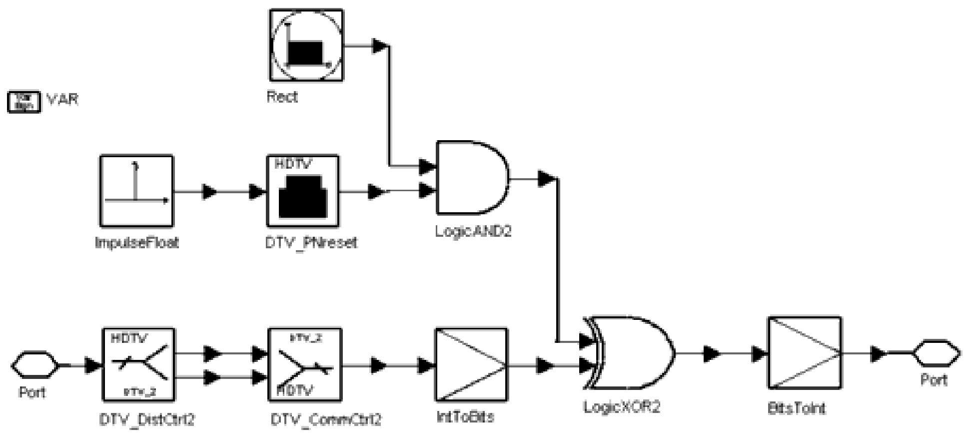
Pin Outputs

Pin	Name	Description	Signal Type
2	Out	output	int

Notes/Equations

1. This subnetwork model randomizes the RS-coded TSP with a block size of 204 bytes in an ISDB-T signal generator. (This subnetwork can also be referred to as an energy-disperser.)
   The schematic for the subnetwork is shown below.

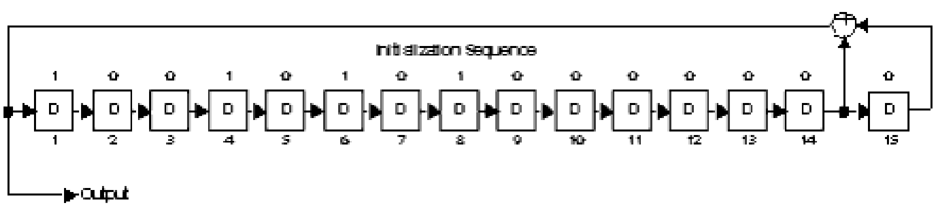
DTV_ISDBRandomize Schematic



2. Randomization is conducted at each hierarchical layer using a PRBS as shown below.

PRBS Generating Polynomial and Circuit

$$G(x) = x^{15} + x^{14} + 1$$

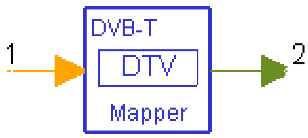


3. All signals except the synchronization bytes in each TSP are XORed bit-by-bit using PRBSs, most significant bit first.
4. The PRBS generator is initialized at the beginning of each OFDM frame with the sequence of 100101010000000 (D1, D2, ... , D15 in PRBS Generating Polynomial and Circuit). In each frame, the PRBS first bit is applied to the most significant bit of the byte next to the TSP synchronization byte (the second byte of the frame).
The shift register will also perform shifting when the TSP synchronization byte arrives.
5. Input of the subnetwork starts with the synchronization byte of the first frame.

References

1. ARIB STD-B31 Version 1.5, *Transmission System for Digital Terrestrial Television Broadcasting*, July 29, 2003.

DTV_Mapper



Description: Uniform and non-uniform mapping for DVB-T and ISDB-T
Library: DTV, Channel Coding
Class: SDFDTV_Mapper

Parameters

Name	Description	Default	Unit	Type	Range
MappingMode	signal constellations and mapping: QPSK, QAM-16, QAM-64	QAM-16		enum	
Alpha	non-uniform factor for DVB-T.	1		int	[1, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	input	input data bits	int

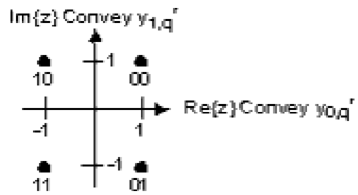
Pin Outputs

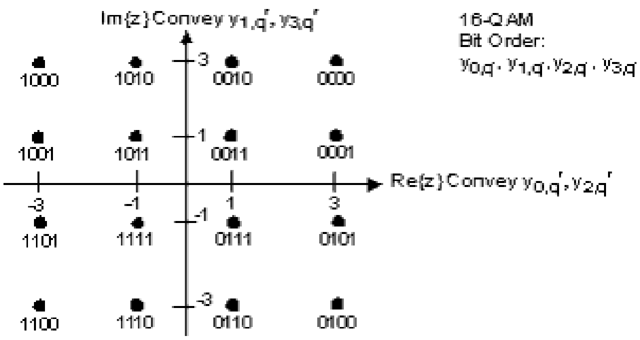
Pin	Name	Description	Signal Type
2	output	signal after constellation mapping	complex

Notes/Equations

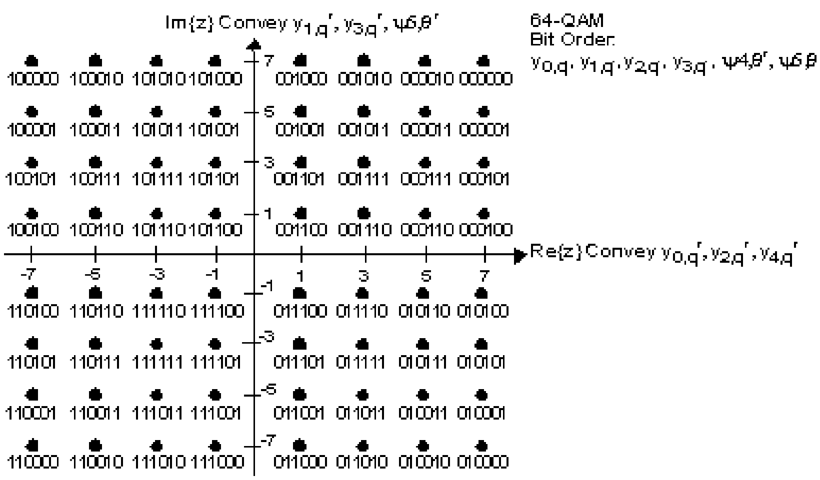
1. This model performs QPSK, 16QAM, 64QAM mapping or non-uniform 16QAM and 64QAM Gray mapping.
   Each firing, 2 tokens for QPSK, 4 tokens for 16QAM, or 6 tokens for 64QAM are consumed and one constellation symbol is generated.
2. The MappingMode parameter specifies the constellation and mapping mode: QPSK, QAM-16 or QAM-64.
3. The Alpha parameter determines the exact proportions of the constellation. Alpha is the minimum distance separating the two constellation points carrying different high-priority bit values divided by the minimum distance separating any two constellation points. While the non-hierarchical transmission uses the same uniform constellation as Alpha=1, non-uniform constellation for hierarchical transmission is also supported using Alpha=2 or 4.
4. Bit patterns based on Alpha and MappingMode settings are shown in QPSK, 16-QAM Mapping Bit Patterns (Non-Hierarchical and Hierarchical, Alpha=1) through Non-Uniform 64-QAM Mapping Bit Patterns (Alpha=4).

QPSK, 16-QAM Mapping Bit Patterns (Non-Hierarchical and Hierarchical, Alpha=1)

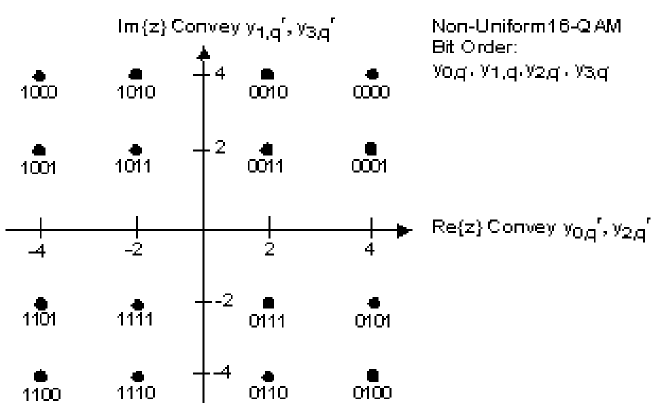




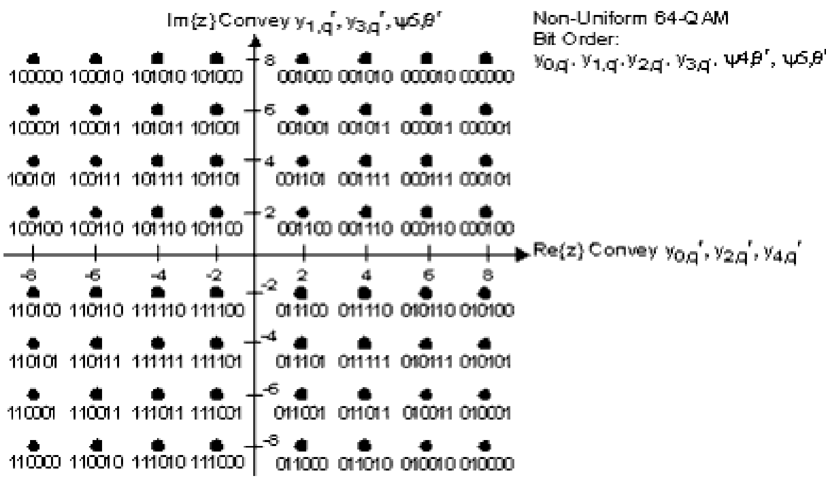
64-QAM Mapping Bit Patterns (Non-Hierarchical and Hierarchical, Alpha=1)



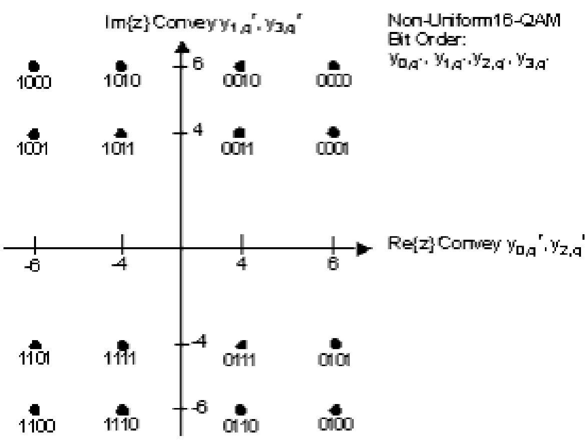
Non-Uniform 16-QAM Mapping Bit Patterns (Alpha=2)



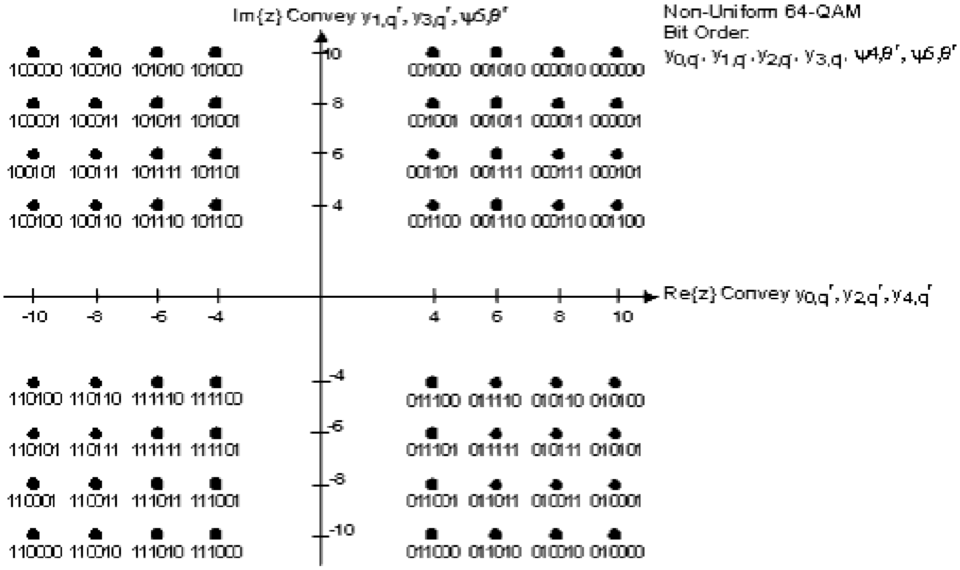
Non-Uniform 64-QAM Mapping Bit Patterns (Alpha=2)



Non-Uniform 16-QAM Mapping Bit Patterns (Alpha=4)



Non-Uniform 64-QAM Mapping Bit Patterns (Alpha=4)



5. The mapped symbols are normalized; normalization factors are shown in the table below.

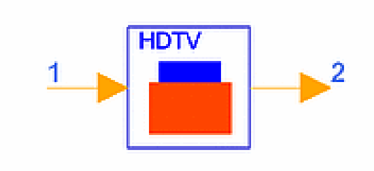
Normalization Factors

Modulation Scheme	Normalization Factor
QPSK	$c = z/(\sqrt{2})$
16-QAM	$c = z/(\sqrt{10})$
16-QAM	$c = z/(\sqrt{20})$
16-QAM	$c = z/(\sqrt{52})$
64-QAM	$c = z/(\sqrt{42})$
64-QAM	$c = z/(\sqrt{60})$
64-QAM	$c = z/(\sqrt{108})$

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.

DTV_PNreset



Description: PN code source with reset input
Library: DTV, Channel Coding
Class: SDFDTV_PNreset

Parameters

Name	Description	Default	Unit	Type	Range
Polynomial	generator polynomial (X^0+X^1+...+X^M)	1 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1		int array	[0, 1]
Initial	initial and reset value in registers	1 0 0 1 0 1 0 1 0 0 0 0 0 0 0		int array	[0, 1]
SignalPoint	output register after each shift	0		int	[0, 31]

Pin Inputs

Pin	Name	Description	Signal Type
1	reset	reset pulse	int

Pin Outputs

Pin	Name	Description	Signal Type
2	output	pseudo random binary sequence	int

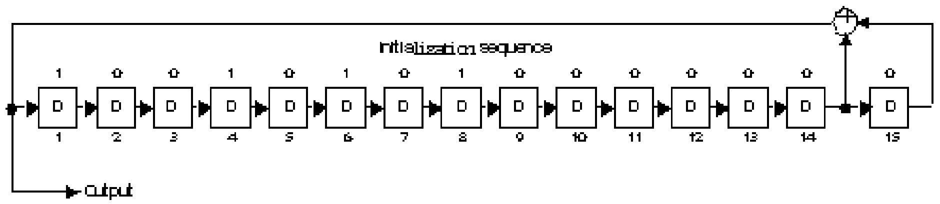
Notes/Equations

1. This model generates a pseudo-random binary sequence with less than 32 internal shift registers and an external reset pin.
2. This model generates pseudo-random binary sequence for energy dispersal of the TSPs. In the ISDB-T specification, the polynomial for this pseudo-random binary sequence generator is:

   $$g(x) = x^{15} + x^{14} + 1$$

   At the start of every OFDM frame, the reset signal becomes valid while the internal shift register is initialized to the sequence of 100101010000000. PRBS generation is shown below.

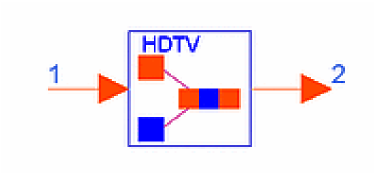
   PRBS Generation



References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.
2. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.

DTV_PuncCoder



Description: Puncture coder
Library: DTV, Channel Coding
Class: SDFDTV_PuncCoder

Parameters

Name	Description	Default	Unit	Type	Range
PuncConvType	punctured convolutional code type: DTV 1/2, DTV 2/3, DTV 3/4, DTV 5/6, DTV 7/8	DTV 1/2		enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	input	input signal to be perforated	anytype

Pin Outputs

Pin	Name	Description	Signal Type
2	output	output signal after perforated	anytype

Notes/Equations

1. This model perforates the input convolutional code to produce a punctured convolutional code. Each firing, *K* tokens are consumed and *N* tokens are produced; *K* and *N* are determined based on code type; refer to the table below.

K and N Values

PuncConvType	K (No. of Input Bytes)	N (No. of Output Bits)
DTV 1/2	2	2
DTV 2/3	4	3
DTV 3/4	6	4
DTV 5/6	10	6
DTV 7/8	14	8

2. Punctured convolutional code is usually generated by perforate a mother convolutional code according to a certain pattern to achieve a different data rate. This model determines the perforation pattern according to the code type chosen, then reads the input convolutional coded bits and outputs the input bit or discards it according to the pattern in the table below.

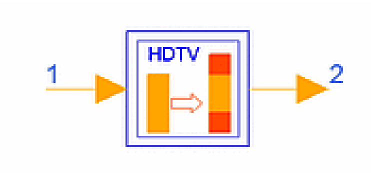
Puncture Pattern and Transmit Sequence

PuncConvType	Puncture Pattern	Transmit Sequence
DTV 1/2	2	2
DTV 2/3	4	3
DTV 3/4	6	4
DTV 5/6	10	6
DTV 7/8	14	8

References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.
2. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.

DTV_PuncConvCoder



Description: Punctured convolutional encoder
Library: DTV, Channel Coding
Class: SDFDTV_PuncConvCoder

Parameters

Name	Description	Default	Unit	Type	Range
PuncConvType	punctured convolutional code type: DTV_1_2, DTV_2_3, DTV_3_4, DTV_5_6, DTV_7_8	DTV_1_2		enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	input	signal to be encoded	int

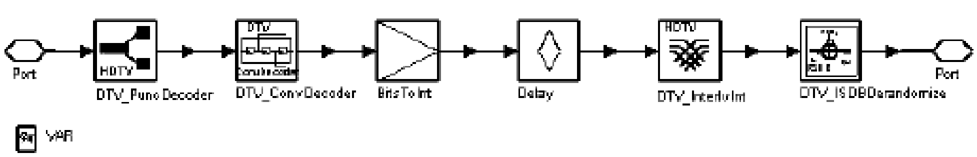
Pin Outputs

Pin	Name	Description	Signal Type
2	output	encoded signal	int

Notes/Equations

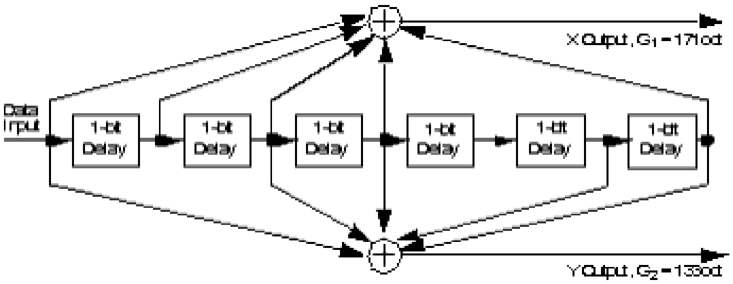
1. This subnetwork model performs punctured convolutional encoding. The schematic for this subnetwork is shown below.

DTV_PuncConvCoder Schematic



2. This subnetwork converts byte input data into bit streams and uses a general convolutional coding model to encode them into the mother convolutional code of data rate 1/2.
A puncture encoder generates the punctured convolutional code. PuncConvType specifies the type of DTV punctured convolutional code.
The encoder is shown below.

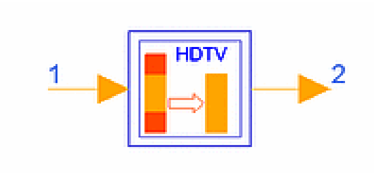
Mother Convolutional Code of Rate 1/2 (Constraint Length=7)



References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.

DTV_PuncConvDecoder



Description: Punctured convolutional decoder
Library: DTV, Channel Coding
Class: SDFDTV_PuncConvDecoder

Parameters

Name	Description	Default	Unit	Type	Range
PuncConvType	punctured convolutional code type: DTV_1_2, DTV_2_3, DTV_3_4, DTV_5_6, DTV_7_8	DTV_1_2		enum	
NumBits	number of soft decision bits	4		int	[1, ∞)
SymbolLen	path memory truncation length	8		int	[1, ∞)
DelayBit	number of bits to delay for delay adjustment	0		int	[0, ∞)†
DelayByte	number of bytes to delay for delay adjustment	0		int	[-∞, 204 - SymbolLen]
DelayCC	number of bits to delay before Viterbi decoder	0		int	[0, ∞)††

† In ISDB and DVB, DelayBit=0
†† In ISDB and DVB, DelayCC=0

Pin Inputs

Pin	Name	Description	Signal Type
1	input	signal to be decoded	int

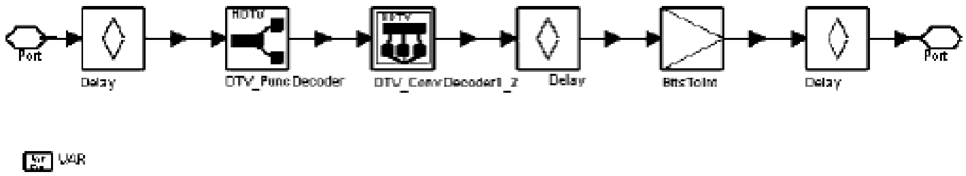
Pin Outputs

Pin	Name	Description	Signal Type
2	output	decoded signal	int

Notes/Equations

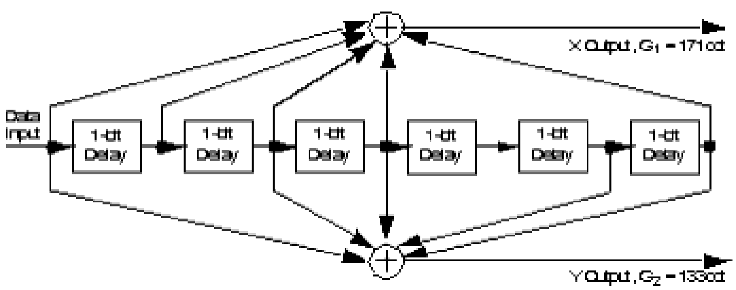
1. This subnetwork model performs punctured convolutional decoding of data rate 1/2 over the input signal. The schematic for this subnetwork is shown below.

DTV_PuncConvDecoder Schematic



2. A puncture decoder model is used to decode the punctured convolutional encoded input to normal convolutional coded data. A general Viterbi convolutional decoding model is used to further decode it. After decoding, bit delay adjustment is performed, bits are packed to bytes and, if necessary, a byte delay adjustment is applied before output.
   The data rate of the mother convolutional code is 1/2.
   The encoder is shown below.

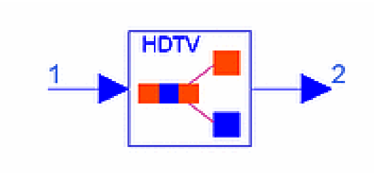
Mother Convolutional Code of Rate 1/2 (Constraint Length=7)



References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.
2. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.

DTV_PuncDecoder



Description: Puncture decoder
Library: DTV, Channel Coding
Class: SDFDTV_PuncDecoder

Parameters

Name	Description	Default	Unit	Type	Range
PuncConvType	Punctured convolutional code type: DTV 1/2, DTV 2/3, DTV 3/4, DTV 5/6, DTV 7/8	DTV 1/2		enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	input	input signal to be refilled	real

Pin Outputs

Pin	Name	Description	Signal Type
2	output	output signal after refilled	real

Notes/Equations

1. This model completes the inverse procedure of the puncture coder that was perforated during puncture encoding. Each firing, *K* tokens are consumed at the input and *N* tokens are produced according to the table below.

   K and N Values

PuncConvType	K	N
DTV 1/2	2	2
DTV 2/3	4	3
DTV 3/4	6	4
DTV 5/6	10	6
DTV 7/8	14	8

2. This model interpolates a zero value to the punctured data stream to form a full-length data stream. The perforation pattern, based on PuncConvType, then interpolates zero into the input bits to form the output according to the pattern in the table below.

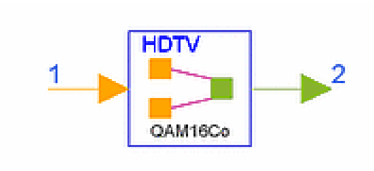
Puncture Pattern and Transmit Sequence

PuncConvType	Puncture Pattern	Transmit Sequence
DTV 1/2	2	2
DTV 2/3	4	3
DTV 3/4	6	4
DTV 5/6	10	6
DTV 7/8	14	8

References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.
2. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.

DTV_QAM16Coder



Description: Uniform and non-uniform 16-QAM encoder for DVB-T and ISDB-T
Library: DTV, Channel Coding
Class: SDFDTV_QAM16Coder

Parameters

Name	Description	Default	Unit	Type	Range
Alpha	non-uniform factor for DVB-T.	1		int	[1, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	input	input data bits	int

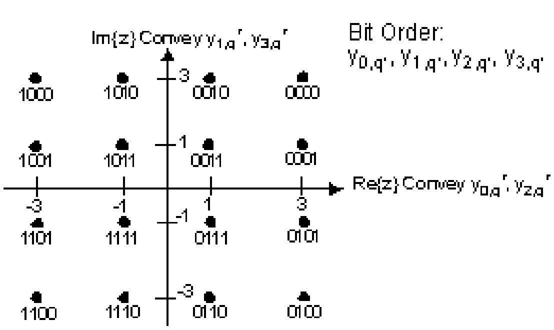
Pin Outputs

Pin	Name	Description	Signal Type
2	output	signal after constellation mapping	complex

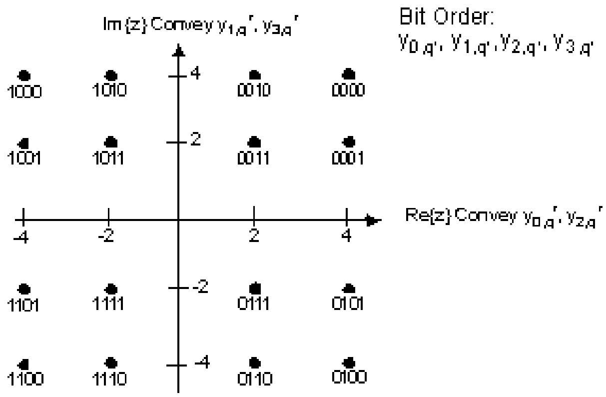
Notes/Equations

1. This model performs 16-QAM mapping and non-uniform 16-QAM Gray mapping.
2. This model groups the input data bits to 4-bit groups and maps them into a complex signal from the 16-QAM constellation (shown in Uniform and Non-Uniform 16-QAM with Alpha = 1 Mapping and Corresponding Bit Pattern), or maps them into a complex signal from the non-uniform 16-QAM constellation, (shown in Non-Uniform 16-QAM with Alpha = 2 Mapping and Corresponding Bit Pattern and Non-Uniform 16-QAM with Alpha = 4 Mapping and Corresponding Bit Pattern).

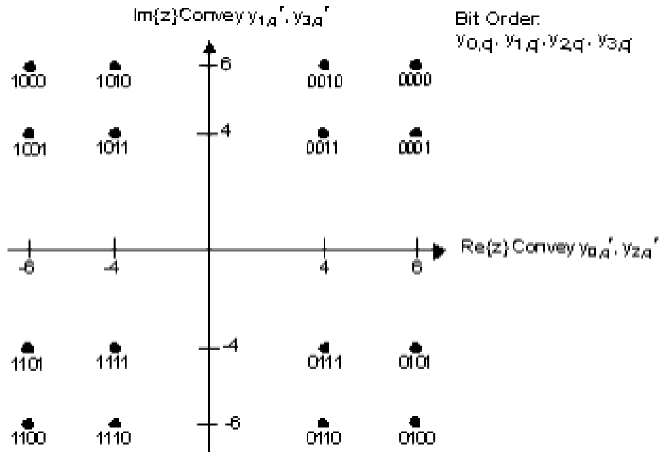
Uniform and Non-Uniform 16-QAM with Alpha = 1 Mapping and Corresponding Bit Pattern



Non-Uniform 16-QAM with Alpha = 2 Mapping and Corresponding Bit Pattern



Non-Uniform 16-QAM with Alpha = 4 Mapping and Corresponding Bit Pattern



After mapping, the output signal is normalized by a normalization factor *c*, the value of *c* is:

$$
\begin{cases}
c = \dfrac{z}{\sqrt{10}}, \alpha = 1 \\
c = \dfrac{z}{\sqrt{20}}, \alpha = 2 \\
c = \dfrac{z}{\sqrt{52}}, \alpha = 4
\end{cases}
$$

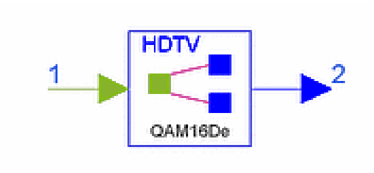
where z is the complex signal from 16-QAM and non-uniform 16-QAM constellation.

References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.
2. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European

Telecommunication Standard, July 1999.

DTV_QAM16Decoder



Description: Uniform and non-uniform 16-QAM decoder for DVB-T and ISDB-T
Library: DTV, Channel Coding
Class: SDFDTV_QAM16Decoder

Parameters

Name	Description	Default	Unit	Type	Range
Alpha	non-uniform factor for DVB-T.	1		int	[1, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	input	signal to be demodulated	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	output	signal after demodulation	real

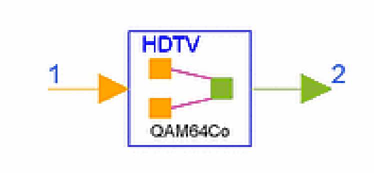
Notes/Equations

1. This model performs 16-QAM de-mapping and non-uniform 16-QAM Gray de-mapping; it is the reverse of the process for DTV_QAM16Coder.
2. This model de-maps the input complex QAM signal data to floating-point data for Viterbi convolutional decoding according to 16-QAM or non-uniform 16-QAM mapping constellation.

References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.
2. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.

DTV_QAM64Coderc



Description: Uniform and non-uniform 64-QAM encoder for DVB-T and ISDB-T
Library: DTV, Channel Coding
Class: SDFDTV_QAM64Coder

Parameters

Name	Description	Default	Unit	Type	Range
Alpha	non-uniform factor for DVB-T.	1		int	[1, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	input	input data bits	int

Pin Outputs

Pin	Name	Description	Signal Type
2	output	signal after constellation mapping	complex

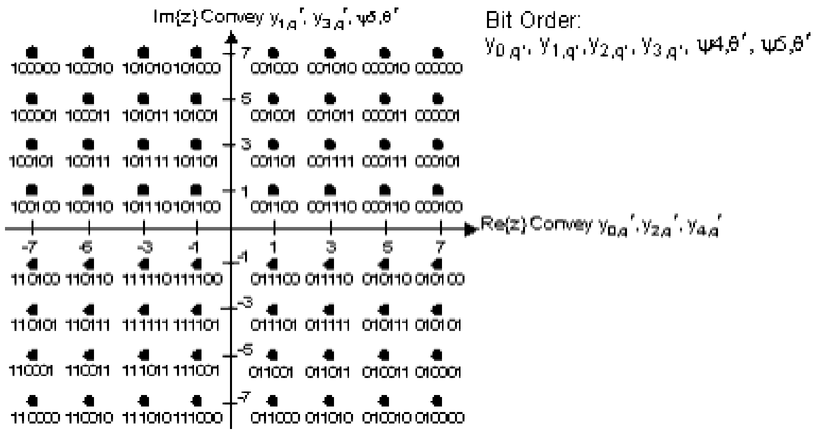
Notes/Equations

1. This model performs 64-QAM mapping and non-uniform 64-QAM Gray mapping.
2. This model groups the input data bits to 6-bit groups and maps them into a complex signal from the 64-QAM constellation (shown in Uniform 64-QAM and Non-Uniform 64-QAM with Alpha = 1 Mapping and Corresponding Bit Pattern), or maps them into a complex signal from non-uniform 64-QAM constellation (shown in Non-Uniform 64-QAM with Alpha = 2 Mapping and Corresponding Bit Pattern and Non-uniform 64-QAM with Alpha = 4 Mapping and Corresponding Bit Pattern).
After mapping, the output signal is normalized by normalization factor *c*, the value of *c* is:

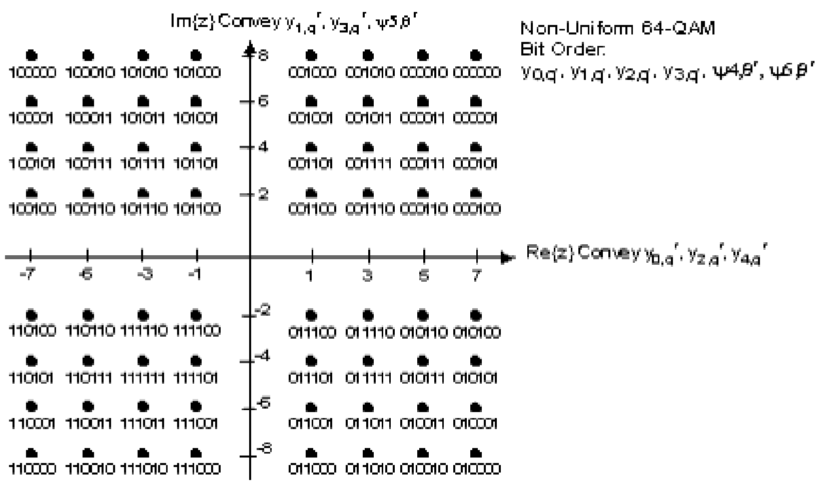
$$\begin{cases} c = \dfrac{z}{\sqrt{42}} & ,\alpha = 1 \\ c = \dfrac{z}{\sqrt{60}} & ,\alpha = 2 \\ c = \dfrac{z}{\sqrt{108}} & ,\alpha = 4 \end{cases}$$

where *z* is the complex signal from 64-QAM and non-uniform 64-QAM constellation.

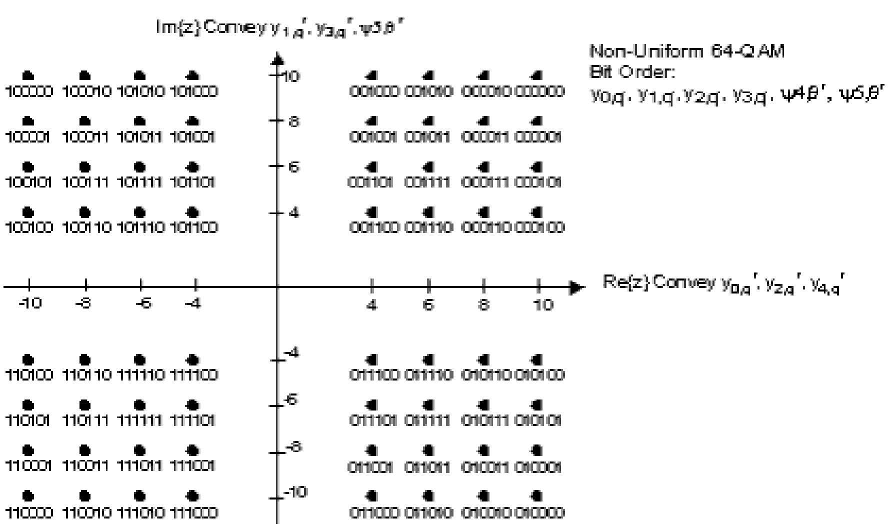
Uniform 64-QAM and Non-Uniform 64-QAM with Alpha = 1 Mapping and Corresponding Bit Pattern



Non-Uniform 64-QAM with Alpha = 2 Mapping and Corresponding Bit Pattern



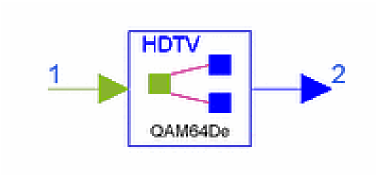
Non-uniform 64-QAM with Alpha = 4 Mapping and Corresponding Bit Pattern



References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.
2. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.

DTV_QAM64Decoder



Description: Uniform and non-uniform 64-QAM decoder for DVB-T and ISDB-T
Library: DTV, Channel Coding
Class: SDFDTV_QAM64Decoder

Parameters

Name	Description	Default	Unit	Type	Range
Alpha	non-uniform factor for DVB-T.	1		int	[1, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	input	signal to be demodulated	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	output	signal after demodulation	real

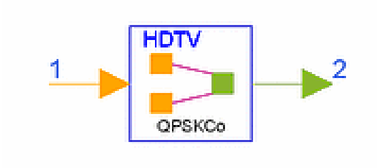
Notes/Equations

1. This model performs 64-QAM de-mapping and non-uniform 64-QAM Gray de-mapping; it is the reverse of the process for DTV_QAM64Coder.
2. This model de-maps the input complex QAM signal data to floating-point data for Viterbi convolutional decoding according to 64-QAM or non-uniform 64-QAM mapping constellation.

References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.
2. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.

DTV_QPSKCoder



Description: QPSK coder
Library: DTV, Channel Coding
Class: SDFDTV_QPSKCoder

Pin Inputs

Pin	Name	Description	Signal Type
1	input	input data bits	int

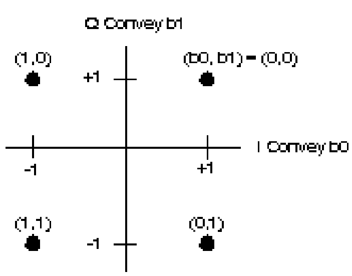
Pin Outputs

Pin	Name	Description	Signal Type
2	output	signal after constellation mapping	complex

Notes/Equations

1. This model performs QPSK constellation mapping and modulation.
2. This model groups the input data bits to 2-bit groups and maps them into complex data according to the QPSK constellation shown below.

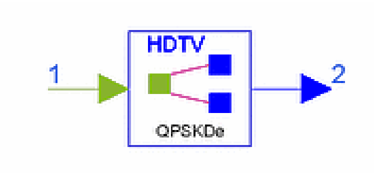
QPSK Mapping and Corresponding Bit Patterns



References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.
2. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.

DTV_QPSKDecoder



Description: QPSK decoder
Library: DTV, Channel Coding
Class: SDFDTV_QPSKDecoder

Pin Inputs

Pin	Name	Description	Signal Type
1	input	signal to be demodulated	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	output	signal after demodulation	real

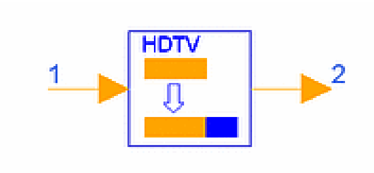
Notes/Equations

1. This model performs QPSK demodulation; it is the reverse of the process for DTV_QPSKCoder.
2. This model maps the input complex QPSK signal data to floating-point data for Viterbi convolutional decoding according to the QPSK mapping constellation.

References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.
2. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.

DTV_RSCoder



Description: Reed-Solomon encoder
Library: DTV, Channel Coding
Class: SDFDTV_RSCoder

Parameters

Name	Description	Default	Symbol	Unit	Type	Range
M	Galois field (2^M) size definition	8	M		int	[2, 16]
K	input code word length	188	K		int	(N-K, N)
N	output word size (K+parity)	204	N		int	[1, 2^M - 1]
DataSequence	data array sequence: Forward, Reverse	Forward			enum	
SpacePlace	place of zero byte (00h) in data array: Head, Tail	Head			enum	
ParitySequence	parity array sequence: forward, reverse	forward			enum	
Encode47H	place 47H in data array: yes, no	yes			enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	input	signal to be encoded	int

Pin Outputs

Pin	Name	Description	Signal Type
2	output	error protected signal	int

Notes/Equations

1. This model performs shortened Reed-Solomon error correcting encoding over the input signal for DVB-T and ISDB-T systems.
   Each firing, *K* tokens are consumed at the input pin and *N* tokens are produced. For the shortened code, $(2^M - 1 - N)$ zero symbols are added in the information symbols and *N* - *K* parity symbols are generated. *N* - *K* parity symbols are appended to the input signal to form the output.
   If DataSequence = Forward, the order of symbols to be encoded is the same as their input order; otherwise, the order is the reverse of their input order.
   If SpacePlace = Head, zero symbols are added before the information symbols; otherwise, they are added behind the information symbols.
   If ParitySequence = forward, the output order of parity symbols is the same as the original order when they are generated; otherwise, the order is reverse of the original order.
   If Encode47H = yes, the first byte 47H, the sync byte of every Transport Stream

Packet (TSP) is treated as the information symbol and encoded; otherwise, it is not encoded and the number of zero symbols added is changed to ($2^M - N$).
Values in DVB-T and ISDB-T are: DataSequence=Forward, SpacePlace=Head, ParitySequence=forward, Encode47H=yes.

2. The value range of the input data is [0, $2^M - 1$].
3. Galois field generator polynomial is automatically selected according to the value of *M*.
4. Implementation

The code format is: RS code (*n*, *k*), defined on Galois Field (2^m).

Galois Field Generator

Galois fields are set up depending on the number of bits per symbol and the number of symbols per block.

Algorithm

Generate GF (2^m) from the non-reducible primitive polynomial. It is defined as the polynomial of least degree, with coefficients in GF(2) and a highest degree coefficient equal to 1. The polynomial is always degree *m*.

The elements of Galois field can have two representations: exponent or polynomial.

Let α represent the root of the primitive polynomial *p(x)*. Then in GF(2^m), for any $0 \le i \le 2^m - 2$

$$\alpha^i = b_i(0) + b_i(1)\alpha + b_i(2)\alpha^2 + \cdots + b_i(m-1)\alpha^{m-1}$$

where the binary vector (b_i (0), b_i (1), ... , b_i (m-1)) is the representation of the integer *polynomial[i]*. Now *exponent[i]* is the element whose polynomial representation is (b_i (0), b_i (1), ... , b_i (m-1)), and *exponent[polynomial[i]]=i*.

The polynomial representation is convenient for addition while the exponent representation for multiplication.

RS Encoder

The RS generator polynomial is more generally defined as

$$g(x) = (x - \alpha^{m_0})(x - \alpha^{m_0+1})\ldots(x - \alpha^{m_0+2t-1})$$

where t is the correctable error number. It can be reduced to a 2t order of polynomial

$$g(x) = x^{2t} + g_{2t-1}x^{2t-1} + \ldots + g_0$$

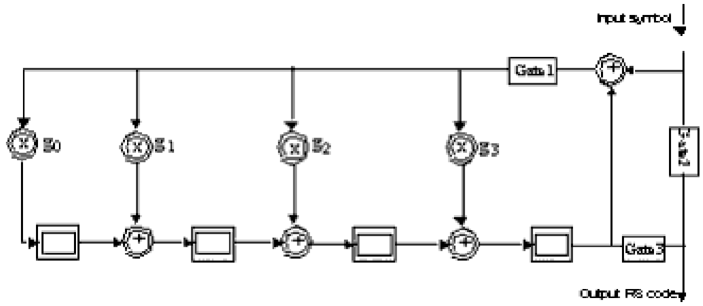
The encoding is done by using a feedback shift register with appropriate connections specified by the element g_i. The encoded symbol is then

$$in(x) \times x^{(n-k)} + parity(x)$$

where *in(x)* is the polynomial representation of the input data, *parity(x)* is the polynomial of the parity symbol.

The RS encoder diagram is shown below.

Reed Solomon Encoder



5. Field generator polynomial of DVB-T is

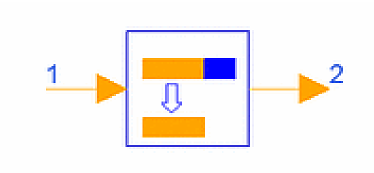
$$p(x) = x^8 + x^4 + x^3 + x^2 + 1$$

The shortened Reed-Solomon code is implemented by adding 51 bytes, all set to zero, before the information bytes at the input of an RS (255,239, t = 8) encoder. After RS coding, these null bytes are discarded, leading to an RS code word of N=204 bytes.

References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.
2. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.

DTV_RSDecoder



Description: Reed-Solomon decoder
Library: DTV, Channel Coding
Class: SDFDTV_RSDecoder

Parameters

Name	Description	Default	Symbol	Unit	Type	Range
M	Galois field (2^M) size definition	8	m		int	[2, 16]
K	size of output block (data)	188	k		int	(N-K, N)
N	size of input block (data + parity)	204	n		int	[1, 2^M - 1]
Error	stop simulation option	0			int	[0, ∞)†
DataSequence	data array sequence: Forward, Reverse	Forward			enum	
SpacePlace	place of zero byte (00h) in data array: Head, Tail	Head			enum	
ParitySequence	parity array sequence: forward, reverse	forward			enum	
Encode47H	place 47H in data array: yes, no	yes			enum	

† When Error>0, simulation will stop if the number of received uncorrectable RS packets is larger than the number specified.

Pin Inputs

Pin	Name	Description	Signal Type
1	input	signal to be decoded	int

Pin Outputs

Pin	Name	Description	Signal Type
2	output	decoded signal	int

Notes/Equations

1. This model performs Reed-Solomon error correcting decoding over the input signal. Each firing, N tokens are consumed at the input port and K tokens are produced. If DataSequence = Forward, the order of symbols to be decoded is the same as their input order; otherwise, the order is the reverse of their input order.
   If SpacePlace = Head, $(2^M - 1 - N)$ zero symbols are added before the information symbols before decoding; otherwise, they are added behind the information symbols. If ParitySequence = forward, the input order of parity symbols is the same as the order needed in decoding; otherwise, the order is reverse of the decoding order.

If Encode47H = yes, the first byte 47H, the sync byte of every Transport Stream Packet (TSP) is treated as the information symbol and decoded; otherwise, it is not decoded and the number of zero symbols added is changed to ($2^M - N$).
Values in DVB-T and ISDB-T are: DataSequence=Forward, SpacePlace=Head, ParitySequence=forward, Encode47H=yes.

2. Galois field generator polynomial is automatically selected according to the value of *M*.
3. Implementation

Decoding Routines

For the shortened code, the same number of zero symbols is inserted into the same position as in the RS encoder, and a Reed-Solomon decoder is used to decode the block. After decoding, the padded symbols are discarded leaving the desired information symbols.

Getting Syndromes

Syndromes indicate an erroneous situation. When the generator polynomial *g(x)* and the received code word *r(x)* are given, the occurrence of one or more errors during transmission of an encoded block is known.
Let

$$v(x) = v_0 + v_1x + v_2x^2 + \ldots + v_{n-1}x^{n-1}$$

where *v(x)* is the polynomial representation of the transmitted symbol.

$$r(x) = r_0 + r_1x + r_2x^2 + \ldots + r_{n-1}x^{n-1}$$

where *r(x)* is the polynomial representation of the received symbol.
Then

$$r(x) = v(x) + e(x)$$

where *e(x)* denotes the error patterns. If $r_i = v_i$, then $e_i = 0$; else $e_i = 1$.

Remember,

$$v(x) = g(x)Q(x)$$

where *Q(x)* is the quotient.

So, if α^i is the root of *g(x)*, then

$v(\alpha^i) = 0$ and $r(\alpha^i) = e(\alpha^i)$

To check the occurrence of errors at the receiver, calculate syndromes *s(i)*; the syndromes are determined by the error patterns

$$s(i) = e(\alpha^{m_0 + i})$$

If one or more of the syndromes are not equal to 0, one or more symbol errors occur in the received data. For example, if

$\alpha^{m_0}, \alpha^{m_0+1}, \ldots, \alpha^{m_0+2t-1}$ are roots of *g(x)*, then

$$s(1) = r(\alpha^{m_0})$$

$$s(2) = r(\alpha^{m_0+1})$$

.

.

.

$$s(2t) = r(\alpha^{m_0+2t-1})$$

Use the syndromes to find the error location polynomial.
Given the syndromes *s(i)*, the decoding algorithm will synthesize an error location polynomial. The roots of the polynomial indicate the error positions. Assuming the received symbols have v symbol errors, the syndromes are represented as follows.

$$s(1) = \beta_1^{m_0} + \beta_2^{m_0} + \ldots + \beta_v^{m_0}$$

$$s(2) = \beta_1^{m_0+1} + \beta_2^{m_0+1} + \ldots \beta_v^{m_0+1}$$

.
.
.

$$s(2t) = \beta_1^{m_0+2t-1} + \beta_2^{m_0+2t-1} + \ldots \beta_v^{m_0+2t-1}$$

where

$$\beta_l = a^{i_l}$$

and

$$a^{i_l}(1 \le l \le v)$$

is the error location and m_0 can be any integer. (Generally, m_0 is 0 or 1.)

Now the error location polynomial is defined as

$$\Omega(x) = (1 + \beta_1^{m_0}x)(1 + \beta_2^{m_0}x)\ldots(1 + \beta_v^{m_0}x)$$
$$= \Omega_0 + \Omega_1 x + \Omega_2 x^2 + \ldots + \Omega_v x^v$$

The Berlekamp iterative algorithm is used to construct this polynomial, which is the key to RS decoding. (The algorithm is described here without proof. For more information, refer to Reference [3]). An iterative table will be filled as shown in the table below.

Berlekamp Iterative Table

μ	$\Omega^{(\mu)}(x)$	d_μ	l_μ	$\mu - l_\mu$
−1	1	1	0	−1
0	1	s_1	0	0
1				
2				
...				
2t				

Where μ is the iterative step number, d^μ is the μ th step iterative difference, l^μ is the order of $\Omega^{(\mu)}$ *(x)*.

If d^μ = 0 then

$$\Omega_\mu^{(\mu+1)}(x) = \Omega_\mu^{(\mu)}(x)$$

and

$$l_{\mu+1} = l_\mu.$$

If $d^\mu \neq 0$, search for lines in the table to find step ρ in which $d\rho \neq 0$ and the value of ρ - $l\rho$ is the maximum, then

$$\Omega^{(\mu+1)}(x) = \Omega^{(\mu)}(x) - d_\mu d_\rho^{-1} x^{(\mu-\rho)} \Omega^{(\rho)}(x)$$

and

$$l_{\mu+1} = max(l_\mu, l_\rho + \mu - \rho).$$

For the two conditions

$$d_{\mu+1} = s_{\mu+2} + \Omega_1^{(\mu+1)} s_{\mu+1} + \ldots + \Omega_{l_\mu+1}^{(\mu+1)} s_{\mu+2-l_{\mu+1}}$$

Iterate until the last line of the table $\Omega^{(2t)}(x)$ is determined. If the order of the polynomial is greater than *t*, which means the received codeword block has more than *t* errors, the error cannot be corrected.

Determining Error Values

In the case of non-binary codes, error values must be known. Error values will be solved and corrected, unless the order of the error location polynomial is greater than t, in which case uncorrected information symbols will not be used.

The minimum order polynomial is found by iterating and solved to obtain the least number of roots (error location number). The inverse element of the root indicates the error location.

The error value is determined by the equation from Reference [3]:

$$e_{jl} = \beta_l^{(1-m_0)} \frac{z(\beta_l^{-1})}{\prod_{i=1}^{v} (1 + \beta_i \beta_l^{-1})}$$

where

$$z(x) = 1 + (s_1 + \Omega_1)x + (s_2 + \Omega_1 s_1 + \Omega_2)x^2 + \ldots + (s_v + \Omega_1 s_{v-1} + \Omega_2 s_{v-2} + \ldots + \Omega_v)x^v$$

then

$$out(x) = r(x) - e(x)$$

4. The field generator polynomial of DVB-T and ISDB-T is

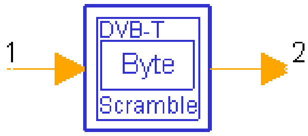
$$p(x) = x^8 + x^4 + x^3 + x^2 + 1$$

The shortened RS code is implemented by adding 51 bytes, all set to zero, before information bytes at the input of an RS (255,239, t=8) encode. After RS decoding null bytes are discarded, leading to an RS decode word of K=188 bytes.

References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.
2. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.
3. E.R. Berlekamp, *Algebraic Coding Theory*, McGraw-Hill, New York, 1968.

DTV_ScrambleByte



Description: Byte scrambler
Library: DTV, Channel Coding
Class: SDFDTV_ScrambleByte

Parameters

Name	Description	Default	Unit	Type	Range
Delay	number of bits to delay for delay adjustment	8		int	[0, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	input	signal to be encoded	int

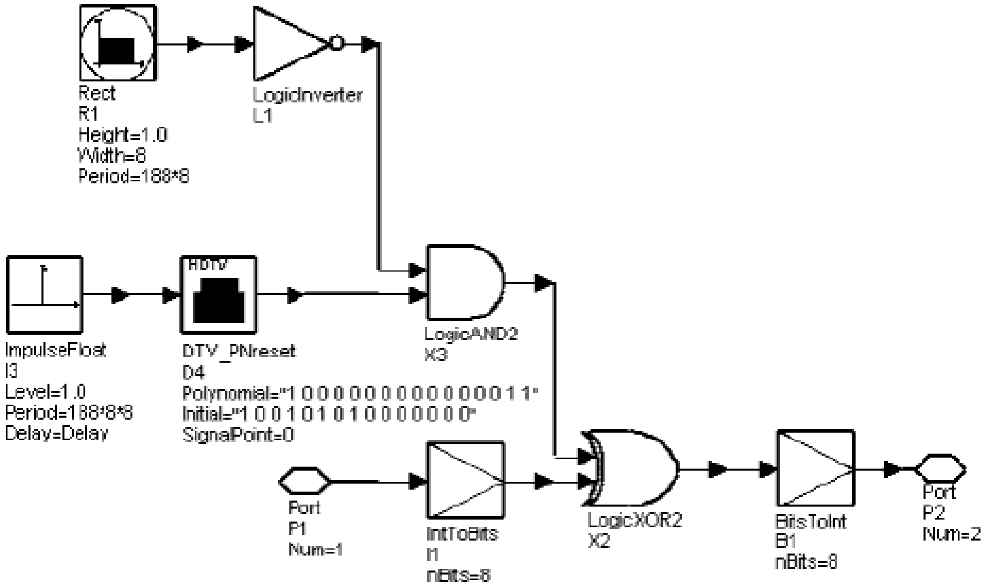
Pin Outputs

Pin	Name	Description	Signal Type
2	output	encoded signal	int

Notes/Equations

1. This subnetwork model randomizes the MPEG-2 transport MUX packet, which is 188 bytes.
   The schematic for this subnetwork is shown below.

DTV_ScrambleByte Schematic



2. The polynomial for the pseudo-random binary sequence generator is:

$$g(x) = x^{15} + x^{14} + 1$$

The first one-sync word byte is unrandomized. Loading of the sequence 100101010000000 into the PRBS registers is initiated at the start of each of the 8 transport packets.

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.

DTV Design Examples

- *DVB-H System Design Examples* (dtv)
- *DVB-T Receiver Design Examples* (dtv)
- *DVB-T System Design Examples* (dtv)
- *ISDB-T System Design Examples* (dtv)

DVB-H System Design Examples

DVB-H design examples can be accessed from the ADS Main window *File > Open > Example > DTV*. Schematics and simulation results for designs in *DTV_DVBH_wrk* are described in this section.

Hierarchical system design:

- DTV_DVBH_Demo_Hierarchical

Non-hierarchical system design:

- DTV_DVBH_Demo_Non-Hierarchical

DTV DVB-H Hierarchical Transmission

DTV_DVBH_Demo_Hierarchical

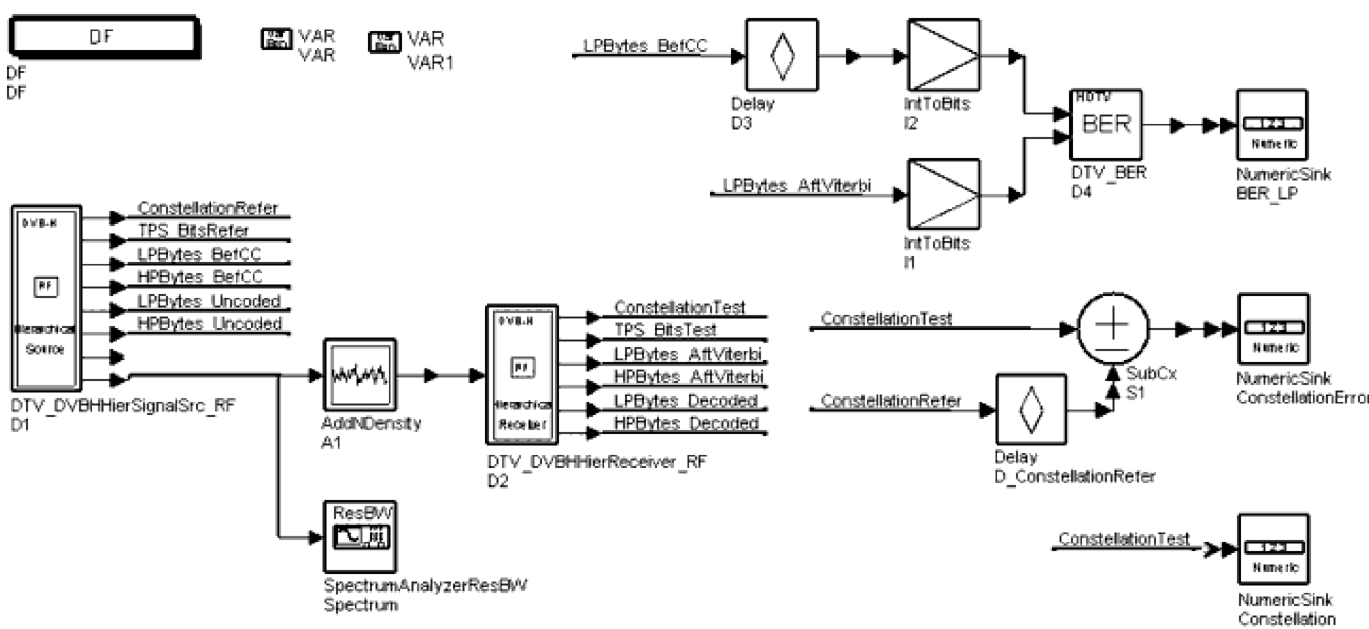
Features

- Mode: 4k
- MappingMode: 64QAM
- Inner interleaving: in-depth
- High priority inner code rate: 2/3
- Low priority inner code rate: 5/6
- Guard interval: 1/16
- Oversampling ratio: 1

Description

This design is a hierarchical transmission example of DVB-H spectrum, constellation, and MER and BER measurements under an AWGN channel.
The schematic for this design is shown below.

DTV_DVBH_Demo_Hierarchical Schematic



Parameters that can be changed by users are contained in VAR.

VAR1 contains delays needed for MER and BER measurements.

For BER measurements after Reed-Solomon decoding, users should:

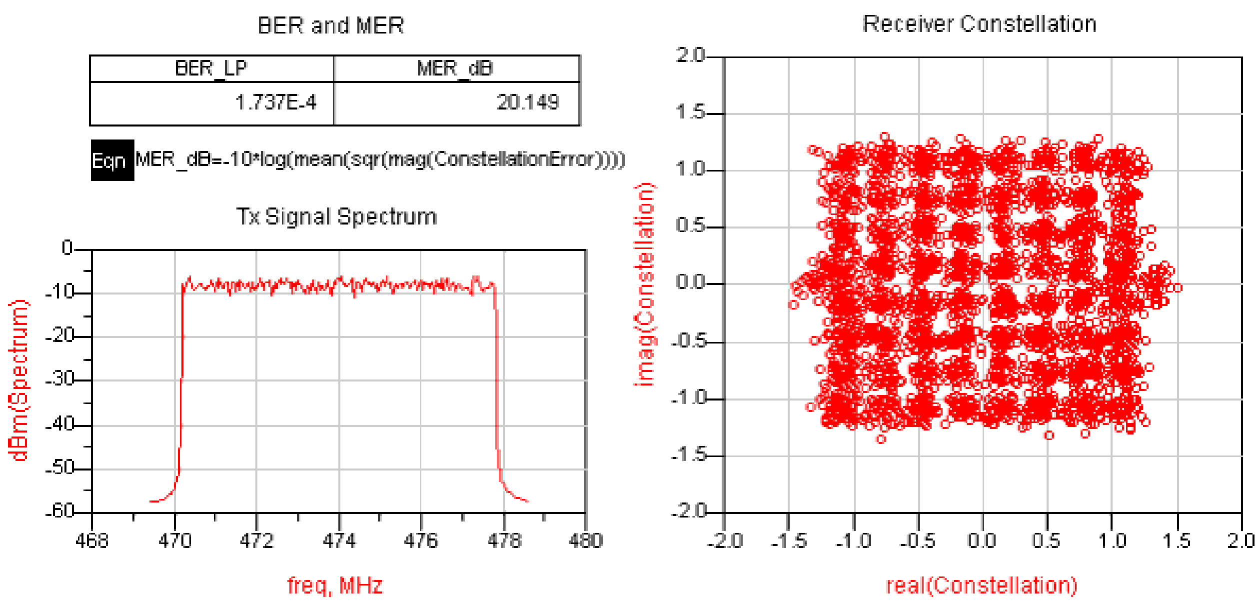
- Replace the Delay D3 component input signal LPBytes_BefCC with LPBytes_Uncoded.
- Replace IntToBits I1 input signal LPBytes_AftViterbi with LPBytes_Decoded.
- Replace DTV_BER and NumericSink BER_LP delay parameter settings Delay_AftVB_LP × 2 with Delay_AftDescramble_LP.
- Replace NumericSink BER_LP delay setting of 1e5 with a value greater than 1e6.

For high priority stream BER measurements, users should replace all *LP* with *HP*.

Simulation Results

Simulation is under an AWGN channel with a carrier-to-noise ratio of 21.4 dB. Simulation results saved in DTV_DVBH_Demo_Hierarchical.dds are shown below.

Simulation Results



Benchmark

- Hardware Platform: Pentium IV 2.26 GHz, 512 MB memory
- Software Platform: Windows 2000, ADS 2004A
- Simulation Time: approximately 1 minute

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.5.1, European Telecommunication Standard, November 2004.

DTV DVB-H Non-Hierarchical Transmission

DTV_DVBH_Demo_Non_Hierarchical

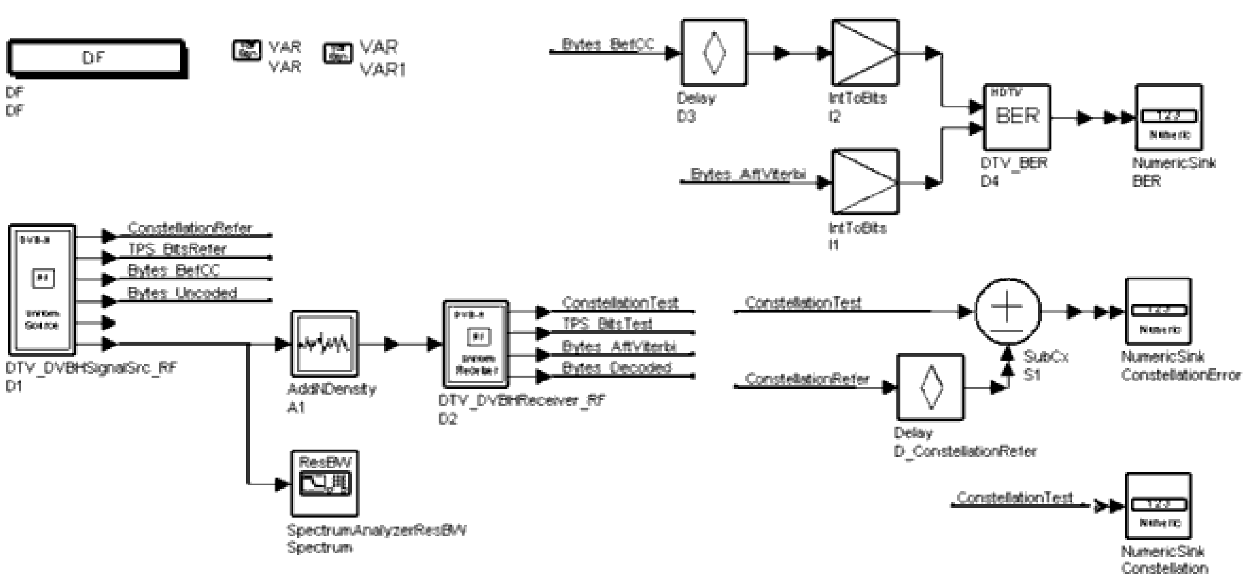
Features

- Mode: 4k
- MappingMode: QPSK
- Inner interleaving: in-depth
- Inner code rate: 1/2
- Guard interval: 1/16
- Oversampling ratio: 1

Description

This design is a non-hierarchical transmission example of DVB-H spectrum, constellation, and MER and BER measurements under an AWGN channel.
The schematic for this design is shown below.

DTV_DVBH_Demo_Non_Hierarchical Schematic



Parameters that can be changed by users are contained in VAR.

VAR1 contains delays needed for MER and BER measurements.

For BER measurements after Reed-Solomon decoding, users should:

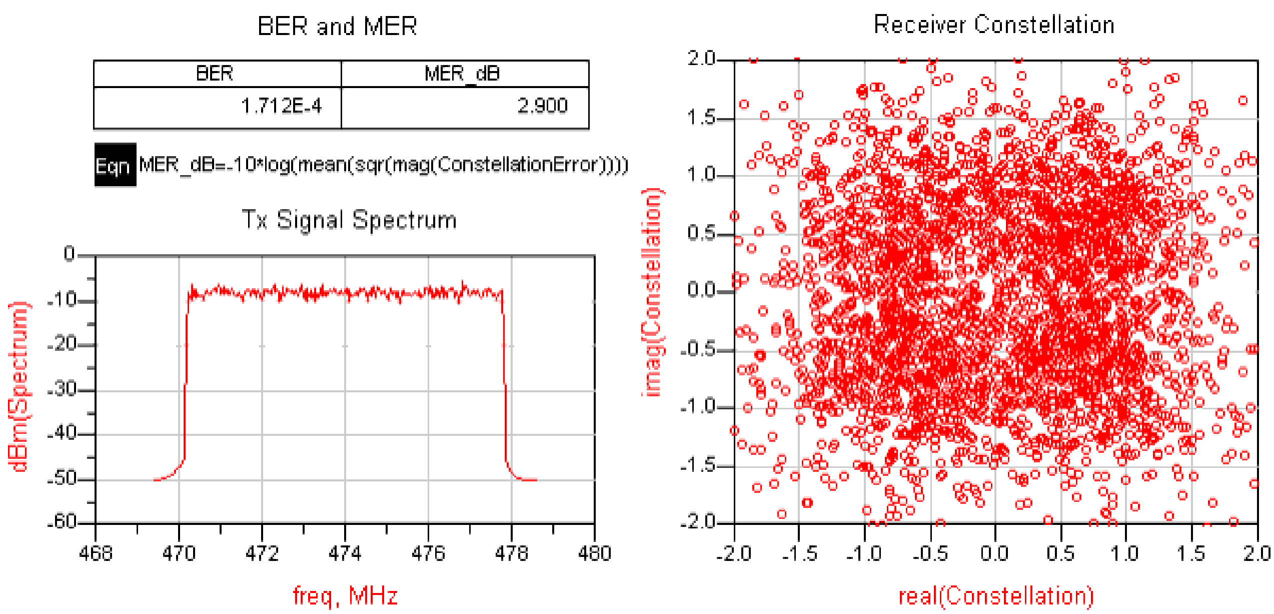
- Replace Delay D3 component input signal Bytes_BefCC with Bytes_Uncoded.
- Replace IntToBits I1 component input signal Bytes_AftViterbi with Bytes_Decoded.

- Replace DTV_BER and NumericSink BER parameter settings Delay_AftVB × 2 with Delay_AftDescramble × 2.
- Replace NumericSink BER delay setting of 1e5 with a value greater than 1e6.

Simulation Results

Simulation is under an AWGN channel with a carrier-to-noise ratio of 4.9 dB. Simulation results saved in DTV_DVBH_Demo_Non_Hierarchical.dds are shown below.

Simulation Results



Benchmark

- Hardware Platform: Pentium IV 2.26 GHz, 512 MB memory
- Software Platform: Windows 2000, ADS 2004A
- Simulation Time: approximately 2 minutes

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.5.1, European Telecommunication Standard, November 2004.

DVB-T Receiver Design Examples

DVB-T receiver design examples can be accessed from the ADS Main window *File > Open > Example > DTV*. Schematics and simulation results for designs in *DTV_DVBT_Rx_wrk* are described in this topic.

Receiver minimum input level sensitivity:

- DTV_DVBT_Rx_Sensitivity_Option1
- DTV_DVBT_Rx_Sensitivity_Option2

AWGN performance:

- DTV_DVBT_Rx_AWGN_Option1
- DTV_DVBT_Rx_AWGN_Option2

Protection ratio for co-channel PAL analog TV:

- DTV_DVBT_Rx_PAL_Cochannel_Option1
- DTV_DVBT_Rx_PAL_Cochannel_Option2

Protection ratio for adjacent channel PAL analog TV:

- DTV_DVBT_Rx_PAL_Adj_Option1
- DTV_DVBT_Rx_PAL_Adjl_Option2

Protection ratio for image channel PAL analog TV:

- DTV_DVBT_Rx_PAL_image_Option1
- DTV_DVBT_Rx_PAL_imagel_Option2

Short delay echo performance:

- DTV_DVBT_Rx_ShortDelay_Option1
- DTV_DVBT_Rx_ShortDelay_Option2

Long delay echo performance:

- DTV_DVBT_Rx_LongDelay_Option1
- DTV_DVBT_Rx_LongDelay_Option2

Single 0dB echo performance:

- DTV_DVBT_Rx_SingleEcho_Option1
- DTV_DVBT_Rx_SingleEcho_Option2

Immunity to impulse interference:

- DTV_DVBT_Rx_Impulse_Option1
- DTV_DVBT_Rx_Impulse_Option2

Multipath performance:

- DTV_DVBT_Rx_Rayleigh_Option1
- DTV_DVBT_Rx_Rayleigh_Option2
- DTV_DVBT_Rx_Ricean_Option1
- DTV_DVBT_Rx_Ricean_Option2

DVB-T AWGN Performance

DTV_DVBT_Rx_AWGN_Option1
DTV_DVBT_Rx_AWGN_Option2

Features: Option 1 Design

- 2K mode
- 64-QAM mapping
- 2/3 coding rate
- 1/32 guard interval
- Signal_Generation_VARs and RF_Channel_Measurement_VARs parameters can be changed by the user

Features: Option 2 Design

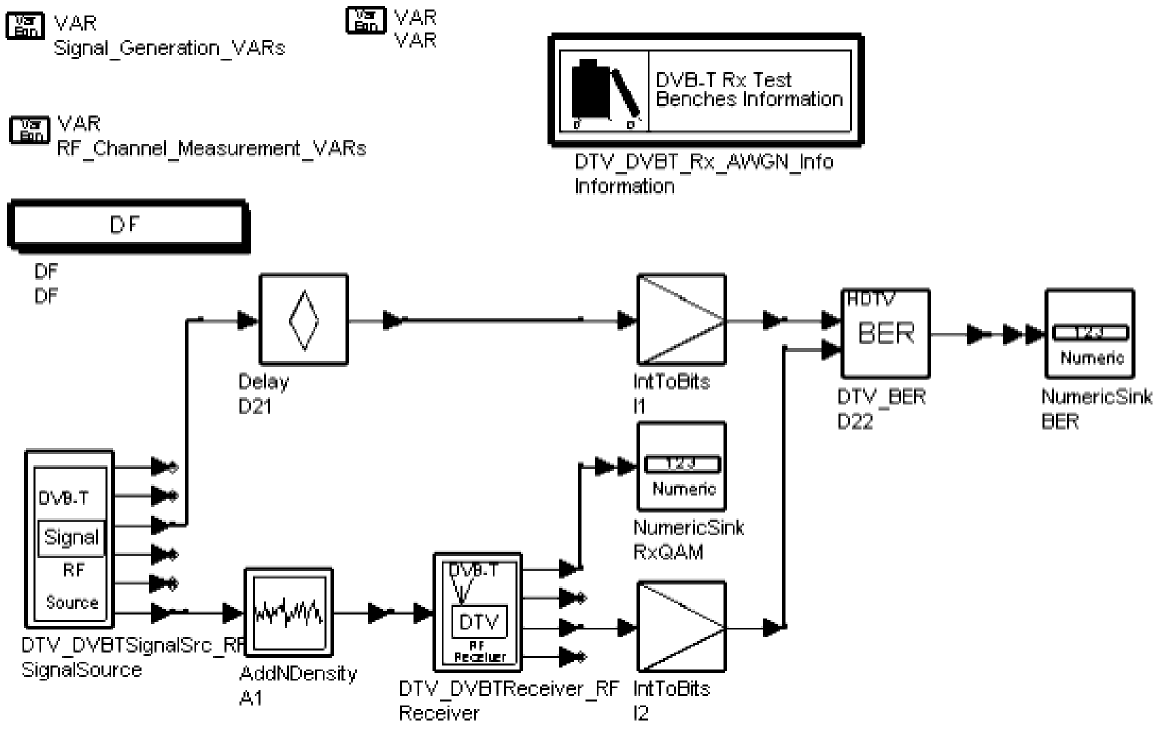
- 2K mode
- 16-QAM mapping
- 3/4 coding rate
- 1/32 guard interval
- Signal_Generation_VARs and RF_Channel_Measurement_VARs parameters can be changed by the user

Description

These designs measure the performance of a DVB-T receiver with AWGN. BER is measured after Viterbi decoding.

The schematic is shown below.

DTV_DVBT_Rx_AWGN Schematic



Simulation Results

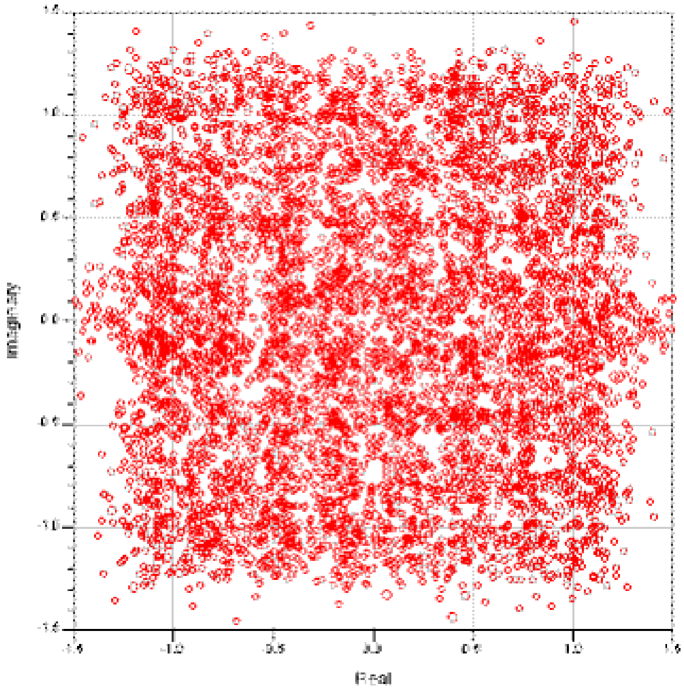
For Option 1, an 18.3 dB carrier-to-noise ratio is used. Simulation results displayed in DTV_DVBT_Rx_AWGN_Option1.dds are shown below.

BER for Option 1

Index	BER
1000	2.995E-4

The demodulated constellations are shown below.

Constellation for Option 1



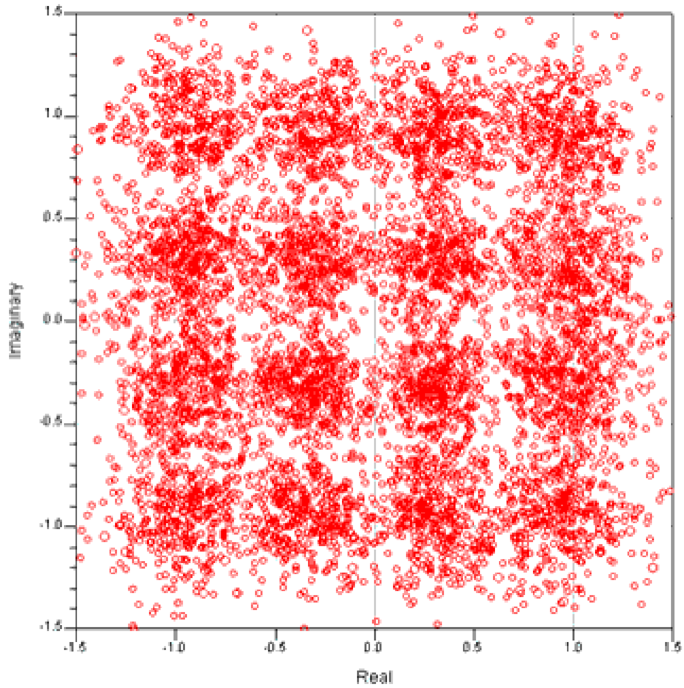
For Option 2, a 13.8 dB carrier-to-noise ratio is used. Simulation results displayed in DTV_DVBT_Rx_AWGN_Option2.dds are shown below.

BER for Option 2

Index	BER
1000	2.489E-4

The demodulated constellation is shown below.

Constellation for Option 2



Benchmark

- Hardware Platform: Pentium IV 2.26 GHz, 512 MB memory
- Software Platform: Windows 2000, ADS 2003C
- Simulation Time: approximately 1 minute

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.
2. DTG RF Sub-Group Document No. 67, *UHF Transmission and Reception*.

DVB-T Digital Adjacent Channel Performance

DTV_DVBT_Rx_Digital_Adj_Option1
DTV_DVBT_Rx_Digital_Adj_Option2

Features: Option 1 Design

- 2K mode
- 64-QAM mapping
- 2/3 coding rate
- 1/32 guard interval
- Signal_Generation_VARs and Measurement_VARs parameters can be changed by the user

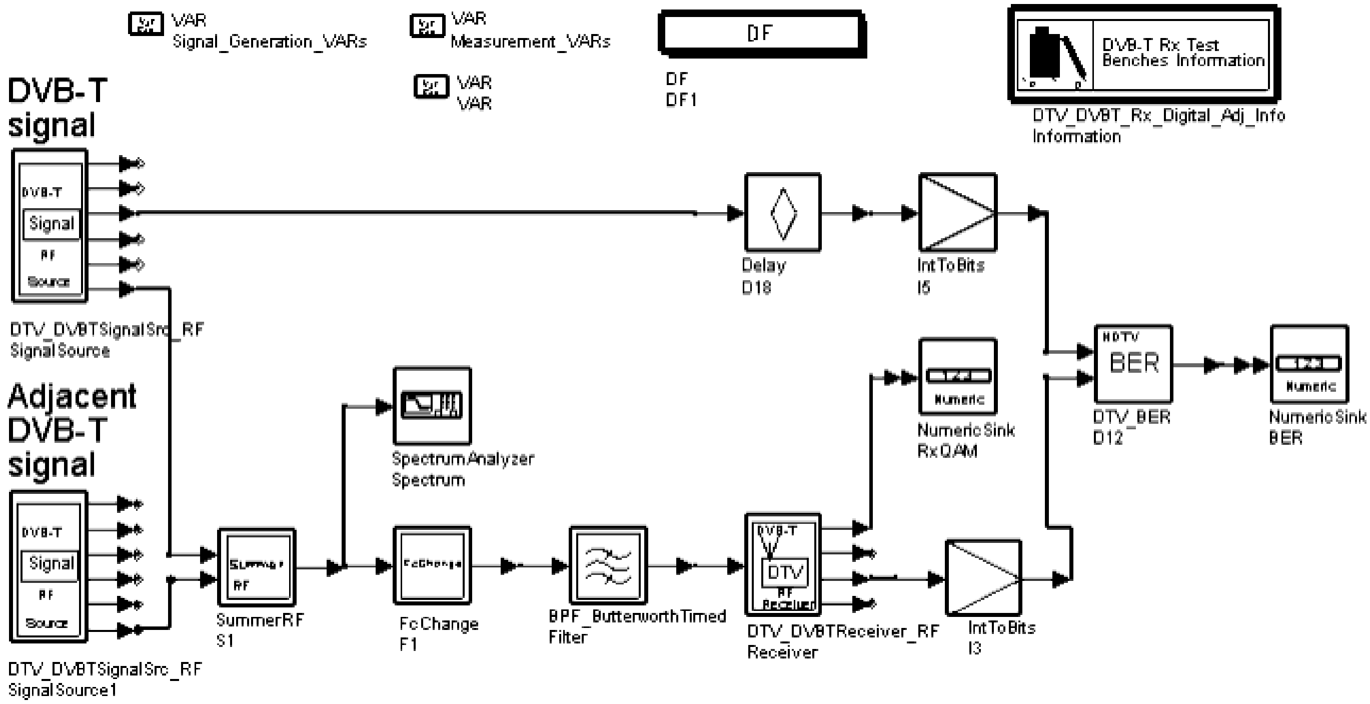
Features: Option 2 Design

- 2K mode
- 16-QAM mapping
- 3/4 coding rate
- 1/32 guard interval
- Signal_Generation_VARs and Measurement_VARs parameters can be changed by the user

Description

These designs measure the performance of a DVB-T receiver with a digital adjacent channel. BER is measured after Viterbi decoding.
The schematic is shown below.

DTV_DVBT_Rx_Digital_Adj Schematic



Simulation Results

Option 1 uses a 30 dB adjacent channel signal interference level relative to the wanted DVB-T signal.

Option 2 uses a 32 dB adjacent channel signal interference level relative to the wanted DVB-T signal.

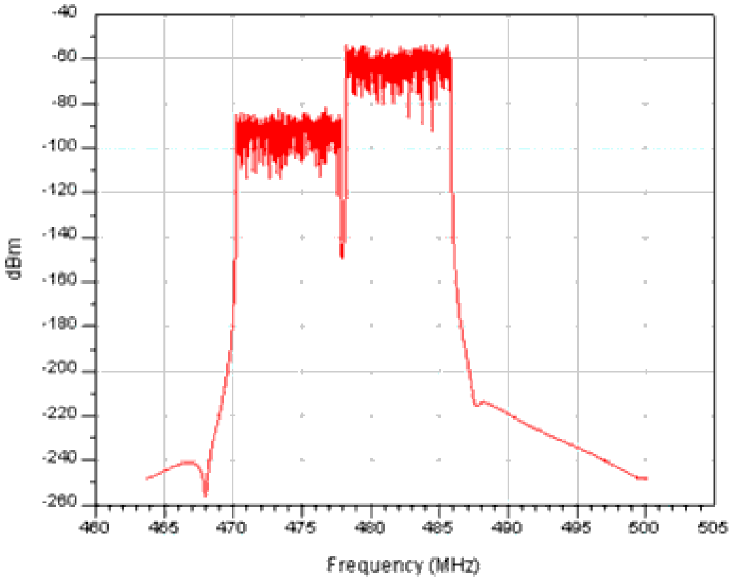
Simulation results displayed in DTV_DVBT_Rx_Digital_Adj_Option1.dds and DTV_DVBT_Rx_Digital_Adj_Option2.dds are shown below.

BER for Option 1 and Option 2

Index	BER
1000	0.000

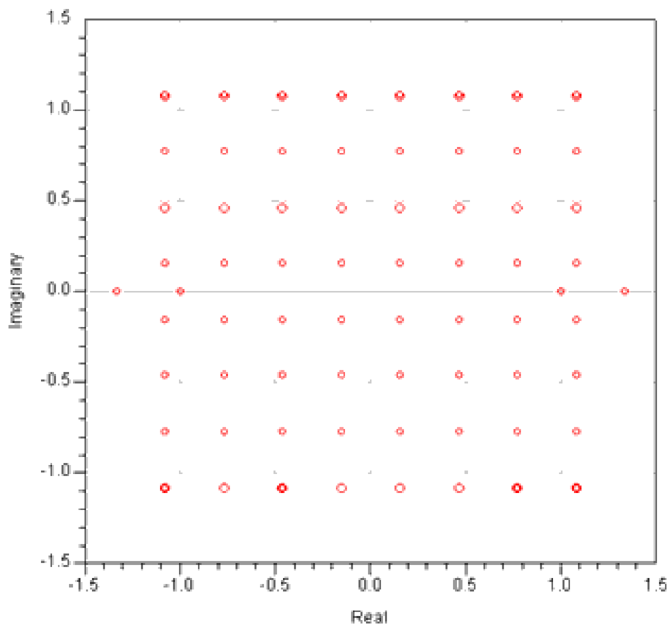
The spectrum for Option 1 is shown below.

Spectrum for Option 1



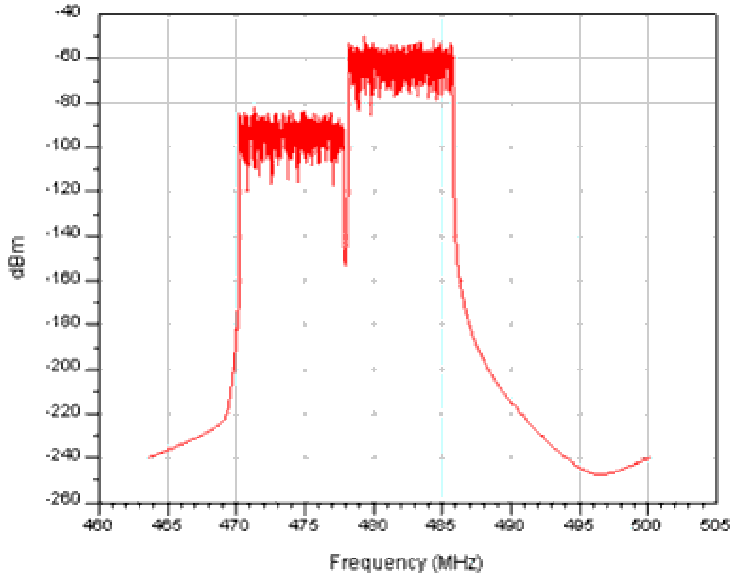
The demodulated constellation is shown below.

Constellation for Option 1



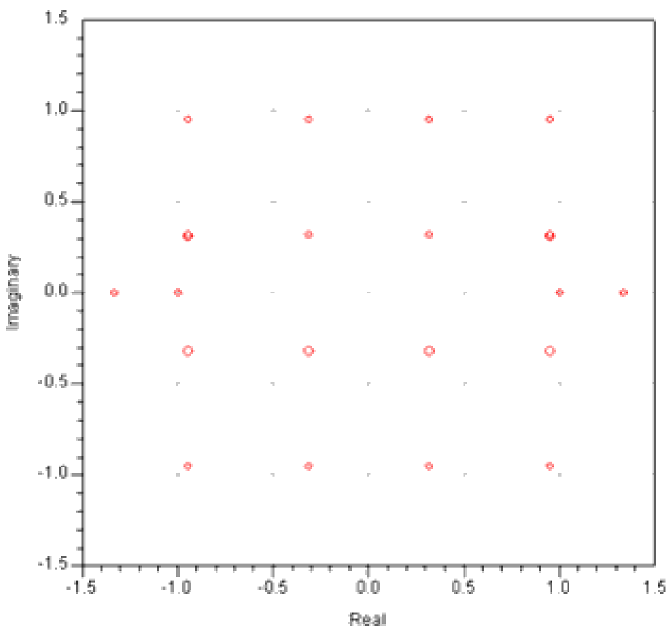
The spectrum for Option 2 is shown below.

Spectrum for Option 2



The demodulated constellation is shown below.

Constellation for Option 2



Benchmark

- Hardware Platform: Pentium IV 2.26 GHz, 512 MB memory
- Software Platform: Windows 2000, ADS 2003C
- Simulation Time: approximately 5 minutes

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.
2. DTG RF Sub-Group Document No. 67, UHF Transmission and Reception.

DVB-T Impulse Interference Performance

DTV_DVBT_Rx_Impulse_Option1
DTV_DVBT_Rx_Impulse_Option2

Features: Option 1 Design

- 2K mode
- 64-QAM mapping
- 2/3 coding rate
- 1/32 guard interval
- Signal_Generation_VARs and RF_Channel_Measurement_VARs parameters can be changed by the user.

Features: Option 2 Design

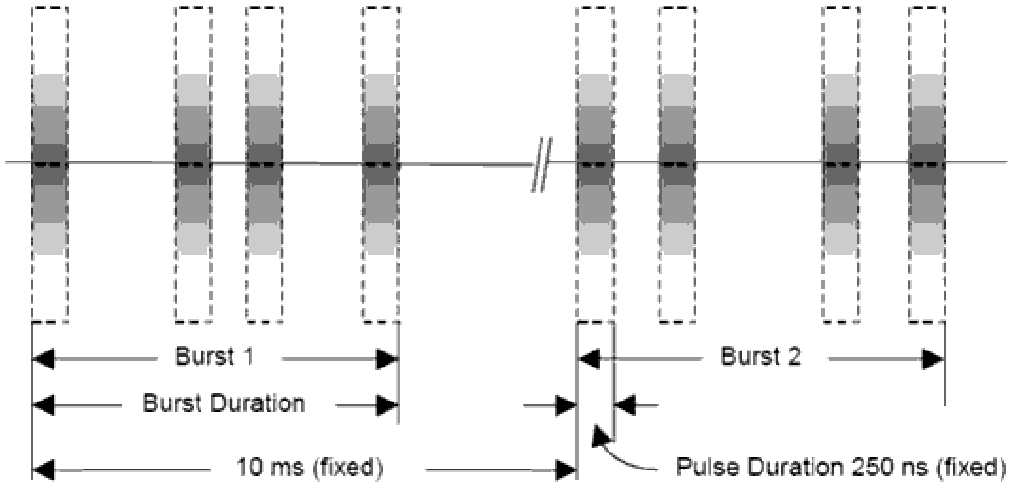
- 2K mode
- 16-QAM mapping
- 3/4 coding rate
- 1/32 guard interval
- Signal_Generation_VARs and RF_Channel_Measurement_VARs parameters can be changed by the user.

Description

These designs measure the performance of a DVB-T receiver with impulse interference. BER is measured after Viterbi decoding.

The impulse interference is made up of bursts that are generated by gating a Gaussian noise source. As shown below, separation of bursts is fixed at 10 msec and pulse duration is fixed at 250 nsec.

Impulse Noise Test Signal



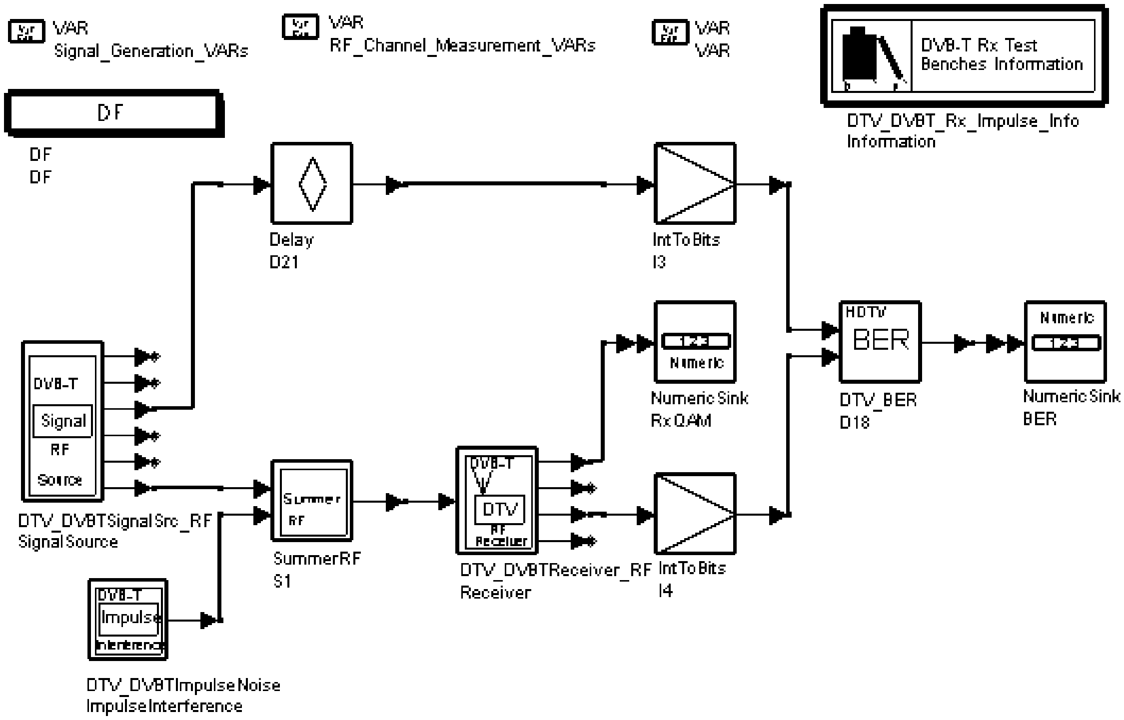
These design supports the tests listed in the table below. The tolerance of the receiver to the test signal should exceed its tolerance to ungated Gaussian noise by a *tolerance factor* that is generally expressed in dB. The tolerance factor is independent of modulation mode, receiver implementation margin, and degradation criterion.

Impulse Noise Tests and Theoretical Receiver Tolerance

Test_No	Pulses per Burst	Pulse Spacing (μsec)	Burst Duration (μsec)	Tolerance Factor (dB)
1	1	0.25	0.25	29.5
2	2	20	40	26.5
3	4	20	80	23.5
4	12	12	144	18.7
5	20	1.5	30	16.5
6	40	0.75	30	13.5

The schematic is shown below.

DTV_DVBT_Rx_Impulse Schematic



Simulation Results

Option 1 uses a 16.5 dB carrier-to-noise ratio and a tolerance factor of 23.5 dB.

Option 2 uses a 12.5 dB carrier-to-noise ratio and a tolerance factor of 23.5 dB.

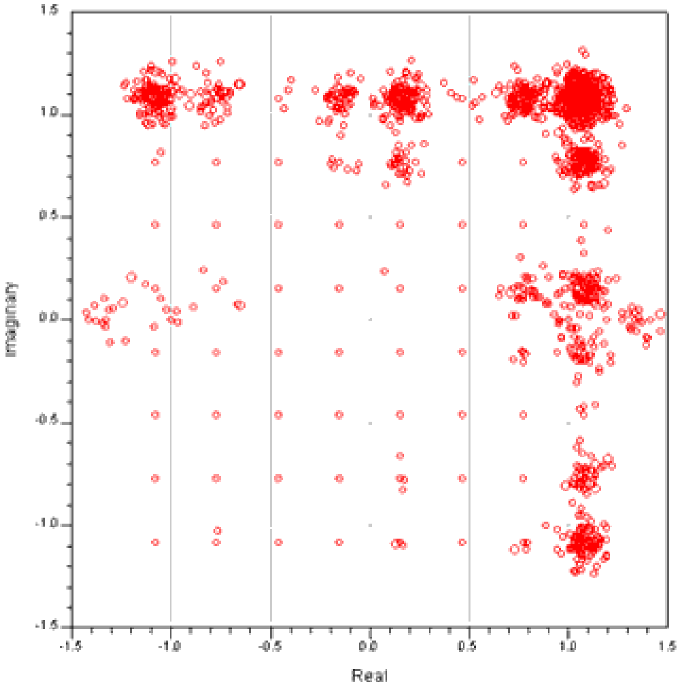
Simulation results displayed in DTV_DVBT_Rx_Impulse_Option1.dds and DTV_DVBT_Rx_Impulse_Option2.dds are shown below.

BER for Option 1 and Option 2

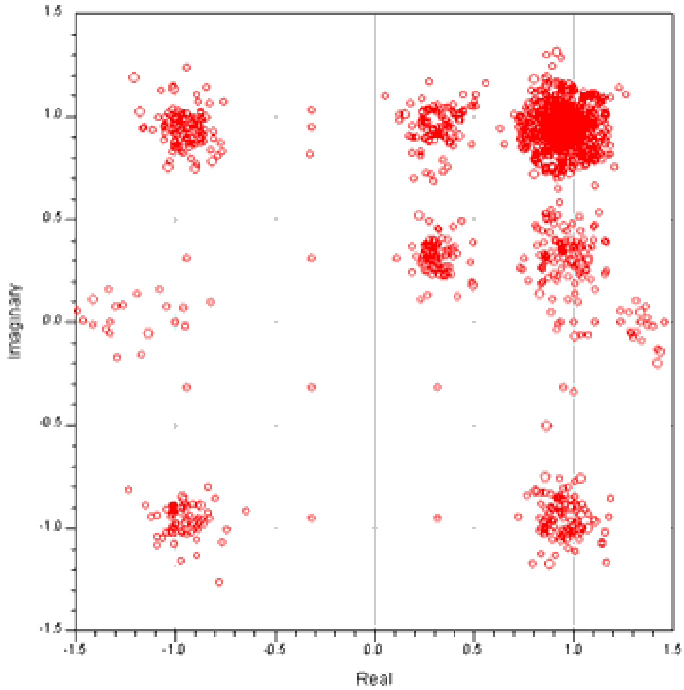
Index	BER
1000	0.000

The demodulated constellations are shown in the figures below.

Constellation for Option 1



Constellation for Option 2



Benchmark

- Hardware Platform: Pentium IV 2.26 GHz, 512 MB memory
- Software Platform: Windows 2000, ADS 2003C
- Simulation Time: approximately 2 minutes

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.
2. DTG RF Sub-Group Document No. 67, *UHF Transmission and Reception*.

DVB-T Long Delay Channel Performance

DTV_DVBT_Rx_LongDelay_Option1
DTV_DVBT_Rx_LongDelay_Option2

Features: Option 1 Design

- 2K mode
- 64-QAM mapping
- 2/3 coding rate
- 1/32 guard interval
- Signal_Generation_VARs and RF_Channel_Measurement_VARs parameters can be set by the user

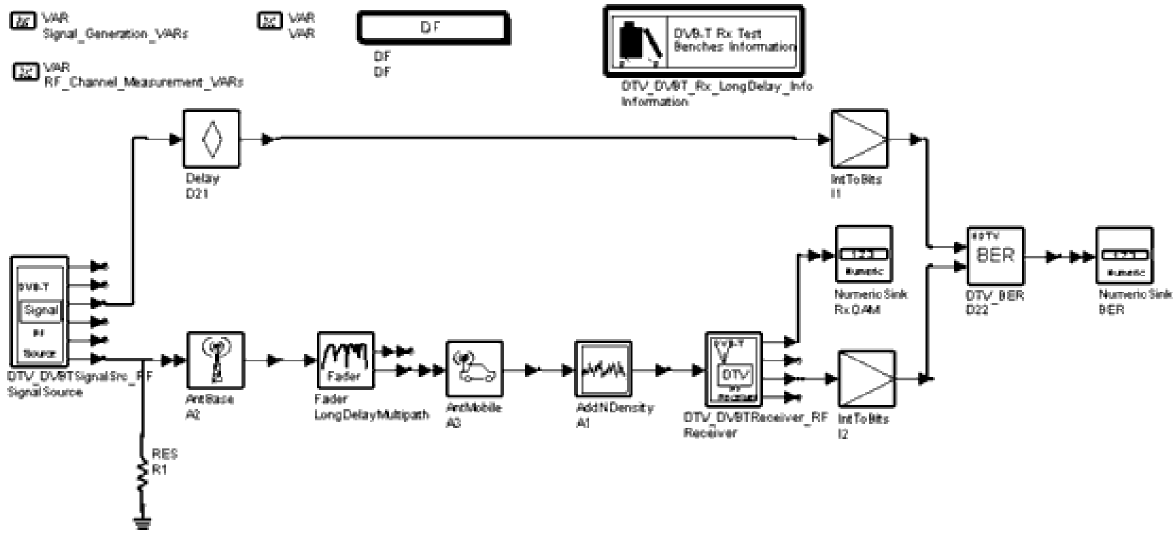
Features: Option 2 Design

- 2K mode
- 16-QAM mapping
- 3/4 coding rate
- 1/32 guard interval
- Signal_Generation_VARs and RF_Channel_Measurement_VARs parameters can be set by the user

Description

These designs measure the performance of a DVB-T receiver with a long delay channel. The long delay combines 6 echoes. There is a dominant direct path and 5 echoes and one outside the guard interval. Path delay and attenuation of the long delay multipath channel are [0, 5, 14, 35, 54, 75] µsec and [0, 9, 22, 25, 27, 28] dB. The phase is set to 0 at channel center.
BER is measured after Viterbi decoding.
The schematic is shown below.

DTV_DVBT_Rx_LongDelay Schematic



Simulation Results

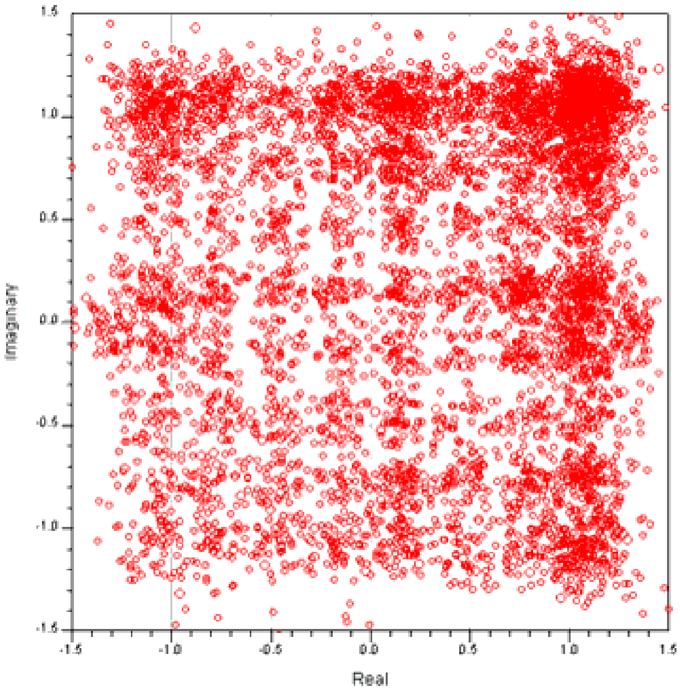
Option 1 uses a 22.3 dB carrier-to-noise ratio. Simulation results displayed in DTV_DVBT_Rx_LongDelay_Option1.dds are shown below.

BER for Option 1

Index	BER
1000	2.133E-4

The demodulated constellations are shown below.

Constellation for Option 1



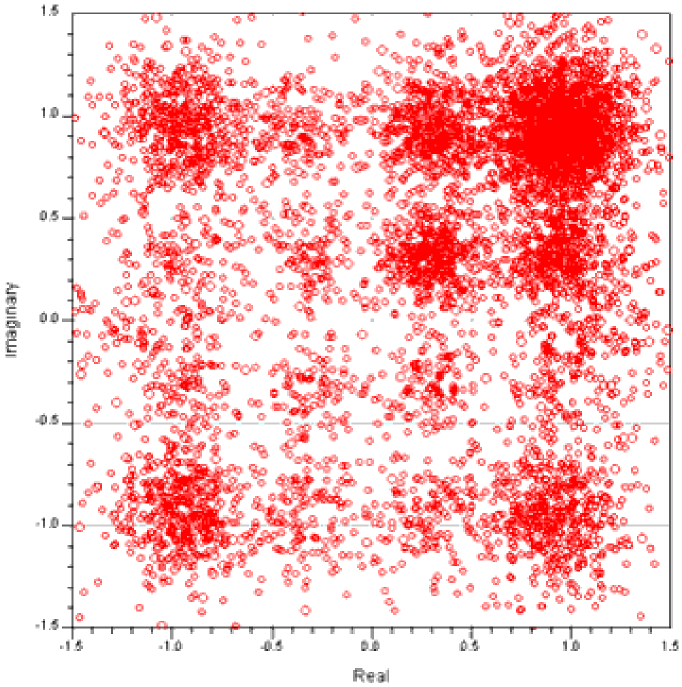
Option 2 uses a 15.8 dB carrier-to-noise ratio. Simulation results displayed in DTV_DVBT_Rx_LongDelay_Option2.dds are below.

BER for Option 2

Index	BER
1000	3.477E-4

The demodulated constellations are shown below.

Constellation for Option 2



Benchmark

- Hardware Platform: Pentium IV 2.26 GHz, 512 MB memory
- Software Platform: Windows 2000, ADS 2003C
- Simulation Time: approximately 15 minutes for Option 1 and 30 minutes for Option 2

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.
2. DTG RF Sub-Group Document No. 67, *UHF Transmission and Reception*.

DVB-T Analog Adjacent Channel Performance

DTV_DVBT_Rx_PAL_Adj_Option1
DTV_DVBT_Rx_PAL_Adj_Option2

Features: Option 1 Design

- 2K mode
- 64-QAM mapping
- 2/3 coding rate
- 1/32 guard interval
- Signal_Generation_VARs and Measurement_VARs parameters can be set by the user

Features: Option 2 Design

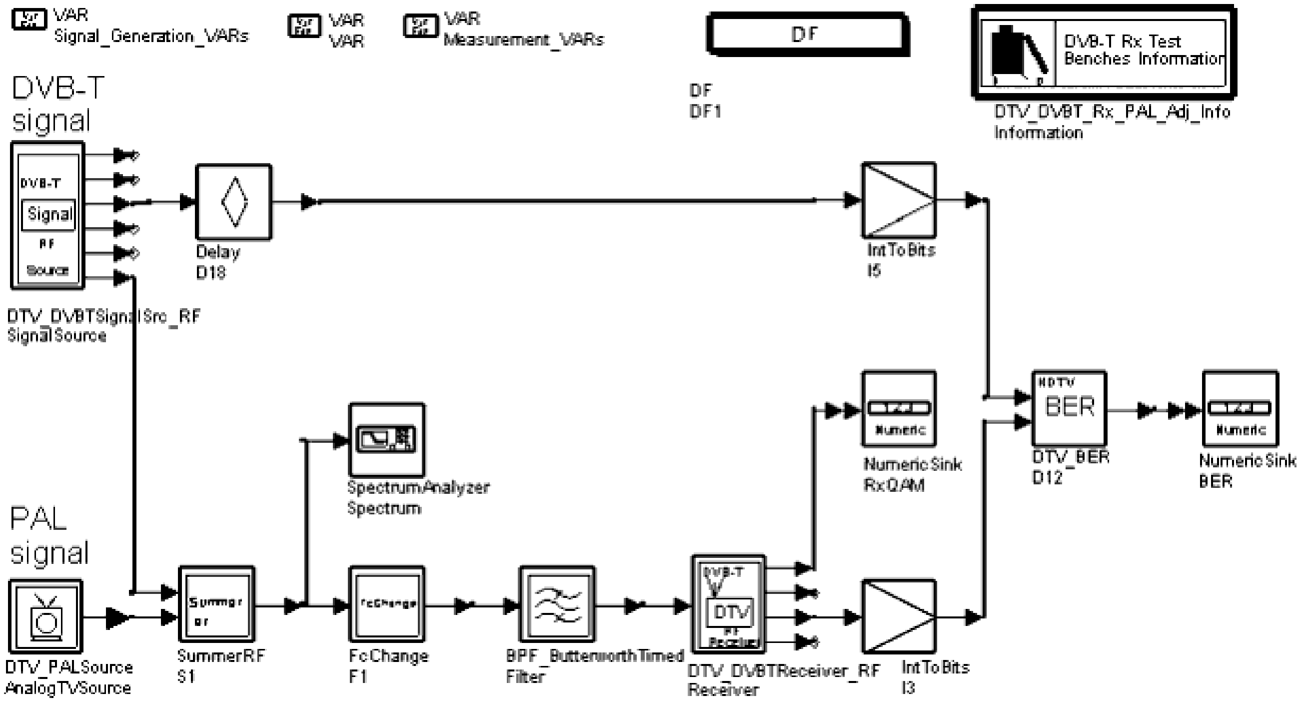
- 2K mode
- 16-QAM mapping
- 3/4 coding rate
- 1/32 guard interval
- Signal_Generation_VARs and Measurement_VARs parameters can be set by the user

Description

These designs measure the protection ratio of an adjacent channel PAL signal. BER is measured after Viterbi decoding.

The schematic is shown below.

DTV_DVBT_Rx_PAL_Adj Schematic



Simulation Results

For Option 1, the adjacent channel PAL signal interference level relative to the wanted DVB-T signal is 35 dB.
For Option 2, the adjacent channel PAL signal interference level relative to the wanted DVB-T signal is 37 dB.

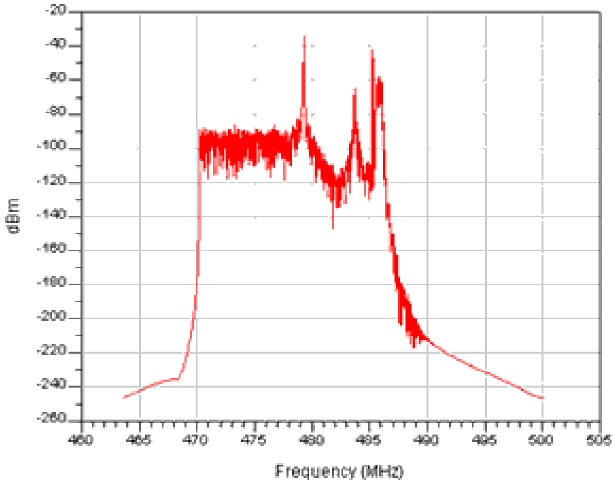
Simulation results displayed in DTV_DVBT_Rx_PAL_Adj_Option1.dds and DTV_DVBT_Rx_PAL_Adj_Option2.dds are shown below.

BER for Option 1 and Option 2

Index	BER
1000	0.000

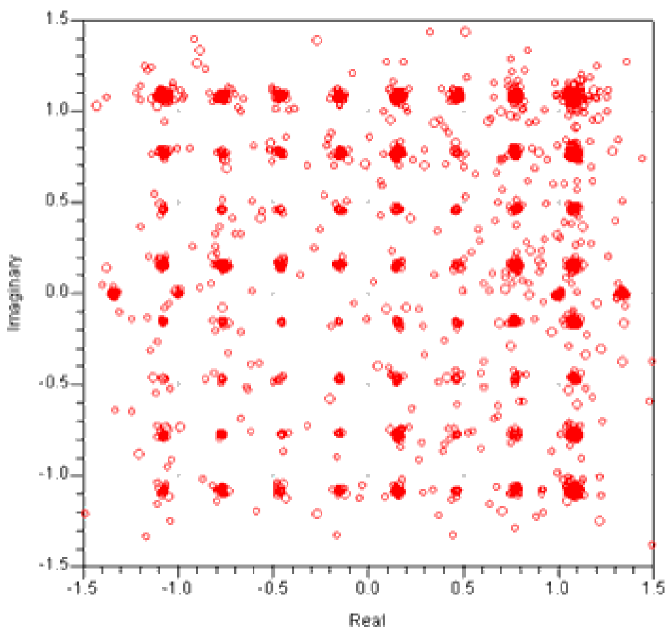
For Option 1, the spectrum is shown below.

Spectrum for Option 1



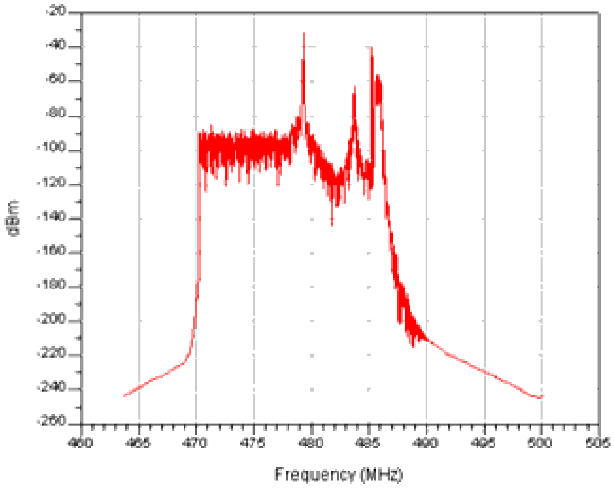
The demodulated constellation is shown below.

Constellation for Option 1



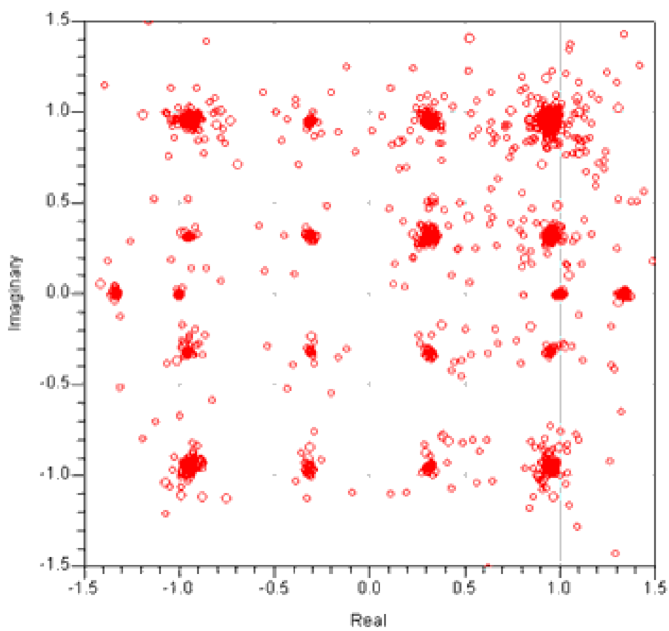
For Option 2, the spectrum is shown below.

Spectrum for Option 2



The demodulated constellation is shown below.

Constellation for Option 2



Benchmark

- Hardware Platform: Pentium IV 2.26 GHz, 512 MB memory
- Software Platform: Windows 2000, ADS 2003C
- Simulation Time: approximately 10 minutes

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and*

modulation for digital terrestrial television. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.
2. DTG RF Sub-Group Document No. 67, *UHF Transmission and Reception*.

DVB-T Analog Co-Channel Performance

DTV_DVBT_Rx_PAL_Cochannel_Option1
DTV_DVBT_Rx_PAL_Cochannel_Option2

Features: Option 1 Design

- 2K mode
- 64-QAM mapping
- 2/3 coding rate
- 1/32 guard interval
- Signal_Generation_VARs and Measurement_VARs parameters can be set by the user

Features: Option 2 Design

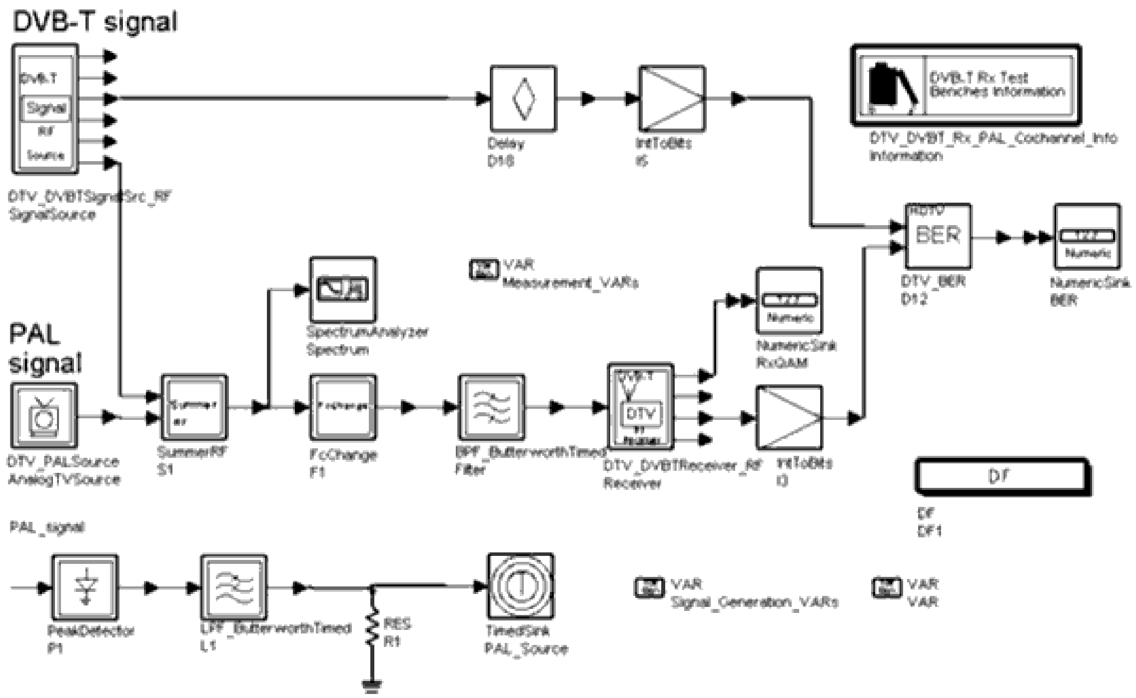
- 2K mode
- 16-QAM mapping
- 3/4 coding rate
- 1/32 guard interval
- Signal_Generation_VARs and Measurement_VARs parameters can be set by the user

Description

These designs measure the protection ratio of a co-channel PAL signal. BER is measured after Viterbi decoding.

The schematic is shown below.

DTV_DVBT_Rx_PAL_Cochannel Schematic



Simulation Results

For Option 1, the co-channel PAL signal interference level relative to the wanted DVB-T signal is 0 dB. Simulation results displayed in DTV_DVBT_Rx_PAL_Cochannel_Option1.dds are shown below.

BER for Option 1

Index	BER
1000	2.852E-4

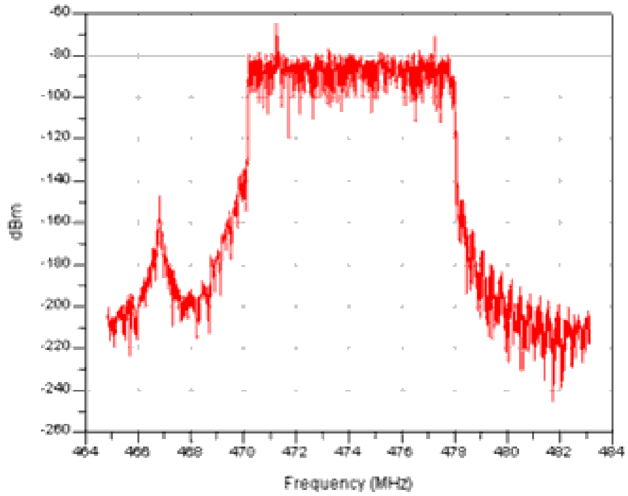
For Option 2, the co-channel PAL signal interference level relative to the wanted DVB-T signal is 0 dB. Simulation results displayed in DTV_DVBT_Rx_PAL_Cochannel_Option2.dds are shown below.

BER for Option 2

Index	BER
1000	8.155E-4

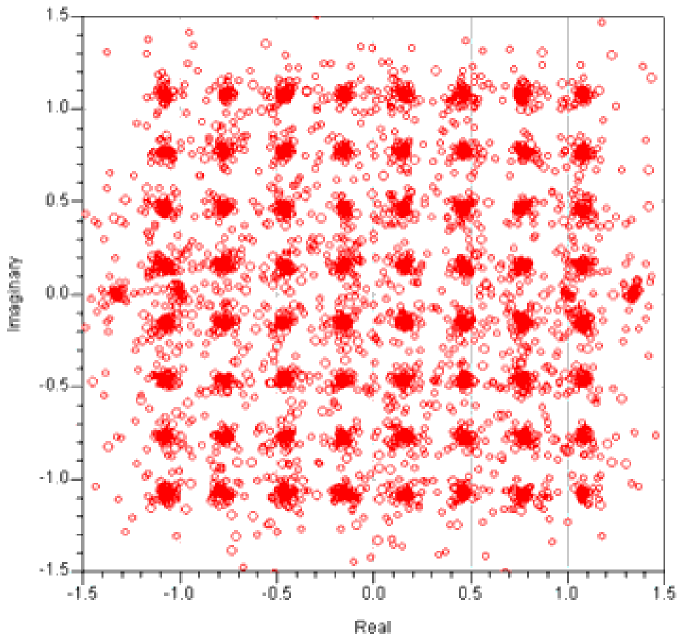
For Option 1, the spectrum is shown below.

Spectrum for Option 1



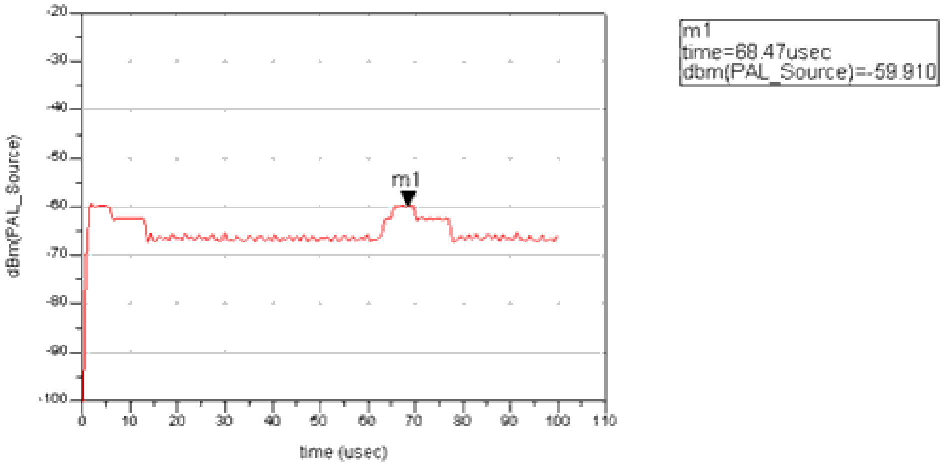
The demodulated constellation is shown below.

Constellation for Option 1



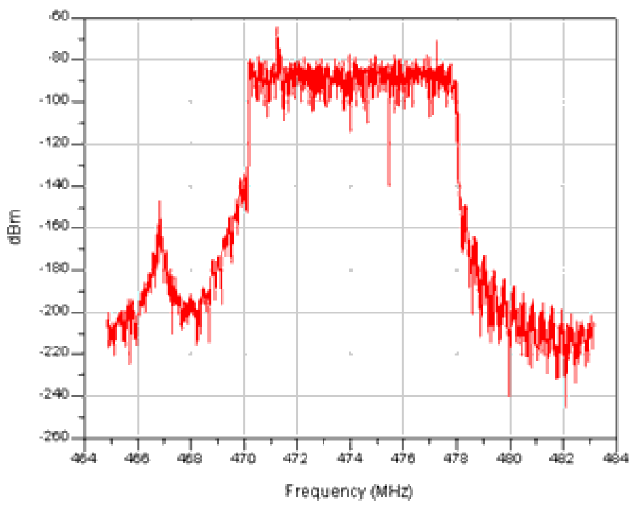
The PAL source peak power shown below is -59.910 dBm, which is the same as the schematic setting.

PAL Source Peak Power for Option 1



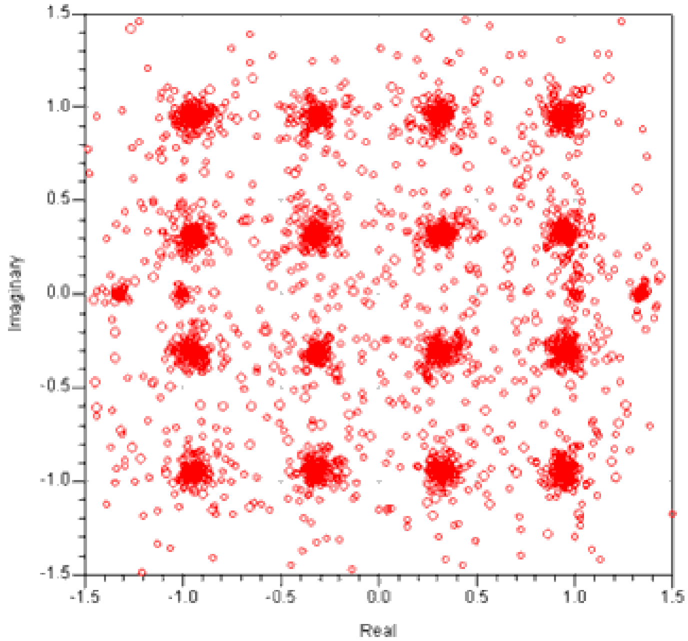
For Option 2, the demodulated constellation is shown below.

Spectrum for Option 2



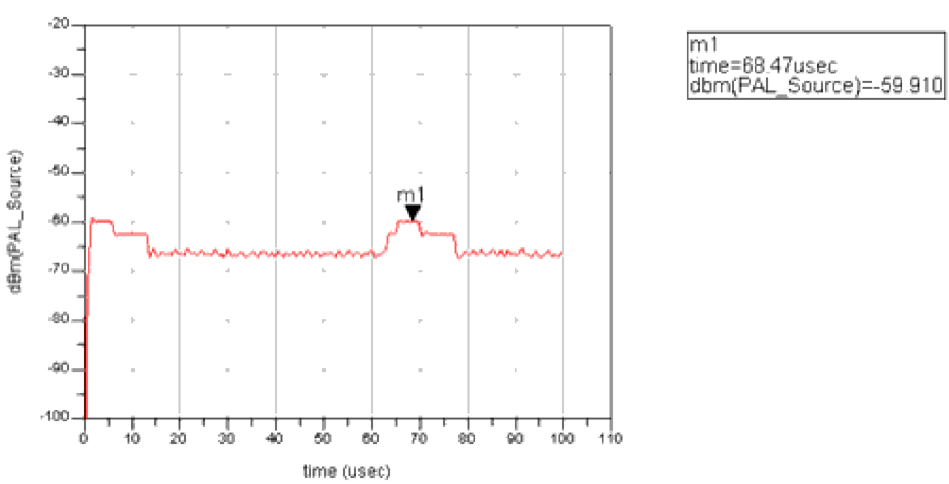
The demodulated constellation is shown below.

Constellation for Option 2



The PAL source peak power shown below is -59.910 dBm, which is the same as the schematic setting.

PAL Source Peak Power for Option 2



Benchmark

- Hardware Platform: Pentium IV 2.26 GHz, 512 MB memory
- Software Platform: Windows 2000, ADS 2003C
- Simulation Time: approximately 5 minutes

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.
2. DTG RF Sub-Group Document No. 67, *UHF Transmission and Reception*.

DVB-T Image Channel Performance

DTV_DVBT_Rx_PAL_Image_Option1
DTV_DVBT_Rx_PAL_Image_Option2

Features: Option 1 Design

- 2K mode
- 64-QAM mapping
- 2/3 coding rate
- 1/32 guard interval
- Signal_Generation_VARs and Measurement_VARs parameters can be set by the user

Features: Option 2 Design

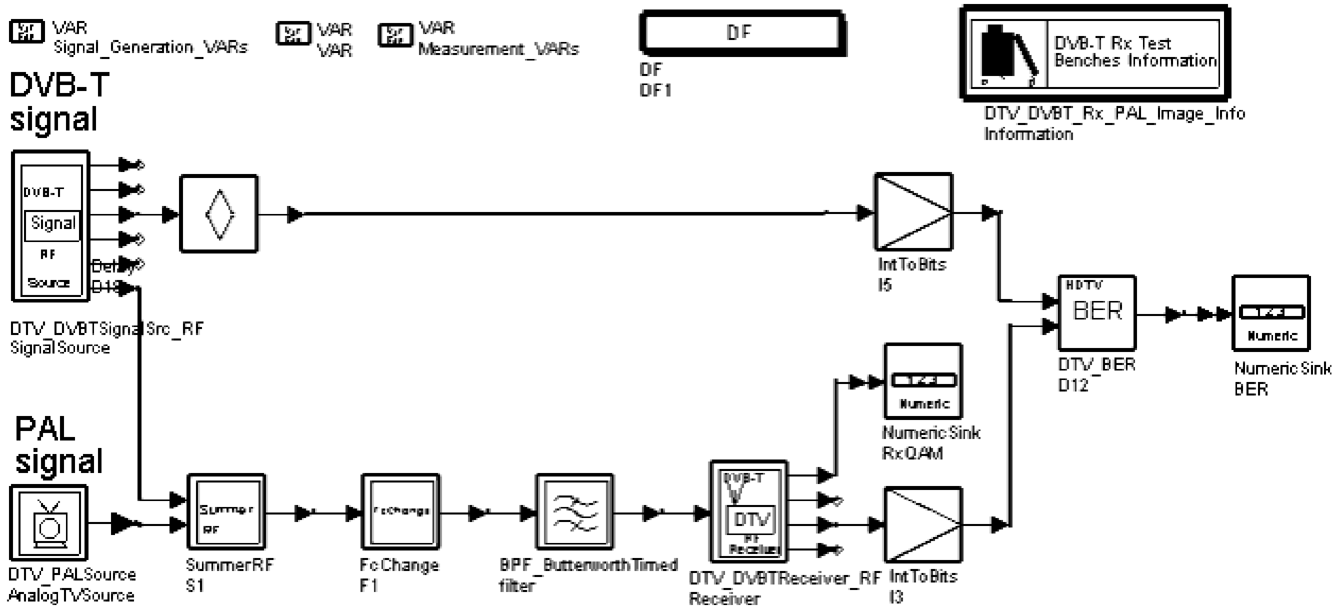
- 2K mode
- 16-QAM mapping
- Coding rate is 3/4
- Guard interval is 1/32
- Signal_Generation_VARs and Measurement_VARs parameters can be set by the user

Description

These designs measure the protection ratio of an image channel PAL signal.

The schematic is shown below.

DTV_DVBT_Rx_PAL_Image Schematic



Simulation Results

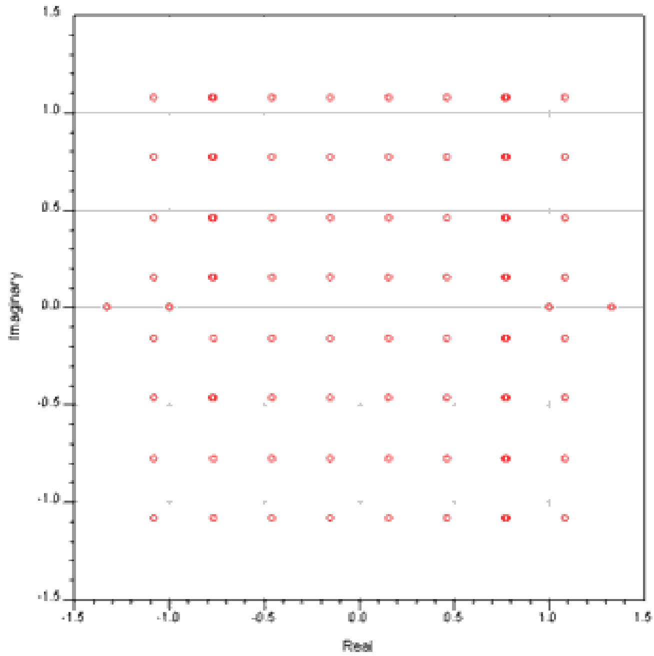
BER is measured after Viterbi decoding.
For Option 1, the image channel PAL signal interference level relative to wanted DVB-T signal is 46 dB.
For Option 2, the image channel PAL signal interference level relative to wanted DVB-T signal is 50 dB.
Simulation results displayed in DTV_DVBT_Rx_PAL_Image_Option1.dds and DTV_DVBT_Rx_PAL_Image_Option2.dds are shown below.

BER for Option 1 and Option 2

Index	BER
1000	0.000

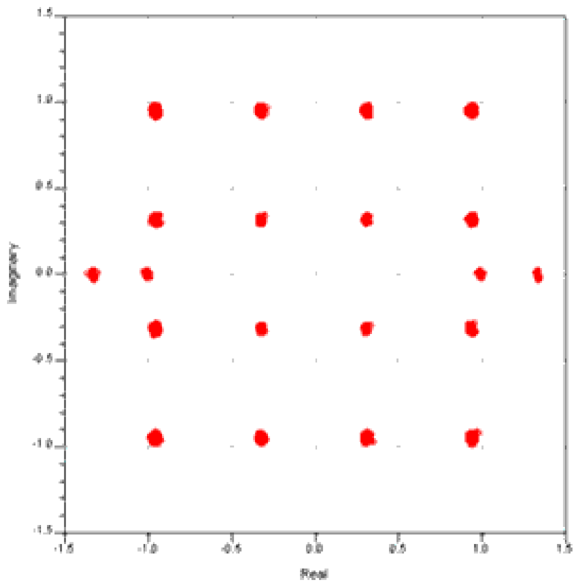
For Option 1, the demodulated constellation is shown below.

Constellation for Option 1



For Option 2, the demodulated constellation is shown below.

Constellation for Option 2



Benchmark

- Hardware Platform: Pentium IV 2.26 GHz, 512 MB memory
- Software Platform: Windows 2000, ADS 2003C
- Simulation Time: approximately 6 hours for Option 1 and 9 hours for Option 2

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.
2. DTG RF Sub-Group Document No. 67, *UHF Transmission and Reception*.

DVB-T Rayleigh Channel (P1) Performance

DTV_DVBT_Rx_Rayleigh_Option1
DTV_DVBT_Rx_Rayleigh_Option2

Features: Option 1 Design

- 2K mode
- 64-QAM mapping
- 2/3 coding rate
- 1/32 guard interval
- Signal_Generation_VARs and RF_Channel_Measurement_VARs parameters can be changed by the user

Features: Option 2 Design

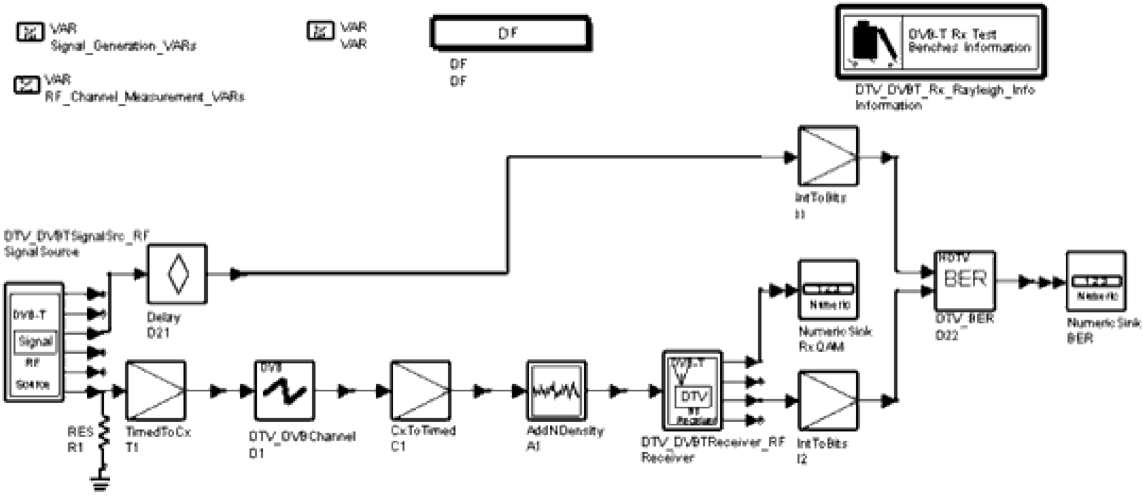
- 2K mode
- 16-QAM mapping
- 3/4 coding rate
- 1/32 guard interval
- Signal_Generation_VARs and RF_Channel_Measurement_VARs parameters can be changed by the user

Description

These designs measure the performance of a DVB-T receiver with a Rayleigh channel (P1).

BER is measured after Viterbi decoding.
The schematic is shown below.

DTV_DVBT_Rx_Rayleigh Schematic



Simulation Results

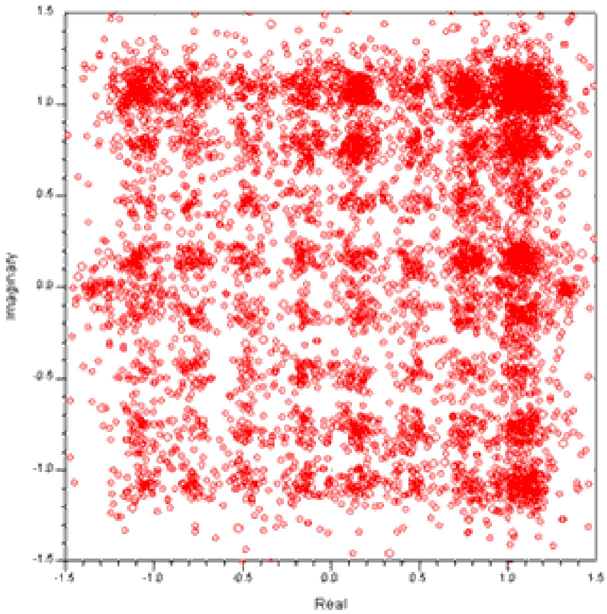
For Option 1, a 22.6 dB carrier-to-noise ratio is used. Simulation results displayed in DTV_DVBT_Rx_Rayleigh_Option1.dds are shown below.

BER for Option 1

Index	BER
1000	4.108E-4

The demodulated constellation is shown below.

Constellation for Option 1



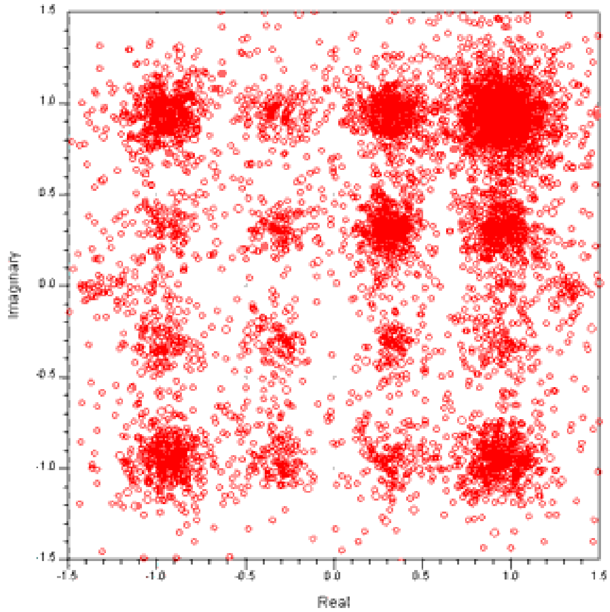
For Option 2, a 19.1 dB carrier-to-noise ratio is used. Simulation results displayed in DTV_DVBT_Rx_Rayleigh_Option2.dds are shown below.

BER for Option 2

Index	BER
1000	3.402E-4

The demodulated constellation is shown below.

Constellation for Option 2



Benchmark

- Hardware Platform: Pentium IV 2.26 GHz, 512 MB memory
- Software Platform: Windows 2000, ADS 2003C
- Simulation Time: approximately 1 minute

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.
2. DTG RF Sub-Group Document No. 67, *UHF Transmission and Reception*.

DVB-T Ricean Channel (F1) Performance

DTV_DVBT_Rx_Ricean_Option1
DTV_DVBT_Rx_Ricean_Option2

Features: Option 1 Design

- 2K mode
- 64-QAM mapping
- 2/3 coding rate
- 1/32 guard interval
- Signal_Generation_VARs and RF_Channel_Measurement_VARs parameters can be changed by the user

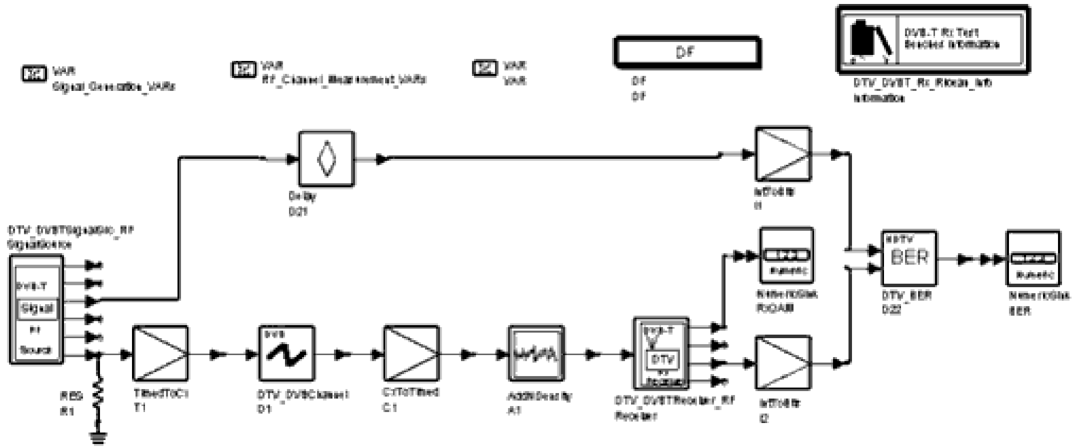
Features: Option 2 Design

- 2K mode
- 16-QAM mapping
- 3/4 coding rate
- 1/32 guard interval
- Signal_Generation_VARs and RF_Channel_Measurement_VARs parameters can be changed by the user

Description

These designs measure the performance of a DVB-T receiver with a Ricean channel (F1).
BER is measured after Viterbi decoding.
The schematic is shown below.

DTV_DVBT_Rx_Ricean Schematic



Simulation Results

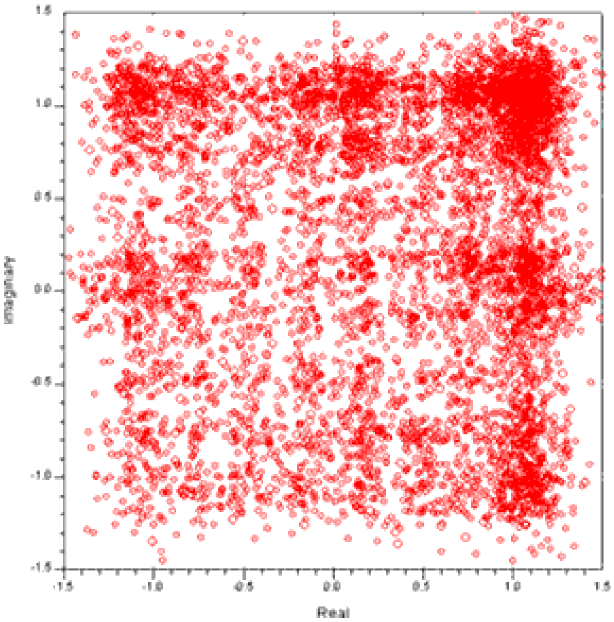
For option 1, a 19.4 dB carrier-to-noise ratio is used. Simulation results displayed in DTV_DVBT_Rx_Ricean_Option1.dds are shown below.

BER for Option 1

Index	BER
1000	2.202E-4

The demodulated constellation is shown below.

Constellation for Option 1



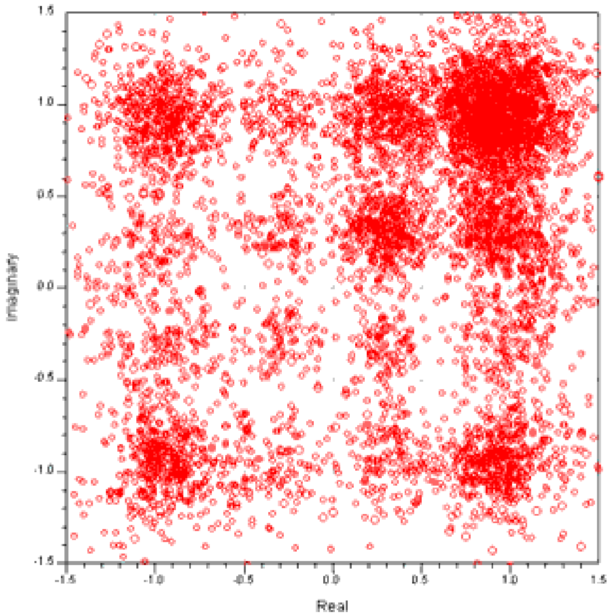
For option 2, a 14.9 dB carrier-to-noise ratio is used. Simulation results displayed in DTV_DVBT_Rx_Ricean_Option2.dds are shown below.

BER for Option 2

Index	BER
1000	2.675E-4

The demodulated constellation is shown below.

Constellation for Option 2



Benchmark

- Hardware Platform: Pentium IV 2.26 GHz, 512 MB memory
- Software Platform: Windows 2000, ADS 2003C
- Simulation Time: approximately 1 minute

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.
2. DTG RF Sub-Group Document No. 67, *UHF Transmission and Reception*.

DVB-T Receiver Minimum Input Level Sensitivity

DTV_DVBT_Rx_Sensitivity_Option1
DTV_DVBT_Rx_Sensitivity_Option2

Features: Option 1 Design

- 2K mode
- 64-QAM mapping
- 2/3 coding rate
- 1/32 guard interval
- Signal_Generation_VARs and Measurement_VARs parameters can be changed by the user

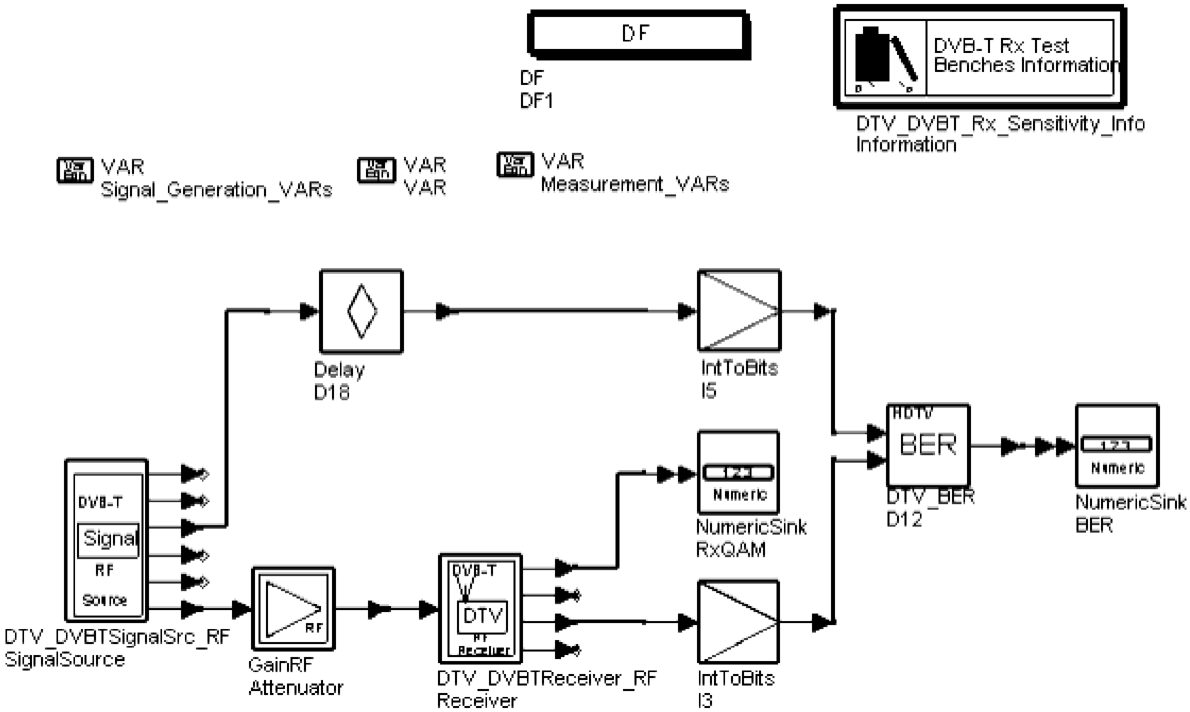
Features: Option 2 Design

- 2K mode
- 16-QAM mapping
- 3/4 coding rate
- 1/32 guard interval
- Signal_Generation_VARs and Measurement_VARs parameters can be changed by the user

Description

These designs measure the performance of a DVB-T receiver with minimum input level sensitivity. BER is measured after Viterbi decoding.
The schematic is shown below.

DTV_DVBT_Rx_Sensitivity Schematic



Simulation Results

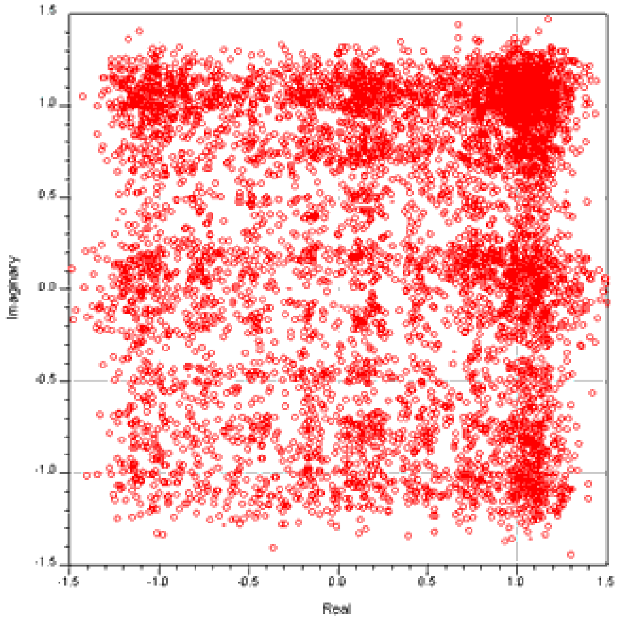
BER is measured after Viterbi decoding.
Option 1 uses a signal power level of -77.9 dBm. Simulation results displayed in DTV_DVBT_Rx_Sensitivity_Option1.dds are shown below.

BER for Option 1

Index	BER
1000	1.388E-5

The demodulated constellation is shown below.

Constellation for Option 1



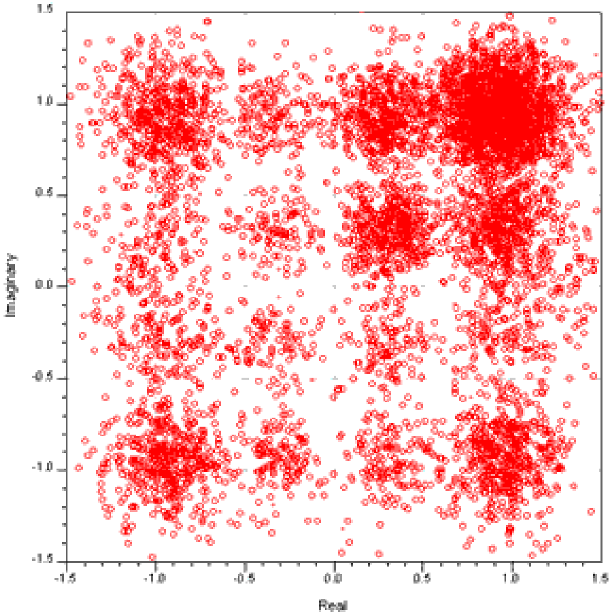
Option 2 uses a signal power level of -82.1 dBm. Simulation results displayed in DTV_DVBT_Rx_Sensitivity_Option2.dds are shown below.

BER for Option 2

Index	BER
1000	7.518E-6

The demodulated constellation is shown below.

Constellation for Option 2



Benchmark

- Hardware Platform: Pentium IV 2.26 GHz, 512 MB memory
- Software Platform: Windows 2000, ADS 2003C
- Simulation Time: approximately 1 minute

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.
2. DTG RF Sub-Group Document No. 67, *UHF Transmission and Reception*.

DVB-T Short Delay Channel Performance

DTV_DVBT_Rx_ShortDelay_Option1
DTV_DVBT_Rx_ShortDelay_Option2

Features: Option 1 Design

- 2K mode
- 64-QAM mapping
- 2/3 coding rate
- 1/32 guard interval
- Signal_Generation_VARs and RF_Channel_Measurement_VARs parameters can be changed by the user

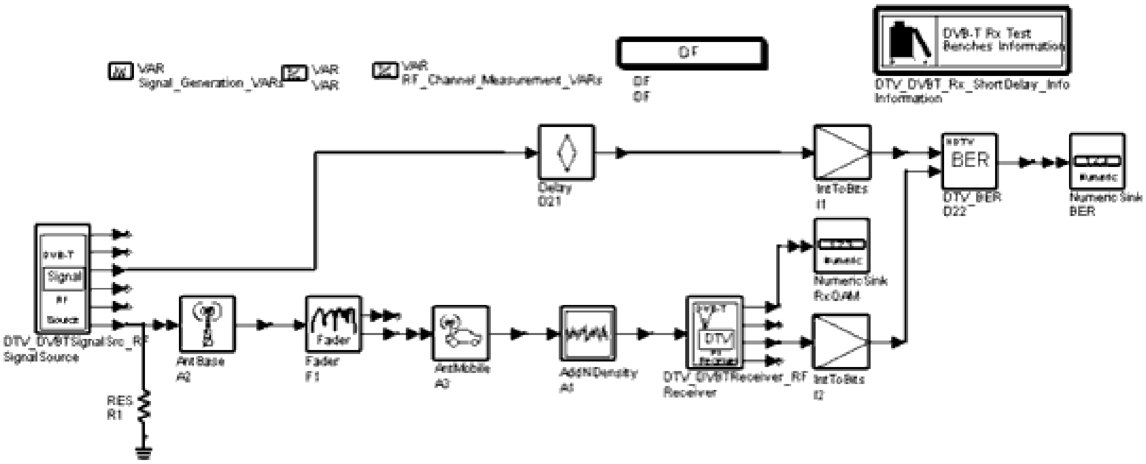
Features: Option 2 Design

- 2K mode
- 16-QAM mapping
- 3/4 coding rate
- 1/32 guard interval
- Signal_Generation_VARs and RF_Channel_Measurement_VARs parameters can be changed by the user

Description

These designs measure the performance of a DVB-T receiver with a short delay channel. The short delay combines 6 echoes. All echoes are within the guard interval and none is dominant: there is no *direct* path. Path delay and attenuation of the short delay multipath channel are [0, 0.05, 0.4, 1.45, 2.3, 2.8] µsec and [2.8, 0.0, 3.8, 0.1, 2.6, 1.3] dB. The phase is set to 0 at the channel center.
BER is measured after Viterbi decoding.
The schematic is shown below.

DTV_DVBT_Rx_ShortDelay Schematic



Simulation Results

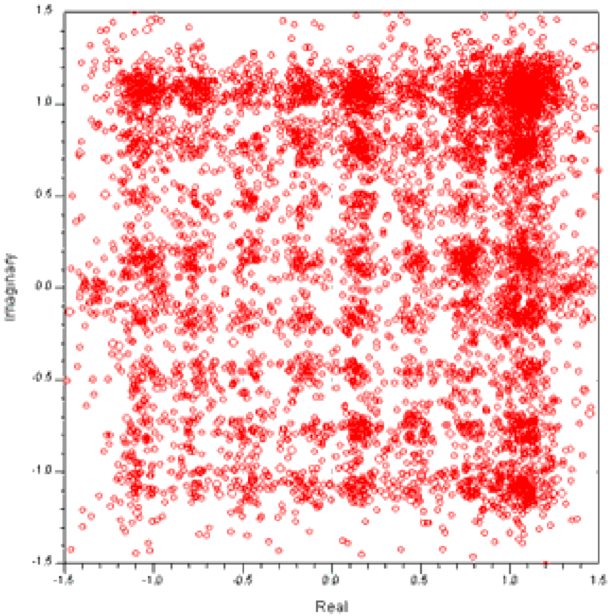
Option 1 has a carrier-to-noise ratio of 22.3 dB. Simulation results displayed in DTV_DVBT_Rx_ShortDelay_Option1.dds are shown below.

BER for Option 1

Index	BER
1000	1.420E-4

The demodulated constellation is shown below.

Constellation for Option 1



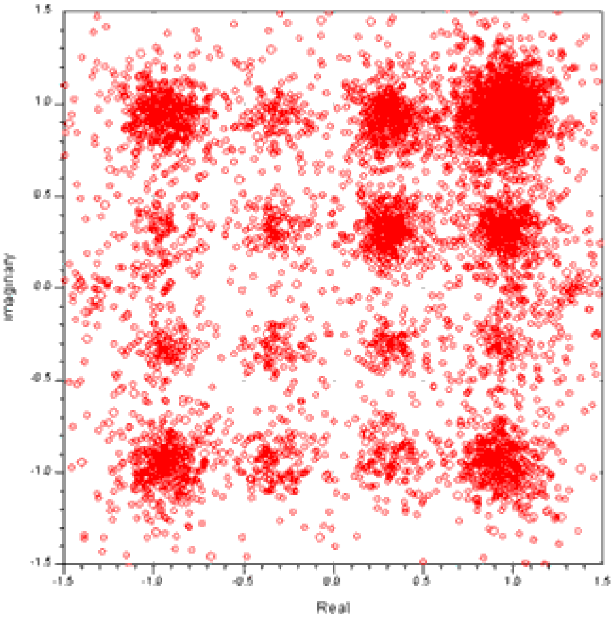
Option 2 has a carrier-to-noise ratio of 18.8 dB. Simulation results displayed in DTV_DVBT_Rx_ShortDelay_Option2.dds are shown below.

BER for Option 2

Index	BER
1000	1.034E-4

The demodulated constellation is shown below.

Constellation for Option 2



Benchmark

- Hardware Platform: Pentium IV 2.26 GHz, 512 MB memory
- Software Platform: Windows 2000, ADS 2003C
- Simulation Time: approximately 15 minutes for Option 1 and 25 minutes for Option 2

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.
2. DTG RF Sub-Group Document No. 67, *UHF Transmission and Reception*.

DVB-T Single Echo Channel Performance

DTV_DVBT_Rx_SingleEcho_Option1
DTV_DVBT_Rx_SingleEcho_Option2

Features: Option 1 Design

- 2K mode
- 64-QAM mapping
- 2/3 coding rate
- 1/32 guard interval
- Signal_Generation_VARs and RF_Channel_Measurement_VARs parameters can be changed by the user

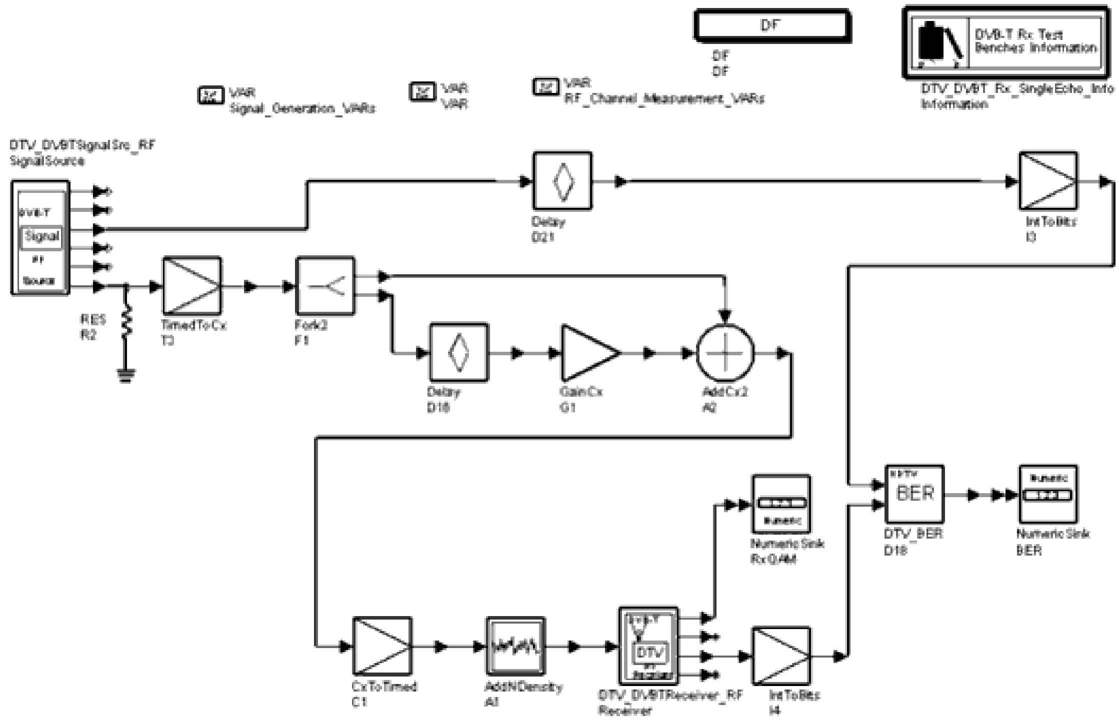
Features: Option 2 Design

- 2K mode
- 16-QAM mapping
- 3/4 coding rate
- 1/32 guard interval
- Signal_Generation_VARs and RF_Channel_Measurement_VARs parameters can be changed by the user

Description

These designs measure the performance of a DVB-T receiver with a single echo channel.
Path delay of the echo channel is 3.5 μsec and the attenuation is 0 dB. The echo phase is set to 90 at the channel center.
BER is measured after Viterbi decoding.
The schematic is shown below.

DTV_DVBT_Rx_SingleEcho Schematic



Simulation Results

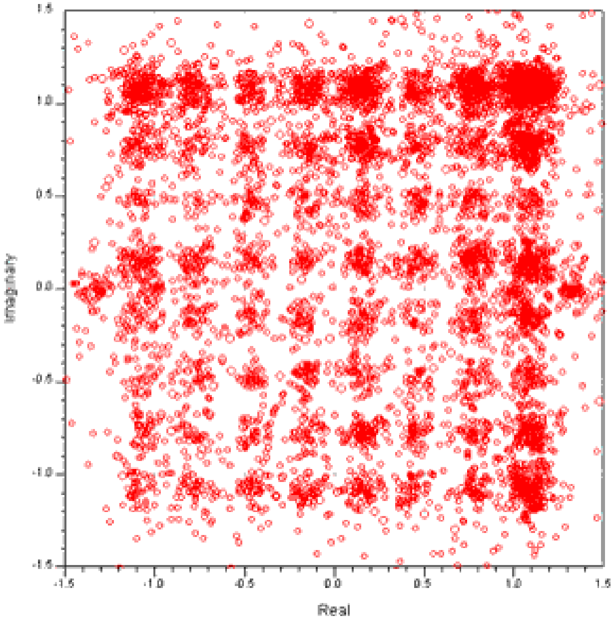
For option 1, a carrier-to-noise ratio of 23.1 dB is used. Simulation results displayed in DTV_DVBT_Rx_SingleEcho_Option1.dds are shown below.

BER for Option 1

Index	BER
1000	1.937E-4

The demodulated constellation is shown below.

Constellation for Option 1



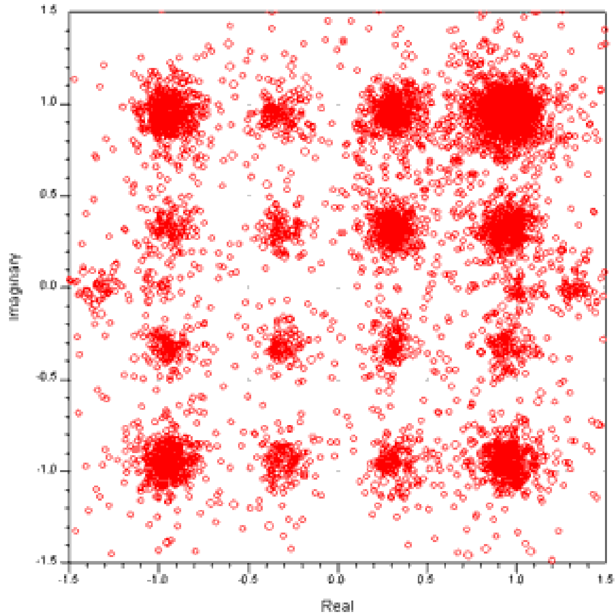
For option 2, a carrier-to-noise ratio of 21.3 dB is used. Simulation results displayed in DTV_DVBT_Rx_SingleEcho_Option2.dds are shown below.

BER for Option 2

Index	BER
1000	2.005E-4

The demodulated constellation is shown below.

Constellation for Option 2



Benchmark

- Hardware Platform: Pentium IV 2.26 GHz, 512 MB memory
- Software Platform: Windows 2000, ADS 2003C
- Simulation Time: approximately 2 minutes

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.
2. DTG RF Sub-Group Document No. 67, *UHF Transmission and Reception*.

DVB-T System Design Examples

DVB-T design examples can be accessed from the ADS Main window *File* > *Open* > *Example* > *DTV*. Schematics and simulation results for the following workspaces are described in this section.

DTV_DVBOFDM_wrk

- DsnDTV_DVBOFDM_16QAM
- DsnDTV_DVBOFDM_64QAM
- DsnDTV_DVBOFDM_PALInterference

DTV_DVBSystem_wrk

- DsnDTV_DVBSystem_16QAM
- DsnDTV_DVBSystem_Hier64QAM
- DsnDTV_DVBOFDM_16QAM_BER

DTV OFDM

OFDM 16-QAM Modulation and Demodulation in DVB-T Systems

DTV_DVBOFDM_wrk Design Name

DsnDTV_DVBOFDM_16QAM

Features

- 16-QAM modulation and demodulation
- TDMA multipath fading channel with Doppler shift. The type of multipath can be selected; Doppler shift can be determined by the mobile speed setting.
- Comparison of DVB and TDMA channel system performance

Description

This example design provides modulation, transmission, and demodulation via a TDMA channel with Doppler shift and DVB channel. Modulation mapping is 16-QAM; the guard interval ratio is 1/16.

After 16-QAM data mapping, OFDM symbols are formed by adding TPS data and pilots. 2048-point inverse FFT (IFFT) is performed. After inserting the guard interval, the complex signal is transmitted; the transmitted signal length is 2048+guard interval.

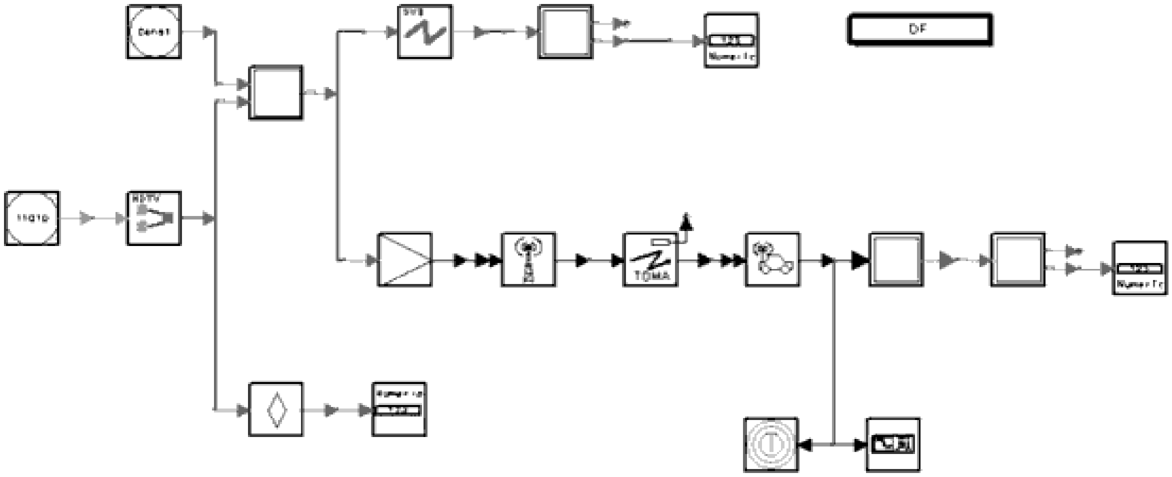
In the receiver, the FFT starting point is determined by the autocorrection function of the received signal. After FFT, the transmitted signal is recovered by the frequency equalizer. According to the DVB-T, the mapped data is received. Data is recovered by the 16-QAM demodulator.

Performance can be viewed in data display files such DsnDTV_DVBOFDM_16QAM and DsnDTV_DVBOFDM_16QAM_EVM.

Schematics

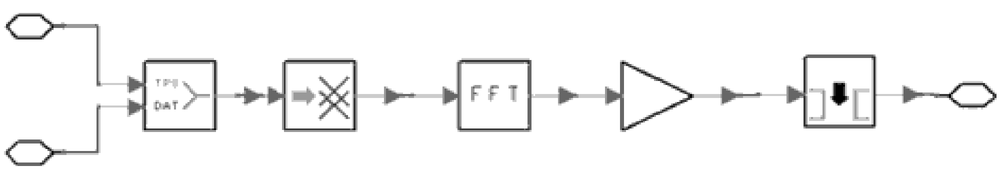
The schematic for this design is shown below.

DTV_DVBOFDM_16QAM

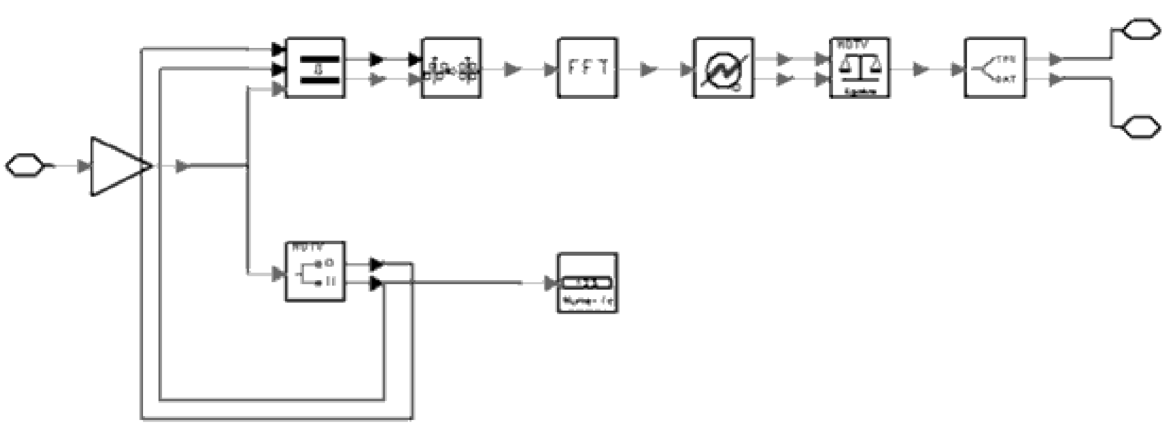


Three subnetworks are used in this design; they are shown below.

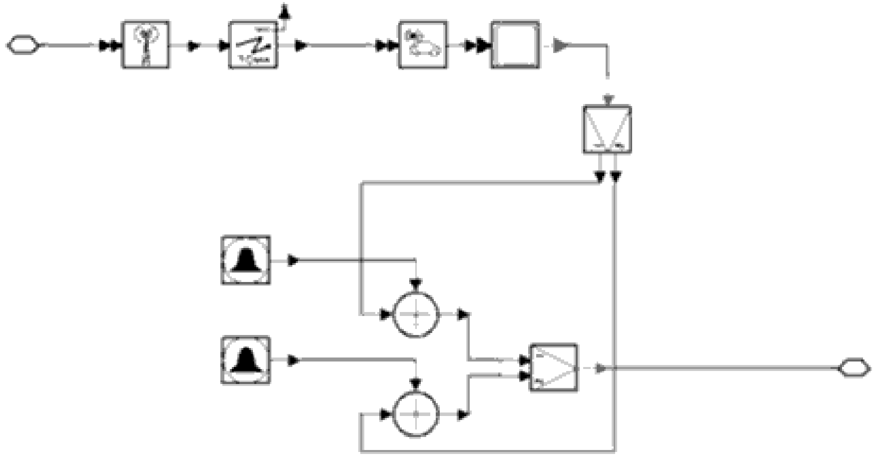
sub_DVBOFDM_Mod



sub_DVBOFDM_Demod



sub_TDMAChannel



Specifications

Symbol (Model)	Specification (Parameter)	Simulation Type	Value
RxSpectrum	Stop	ADS Ptolemy	224 × (2048+128)/2048 × 2 μsec
RxSignal	Stop	ADS Ptolemy	224 × (2048+128)/2048 μsec
PropNADCtdma	Type	ADS Ptolemy	TwoPath
PropNADCtdma	Pathloss	ADS Ptolemy	No
PropNADCtdma	Env	ADS Ptolemy	TypicalSuburban
PropNADCtdma	Delay	ADS Ptolemy	0.5 μsec
PropNADCtdma	Test	ADS Ptolemy	Tap1
AntMobile	Vx	ADS Ptolemy	100.0 km/hr
AntMobile	Vy	ADS Ptolemy	0.0 km/hr

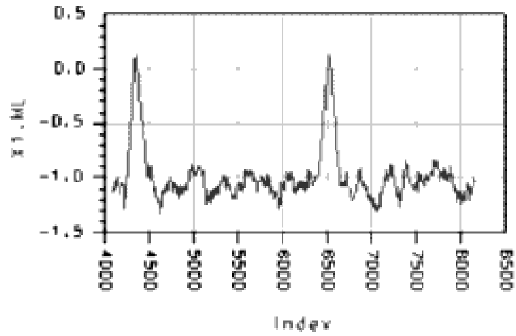
Notes

1. In this example, the guard interval ratio is 1/16, so the guard interval is 128. (According to DVB-T, in the 2K mode the guard interval is 64, 128, 256, or 512, which corresponds to 1/32, 1/16, 1/8, or 1/4 guard interval ratio, respectively.)
2. All parameters are related to the guard interval (except TDMA channel parameters). If the guard interval is changed, parameters will be changed to the corresponding values.
3. The TDMA channel condition varies according to channel parameter modification. Parameters include Type, Pathloss, Env, Delay, and Test in the PropNADCtdma model, and Vx and Vy in the AntMobile model.

Simulation Results

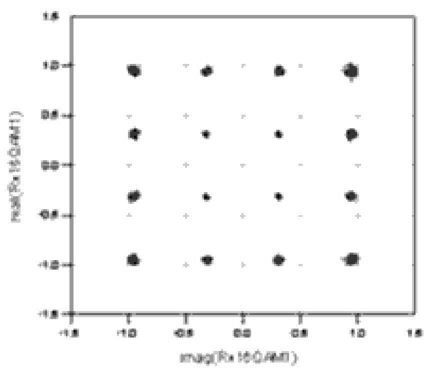
The figure below shows the magnitude of ML function of received signal used to find the FFT start. The maximum value appears in every (2048+128) points, the point of the maximum magnitude value is the FFT start.

ML Magnitude



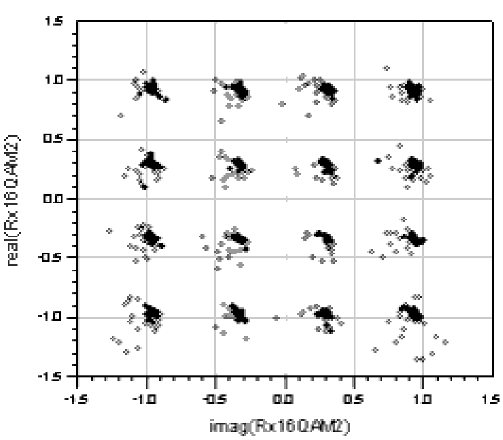
The figure below shows the received constellation after OFDM demodulation via DVB channel. Results show the hard decision before the 16-QAM demodulation is correct

Received Constellation After OFDM Demodulation



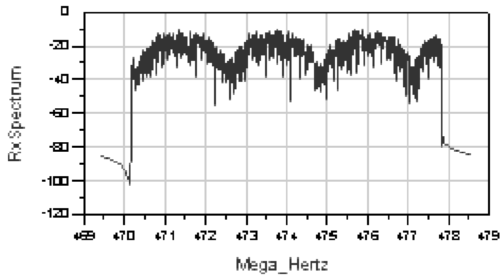
The figure shows the received constellation after OFDM demodulation via TDMA channel. Results show OFDM system performance

Received Constellation after OFDM Demodulation



The figure below shows the spectrum of the wireless channel signal; center frequency is 474 MHz.

Spectrum of Signal Received from Wireless Channel



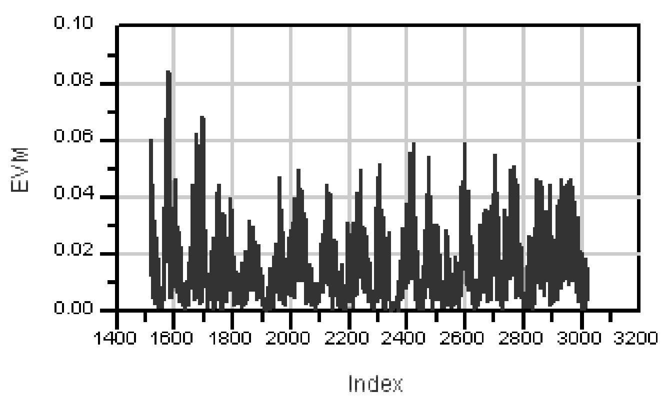
The figure below shows the adjacent-channel power ratio. The equation is:
ACPR=acpr_vr(DsnDTV_DVBOFDM_16QAM..RxSignal,50.0, {-3.9MHz,3.9MHz},{-12MHz,-4.25MHz},{4.25MHz,12MHz})

Adjacent-Channel Power Ratio

ACPR	
ACPR(1)	ACPR(2)
-41.258	-38.835

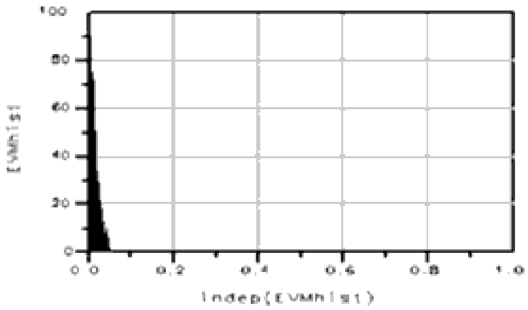
The figure below shows the relative magnitude error, which is defined as:
EVM=mag(DsnDTV_DVBOFDM_16QAM..Rx16QAM1-DsnDTV_DVBOFDM_16QAM.Tx16QAM)/mean(mag(DsnDTV_DVBOFDM_16QAM..Tx16QAM)).

Relative Magnitude Error



The figure below shows the EVM histogram, which shows most EVM < 0.1. EVMhist is defined as: EVMhist=histogram(EVM,1001,0.0,1.0)

EVM Histogram



Benchmark

- Hardware Platform: Pentium II 200 MHz, 96 MB memory
- Software Platform: Windows NT 4.0 Workstation, ADS 1.3
- Data Points: 10 OFDM symbols
- Simulation Time: 34 seconds

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.

OFDM 64-QAM Modulation and Demodulation in DVB-T Systems

DTV_DVBOFDM_wrk Design Name

DsnDTV_DVBOFDM_64QAM

Features

- 64-QAM modulation and demodulation
- TDMA multipath fading channel with Doppler shift. The type of multipath can be

selected; Doppler shift can be determined by the mobile speed setting.
- DVB and TDMA channel performance comparison

Description

This example design provides modulation, transmission and demodulation via a TDMA channel with Doppler shift and DVB channel. Modulation mapping is 64-QAM; the guard interval ratio is 1/16.

After 64-QAM data mapping, OFDM symbols are formed by adding TPS data and pilots. 2048-point inverse FFT (IFFT) is performed. After inserting the guard interval, the complex signal is transmitted. Transmitted signal length is 2048+guard interval.

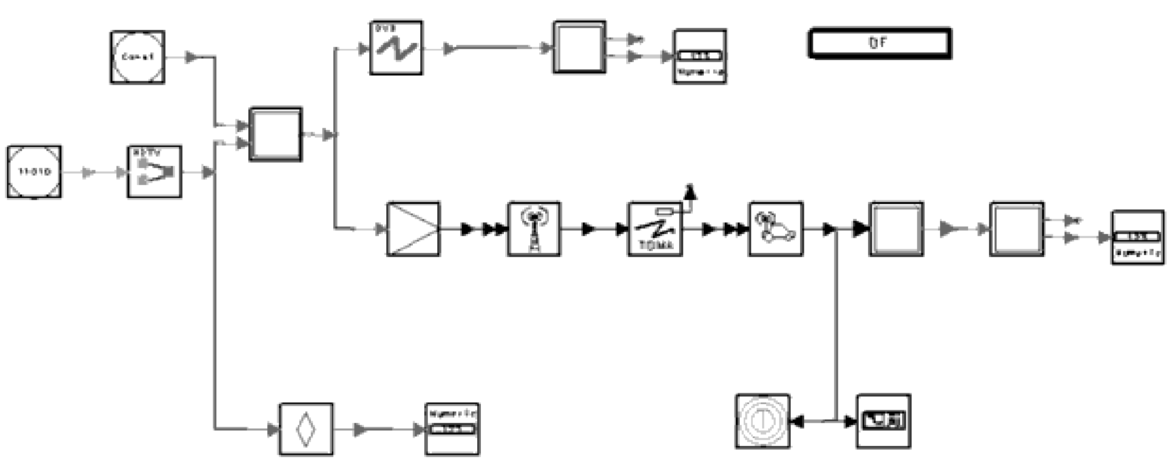
In the receiver, the FFT starting point is determined by the autocorrection function of the received signal. After FFT, the transmitted signal is recovered by the frequency equalizer. According to the DVB-T, the mapped data is received. Data is recovered by the 64-QAM demodulator.

Performance can be viewed in the data display files such as DsnDTV_DVBOFDM_64QAM and DsnDTV_DVBOFDM_64QAM_EVM.

Schematics

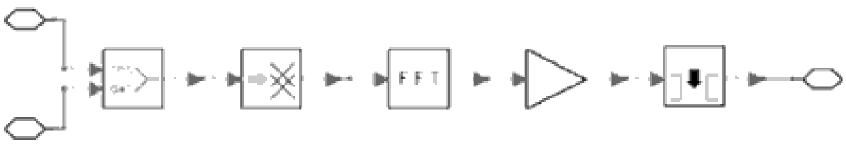
The figure below shows the schematic for this design.

DTV_DVBOFDM_64QAM

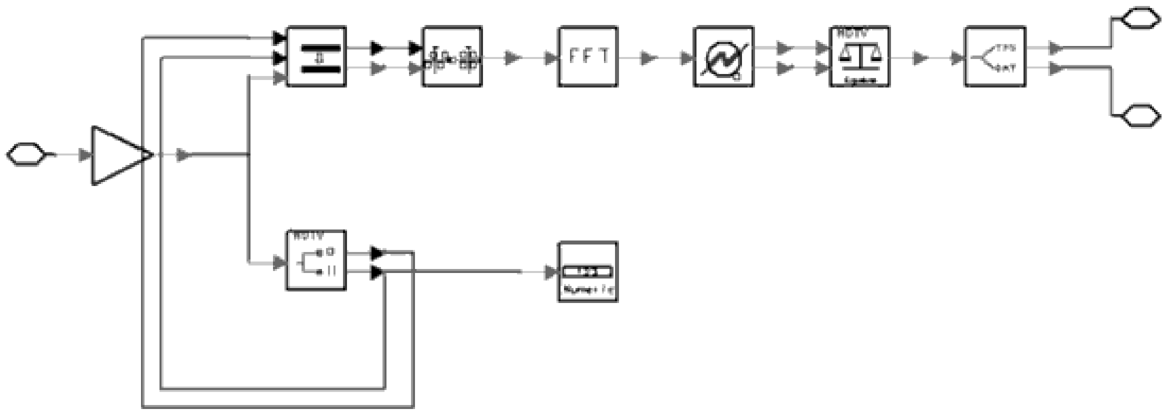


Three subnetworks are used in this design; they are shown below.

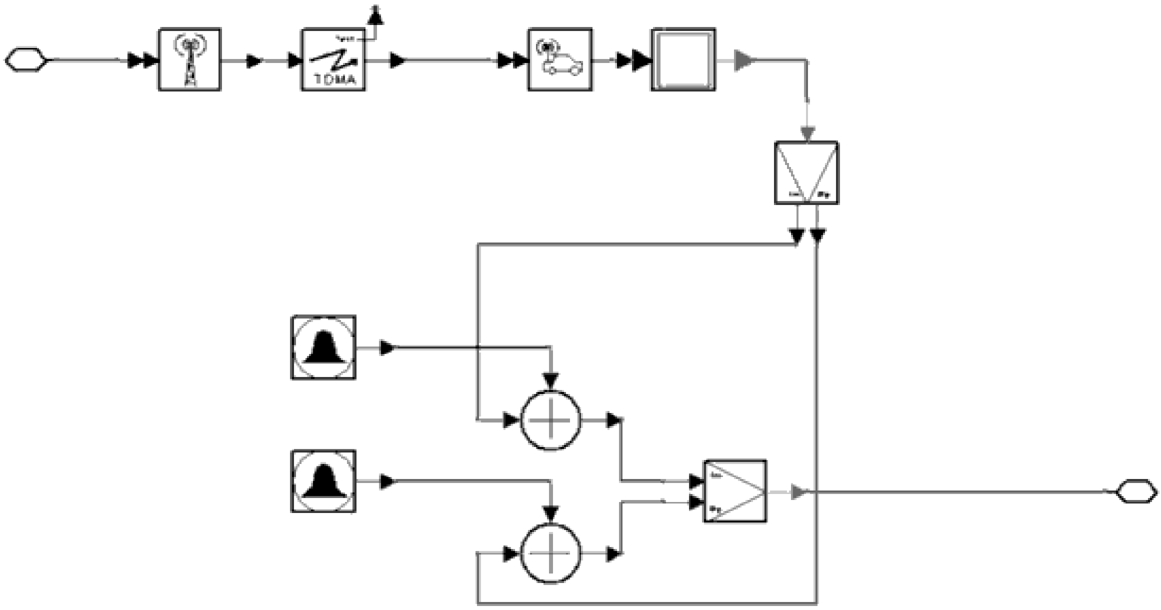
sub_DVBOFDM_Mod



sub_DVBOFDM_Demod



sub_TDMAChannel



Specifications

Symbol (Model)	Specification (Parameter)	Simulation Type	Value
RxSpectrum	Stop	ADS Ptolemy	224 × (2048+128)/2048 × 2 μsec
RxSignal	Stop	ADS Ptolemy	224 × (2048+128)/2048 μsec
PropNADCtdma	Type	ADS Ptolemy	TwoPath
PropNADCtdma	Pathloss	ADS Ptolemy	No
PropNADCtdma	Env	ADS Ptolemy	TypicalSuburban
PropNADCtdma	Delay	ADS Ptolemy	2.5 μsec
PropNADCtdma	Test	ADS Ptolemy	Tap1
AntMobile	Vx	ADS Ptolemy	30.0 km/hr
AntMobile	Vy	ADS Ptolemy	0.0 km/hr

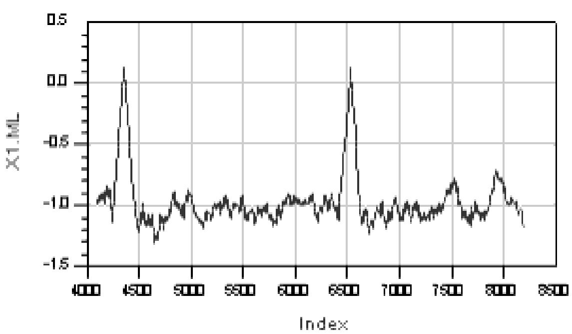
Notes

1. In this example, the guard interval ratio is 1/16, so the guard interval is 128. (According to DVB-T, in the 2K mode the guard interval is 64, 128, 256, or 512, which corresponds to 1/32, 1/16, 1/8, or 1/4 guard interval ratio, respectively.)
2. All parameters are related to the guard interval (except TDMA channel parameters). If the guard interval is changed, parameters will be changed to the corresponding values.
3. The TDMA channel condition varies according to channel parameter modification. Parameters include Type, Pathloss, Env, Delay, and Test in the PropNADCtdma model, and Vx and Vy in the AntMobile model.

Simulation Results

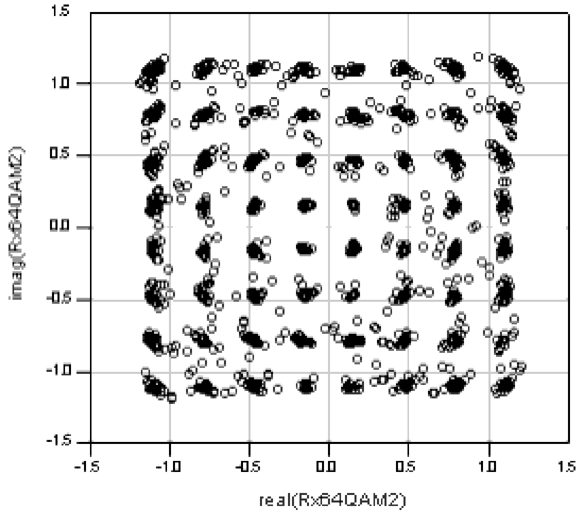
The figure below shows the magnitude of the ML function of the received signal used to find the FFT start point. The maximum value appears in every (2048+128) points, the point of the maximum magnitude value is the starting point of the FFT.

Maximum Likelihood Magnitude



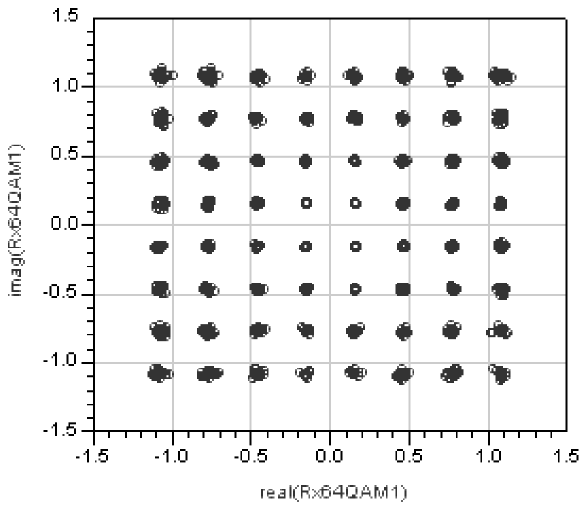
The figure below shows the received constellation after OFDM demodulation via TDMA channel. Results show the hard decision before the 64-QAM demodulation is correct.

Received Constellation After OFDM Demodulation Via TDMA Channel



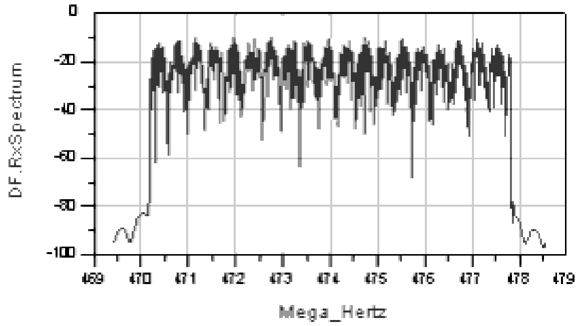
The figure below shows the received constellation after OFDM demodulation via DVB channel. Results show OFDM system performance.

Received Constellation After OFDM Demodulation Via DVB Channel



The figure below shows the spectrum of wireless channel signal received. Center frequency is 474 MHz.

Spectrum of Wireless Channel Signal Received



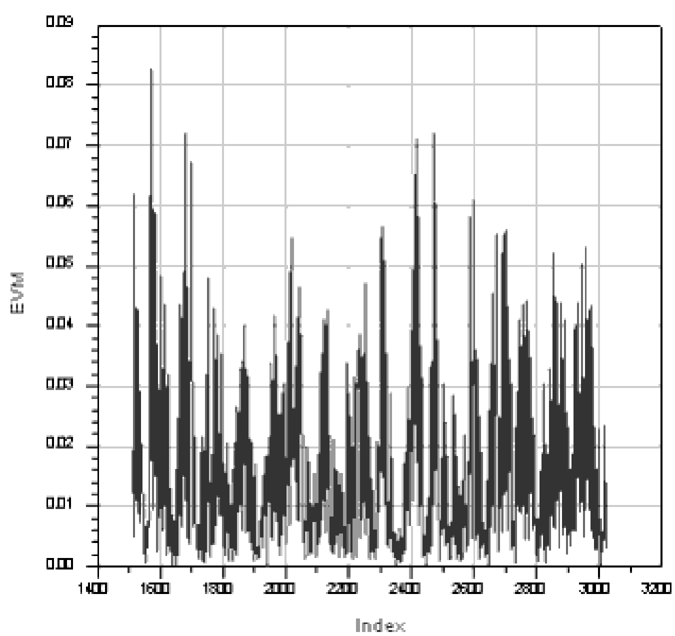
The figure below shows adjacent-channel power ratio. The equation is:
ACPR=acpr_vr(DsnDTV_DVBOFDM_64QAM..RxSignal, 50.0,{-3.9MHz,3.9MHz},{-12MHz,-4.25MHz},{4.25MHz,12MHz}).

Adjacent-Channel Power Ratio

ACPR	
ACPR(1)	ACPR(2)
-46.101	-46.869

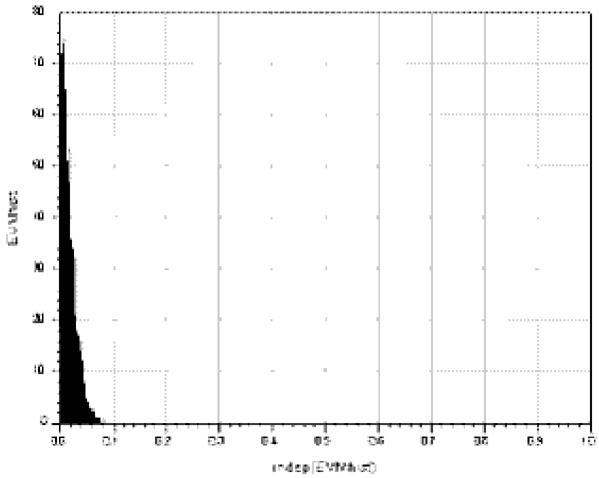
The figure below shows the relative magnitude error, which is defined as:
EVM=mag(DsnDTV_DVBOFDM_64QAM..Rx64QAM1-DsnDTV_DVBOFDM_64QAM..Tx64QAM)/mean(mag(DsnDTV_DVBOFDM_64QAM..Tx64QAM))

Relative Magnitude Error



The figure below shows the EVM histogram, which shows most EVM < 0.1. The EVMhist is defined as: EVMhist=histogram(EVM,1001,0.0,1.0)

EVM Histogram



Benchmark

- Hardware Platform: Pentium II 200 MHz, 96 MB memory
- Software Platform: Windows NT 4.0 Workstation, ADS 1.3
- Data Points: 10 OFDM symbols
- Simulation Time: 34 seconds

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.

OFDM, 64-QAM DTV and PAL Signal Interference Test in DTV Systems

DTV_DVBOFDM_wrk Design Name

DsnDTV_DVBOFDM_PALInterference

Features

- 64-QAM modulation and demodulation
- Adjacent channel interference between analog PAL TV signal and digital DVB-T signal
- Compares analog PAL TV signal and received PAL TV signal that has adjacent channel DVB-T signal interference
- Constellation of received DVB-T signal with adjacent channel PAL signal interference

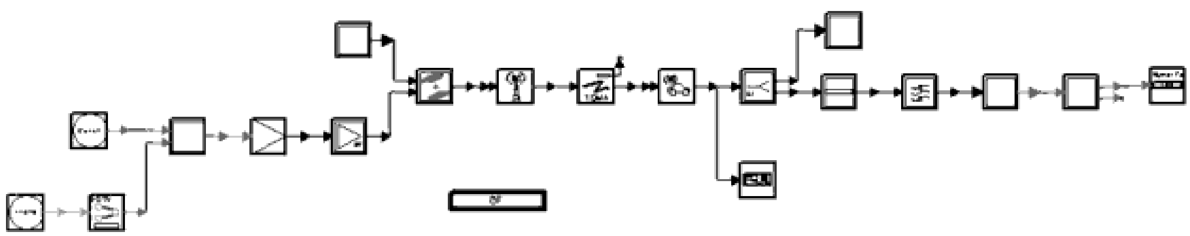
Description

This design is an OFDM example that tests the adjacent channel interference between the analog PAL TV signal and the digital DVB-T signal. The DVB-T signal has weak interference but the analog TV signal experiences strong interference. This effect is saved Data Display (DsnDTV_DVBOFDM_PALInterference1.dds). The center frequency of DVB-T is 482 MHz. The PAL spectrum experiences adjacent channel interference at higher frequency.

Schematics

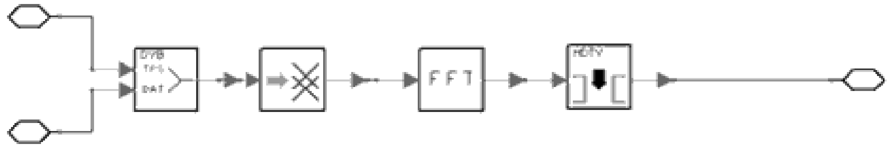
The figure below shows the schematic for this design.

DsnDTV_DVBOFDM_PALInterference

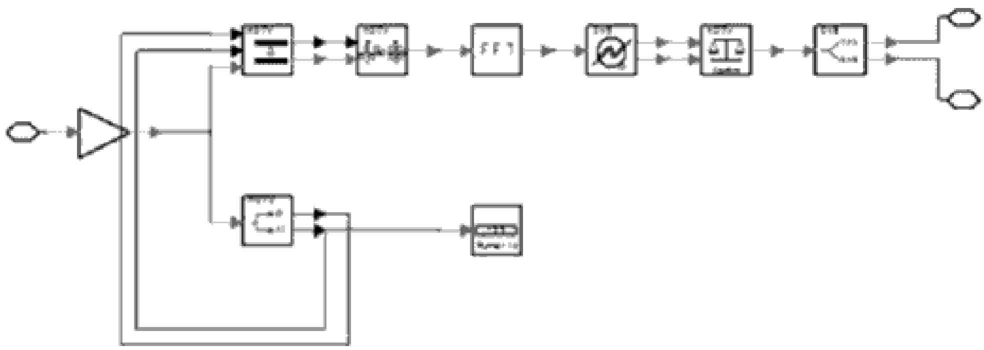


Two subnetworks are used in this design; they are shown below.

sub_OFDM_Mod



sub_DVBOFDM_Demod



Specifications

Specification (Parameter)	Simulation Type	Value
IFFTSize	ADS Ptolemy	2048 × 4
FFTSize	ADS Ptolemy	2048 × 4
GuardInterval	ADS Ptolemy	128 × 4
IFFTOrder	ADS Ptolemy	13
FFTOrder	ADS Ptolemy	13
MaxDelay	ADS Ptolemy	2048 × 4

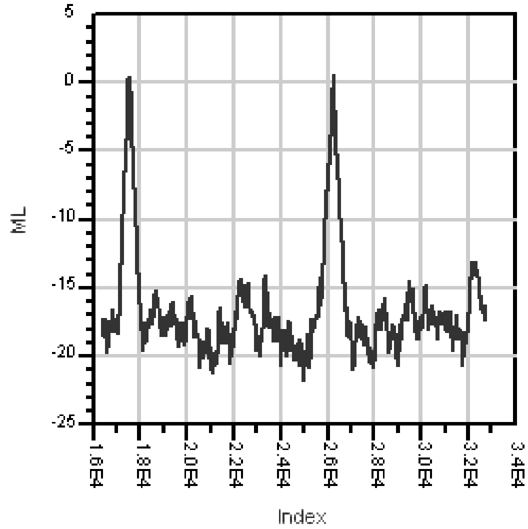
Notes

1. In this example, the guard interval ratio is 1/16, so the guard interval is 128. (According to DVB-T, in the 2K mode the guard interval is 64, 128, 256, or 512, which corresponds to 1/32, 1/16, 1/8, or 1/4 guard interval ratio, respectively.)
2. Except for TDMA channel parameters, all parameters are related to the guard interval. If the guard interval is changed, they will be changed to the corresponding values.
3. The TDMA channel condition varies according to channel parameter modification. Parameters include Type, Pathloss, Env, Delay, and Test in the PropNADCtdma model, and Vx and Vy in the AntMobile model.

Simulation Results

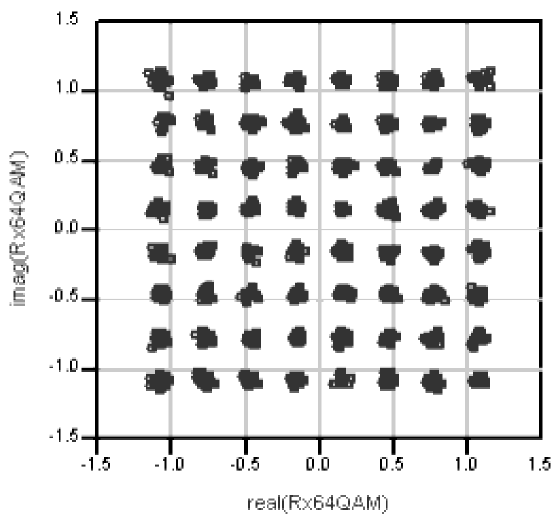
The figure below shows the ML (maximum likelihood) magnitude which shows the magnitude of ML function of the received signal used to find the FFT starting point. The maximum value appears in every 4 × (2048+128) points; the maximum magnitude value is the FFT starting point.

Maximum Likelihood Magnitude

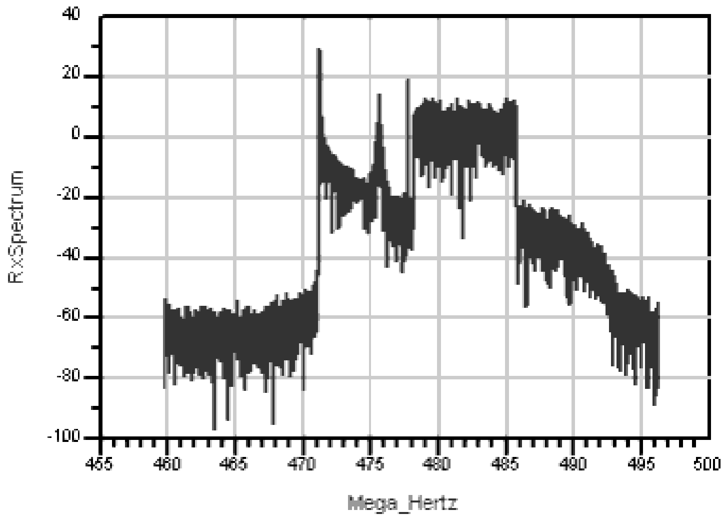


The figure below shows the received QAM constellation after OFDM demodulation via TDMA channel with adjacent band PAL signal interference.

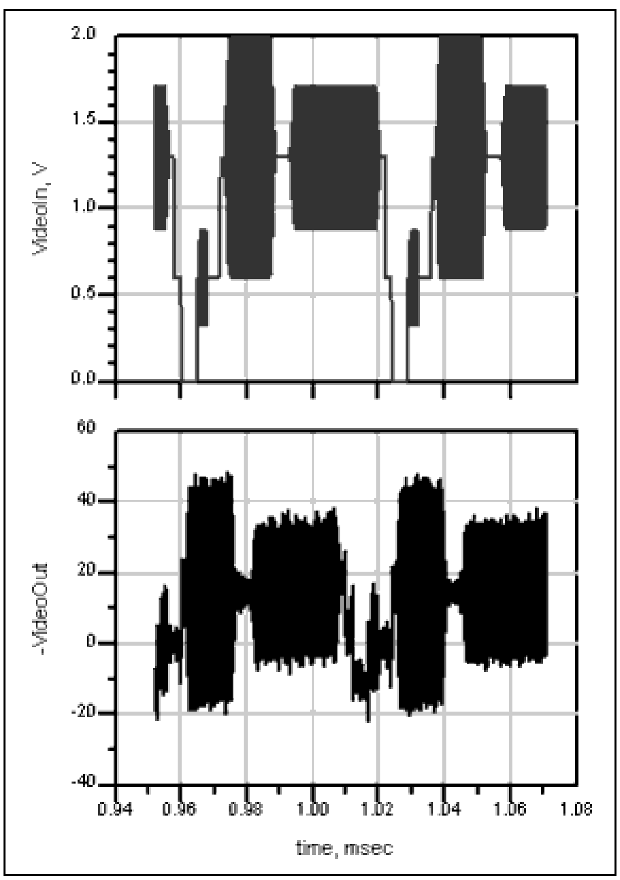
Received 64-QAM Constellation after OFDM Demodulation Via TDMA Channel



Spectrum of Signal Received from Wireless Channel



Comparison of PAL Video Input Signal and Output Signal with Adjacent Band DVB-T Signal Interference



Benchmark

- Hardware Platform: Pentium II 200 MHz, 96 MB memory

- Software Platform: Windows NT 4.0 Workstation, ADS 1.3
- Data Points: 10 OFDM symbols
- Simulation Time: 2 hours

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.

DTV DVB System

OFDM 16-QAM DVB-T System without Channel Coding BER

DTV_DVBSystem_wrk Design Name

DsnDTV_DVBOFDM_16QAM_BER

Features

- 16-QAM modulation and demodulation
- Guard interval
- Displays include:
  ML (maximum likelihood) estimation for OFDM frame synchronization,
  Angle (phase offset due to carrier frequency) for OFDM carrier synchronization, TxBit, RxBit, and Rx16QAM
- BER performance test for Gaussian, Ricean, and Rayleigh channels

Description

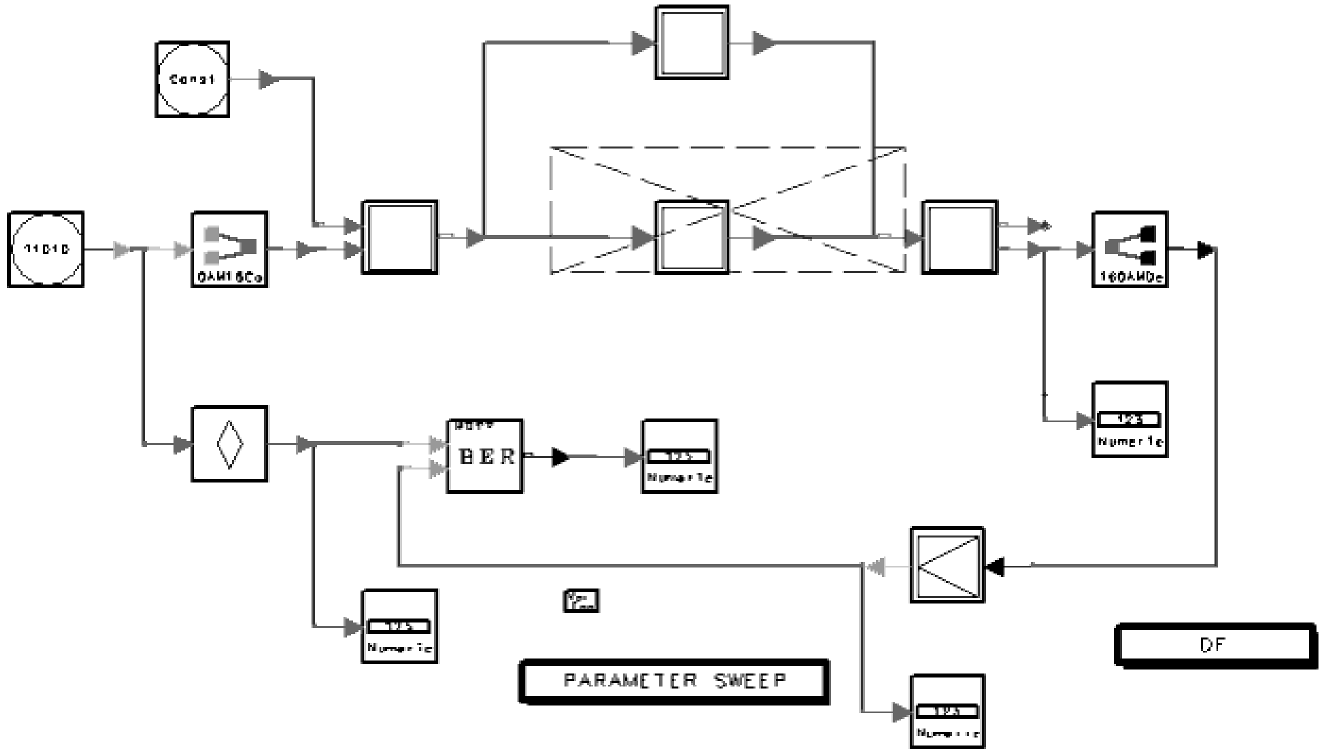
This OFDM adaptation for DVB-T 2K mode design example tests the BER without channel coding. Modulation mapping is 16-QAM; the guard interval ratio is 1/16.

Simulation results can be compared to those of DsnDTV_DVBSystem_16QAM, which tests the BER with channel coding and interleaving.

Schematics

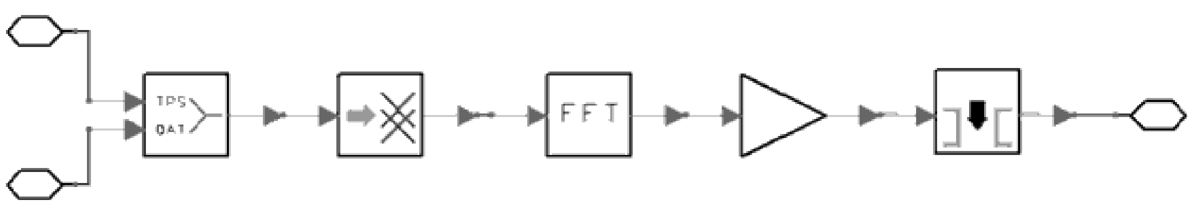
The figure below shows the schematic for this design.

DsnDTV_DVBOFDM_16QAM_BER

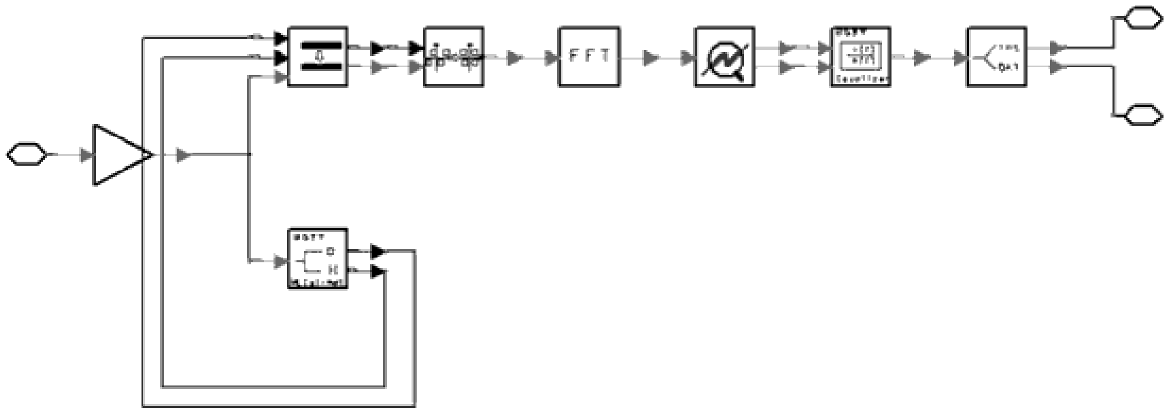


Two subnetworks are used in this design; they are shown below.

sub_DVBOFDM_Mod



sub_DVBOFDM_Demod



Specifications

Symbol (Model)	Specification (Parameter)	Simulation Type	Value
	Carriers	ADS Ptolemy	1705
	Data	ADS Ptolemy	1512
	IFFTSize	ADS Ptolemy	2048
	FFTSize	ADS Ptolemy	2048
	Guard	ADS Ptolemy	128
	IFFTOrder	ADS Ptolemy	11
	FFTOrder	ADS Ptolemy	11
	MaxDelay	ADS Ptolemy	2047
DTV_DVBChannel	SampleTime	ADS Ptolemy	224.0e-6/2048

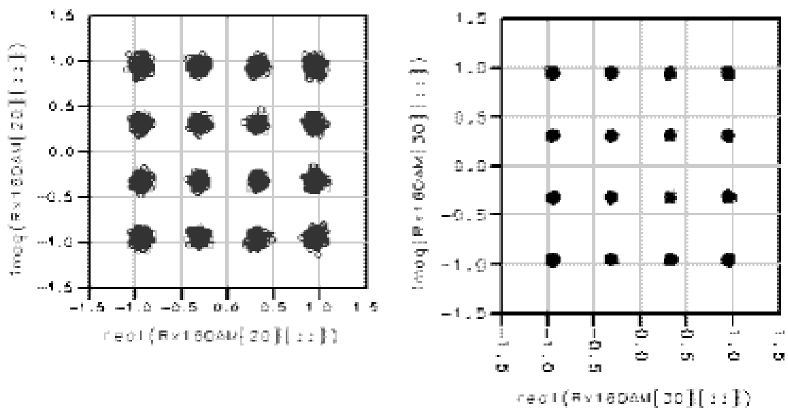
Notes

1. In this example, the guard interval ratio is 1/16, so the guard interval is 128. (According to DVB-T, in the 2K mode the guard interval is 64, 128, 256, or 512, which corresponds to 1/32, 1/16, 1/8, or 1/4 guard interval ratio, respectively.)
2. This design can be used for three different simulations: Gaussian channel, Ricean channel (F1) and Rayleigh channel.

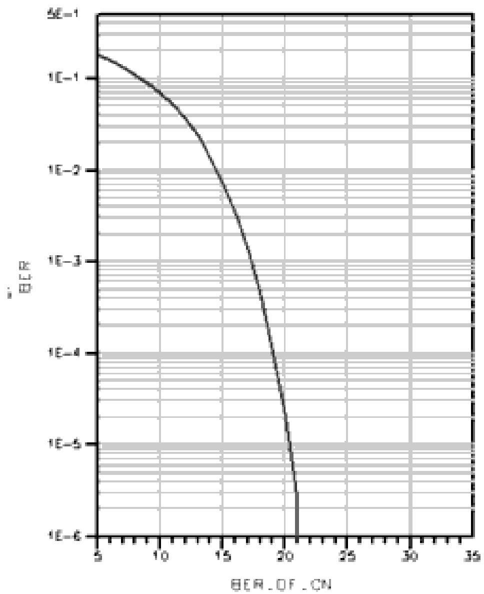
Simulation Results

- Additive white Gaussian noise was added to set the carrier-to-noise (CN) ratio at the input of the receiver. Constellation of OFDM Demodulation Signal at Different CN shows the received constellation after OFDM demodulation when the CN is 15dB and 25dB in Gaussian channel simulation. The results show the higher CN is better than the lower.
Gaussian Channel BER shows the BER at different CN.

Constellation of OFDM Demodulation Signal at Different CN



Gaussian Channel BER



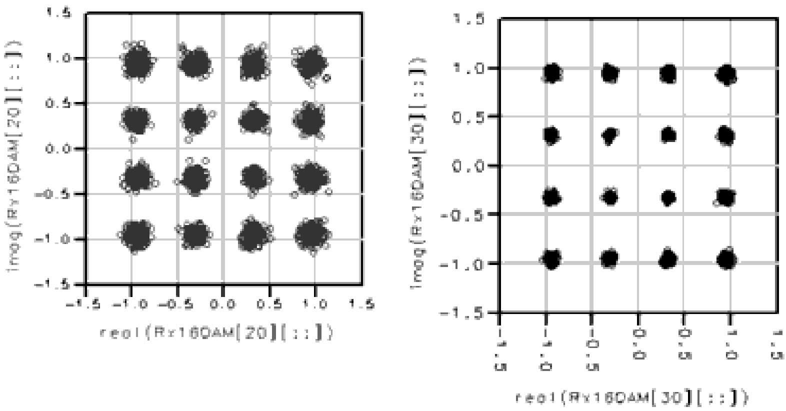
- Ricean channel
  Measurements of BER vs. CN were made using a Ricean channel simulator. The channel parameter is from DVB-T. In our DTV simulation system, this Ricean channel is simulated by sub_DVBChannel subnetwork, its parameters were set as follows:

Symbol	Specification	Simulation Type	Value
sub_DVBChannel	NoiseGain	ADS Ptolemy	5.45/exp(CN/10.0 × ln(10))
DVBChannel	ChannelModel	ADS Ptolemy	Fixed Reception F1

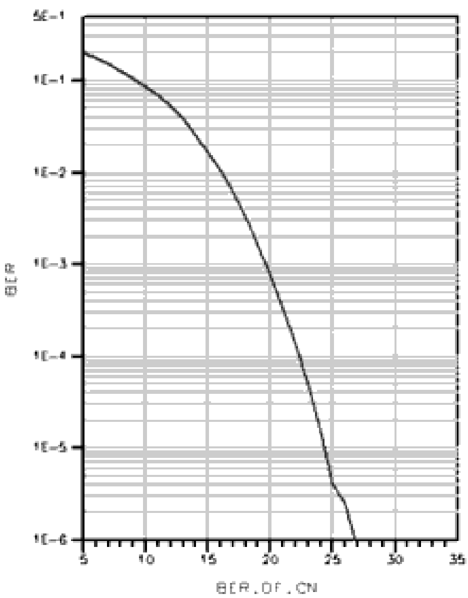
  This simulation result was not included in this DTV package because of the limitation of DTV package size. If users want to prove the BER performance of this channel, users can set the parameters above and run this design example. The simulation time is very long.
  Constellation of OFDM Demodulation Signal at Different CN shows the received constellation after OFDM demodulation when the CN is 15dB and 25dB, respectively in the Ricean channel simulation. The results show the result of higher CN is better than that of lower CN.
  Ricean Channel BER shows the BER of different CN when the simulation channel is

Ricean channel.

Constellation of OFDM Demodulation Signal at Different CN



Ricean Channel BER



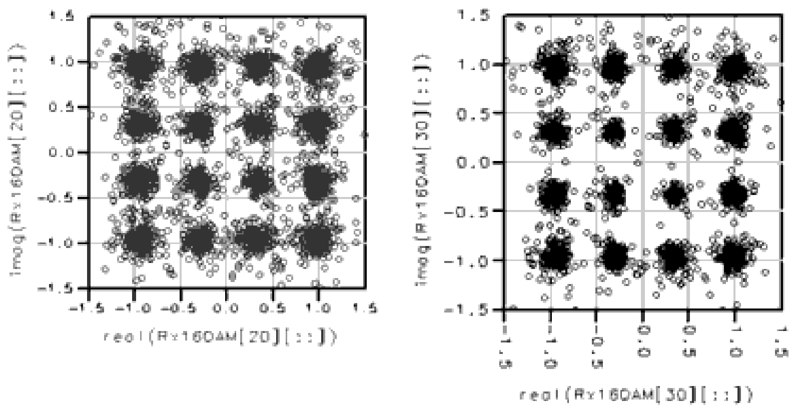
- Rayleigh channel
  Measurements of BER vs. CN were made using a Rayleigh channel simulator. The channel parameter is from DVB-T. In our DTV simulation system, this Ricean channel is simulated by sub_DVBChannel subnetwork, its parameters were set as follows:

Symbol	Specification	Simulation Type	Value
sub_DVBChannel	NoiseGain	ADS Ptolemy	0.45/exp(CN/10.0 × ln(10))
DVBChannel	ChannelModel	ADS Ptolemy	Portable Reception P1

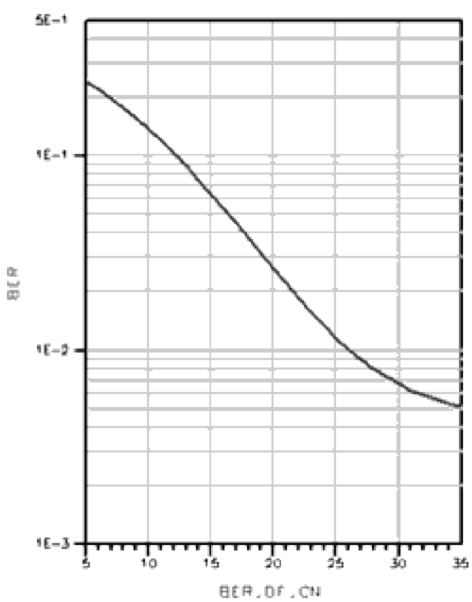
  This simulation result was not included in this DTV package because of the limitation of DTV package size. If users want to prove the BER performance of this channel, users can set the parameters above and run this design example. The simulation time is very long.
  Constellation of OFDM Demodulation Signal at Different CN shows the received constellation after OFDM demodulation when the CN is 15dB and 25dB. The results

show the higher CN is better than the lower.
Rayleigh Channel BER shows the BER of different CN.
Gaussian, Ricean, and Rayleigh Simulation Channel BERs shows BERs of the three channels; the AWGN channel is the best.

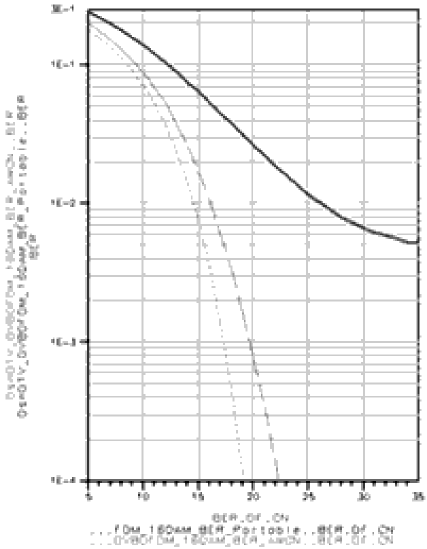
Constellation of OFDM Demodulation Signal at Different CN



Rayleigh Channel BER



Gaussian, Ricean, and Rayleigh Simulation Channel BERs



Benchmark

- Hardware Platform: Pentium II 200 MHz, 128 MB memory
- Software Platform: Windows NT 4.0 Workstation, ADS 1.3
- Data Points: 200 OFDM symbols
- Simulation Time: Approximately one hour and 38 minutes for each channel model

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.

16-QAM DVB-T System Design

DTV_DVBSystem_wrk Design Name

DsnDTV_DVBSystem_16QAM

Features

- 16-QAM modulation and demodulation
- 2K mode OFDM adaptation
- Channel coding and decoding, including Reed-Solomon, 1/2 punctured convolutional coding

- Inner and outer interleaving
- BER performance test for Gaussian, Ricean, and Rayleigh channels

Description

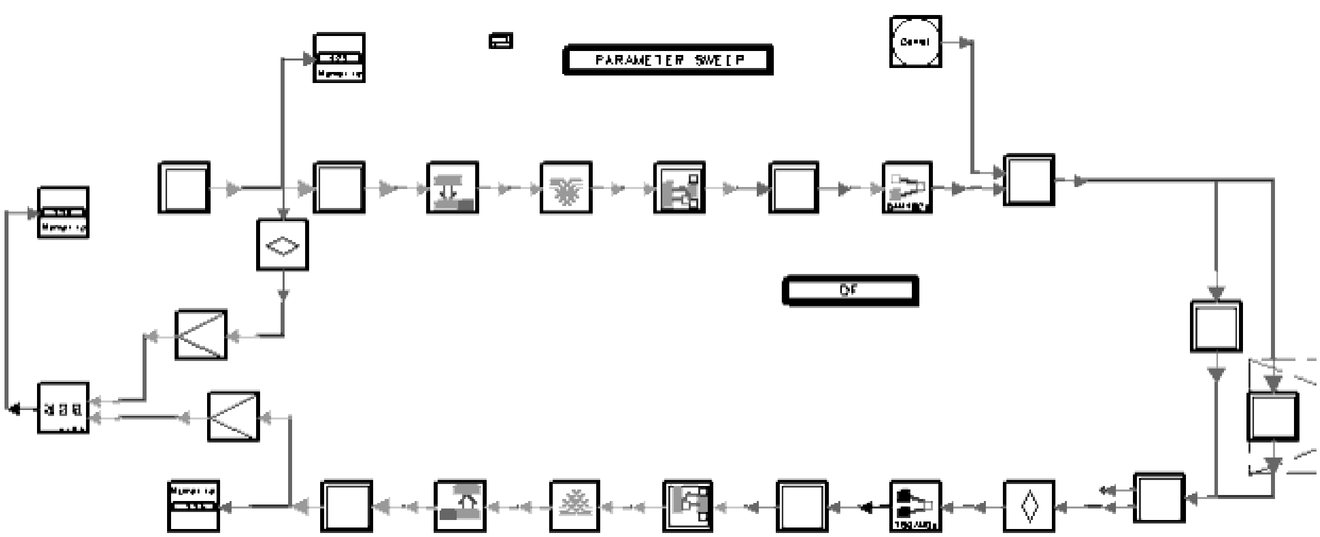
This DVB-T system design includes inner and outer interleaving, Reed-Solomon and convolutional coding, and full OFDM adaptation. Modulation modes and code rates are uniform 16-QAM and 1/2, respectively. In the OFDM adaptation, the full system design works in 2K mode. The IFFT/ FFT is 2048; the Guard interval is 1/16 the IFFT size. Simulation channels are Gaussian, Ricean, and Rayleigh.

The byte in transmitter and receiver, the BER of the three simulation channels are shown in the simulation results. The BER of the channels in this design are compared to the DVB system without channel coding and interleaving in the *DsnDTV_DVBOFDM_16QAM_BER*.

Schematics

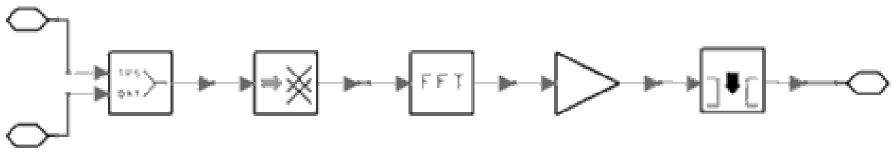
The figure below shows the schematic for this design.

DTV_DVBSystem_16QAM

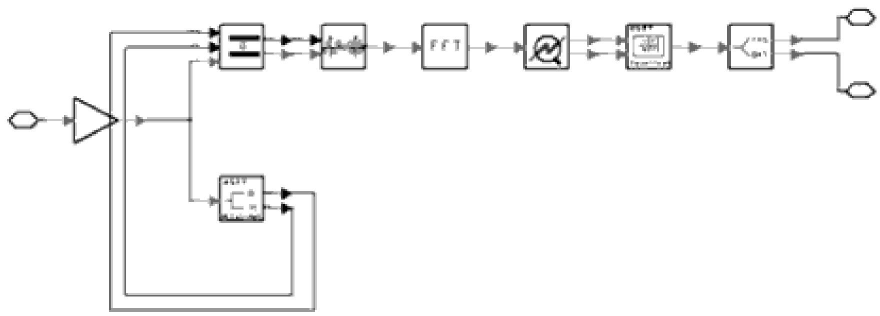


Four subnetworks are used in this design; they are shown below.

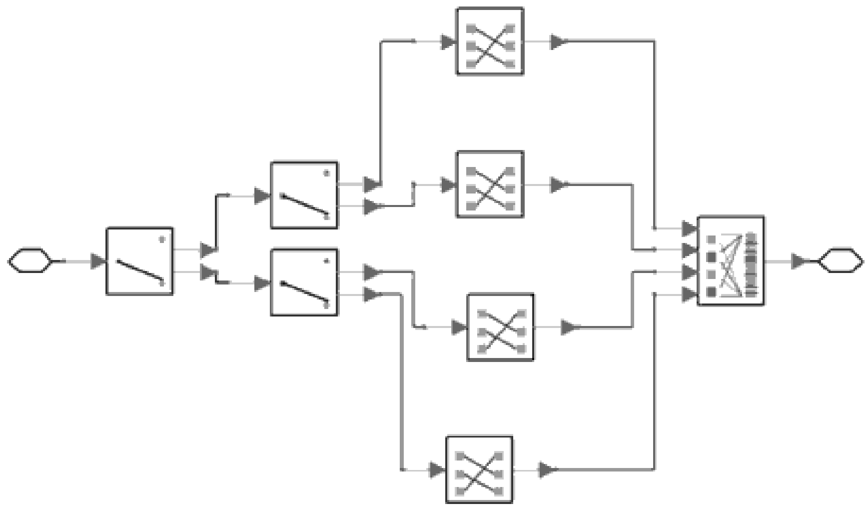
sub_DVBOFDM_Mod



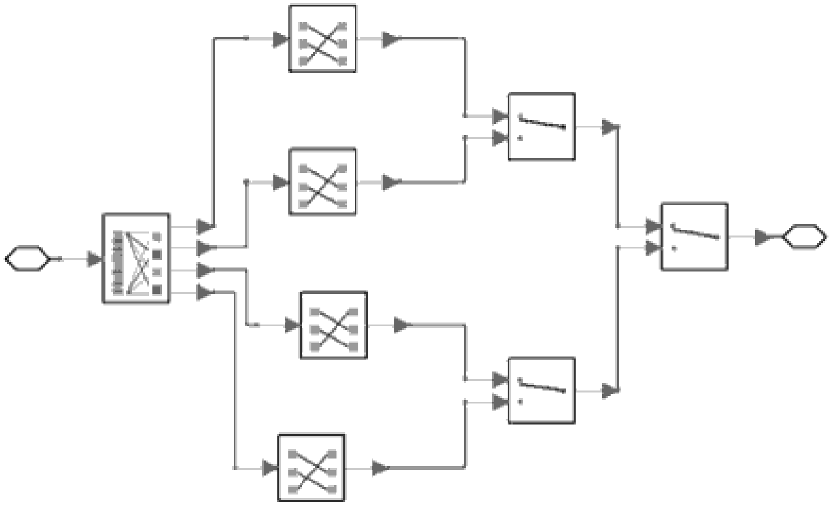
sub_DVBOFDM_Demod



sub_DVBInnerInterlv



sub_DVBInnerDeinterlv



Specifications

Specification (Parameter)	Simulation Type	Value
Carriers	ADS Ptolemy	1705
Data	ADS Ptolemy	1512
IFFTSize	ADS Ptolemy	2048
FFTSize	ADS Ptolemy	2048
Guard	ADS Ptolemy	128
IFFTOrder	ADS Ptolemy	11
FFTOrder	ADS Ptolemy	11
MaxDelay	ADS Ptolemy	2047
Ru	ADS Ptolemy	0.9

Notes

1. The propagation channel model used in this example is a standard terrestrial television propagation channel as defined in the DVB-T specification.
2. The *DelayByte* parameter of the punctured convolutional decoder (*DTV_PuncConvDecoder* (dtv) model) is used to adjust delays caused by OFDM demodulation (which is one OFDM symbol) and one additional OFDM symbol delay (which corresponds to the *DTV_DVBSymDeinterlv4b* (dtv) model) because this model uses an even number of OFDM symbols.

Simulation Results

- AWGN Channel
  Additive white Gaussian noise was added to set the carrier-to-noise (CN) ratio at the receiver input.
  Compare RxTSP with TxTSP with Different CN shows the transmitted and received TSP data when the CN ratio is 5dB and 8dB in Gaussian channel simulation. In

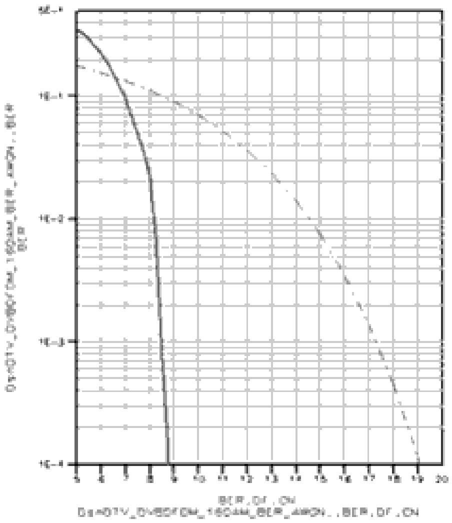
Compare RxTSP with TxTSP with Different CN, the first column is the received TSP of CN=5dB; the second column is the received TSP of CN=8dB; the last line is the transmitted TSP. Compared to TxTSP, the first line has more errors than the second line.

Compare RxTSP with TxTSP with Different CN

Index	...][::]	...][::]	Index	...][::]
2821	222.000	100.000	1	100.000
2822	204.000	204.000	2	204.000
2823	145.000	145.000	3	145.000
2824	23.000	23.000	4	23.000
2825	128.000	135.000	5	135.000
2826	129.000	124.000	6	124.000
2827	111.000	223.000	7	223.000
2828	251.000	251.000	8	251.000
2829	35.000	15.000	9	15.000
2830	35.000	40.000	10	40.000
2831	28.000	8.000	11	8.000
2832	211.000	211.000	12	211.000
2833	25.000	41.000	13	41.000
2834	251.000	251.000	14	251.000
2835	4.000	4.000	15	4.000
2836	15.000	153.000	16	153.000
2837	139.000	224.000	17	224.000
2838	213.000	204.000	18	204.000
2839	81.000	243.000	19	243.000
2840	11.000	11.000	20	11.000
2841	137.000	37.000	21	37.000
2842	221.000	221.000	22	221.000
2843	155.000	231.000	23	231.000
2844	114.000	114.000	24	114.000
2845	157.000	157.000	25	157.000
2846	125.000	125.000	26	125.000
2847	71.000	71.000	27	71.000
2848	154.000	154.000	28	154.000
2849	89.000	142.000	29	142.000
2850	189.000	241.000	30	241.000
2851	18.000	115.000	31	115.000
2852	91.000	91.000	32	91.000
2853	158.000	157.000	33	157.000
2854	181.000	47.000	34	47.000
2855	23.000	223.000	35	223.000
2856	3.000	3.000	36	3.000
2857	155.000	159.000	37	159.000
2858	154.000	154.000	38	154.000
2859	87.000	87.000	39	87.000
2860	160.000	211.000	40	211.000

The BERs of the full system and OFDM system (without channel coding in DsnDTV_DVBOFDM_16QAM_BER) are shown in Gaussian Channel BER (solid line = full system; dash line = DsnDTV_DVBOFDM_16QAM_BER). Channel coding gain is approximately 8.5dB at 0.001 BER.
According to DVB-T, in 16-QAM modulation, code rate is 1/2, and Gaussian channel model condition, the required CN for BER=0.0002 after Viterbi QEF and Reed-Solomon coding is 8.8dB. In Gaussian Channel BER (solid line = full system; dash line = DsnDTV_DVBOFDM_16QAM_BER), CN is approximately 8.8dB for BER=0.0002. The simulation results shows this design is correct in the Gaussian channel.

Gaussian Channel BER



(solid line = full system;
dash line = DsnDTV_DVBOFDM_16QAM_BER)

- Ricean channel
  Measurements of BER vs. CN were made using a Ricean channel simulator. The channel parameter is from DVB-T. In our DTV simulation system, this Ricean channel is simulated by sub_DVBChannel subnetwork, its parameters were set as follows:

Symbol	Specification	Simulation Type	Value
sub_DVBChannel	NoiseGain	ADS Ptolemy	5.45/exp(CN/10.0 × ln(10))
DVBChannel	ChannelModel	ADS Ptolemy	Fixed Reception F1

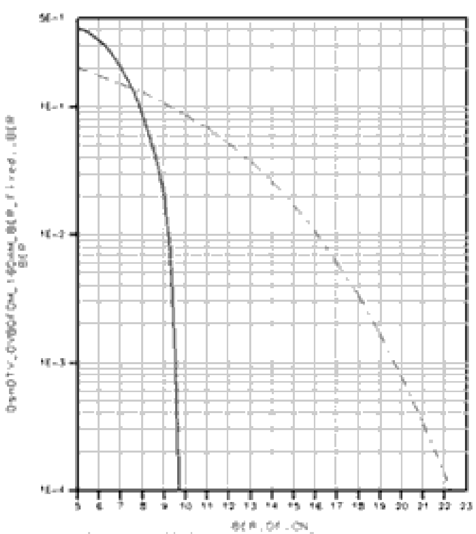
Compare RxTSP with TxTSP with Different CN show the transmitted and received TSP data when CN ratio is 5dB and 8dB in the Ricean channel simulation. The first column is the received TSP of CN=5dB, the second column is the received TSP of CN=8dB; the last column is the transmitted TSP. Compared to TxTSP, the first line has more errors than the second line.

Compare RxTSP with TxTSP with Different CN

Index	...][::]	...][::]	Index	...][::]
2821	222.000	22.000	1	100.000
2822	204.000	204.000	2	204.000
2823	64.000	145.000	3	145.000
2824	17.000	23.000	4	23.000
2825	145.000	135.000	5	135.000
2826	160.000	124.000	6	124.000
2827	236.000	236.000	7	223.000
2828	251.000	251.000	8	251.000
2829	16.000	16.000	9	16.000
2830	116.000	40.000	10	40.000
2831	44.000	210.000	11	6.000
2832	215.000	211.000	12	211.000
2833	26.000	41.000	13	41.000
2834	251.000	251.000	14	251.000
2835	4.000	4.000	15	4.000
2836	5.000	153.000	16	153.000
2837	139.000	230.000	17	224.000
2838	213.000	213.000	18	204.000
2839	211.000	243.000	19	243.000
2840	224.000	11.000	20	11.000
2841	254.000	137.000	21	37.000
2842	221.000	221.000	22	221.000
2843	54.000	231.000	23	231.000
2844	215.000	114.000	24	114.000
2845	168.000	167.000	25	167.000
2846	126.000	126.000	26	126.000
2847	71.000	71.000	27	71.000
2848	164.000	164.000	28	164.000
2849	53.000	142.000	29	142.000
2850	133.000	241.000	30	241.000
2851	150.000	18.000	31	115.000
2852	120.000	91.000	32	91.000
2853	158.000	158.000	33	167.000
2854	45.000	179.000	34	47.000
2855	253.000	223.000	35	223.000
2856	65.000	9.000	36	9.000
2857	123.000	159.000	37	159.000
2858	75.000	154.000	38	154.000
2859	215.000	87.000	39	87.000
2860	23.000	211.000	40	211.000

The BERs of the full system and OFDM system (without channel coding in DsnDTV_DVBOFDM_16QAM_BER) are shown in Ricean Channel BER (solid line = full system; dash line = DsnDTV_DVBOFDM_16QAM_BER). Channel coding gain is approximately 10dB at 0.001 BER. According to DVB-T, in 16-QAM modulation, code rate is 1/2, and Gaussian channel model condition, the required CN for BER=0.0002 after Viterbi QEF after Reed-Solomon coding is 9.6dB. In Ricean Channel BER (solid line = full system; dash line = DsnDTV_DVBOFDM_16QAM_BER), CN is approximately 9.6dB for BER=0.0002. The simulation results shows this design is correct in the Ricean channel.

Ricean Channel BER



(solid line = full system;
dash line = DsnDTV_DVBOFDM_16QAM_BER)

- Rayleigh channel
  Measurements of BER vs. CN were made using a Rayleigh channel simulator. The channel parameter is from DVB-T. In our DTV simulation system, this Ricean channel is simulated by sub_DVBChannel subnetwork, its parameters were set as follows:

Symbol	Specification	Simulation Type	Value
sub_DVBChannel	NoiseGain	ADS Ptolemy	0.45/exp(CN/10.0 × ln(10))
DVBChannel	ChannelModel	ADS Ptolemy	Portable Reception P1

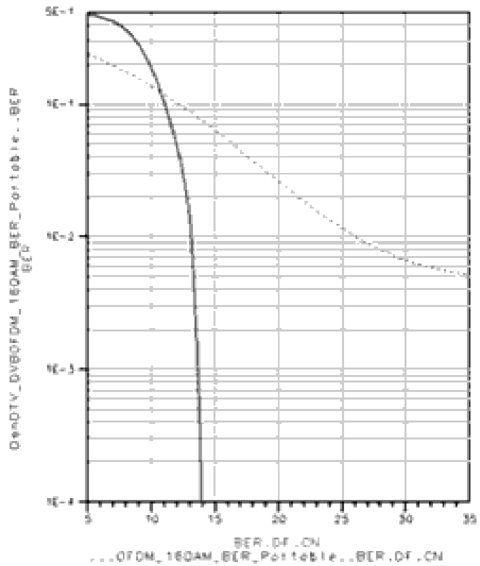
  This simulation result was not included in this DTV package because of the limitation of DTV package size. To prove the BER performance of this channel, set the parameters and run this design example; simulation time is very long.
  Compare RxTSP with TxTSP with different CN shows the transmitted and received TSP data when CN is 5dB and 8dB in Rayleigh channel simulation. The first column is the received TSP of CN=5dB, the second column is the received TSP of CN=8dB; the last column is the transmitted TSP. Compared to the TxTSP, the first column shows many errors, while the second column has fewer errors.

Compare RxTSP with TxTSP with different CN

Index	...	...	Index	...
2821	100.000	100.000	1	100.000
2822	255.000	204.000	2	204.000
2823	211.000	214.000	3	145.000
2824	223.000	138.000	4	23.000
2825	40.000	188.000	5	135.000
2826	8.000	8.000	6	124.000
2827	223.000	141.000	7	223.000
2828	254.000	47.000	8	251.000
2829	87.000	18.000	9	18.000
2830	192.000	138.000	10	40.000
2831	26.000	28.000	11	8.000
2832	2.000	211.000	12	211.000
2833	41.000	41.000	13	41.000
2834	196.000	251.000	14	251.000
2835	108.000	12.000	15	4.000
2836	125.000	125.000	16	153.000
2837	248.000	252.000	17	224.000
2838	8.000	8.000	18	204.000
2839	36.000	78.000	19	243.000
2840	77.000	11.000	20	11.000
2841	165.000	82.000	21	37.000
2842	17.000	65.000	22	221.000
2843	168.000	251.000	23	231.000
2844	28.000	158.000	24	114.000
2845	208.000	111.000	25	167.000
2846	247.000	128.000	26	126.000
2847	188.000	194.000	27	71.000
2848	164.000	164.000	28	164.000
2849	42.000	158.000	29	142.000
2850	9.000	219.000	30	241.000
2851	19.000	115.000	31	115.000
2852	178.000	68.000	32	91.000
2853	39.000	167.000	33	167.000
2854	5.000	47.000	34	47.000
2855	158.000	99.000	35	223.000
2856	48.000	48.000	36	9.000
2857	123.000	159.000	37	159.000

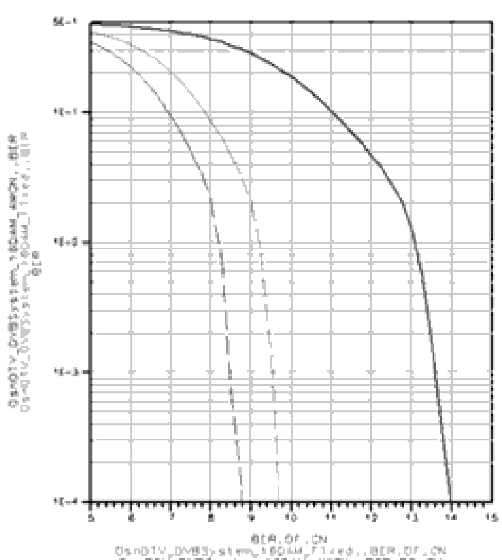
  The BERs of the full system and OFDM system (without channel coding in DsnDTV_DVBOFDM_16QAM_BER) are shown in Rayleigh Channel BER (solid line = full system; dotted line = DsnDTV_DVBOFDM_16QAM_BER). Channel coding gain is approximately 12.0dB at 0.001 BER. According to the DVB-T, in 16-QAM modulation, code rate is 1/2, and Rayleigh channel model condition, the required CN for BER=0.0002 after Viterbi QEF after Reed-Solomon coding is 11.2dB. In Rayleigh Channel BER (solid line = full system; dotted line = DsnDTV_DVBOFDM_16QAM_BER), CN is approximately 13.8dB for BER=0.0002.

Rayleigh Channel BER (solid line = full system; dotted line = DsnDTV_DVBOFDM_16QAM_BER)



The simulated system performance in DVB-T Appendix A is obtained at *Perfect channel estimation and without phase noise condition* ; the performance in DVB-T Table A.1 is the best performance. In our simulation, channel estimation is not perfect because of noise (the channel estimation may have some distortion). Moreover, the frequency equalizer may enhance noise power because of fading. Therefore, the 2.6dB difference between our simulation and DVB-T is suitable because there is no fading in Gaussian and Ricean channels.
Gaussian, Ricean, Rayleigh Simulation Channel BERs is shown the BERs of all the three simulation channels. From Gaussian, Ricean, Rayleigh Simulation Channel BERs , the performance of the Gaussian channel is the best, then the Ricean channel, the performance of the Rayleigh channel is the worst.

Gaussian, Ricean, Rayleigh Simulation Channel BERs



Benchmark

- Hardware Platform: Pentium II 200 MHz, 128 MB memory
- Software Platform: Windows NT 4.0 Workstation, ADS 1.3
- Data Points: 188 × 3 Bytes
- Simulation Time: Approximately 16 hours for Rayleigh channel model, 10 hours for Ricean channel model, 9 hours for Gaussian channel model

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.

Hierarchical 64-QAM DVB-T System Design

DTV_DVBSystem_wrk Design Name

DsnDTV_DVBSystem_Hier64QAM

Features

- Channel coding and decoding, including Reed-Solomon coding, punctured convolutional coding
- 2K mode OFDM adaptation
- Inner and outer interleaving
- Hierarchical 64-QAM modulation and demodulation

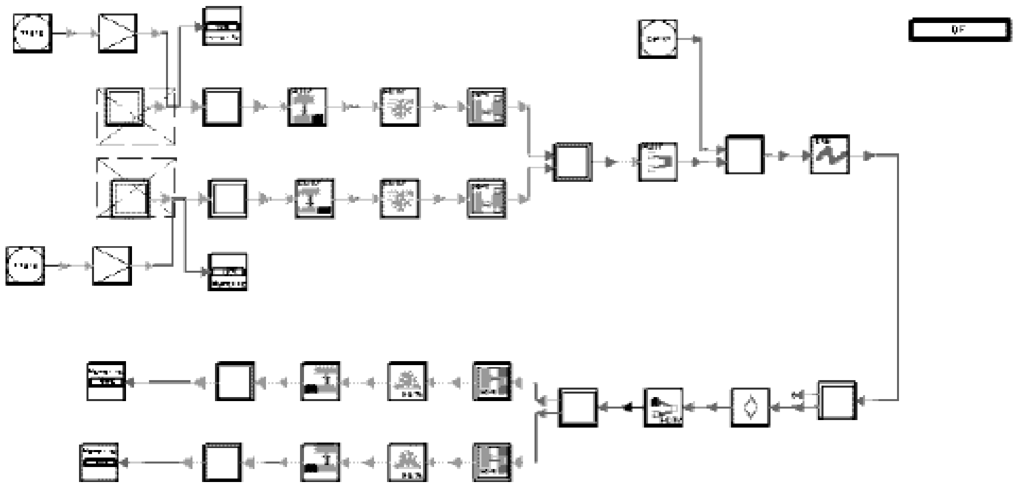
Description

This is a hierarchical DVB-T system design example. It includes inner and outer interleaving, Reed-Solomon and convolutional coding and full OFDM adaptation system. The modulation mode is hierarchical 64-QAM. Code rates for HP level(r1) and LP level(r2) are 1/2 and 5/6, respectively. In the OFDM adaptation, the full system design works in 8K mode. The IFFT/ FFT size is 8192 and the Guard interval is 1/16 of IFFT size. The simulation channel is the DVB channel. The byte in transmitter and receiver are shown in the simulation results.

Schematics

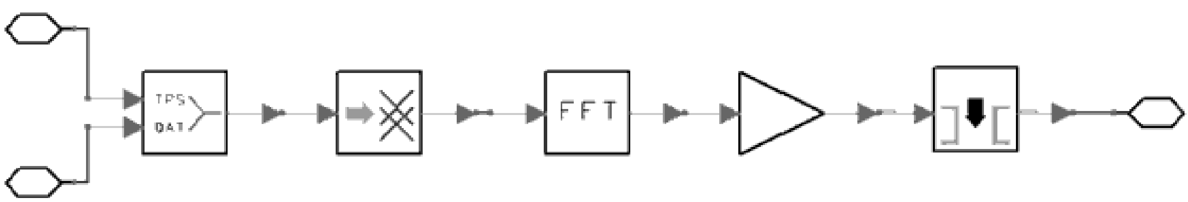
The figure below shows the schematic for this design.

DsnDTV_DVBSystem_Hier64QAM

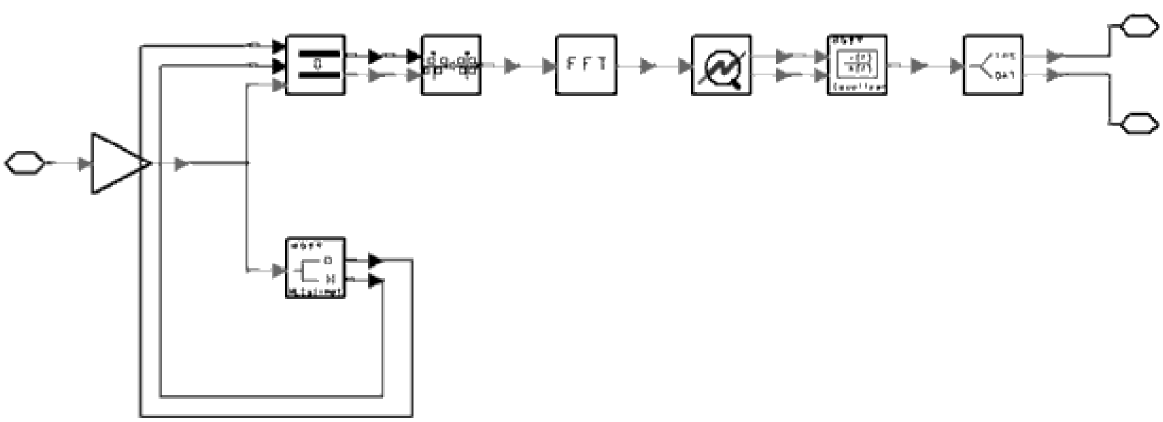


Four subnetworks are used in this design; they are shown below.

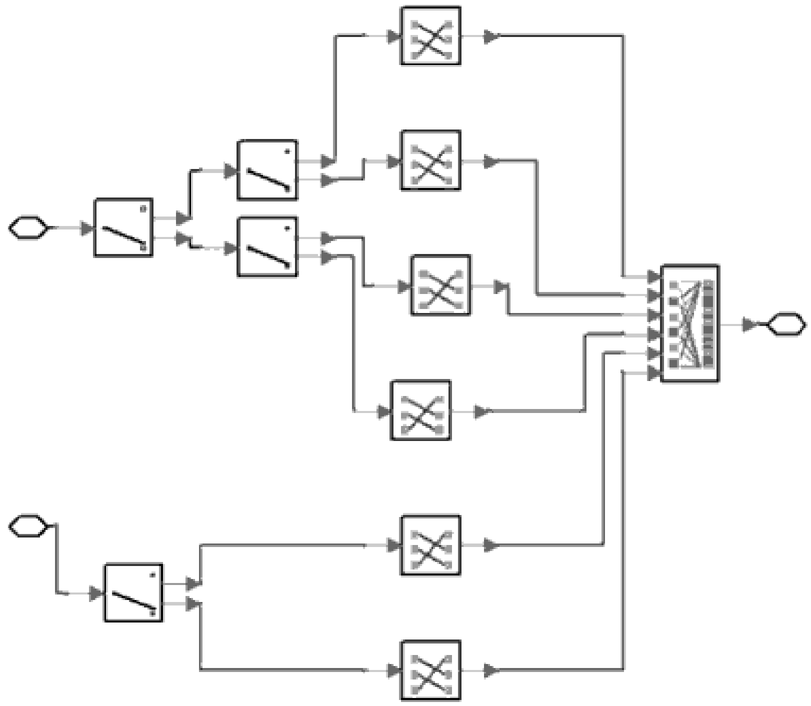
sub_DVBOFDM_Mod



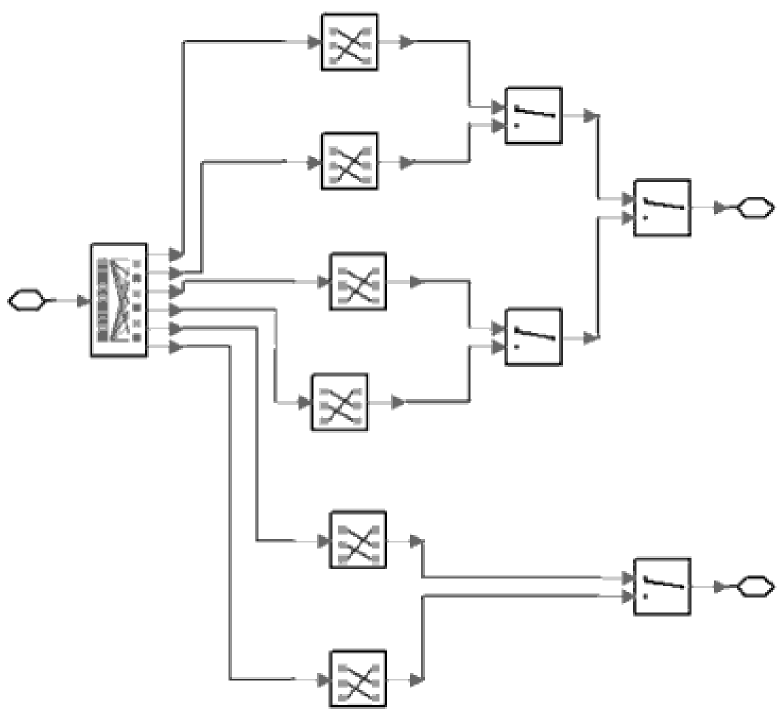
sub_DVBOFDM_Demod



sub_DVBHier_InnerInterlv



sub_DVBHier_InnerDeinterlv



Specifications

Specification (Parameter)	Simulation Type	Value
Carriers	ADS Ptolemy	6817
Data	ADS Ptolemy	6048
IFFTSize	ADS Ptolemy	8192
FFTSize	ADS Ptolemy	8192
Guard	ADS Ptolemy	512
IFFTOrder	ADS Ptolemy	13
FFTOrder	ADS Ptolemy	13
MaxDelay	ADS Ptolemy	8192
Ru	ADS Ptolemy	0.9

Notes

1. The propagation channel model used in this example is a standard terrestrial television propagation channel which is defined in the DVB-T specification.
2. The *DelayByte* parameter of the punctured convolutional decoder (*DTV_PuncConvDecoder* (dtv) model) is used to adjust delays caused by OFDM demodulation (which is one OFDM symbol) and one additional OFDM symbol delay (which corresponds to the DTV_DVBSymDeinterlv6b model) because this model uses an even number of OFDM symbols.

Simulation Results

Compare HP RxTSP with HP TxTSP shows the transmitted HP (high priority) TSP data and the received HP TSP data. Compare LP RxTSP with LP TxTSP shows the transmitted LP (low priority) TSP data and the received LP low data.

Compare HP RxTSP with HP TxTSP

Index	RxTSP	Index	TxTSP1
6768	100.000	0	100.000
6769	204.000	1	204.000
6770	145.000	2	145.000
6771	23.000	3	23.000
6772	135.000	4	135.000
6773	124.000	5	124.000
6774	223.000	6	223.000
6775	251.000	7	251.000
6776	16.000	8	16.000
6777	40.000	9	40.000
6778	6.000	10	6.000
6779	211.000	11	211.000
6780	41.000	12	41.000
6781	251.000	13	251.000
6782	4.000	14	4.000
6783	153.000	15	153.000
6784	224.000	16	224.000
6785	204.000	17	204.000
6786	243.000	18	243.000
6787	11.000	19	11.000
6788	37.000	20	37.000
6789	221.000	21	221.000
6790	231.000	22	231.000
6791	114.000	23	114.000
6792	167.000	24	167.000
6793	126.000	25	126.000
6794	71.000	26	71.000
6795	164.000	27	164.000
6796	142.000	28	142.000
6797	241.000	29	241.000
6798	115.000	30	115.000
6799	91.000	31	91.000
6800	167.000	32	167.000
6801	47.000	33	47.000
6802	223.000	34	223.000
6803	9.000	35	9.000
6804	159.000	36	159.000
6805	154.000	37	154.000

Compare LP RxTSP with LP TxTSP

Index	RxTSP1	Index	TxTSP
3572	97.000	0	97.000
3573	243.000	1	243.000
3574	24.000	2	24.000
3575	86.000	3	86.000
3576	69.000	4	69.000
3577	155.000	5	155.000
3578	199.000	6	199.000
3579	41.000	7	41.000
3580	89.000	8	89.000
3581	207.000	9	207.000
3582	111.000	10	111.000
3583	58.000	11	58.000
3584	45.000	12	45.000
3585	213.000	13	213.000
3586	67.000	14	67.000
3587	117.000	15	117.000
3588	226.000	16	226.000
3589	79.000	17	79.000
3590	127.000	18	127.000
3591	212.000	19	212.000
3592	122.000	20	122.000
3593	91.000	21	91.000
3594	59.000	22	59.000
3595	182.000	23	182.000
3596	102.000	24	102.000
3597	230.000	25	230.000
3598	145.000	26	145.000
3599	158.000	27	158.000
3600	43.000	28	43.000
3601	78.000	29	78.000
3602	222.000	30	222.000
3603	154.000	31	154.000
3604	145.000	32	145.000
3605	42.000	33	42.000
3606	24.000	34	24.000
3607	123.000	35	123.000
3608	96.000	36	96.000
3609	19.000	37	19.000
3610	138.000	38	138.000

Benchmark

- Hardware Platform: Pentium II 200 MHz, 128 MB memory
- Software Platform: Windows NT 4.0 Workstation, ADS 1.3
- Data Points: 188 × 3 Bytes
- Simulation Time: Approximately 1.5 hours

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.

ISDB-T System Design Examples

ISDB-T design examples can be accessed from the ADS Main window *File* > *Open* > *Example* > *DTV*. Schematics and simulation results for the following workspaces are described in this topic.

DTV_ISDB_wrk

- DTV_ISDB_Demo_OneLay
- DTV_ISDB_Demo_TwoLay
- DTV_ISDB_Demo_ThreeLay
- DTV_ISDB_Demo_Partial

DTV_ISDBOFDM_wrk

- DsnDTV_ISDBOFDM_64QAM
- DsnDTV_ISDBOFDM_DQPSK
- DsnDTV_ISDBOFDM_NTSCInterference
- DsnDTV_ISDBOFDM_TwoLay
- DsnDTV_ISDBOFDM_ThrLay

DTV_ISDBSystem_wrk

- DsnDTV_ISDBOFDM_64QAM_BER
- DsnDTV_ISDBOFDM_DQPSK_BER
- DsnDTV_ISDBOneLay_64QAM
- DsnDTV_ISDBOneLay_DQPSK
- DsnDTV_ISDBTwoLay_System
- DsnDTV_ISDBThrLay_System
- DsnDTV_TMCCMod
- DsnDTV_TMCCThrLay

DTV ISDB Workspace Examples

DTV_ISDB_wrk

- DTV_ISDB_Demo_OneLay
- DTV_ISDB_Demo_TwoLay
- DTV_ISDB_Demo_ThreeLay
- DTV_ISDB_Demo_Partial

DTV ISDB Demo for 1-Layer System

DTV_ISDB_Demo_OneLay

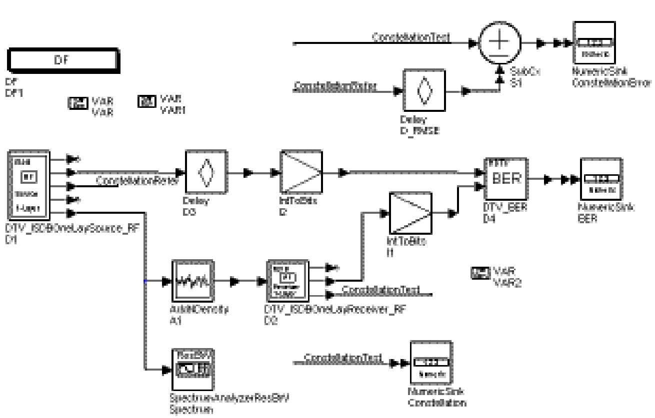
Features

- Mode: 8k (Mode 3)
- MappingMode: 64 QAM
- Inner code rate: 7/8
- Time interleave type: 2 (2 symbols)
- Segments: 13
- Guard interval: 1/8
- Oversampling ratio: 1

Description

This design is a 1-layer example of ISDB-T spectrum, constellation, MER, and BER measurements under an AWGN channel.
The schematic for this design is shown below.

DTV_ISDB_Demo_OneLay Schematic



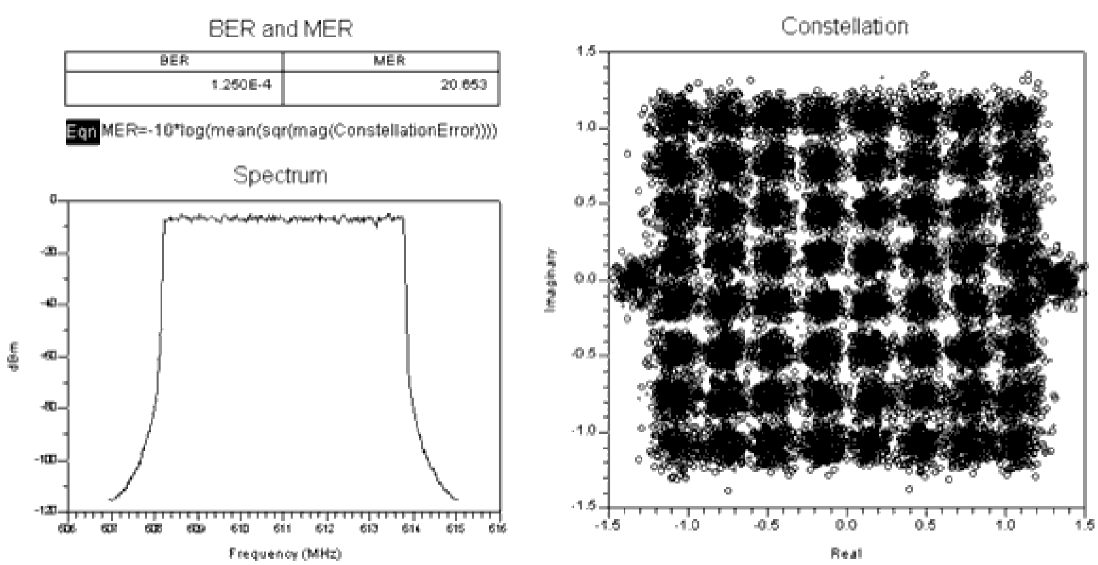
Users can change parameter settings in VAR and VAR1.
VAR2 contains delays needed for MER and BER measurements.
For BER measurements after Reed-Solomon decoding, users must take the following action:

- Move the starting point of the line that connects D1 and D3 from the current pin to the uppermost pin in D1.
- Then, replace the delay parameter D_AfterDerandomize with D_AfterRSDecoder in D3 and D4.

Simulation Results

The simulation is under an AWGN channel with a carrier-to-noise ratio of 22.0 dB. Simulation results are stored in DTV_ISDB_Demo_OneLay.dds and shown below.

Simulation Results



Benchmark

- Hardware Platform: Pentium IV 2.26 GHz, 512 MB memory
- Software Platform: Windows 2000, ADS 2004A
- Simulation Time: approximately 10 minutes

References

1. ARIB STD-B31 Version 1.5, *Transmission System for Digital Terrestrial Television Broadcasting*, July 29, 2003.

DTV ISDB Demo for 2-Layer System

DTV_ISDB_Demo_TwoLay

Features

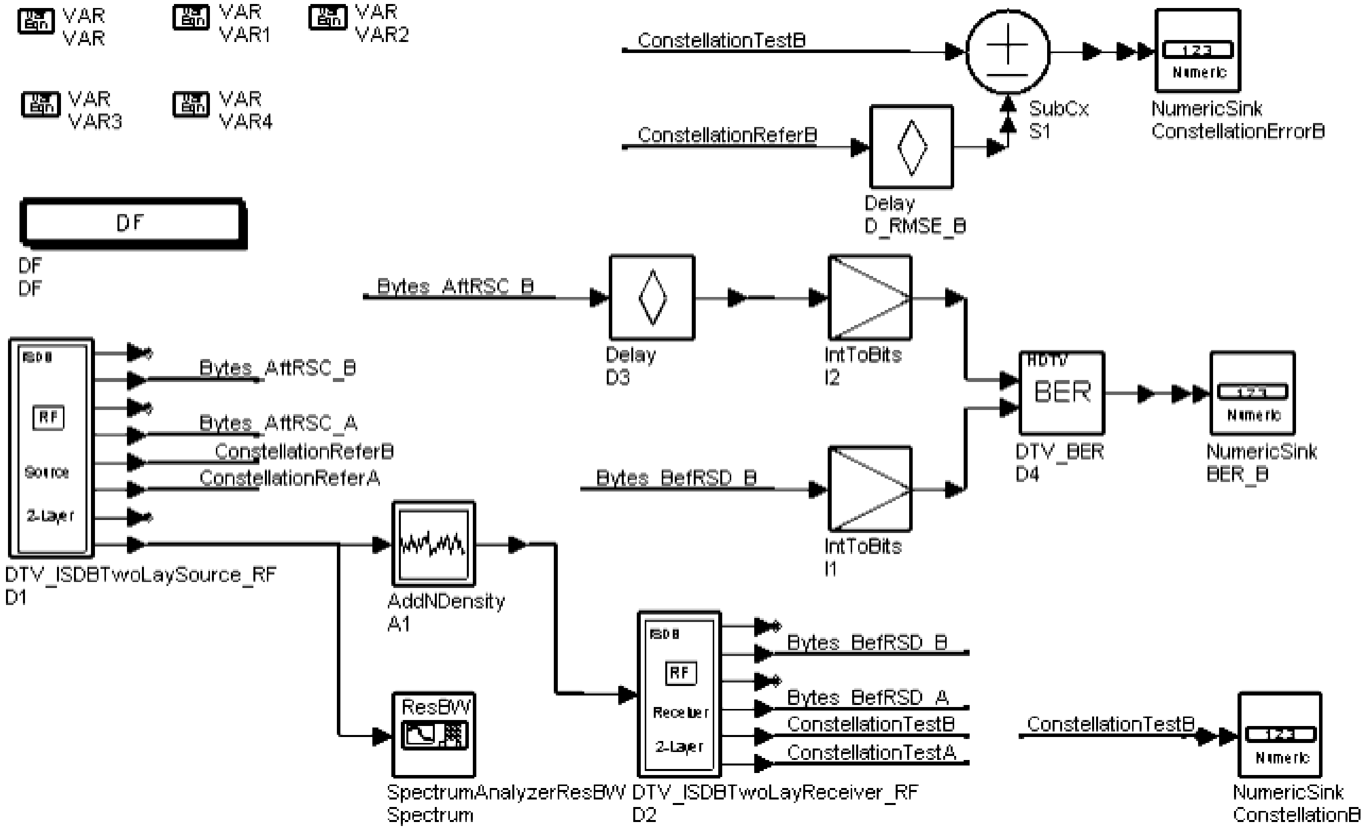
- Mode: 8k (Mode 3)
- MappingMode: QPSK (layer A), 64 QAM (layer B)
- Inner code rate: 1/2 (layer A), 3/4 (layer B)
- Time interleave type: 2 (2 symbols, layer A), 2 (2 symbols, layer B)
- Segments: 1 (layer A), 12 (layer B)
- Guard interval: 1/8
- Oversampling ratio: 1

Description

This design is a 2-layer example of ISDB-T spectrum, constellation, MER, and BER measurements under an AWGN channel.

The schematic for this design is shown below.

DTV_ISDB_Demo_TwoLay Schematic



Parameters can be set through VAR, VAR1 and VAR2.
VAR3 and VAR4 contain delays needed for MER and BER measurements.

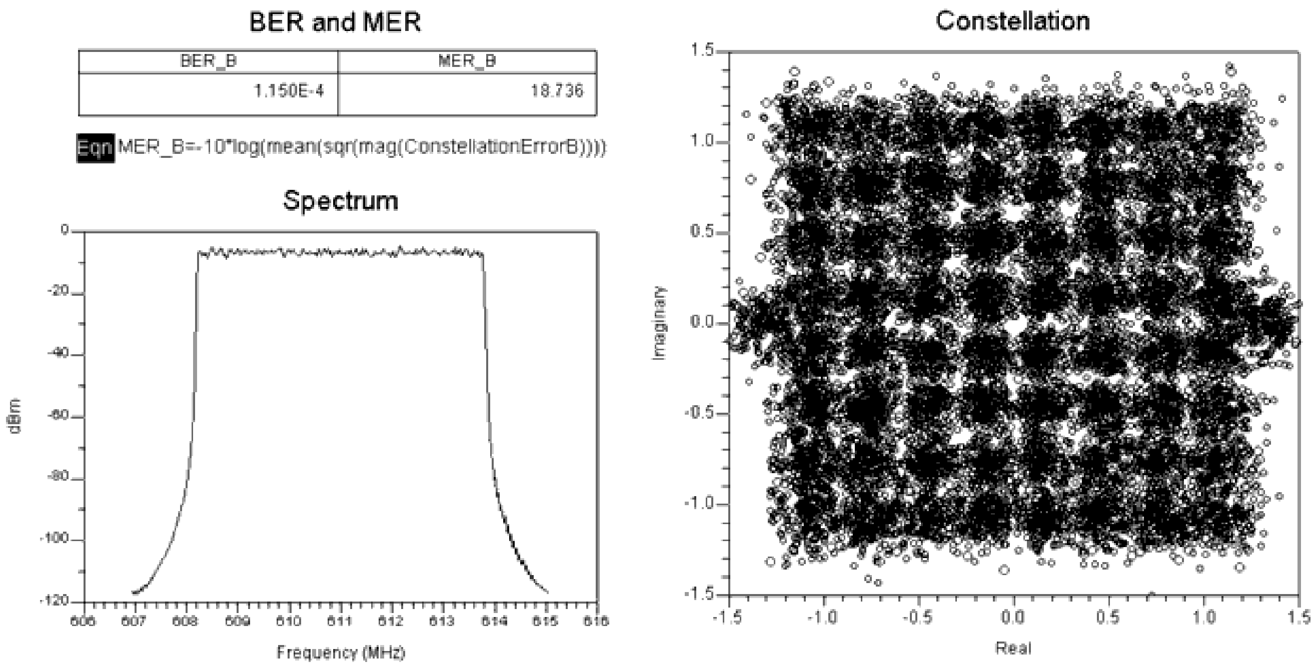
For BER measurements after Reed-Solomon decoding, users must take the following action:

- Move the starting point of the line that connects D1 and D3 from the current pin Bytes_AftRSC to pin Bytes_Uncoded in D1.
- Then, replace the delay parameter D_AfterDerandomize with D_AfterRSDecoder in D3 and D4.

Simulation Results

The simulation is under an AWGN channel with carrier-to-noise ratio of 20.1 dB.
Simulation results are stored in DTV_ISDB_Demo_TwoLay.dds and are shown below.

Simulation Results



Benchmark

- Hardware Platform: Pentium IV 2.26 GHz, 512 MB memory
- Software Platform: Windows 2000, ADS 2004A
- Simulation Time: approximately 40 minutes

References

1. ARIB STD-B31 Version 1.5, *Transmission System for Digital Terrestrial Television Broadcasting*, July 29, 2003.

DTV ISDB Demo for 3-Layer System

DTV_ISDB_Demo_ThreeLay

Features

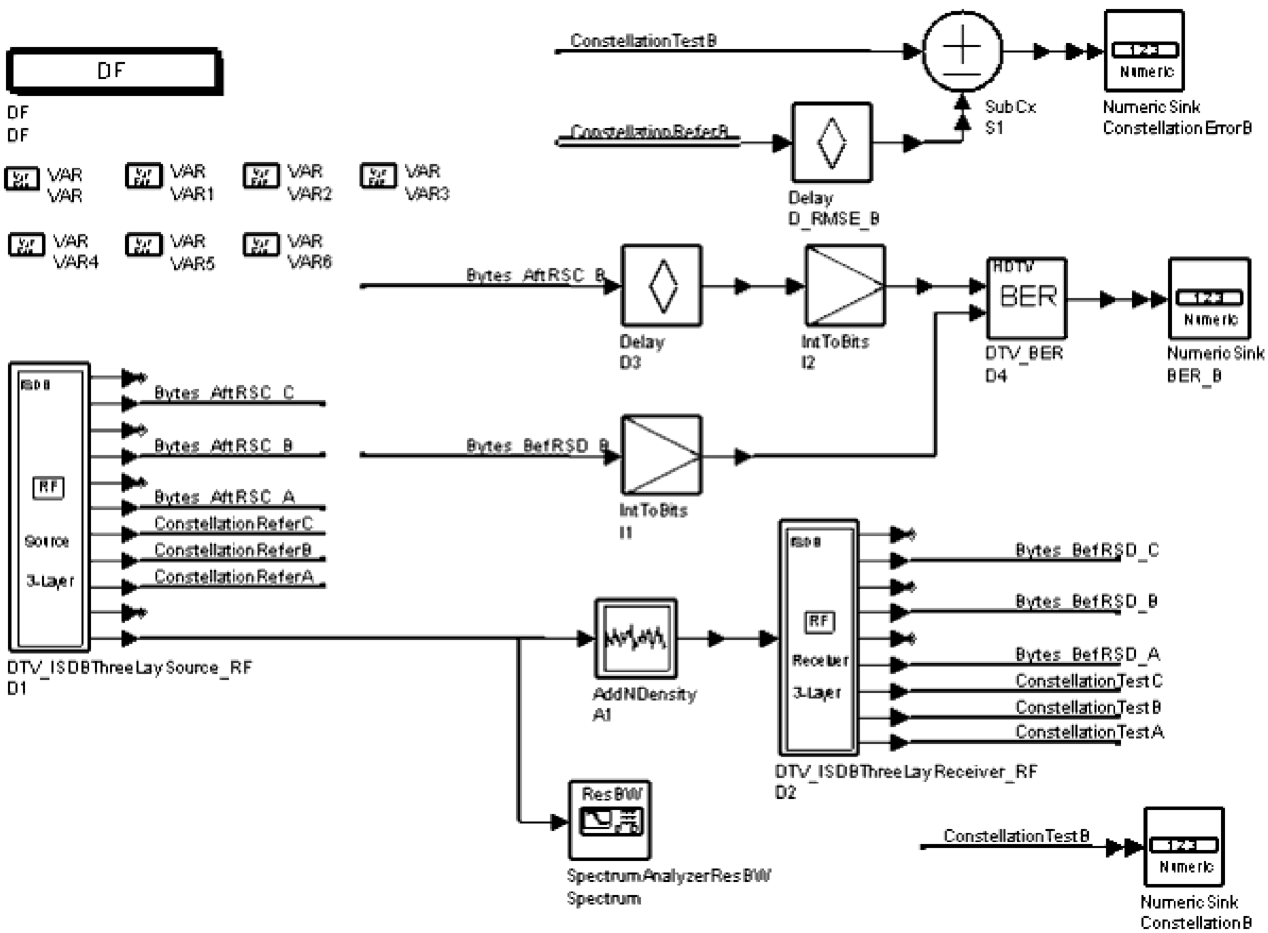
- Mode: 8k (Mode 3)
- MappingMode: QPSK (layer A), 16 QAM (layer B), 64 QAM (layer C)
- Inner code rate: 3/4 (layer A), 2/3 (layer B), 5/6 (layer C)
- Time interleave type: 2 (2 symbols, layer A), 2 (2 symbols, layer B), 2 (2 symbols, layer C)
- Segments: 1 (layer A), 4 (layer B), 8 (layer C)
- Guard interval: 1/8

- Oversampling ratio: 1

Description

This design is a 3-layer example of ISDB-T spectrum, constellation, MER, and BER measurements under an AWGN channel.
The schematic for this design is shown below. Parameters can be set through VAR, VAR1, VAR2, and VAR3.

DTV_ISDB_Demo_ThreeLay Schematic



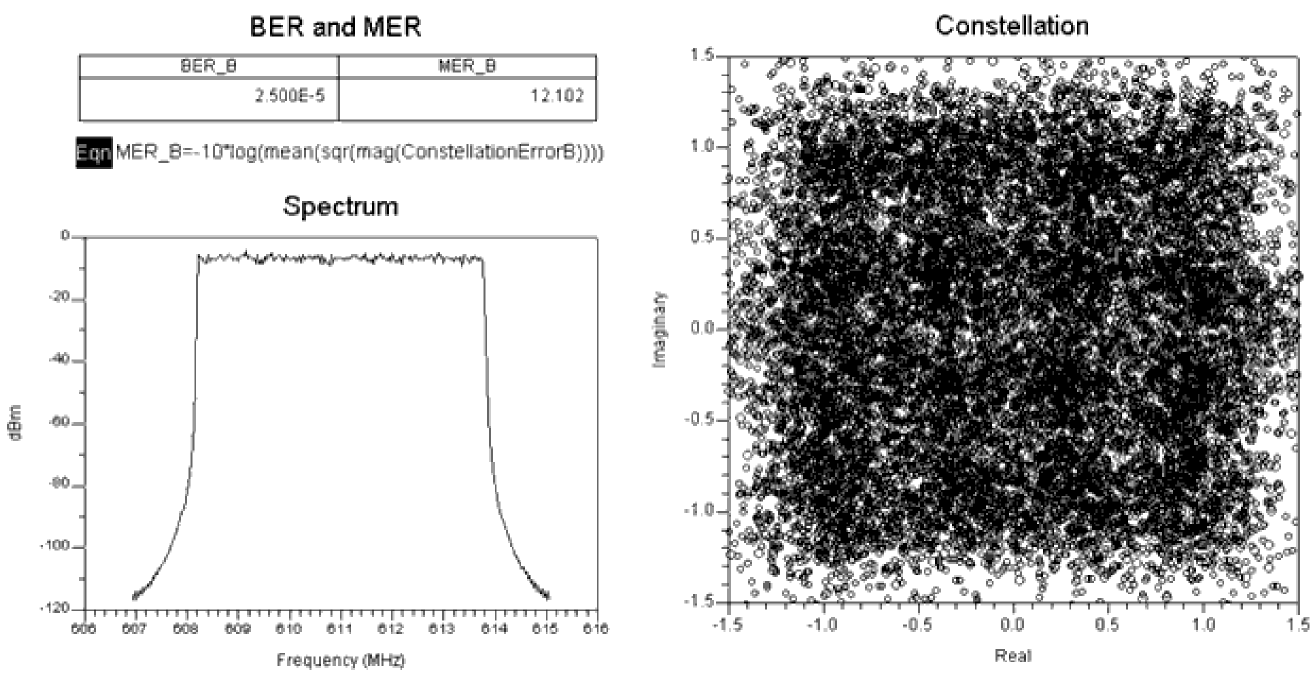
VAR4, VAR5, and VAR6 contain delays needed for MER and BER measurements.
For BER measurements after Reed-Solomon decoding, users must take the following action:

- Move the starting point of the line that connects D1 and D3 from the current pin Bytes_AftRSC to pin Bytes_Uncoded in D1.
- Then, replace the delay parameter D_AfterDerandomize with D_AfterRSDecoder in D3 and D4.

Simulation Results

The simulation is under AWGN channel with the C/N (Carrier to Noise Ratio) of 13.5 dB. Simulation results are stored in DTV_ISDB_Demo_ThreeLay.dds and are also shown below.

Simulation Results



Benchmark

- Hardware Platform: Pentium IV 2.26 GHz, 512 MB memory
- Software Platform: Windows 2000, ADS 2004A
- Simulation Time: approximately 6 minutes

References

1. ARIB STD-B31 Version 1.5, *Transmission System for Digital Terrestrial Television Broadcasting*, July 29, 2003.

DTV ISDB Demo for Partial Reception System

DTV_ISDB_Demo_Partial

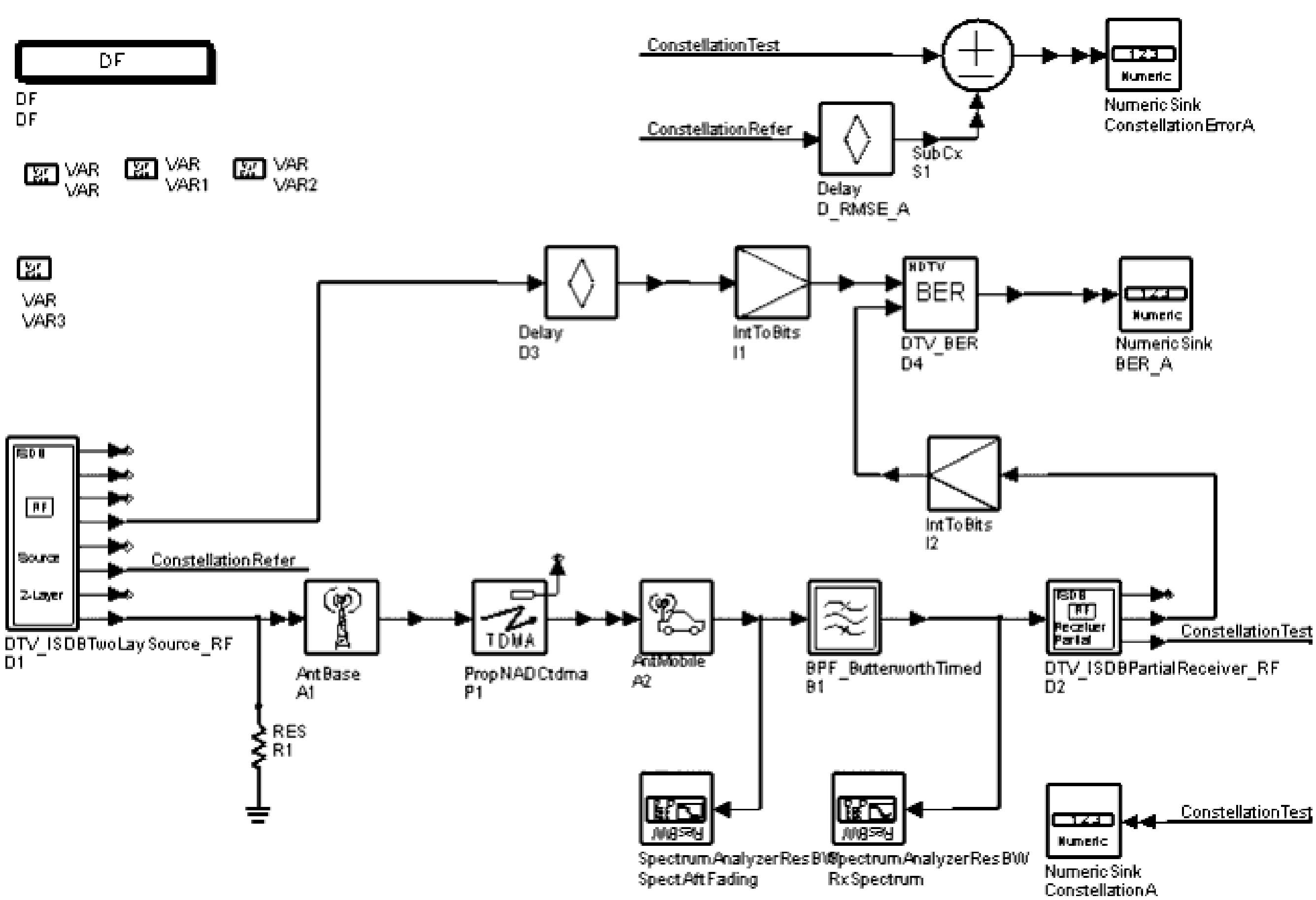
Features

- Mode: 8k (Mode 3)
- MappingMode: 16 QAM (layer A), 64 QAM (layer B)
- Inner code rate: 1/2 (layer A), 7/8 (layer B)
- Time interleave type: 2 (2 symbols, layer A), 2 (2 symbols, layer B)
- Segments: 1 (layer A), 12 (layer B)
- Guard interval: 1/8
- Oversampling ratio: 1

Description

This design is a partial reception example of ISDB-T spectrum, constellation, MER and BER measurements under fading channel.
The schematic for this design is below. Parameters that can be changed by users are contained in VAR, Var1 and VAR2.

DTV_ISDB_Demo_Partial Schematic



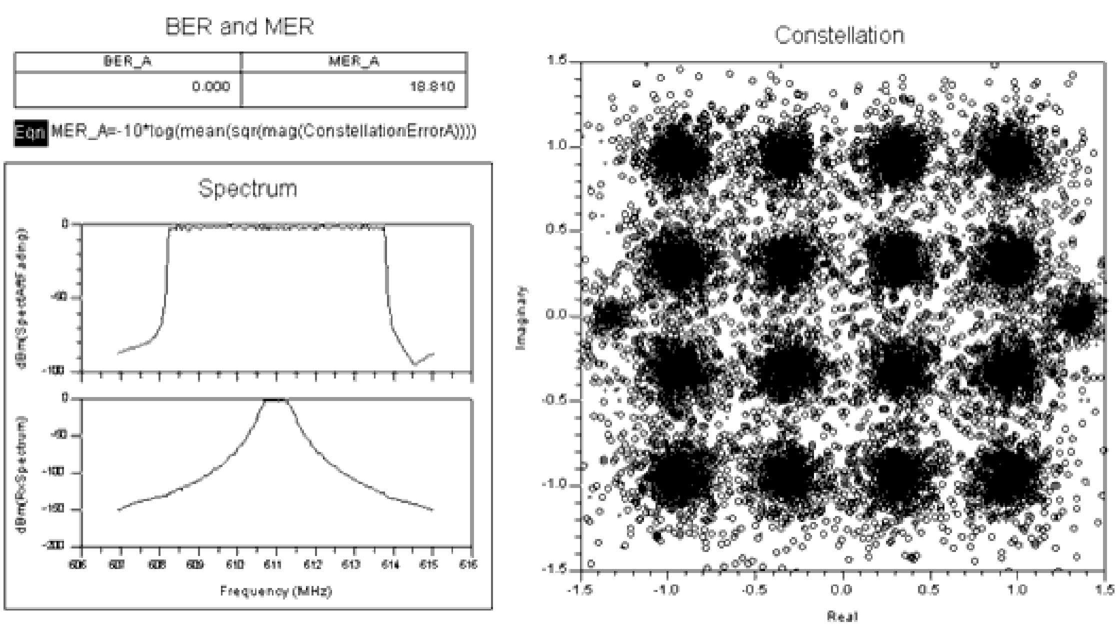
Var3 contains delays needed for MER and BER measurements.
For BER measurements after Reed-Solomon decoding, users must take the following action:

- Move the starting point of the line that connects D1 and D3 from the current pin to the upper pin in D1.
- Then, replace the delay parameter D_AfterDerandomize with D_AfterRSDecoder in D3 and D4.

Simulation Results

The simulation is under a fading channel without AWGN. Simulation results are stored in DTV_ISDB_Demo_Partial.dds and are shown below.

Simulation Results



Benchmark

- Hardware Platform: Pentium IV 2.26 GHz, 512 MB memory
- Software Platform: Windows 2000, ADS 2004A
- Simulation Time: approximately 8 minutes

References

1. ARIB STD-B31 Version 1.5, *Transmission System for Digital Terrestrial Television Broadcasting*, July 29, 2003.

DTV ISDB OFDM Workspace Example

DTV_ISDBOFDM_wrk

- DsnDTV_ISDBOFDM_64QAM
- DsnDTV_ISDBOFDM_DQPSK
- DsnDTV_ISDBOFDM_NTSCInterference
- DsnDTV_ISDBOFDM_TwoLay
- DsnDTV_ISDBOFDM_ThrLay

OFDM 64-QAM Modulation and Demodulation in ISDB-T Systems

DTV_ISDBOFDM_wrk Design Name

DsnDTV_ISDBOFDM_64QAM

Features

- 64-QAM modulation and demodulation
- Guard interval
- TDMA multipath fading channel with Doppler shift. The type of multipath can be selected; Doppler shift can be determined by the mobile speed setting.
- Displays include:
  ML (maximum likelihood)
  RxSpectrum (spectrum of received signal from the channel)
  RxQAM (received signal constellation after OFDM demodulation)

Description

This design is an example of modulation, transmission and demodulation sections via a TDMA multipath channel with Doppler shift. In this example, a single layer transmission is used in mode 3, which includes 13 segments. Modulation mapping is 64-QAM; the guard interval ratio is 1/16.

After 64-QAM data mapping, the 13 OFDM segments are formed by adding TMCC and AC data, and scattered pilots. After the spectral order of the segments is changed, 8192-point inverse FFT (IFFT) is performed. After inserting the guard interval, the complex signal is transmitted; the transmitted signal length is 8192+guard interval.

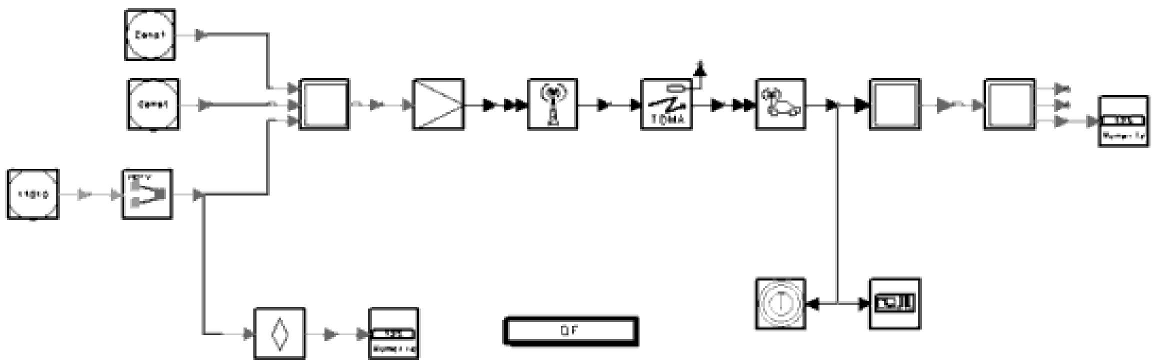
In the receiver, the FFT starting point is determined by the ML function of the received signal. After FFT, the transmitted signal is recovered by a simple frequency equalizer. According to the ISDB-T, the mapping data was received. Data is recovered by the 64-QAM demodulator.

System performance can be viewed during simulation.

Schematics

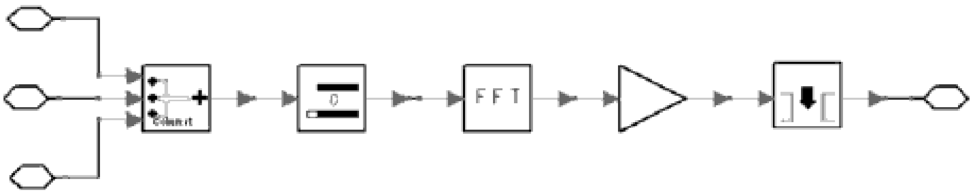
The figure below shows the schematic for this design.

DsnDTV_ISDBOFDM_64QAM

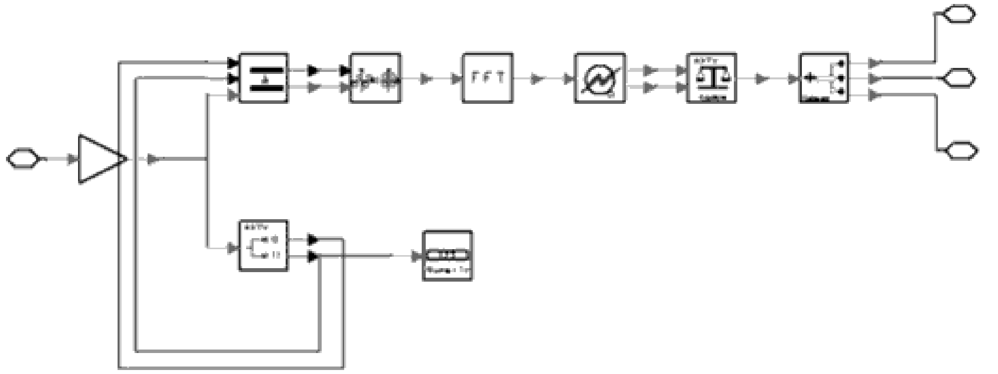


Subnetwork designs are shown in the figures below.

sub_ISDBOFDM_Mod



sub_ISDBOFDM_Demod



Specifications

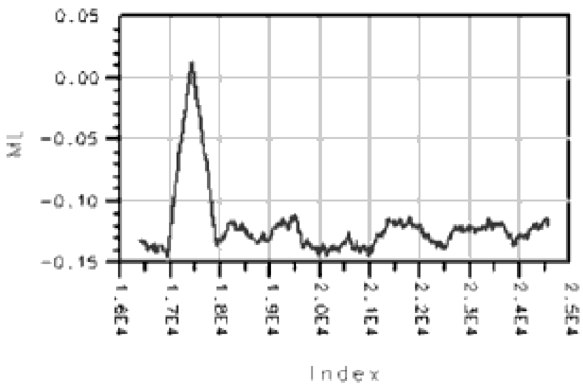
Symbol (Model)	Specification (Parameter)	Simulation Type	Value
PropNADCtdma	Type	ADS Ptolemy	TwoPath
PropNADCtdma	Pathloss	ADS Ptolemy	No
PropNADCtdma	Env	ADS Ptolemy	TypicalUrban
PropNADCtdma	Delay	ADS Ptolemy	1.0 μsec
PropNADCtdma	Test	ADS Ptolemy	Tap1
AntMobile	Vx	ADS Ptolemy	30 km/hr
AntMobile	Vy	ADS Ptolemy	0.0 km/hr

Notes

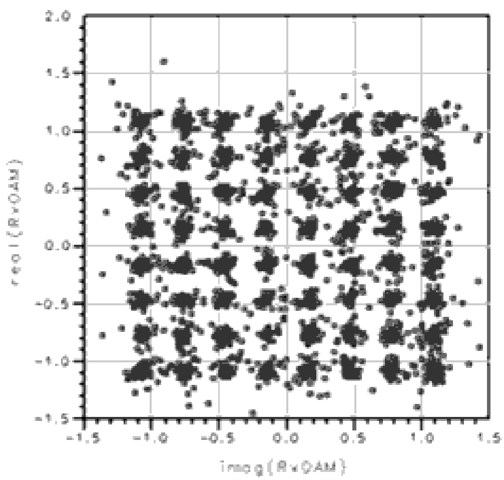
1. In this example, the guard interval ratio is 1/16, so the guard interval is 512. (According to ISDB-T, in mode 3 the guard interval is 256, 512, 1024, or 2048, which corresponds to 1/32, 1/16, 1/8, or 1/4 guard interval ratio, respectively.)
2. All parameters are related to the guard interval (except TDMA channel parameters). If the guard interval is changed, parameters will be changed to the corresponding values.
3. The TDMA channel condition varies according to channel parameter modification. Parameters include Type, Pathloss, Env, Delay, and Test in the PropNADCtdma model, and Vx and Vy in the AntMobile model.

Simulation Results

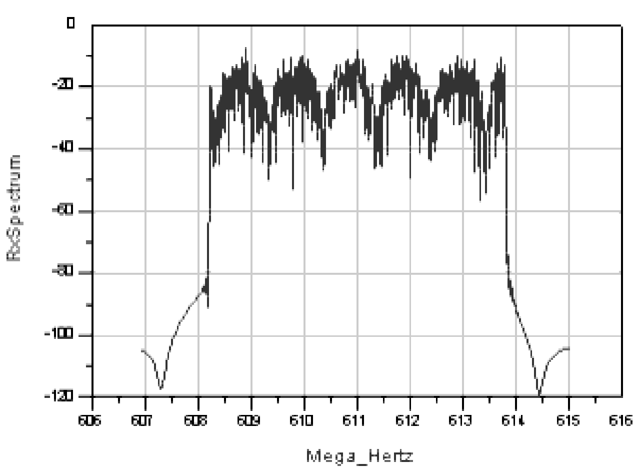
ML magnitude, shows the magnitude of ML function of received signal used to find FFT start. The maximum value appears in every (8192+512) points, the point of the maximum magnitude value is the FFT start.



Received constellation after OFDM demodulation by TDMA channel. Results show OFDM system performance.



Spectrum of signal received from wireless channel. Center frequency is 611MHz

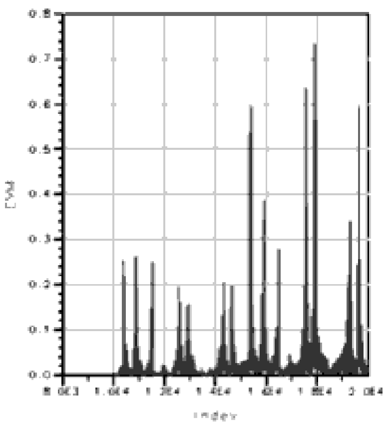


Adjacent-Channel Power Ratio ACPR=acpr_vr(DsnDTV_ISDBOFDM_64QAM.RxSignal,50.0, {-2.808MHz,2.808MHz},{-

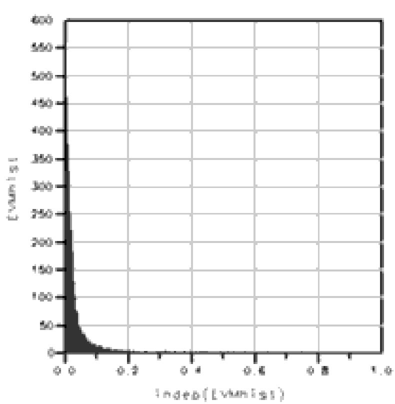
Adjacent-Channel Power Ratio ACPR=acpr_vr(DsnDTV_ISDBOFDM_64QAM.RxSignal,50.0, {-2.808MHz,2.808MHz},{-8.808MHz,-3.192MHz},{3.192MHz,8.808MHz})

ACPR	
ACPR(1)	ACPR(2)
-50.311	-51.380

Relative magnitude error, which is defined as: EVM=mag(DsnDTV_ISDBOFDM_64QAM. RxQAM-DsnDTV_ISDBOFDM_64QAM. TxQAM)/mean(mag(DsnDTV_ISDBOFDM_64QAM..TxQAM))



EVM histogram, which shows most EVM < 0.1. EVMhist is defined as: EVMhist=histogram(EVM,1001,0.0,1.0)



EVMavr=mean(EVM)

EVMovr
0.029

Benchmark

- Hardware Platform: Pentium II 200 MHz, 96 MB memory
- Software Platform: WindowsNT 4.0 Workstation, ADS 1.3
- Data Points: 10 symbols
- Simulation Time: 78 seconds

References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.

OFDM DQPSK Modulation and Demodulation in ISDB-T Systems

DTV_ISDBOFDM_wrk Design Name

DsnDTV_ISDBOFDM_DQPSK

Features

- DQPSK modulation and demodulation
- Guard interval
- TDMA multipath fading channel with Doppler shift. The multipath type can be selected and the Doppler shift can be determined by setting the mobile's speed.
- Displays include:
  ML (maximum likelihood function)
  RxSpectrum (spectrum of signal received from the channel)
  RxDQPSK (received signal constellation after OFDM demodulation)

Description

This design is an example of modulation, transmission and demodulation sections via a

TDMA multipath channel with Doppler shift. In this example, a single layer transmission is used in mode 3, which includes 13 segments. Modulation mapping is DQPSK; the guard interval ratio is 1/16.

After DQPSK data mapping, the 13 OFDM segments are formed by adding TMCC and AC data, and scattered pilots. After the spectral order of the segments is changed, 8192-point inverse FFT (IFFT) is performed. After inserting the guard interval, the complex signal is transmitted; the transmitted signal length is 8192+guard interval.

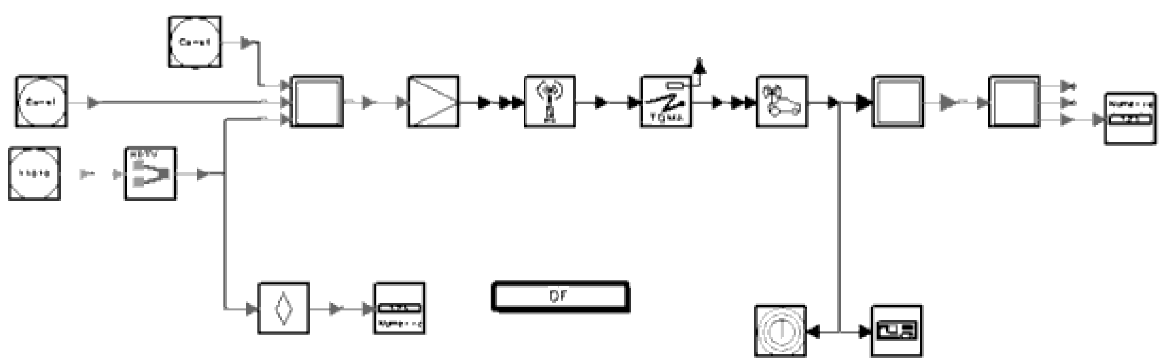
In the receiver, the FFT starting point is determined by the ML function of the received signal. After FFT, the transmitted signal is recovered by simple frequency equalizer. According to the ISDB-T, the mapping data was received. TSP data is recovered by the DQPSK demodulator.

System performance can be viewed during simulation.

Schematics

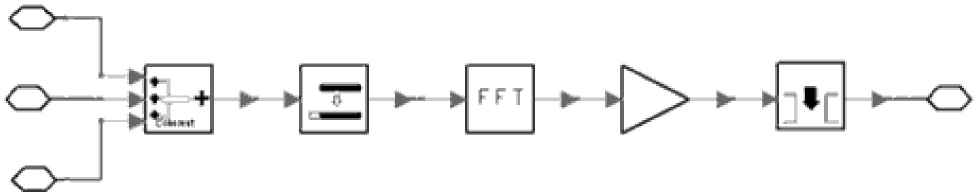
The figure below shows the schematic for this design.

DsnDTV_ISDBOFDM_DQPSK

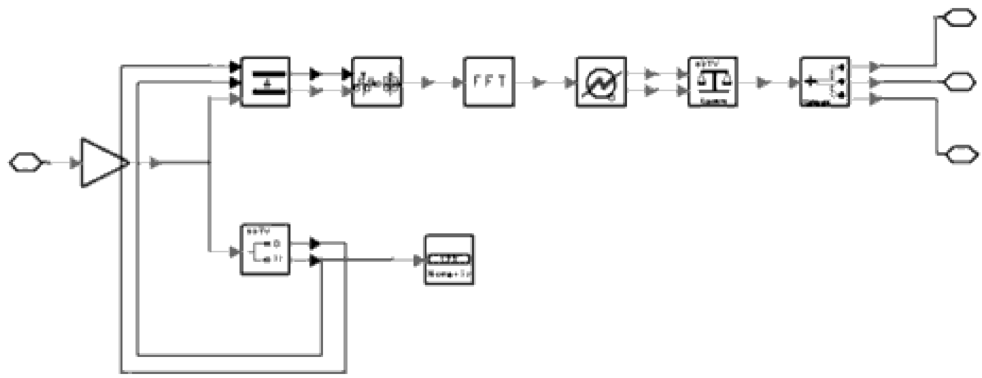


Subnetwork designs are shown in the figures below.

sub_ISDBOFDM_Mod



sub_ISDBOFDM_Demod



Specifications

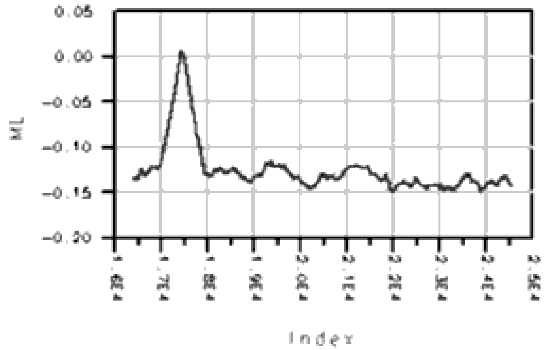
Symbol (Model)	Specification (Parameter)	Simulation Type	Value
PropNADCtdma	Type	ADS Ptolemy	TwoPath
PropNADCtdma	Pathloss	ADS Ptolemy	No
PropNADCtdma	Env	ADS Ptolemy	TypicalUrban
PropNADCtdma	Delay	ADS Ptolemy	6 µsec
PropNADCtdma	Test	ADS Ptolemy	Tap1
AntMobile	Vx	ADS Ptolemy	30 km/hr
AntMobile	Vy	ADS Ptolemy	0.0 km/hr

Notes

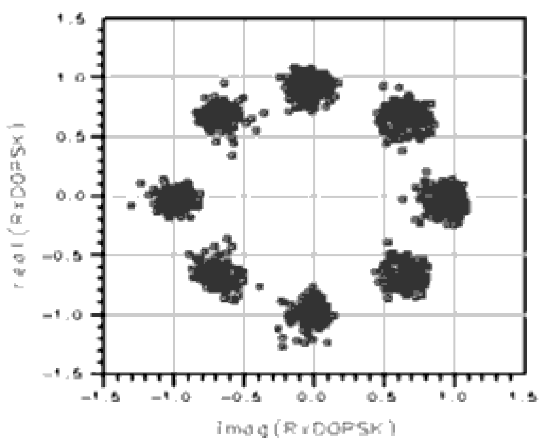
1. In this example, the guard interval ratio is 1/16, so the guard interval is 512. (According to ISDB-T, in mode 3 the guard interval is 256, 512, 1024, or 2048, which corresponds to 1/32, 1/16, 1/8, or 1/4 guard interval ratio, respectively.)
2. All parameters are related to the guard interval (except TDMA channel parameters). If the guard interval is changed, parameters will be changed to the corresponding values.
3. The TDMA channel condition varies according to channel parameter modification. Parameters include Type, Pathloss, Env, Delay, and Test in the PropNADCtdma model, and Vx and Vy in the AntMobile model.

Simulation Results

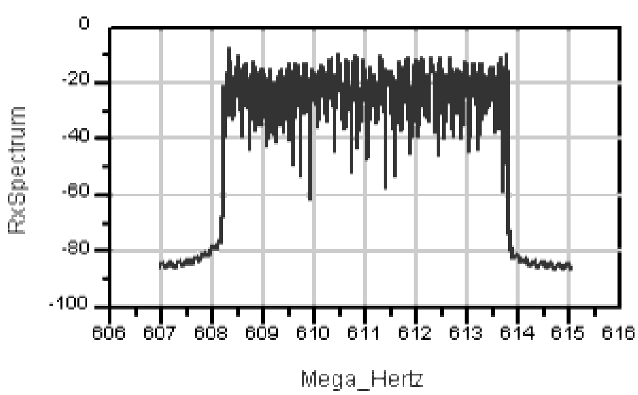
ML magnitude shows the magnitude of ML function of the received signal used to find the FFT start. The maximum value appears in every (8192+512) points, the point of the maximum magnitude value is the FFT start.



Received constellation after OFDM demodulation by TDMA channel. Results show OFDM system performance.



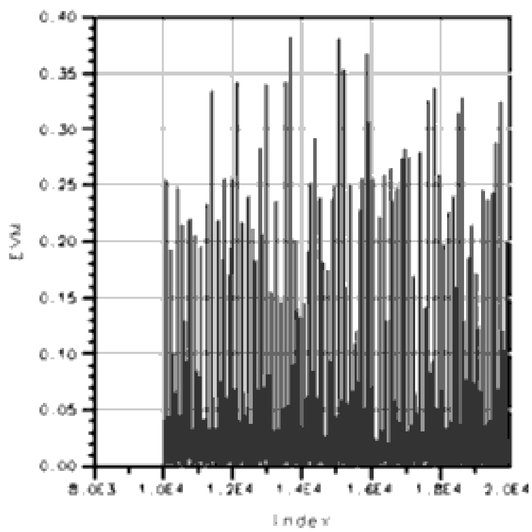
Spectrum of Signal Received from Wireless Channel. Center frequency is 611 MHz



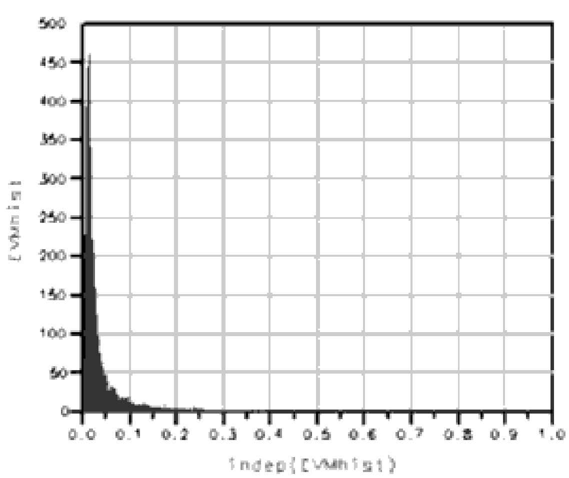
Adjacent-Channel Power Ratio ACPR=acpr_vr(DsnDTV_ISDBOFDM_DQPSK..RxSignal,50.0, {-2.808MHz,2.808MHz},{-8.808MHz,-3.192MHz},{3.192MHz,8.808MHz})

ACPR	
ACPR(1)	ACPR(2)
-50.081	-50.360

Relative magnitude error, which is defined as: EVM=mag(DsnDTV_ISDBOFDM_DQPSK... RxDQPSK-DsnDTV_ISDBOFDM_DQPSK...TxDQPSK) mean(mag(DsnDTV_ISDBOFDM_DQPSK...TxDQPSK))



Histogram of EVM, which shows most EVM < 0.1. EVMhist is defined as: EVMhist=histogram(EVM,1001,0.0,1.0)



Benchmark

- Hardware Platform: Pentium II 200 MHz, 96 MB memory
- Software Platform: WindowsNT 4.0 Workstation, ADS 1.3
- Data Points: 10 symbols
- Simulation Time: 110 seconds

References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.

DTV and NTSC Signal Interference Test in ISDB-T Systems

DTV_ISDBOFDM_wrk Design Name

DsnDTV_ISDBOFDM_NTSCInterference

Features

- 64-QAM modulation and demodulation
- Adjacent channel interference between NTSC and ISDB-T signal
- Displays include:
  ML (maximum likelihood function),
  RxSpectrum (spectrum of signal received from the channel),
  RxQAM (received signal constellation after OFDM demodulation),
  Videoin, Videoout
- Comparison of analog NTSC TV signal and received NTSC TV signal that has adjacent channel ISDB-T signal interference

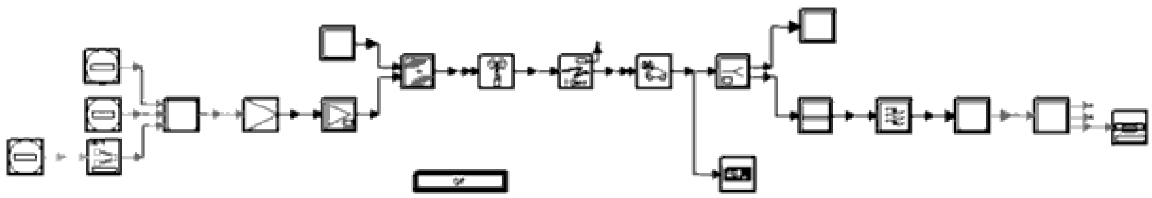
Description

This design is an OFDM example that tests the adjacent interference between the analog NTSC TV signal and the digital ISDB-T signal. ISDB-T signal experiences weak interference while the analog NTSC signal experiences strong interference. This effect is saved in Data Display (DsnDTV_ISDBOFDM_NTSCInterference1.dds). The analog NTSC spectrum experiences interference at frequencies over 6 MHz. The ISDB-T signal center frequency is 611.15 MHz, which is shifted 150 kHz.

Schematics

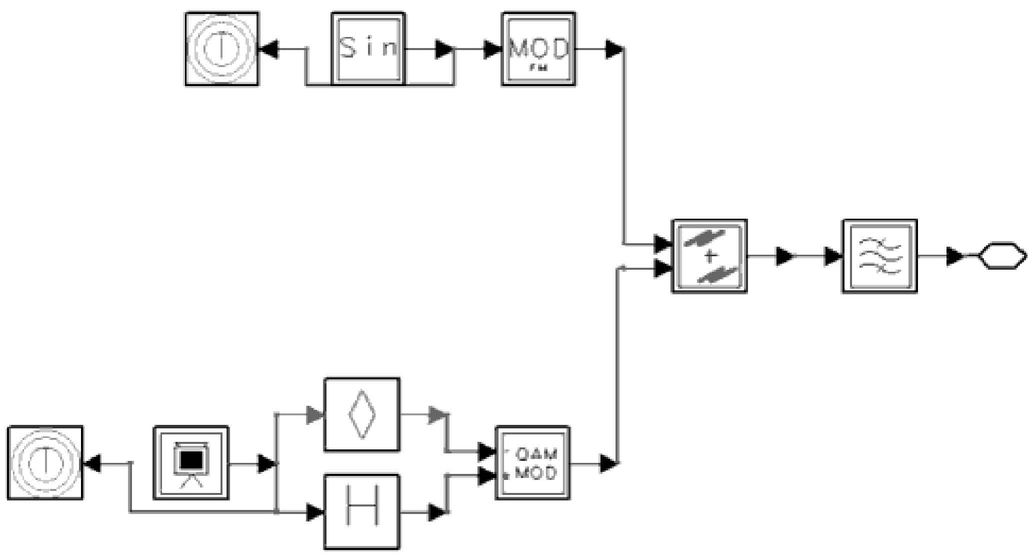
The figure below shows the schematic for this design.

DsnDTV_ISDBOFDM_NTSCInterference

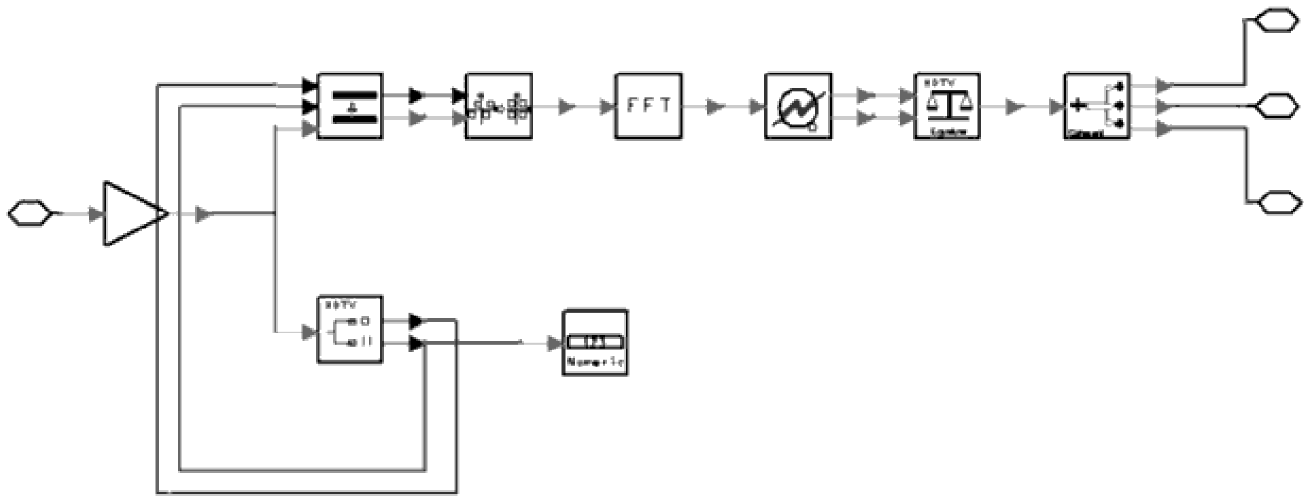


Subnetwork designs are shown in the figures below.

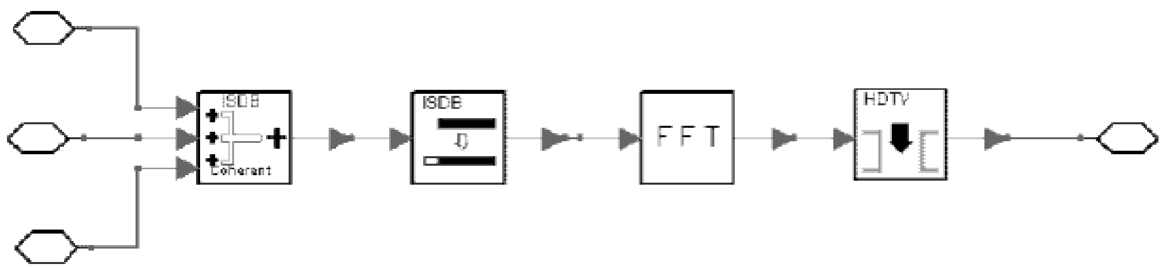
Sub_Mod_Analog



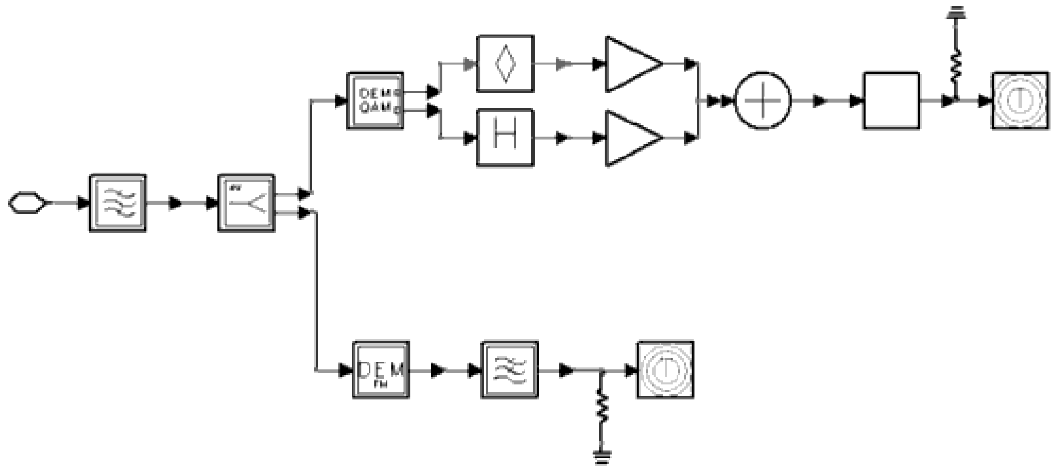
Sub_ISDBOFDM_Demod



Sub_ISDBOFDM_Mod



Sub_Demod_Analog



Specifications

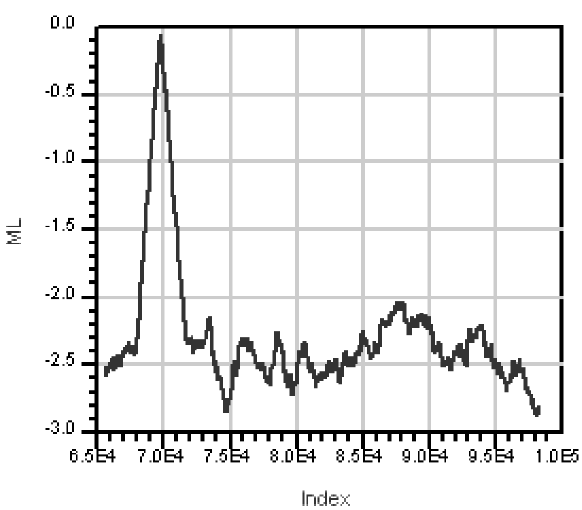
Specification (Parameter)	Simulation Type	Value
Carriers	ADS Ptolemy	432
Segments	ADS Ptolemy	13
IFFTSize	ADS Ptolemy	8192 × 4
FFTSize	ADS Ptolemy	8192 × 4
GuardInterval	ADS Ptolemy	512 × 4
IFFTOrder	ADS Ptolemy	15
FFTOrder	ADS Ptolemy	15
MaxDelay	ADS Ptolemy	8192 × 4

Notes

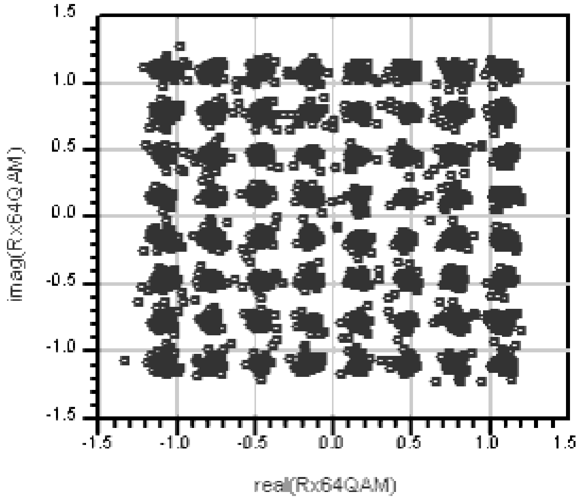
1. In this example, the guard interval ratio is 1/16, so the guard interval is 512. (According to ISDB-T, in mode 3 the guard interval is 256, 512, 1024, or 2048, which corresponds to 1/32, 1/16, 1/8, or 1/4 guard interval ratio, respectively.)
2. All parameters are related to the guard interval (except TDMA channel parameters). If the guard interval is changed, parameters will be changed to the corresponding values.
3. The TDMA channel condition varies according to channel parameter modification. Parameters include Type, Pathloss, Env, Delay, and Test in the PropNADCtdma model, and Vx and Vy in the AntMobile model.

Simulation Results

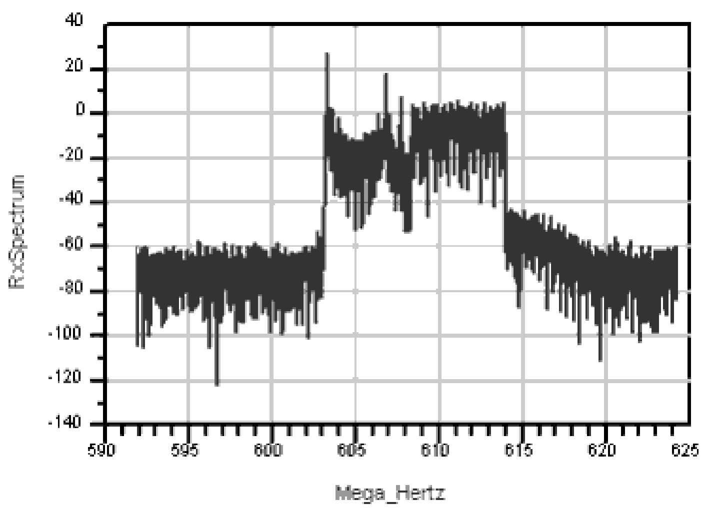
ML magnitude shows the magnitude of ML function of received signal used to find FFT start. Maximum value appears in every 4 × (8192+512) points, the point of the maximum magnitude value is the FFT start.



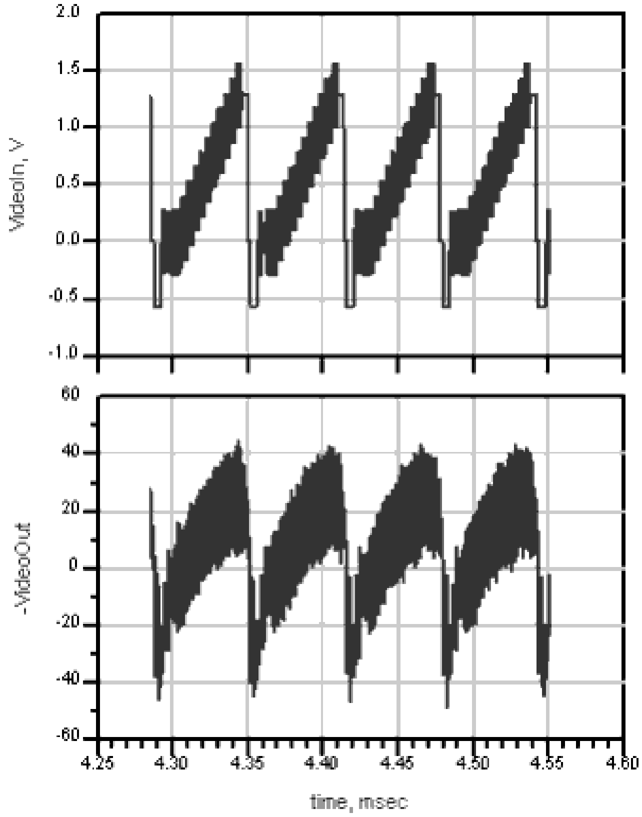
Received 64QAM Constellation after OFDM demodulation by TDMA channel with NTSC Signal Interference.



Spectrum of Signal Received from Wireless Channel



NTSC Video Input and Output Signals with ISDB-T Signal Interference



Benchmark

- Hardware Platform: Pentium II 200 MHz, 96 MB memory
- Software Platform: WindowsNT 4.0 Workstation, ADS 1.3
- Data Points: 10 symbols
- Simulation Time: 8.5 hours

References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.

OFDM 2-Layer Modulation and Demodulation in ISDB-T Systems

DTV_ISDBOFDM_wrk Design Name

DsnDTV_ISDBOFDM_TwoLay

Features

- 64-QAM modulation and demodulation
- DQPSK modulation and demodulation
- Guard interval
- TDMA multipath fading channel with Doppler shift. The kind of the multipath can be selected and the Doppler shift can be determined by setting the mobile's speed.
- Displays include:
  ML (maximum likelihood function)
  RxSpectrum (spectrum of signal received from the channel)
  RxQAM (received signal constellation after OFDM demodulation)
  RxDQPSK

Description

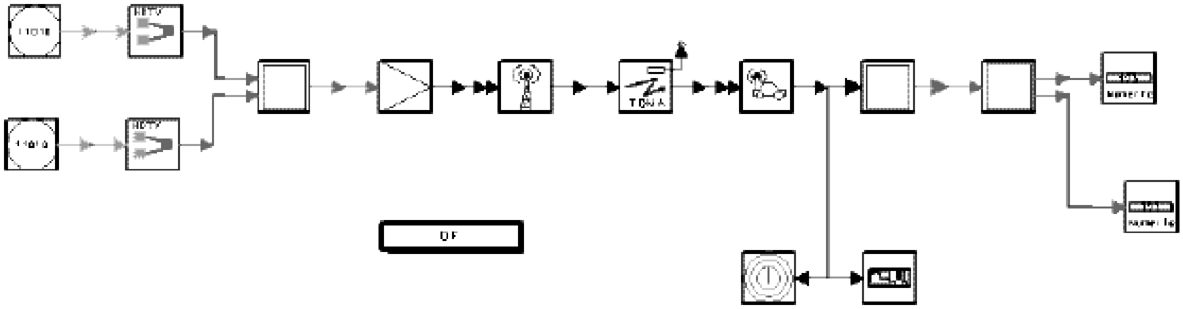
This design is a 2-layer OFDM design example of ISDB-T. It includes 13 segments (5 segments for Layer A, 8 segments for Layer B). Modulation modes are DQPSK and 64-QAM in Layer A and Layer B, respectively.

The IFFT/ FFT size is 2048; the guard interval is 1/8 of IFFT size. The simulation channel is the TDMA channel. The byte in transmitter and receiver, the received DQPSK constellation and 64-QAM constellation are shown in the simulation results.

Schematics

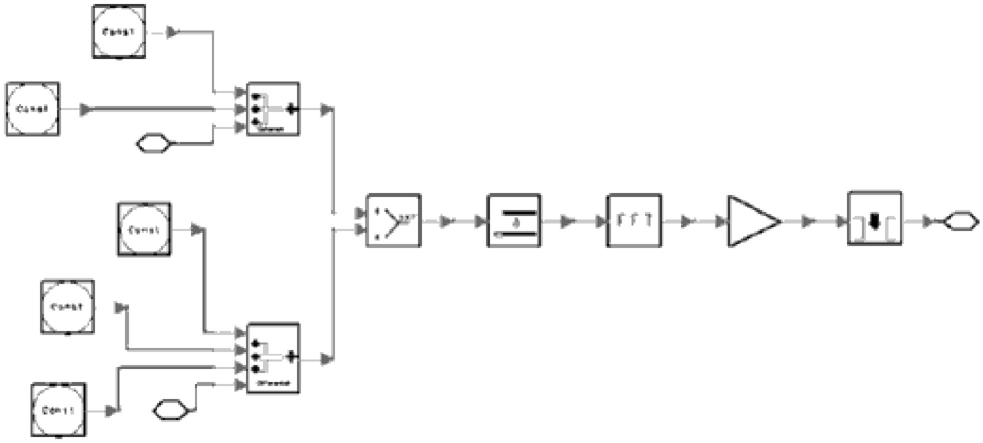
The figure below shows the schematic for this design.

DsnDTV_ISDBOFDM_TwoLay

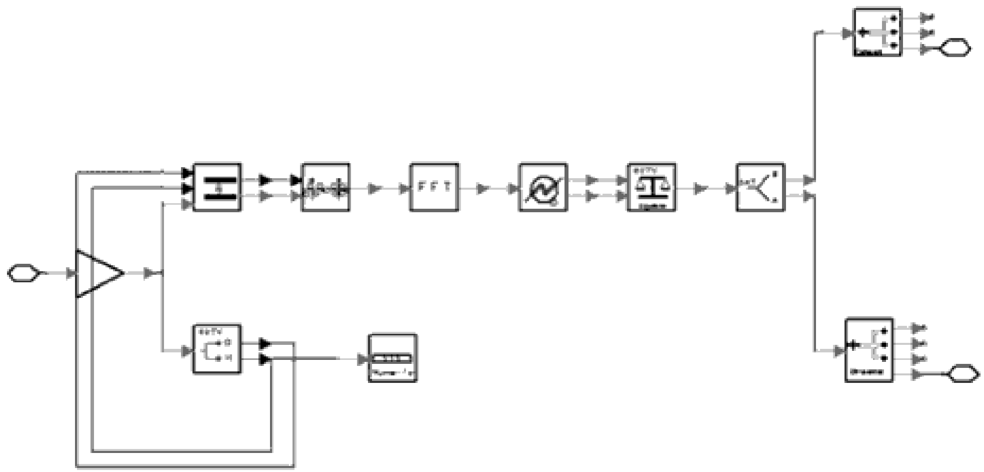


Subnetwork designs are shown below.

sub_ISDBOFDM_TwoLayMod



sub_ISDBOFDM_TwoLayDemod



Specifications

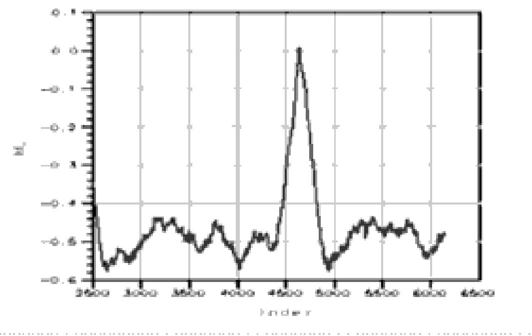
Symbol (Model)	Specification (Parameter)	Simulation Type	Value
	Carriers	ADS Ptolemy	108
	Segments	ADS Ptolemy	13
	IFFTSize	ADS Ptolemy	2048
	FFTSize	ADS Ptolemy	2048
	Guard	ADS Ptolemy	256
	IFFTOrder	ADS Ptolemy	11
	FFTOrder	ADS Ptolemy	11
	MaxDelay	ADS Ptolemy	2047
	SegmentsA	ADS Ptolemy	5
	SegmentsB	ADS Ptolemy	8
	Ru	ADS Ptolemy	0.9
PropNADCtdma	Type	ADS Ptolemy	FlatFading
PropNADCtdma	Pathloss	ADS Ptolemy	No
PropNADCtdma	Env	ADS Ptolemy	TypicalUrban
PropNADCtdma	Test	ADS Ptolemy	Tap1
AntMobile	Vx	ADS Ptolemy	30 km/hr
AntMobile	Vy	ADS Ptolemy	0.0 km/hr

Notes

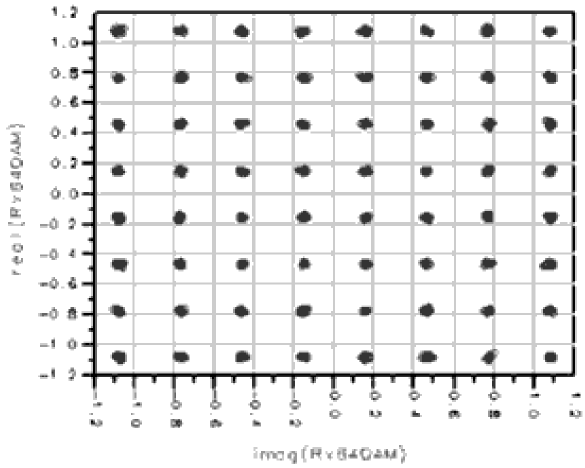
1. The modification of the guard interval is according to the ISDB-T. In mode 1, the value of the guard interval is 64, 128, 256, and 512 corresponding to the 1/32, 1/16, 1/8, and 1/4 guard interval ratio, respectively. In this example, the guard interval ratio is 1/8, so the guard interval is 256.
2. All parameters are related to the guard interval (except TDMA channel parameters). If the guard interval is changed, parameters will be changed to the corresponding values.
3. The TDMA channel condition varies according to channel parameter modification. Parameters include Type, Pathloss, Env, Delay, and Test in the PropNADCtdma model, and Vx and Vy in the AntMobile model.

Simulation Results

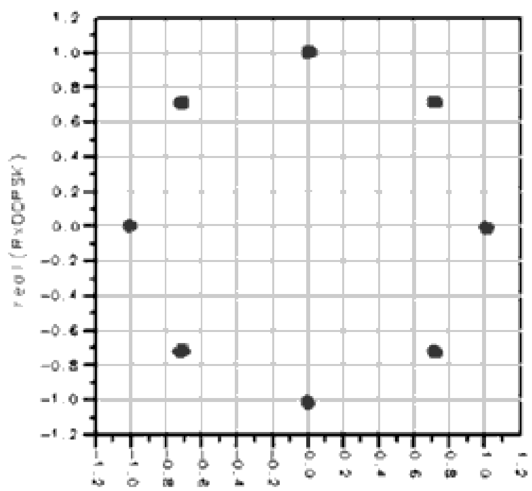
ML magnitude shows the magnitude of ML function of the received signal used to find the FFT start. The maximum value appears in every (2048+128) points, the point of the maximum magnitude value is the FFT start.



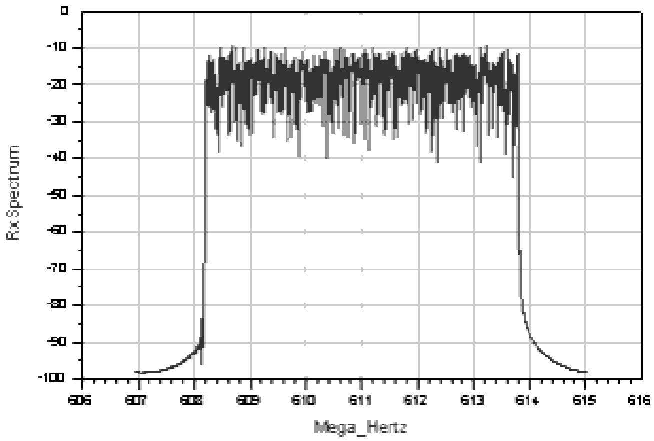
Received 64-QAM constellation after OFDM demodulation by TDMA channel. Results show OFDM system performance.



Received DQPSK constellation after OFDM demodulation by TDMA channel. Results show OFDM system performance.



Spectrum of Signal Received from Wireless Channel. Center frequency is 611 MHz



Adjacent-Channel Power Ratio ACPR=acpr_vr(DsnDTV_ISDBOFDM_TwoLay...RxSignal,50.0, {-2.808MHz,2.808MHz}, {-8.808MHz,-3.192MHz}, {3.192MHz,8.808MHz})

ACPR	
ACPR(1)	ACPR(2)
-42.298	-43.005

Benchmark

- Hardware Platform: Pentium II 200 MHz, 96 MB memory
- Software Platform: WindowsNT 4.0 Workstation, ADS 1.3
- Data Points: 10 symbols
- Simulation Time: 20 seconds

References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.

OFDM 3-Layer Modulation and Demodulation in ISDB-T Systems

DTV_ISDBOFDM_wrk Design Name

DsnDTV_ISDBOFDM_ThrLay

Features

- 64-QAM modulation and demodulation
- DQPSK modulation and demodulation
- 16-QAM modulation and demodulation
- Guard interval
- TDMA multipath fading channel with Doppler shift. The kind of the multipath can be selected and the Doppler shift can be determined by setting the mobile's speed.
- Displays include:
  ML (maximum likelihood function)
  RxSpectrum (spectrum of signal received from the channel)
  RxQAM (received signal constellation after OFDM demodulation)
  Rx16QAM
  RxDQPSK

Description

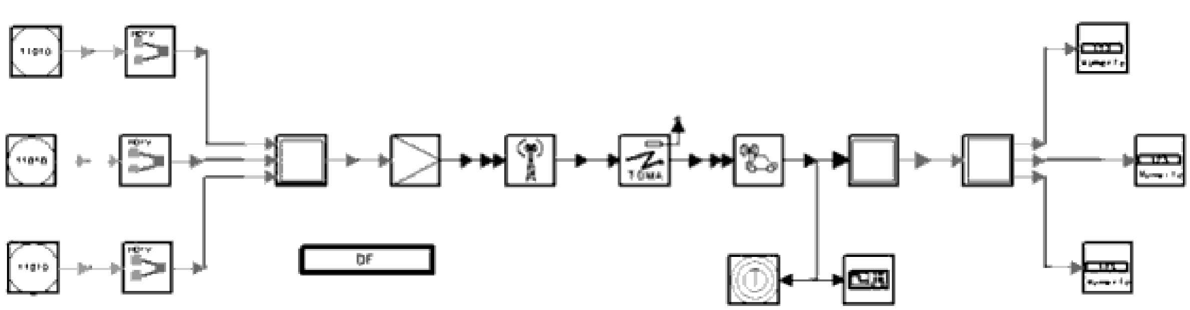
This design is a 3-layer OFDM design example of ISDB-T. It includes 13 segments (1 segment for Layer A, 5 segments for Layer B, and 7 segments for Layer C). The modulation modes are 64-QAM, and DQPSK, and 16-QAM, in Layer A, Layer B, and Layer C, respectively. In the OFDM adaptation, the 3-layer OFDM design works in mode 1. The IFFT/ FFT size is 2048; the Guard interval is 1/16 of IFFT size. The simulation channel is the TDMA channel.

The received 64-QAM, DQPSK, and 16-QAM constellations are shown in the simulation results.

Schematics

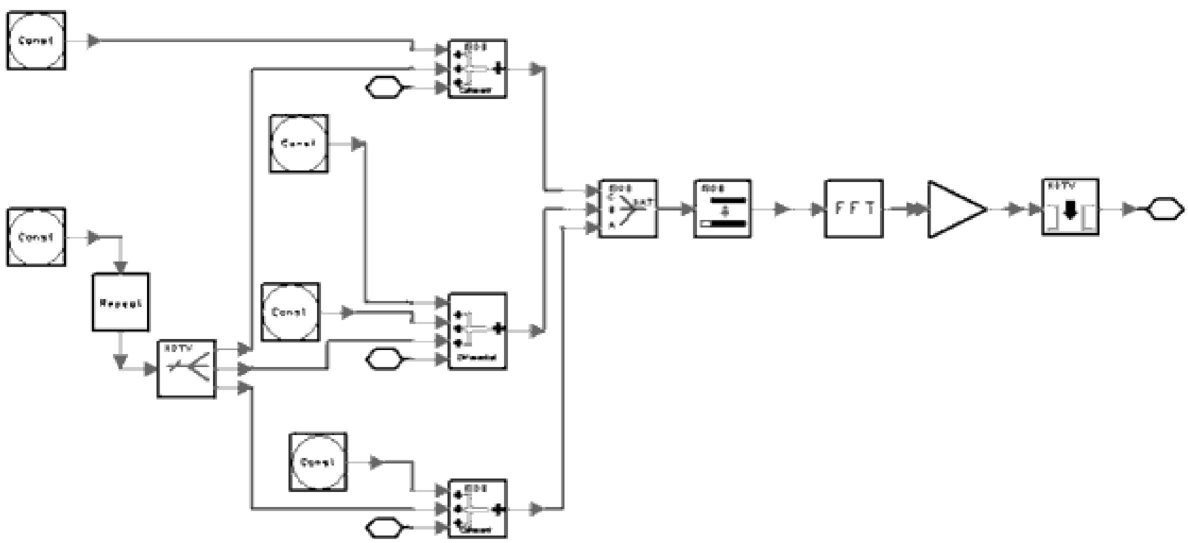
The figure below shows the schematic for this design.

DsnDTV_ISDBOFDM_ThrLay

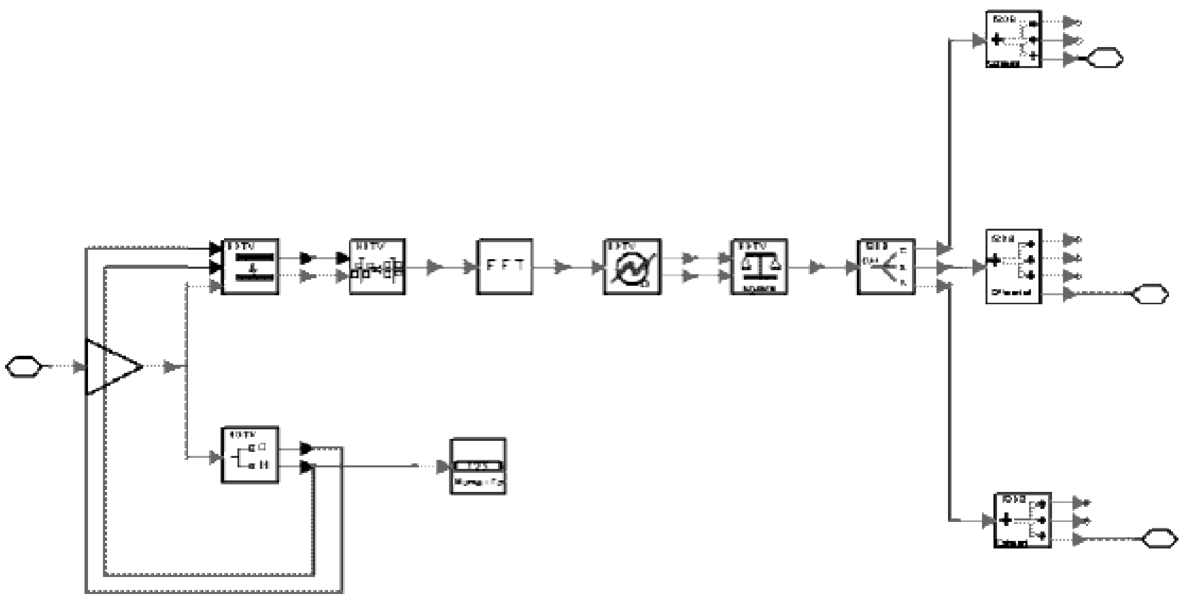


Subnetwork designs are shown in the figures below.

sub_ISDBOFDM_ThrLayMod



sub_ISDBOFDM_ThrLayDemod



Specifications

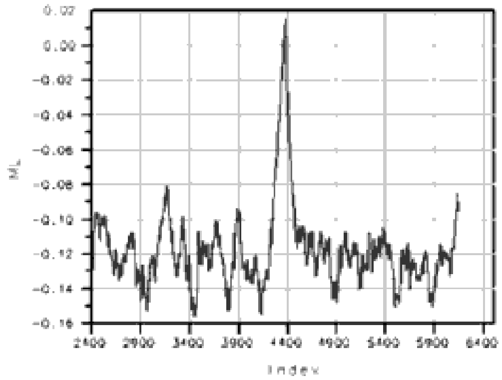
Symbol (Model)	Specification (Parameter)	Simulation Type	Value
	Carriers	ADS Ptolemy	108
	Segments	ADS Ptolemy	13
	IFFTSize	ADS Ptolemy	2048
	FFTSize	ADS Ptolemy	2048
	Guard	ADS Ptolemy	128
	IFFTOrder	ADS Ptolemy	11
	FFTOrder	ADS Ptolemy	11
	MaxDelay	ADS Ptolemy	2047
	SegmentsA	ADS Ptolemy	1
	SegmentsB	ADS Ptolemy	5
	SegmentsC	ADS Ptolemy	7
	Ru	ADS Ptolemy	0.9
PropNADCtdma	Type	ADS Ptolemy	TwoPath
PropNADCtdma	Pathloss	ADS Ptolemy	No
PropNADCtdma	Env	ADS Ptolemy	TypicalUrban
PropNADCtdma	Delay	ADS Ptolemy	0.5 μsec
PropNADCtdma	Test	ADS Ptolemy	Tap1
AntMobile	Vx	ADS Ptolemy	30 km/hr
AntMobile	Vy	ADS Ptolemy	0.0 km/hr

Notes

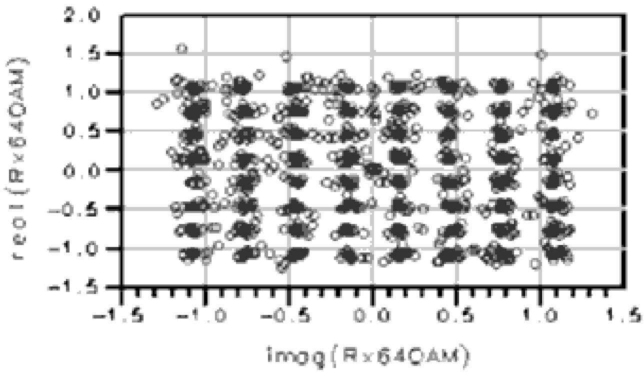
1. The modification of the guard interval is according to the ISDB-T. In mode 1, the value of the guard interval is 64, 128, 256, and 512 corresponding to the 1/32, 1/16, 1/8, and 1/4 guard interval ratio, respectively. In this example, the guard interval ratio is 1/16, so the guard interval is 128.
2. All parameters are related to the guard interval (except TDMA channel parameters). If the guard interval is changed, parameters will be changed to the corresponding values.
3. The TDMA channel condition varies according to channel parameter modification. Parameters include Type, Pathloss, Env, Delay, and Test in the PropNADCtdma model, and Vx and Vy in the AntMobile model .

Simulation Results

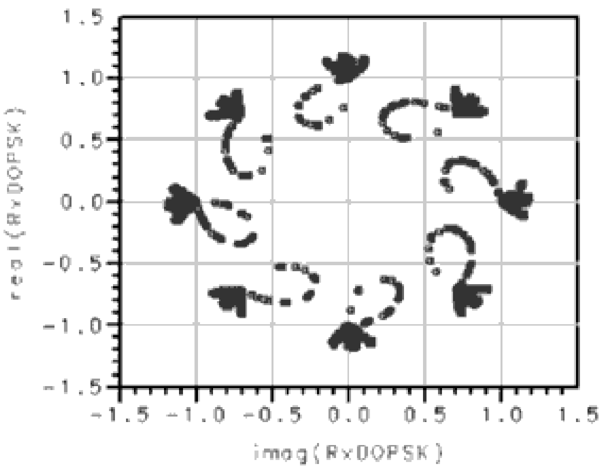
ML magnitude which shows magnitude of ML function of received signal used to find FFT start. Maximum value appears in every (2048+128) points, the point of the maximum magnitude value is the FFT start.



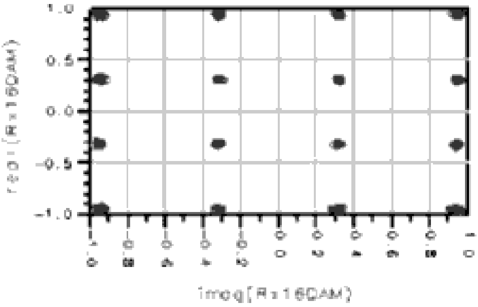
Received 64-QAM Constellation after OFDM Demodulation by TDMA channel. Results show OFDM System Performance.



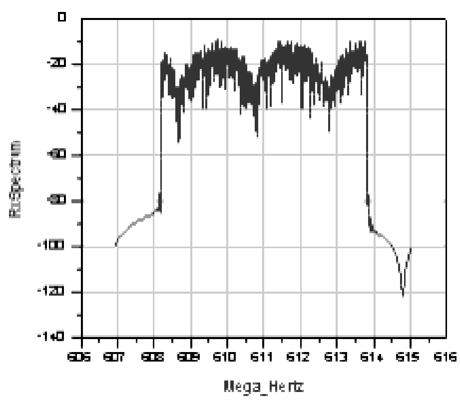
Received DQPSK Constellation after OFDM Demodulationby TDMA Channel. Results show OFDM system performance.



Received 16-QAM Constellation after OFDM Demodulation by TDMA Channel.



Spectrum of Signal Received from Wireless Channel. Center frequency = 611MHz



Adjacent-Channel Power Ratio. ACPR=acpr_vr(DsnDTV_ISDBOFDM_ThrLay..RxSignal, 50.0, {-2.808MHz,2.808MHz}, {-8.808MHz,-3.192MHz}, {3.192MHz,8.808MHz})

ACPR	
ACPR(1)	ACPR(2)
-41.689	-48.332

Benchmark

- Hardware Platform: Pentium II 200 MHz, 96 MB memory
- Software Platform: WindowsNT 4.0 Workstation, ADS 1.3
- Data Points: 10 symbols
- Simulation Time: 500 seconds

References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.

DTV ISDB System Workspace Examples

DTV_ISDBSystem_wrk

- DsnDTV_ISDBOFDM_64QAM_BER
- DsnDTV_ISDBOFDM_DQPSK_BER
- DsnDTV_ISDBOneLay_64QAM
- DsnDTV_ISDBOneLay_DQPSK
- DsnDTV_ISDBTwoLay_System
- DsnDTV_ISDBThrLay_System
- DsnDTV_TMCCMod
- DsnDTV_TMCCThrLay

OFDM 64-QAM ISDB-T System without Channel Coding BER

DTV_ISDBSystem_wrk Design Name

DsnDTV_ISDBOFDM_64QAM_BER

Features

- 64-QAM modulation and demodulation
- Gaussian simulation channels
- Bit error rate is tested
- Without channel coding and interleaving
- Received signal constellation is displayed

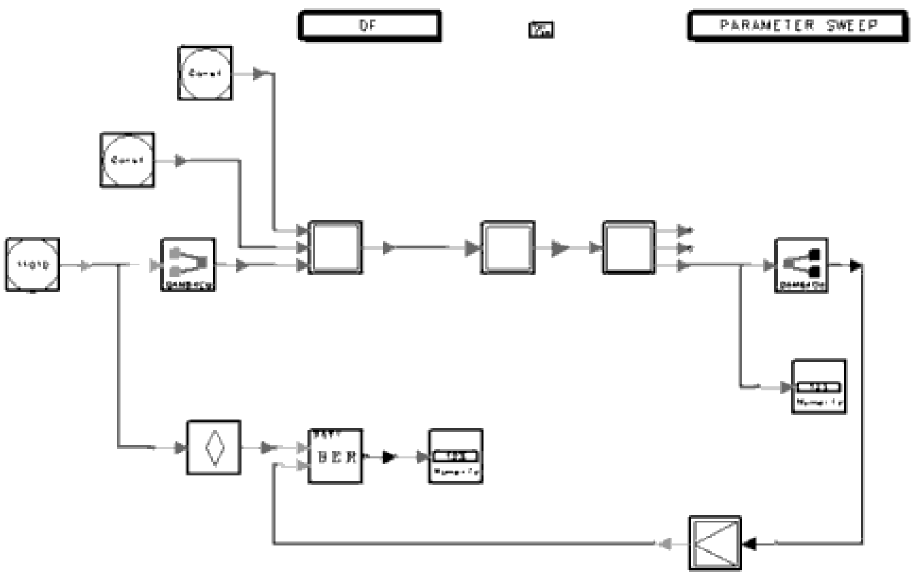
Description

This design example is an OFDM adaptation for ISDB-T to test the BER of an ISDB-T system without channel coding. In mode 1, the guard interval ratio is 1/8; modulation mode is 64-QAM.
Simulation results will be compared to those of *DsnDTV_ISDBOneLay_64QAM*, which tests the BER with channel coding and interleaving.

Schematics

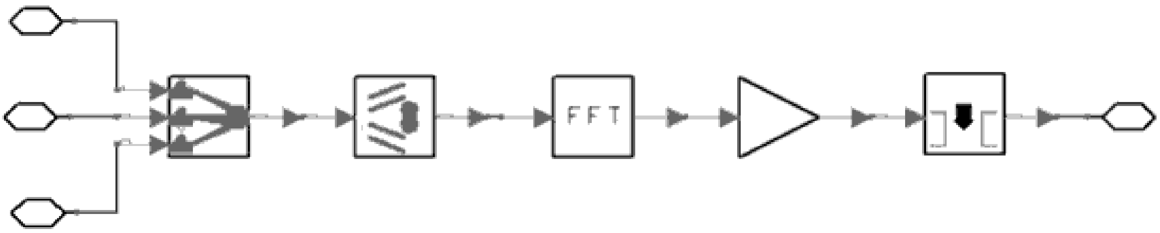
The figure below shows the schematic for this design.

DsnDTV_ISDBOFDM_64QAM_BER

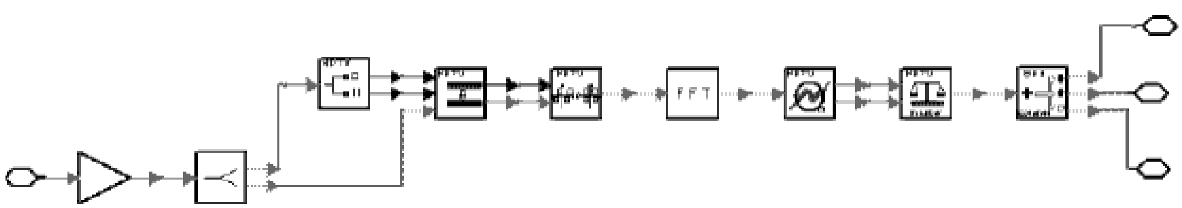


Subnetwork designs are shown in the figures below.

sub_ISDBOFDM_CohMod



sub_ISDBOFDM_CohDemod



Specifications

Specification (Parameter)	Simulation Type	Value
Carriers	ADS Ptolemy	108
IFFTSize	ADS Ptolemy	2048
FFTSize	ADS Ptolemy	2048
Guard	ADS Ptolemy	256
IFFTOrder	ADS Ptolemy	11
FFTOrder	ADS Ptolemy	11
MaxDelay	ADS Ptolemy	2047

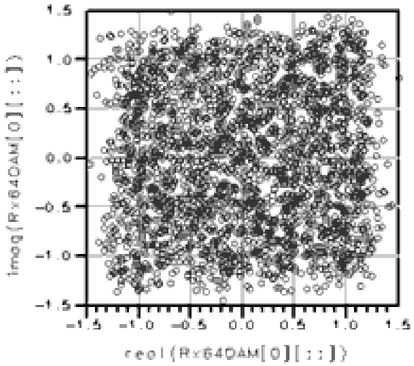
Notes

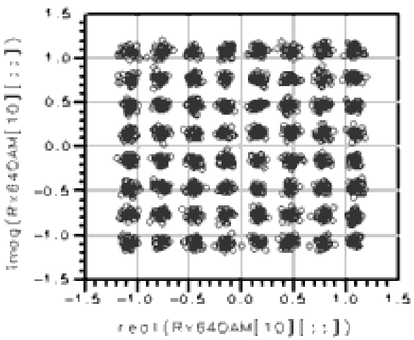
1. The modification of the guard interval is according to the ISDB-T. In mode 1, the value of the guard interval is 64, 128, 256, and 512, corresponding to the 1/32, 1/16, 1/8, and 1/4 guard interval ratio, respectively. In this example, the guard interval ratio is 1/8, so the guard interval is 256.
2. This design uses the AWGN channel. The DsnDTV_ISDBOFDM_64QAM_BER_AWGN.ds is the simulation of Gaussian channel (AWGN).

Simulation Results

The figure below shows the received constellation after OFDM demodulation when CN is 15dB and 25dB in Gaussian channel simulation. The results show the higher CN is better than the lower.

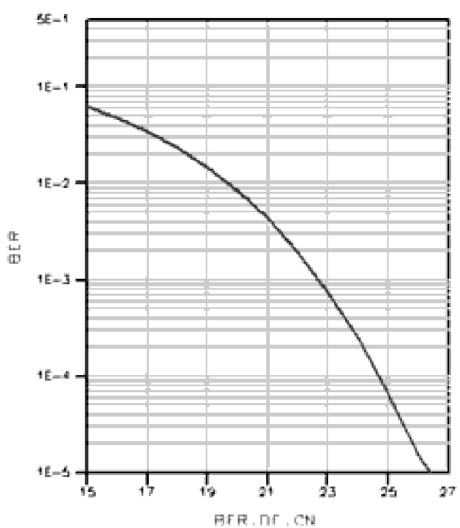
Constellation of OFDM Demodulation Signal at Different CN





The figure below shows Gaussian channel BER of different CN.

Gaussian Channel BER



Benchmark

- Hardware Platform: Pentium II 200 MHz, 128 MB memory
- Software Platform: WindowsNT 4.0 Workstation, ADS 1.3
- Data Points: 200 OFDM symbols
- Simulation Time: 58 minutes

References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.

OFDM DQPSK ISDB-T System without Channel Coding BER

DTV_ISDBSystem_wrk Design Name

DsnDTV_ISDBOFDM_DQPSK_BER

Features

- DQPSK modulation and demodulation
- Gaussian simulation channels
- Bit error rate is tested
- Without channel coding and interleaving
- Received signal constellation is displayed

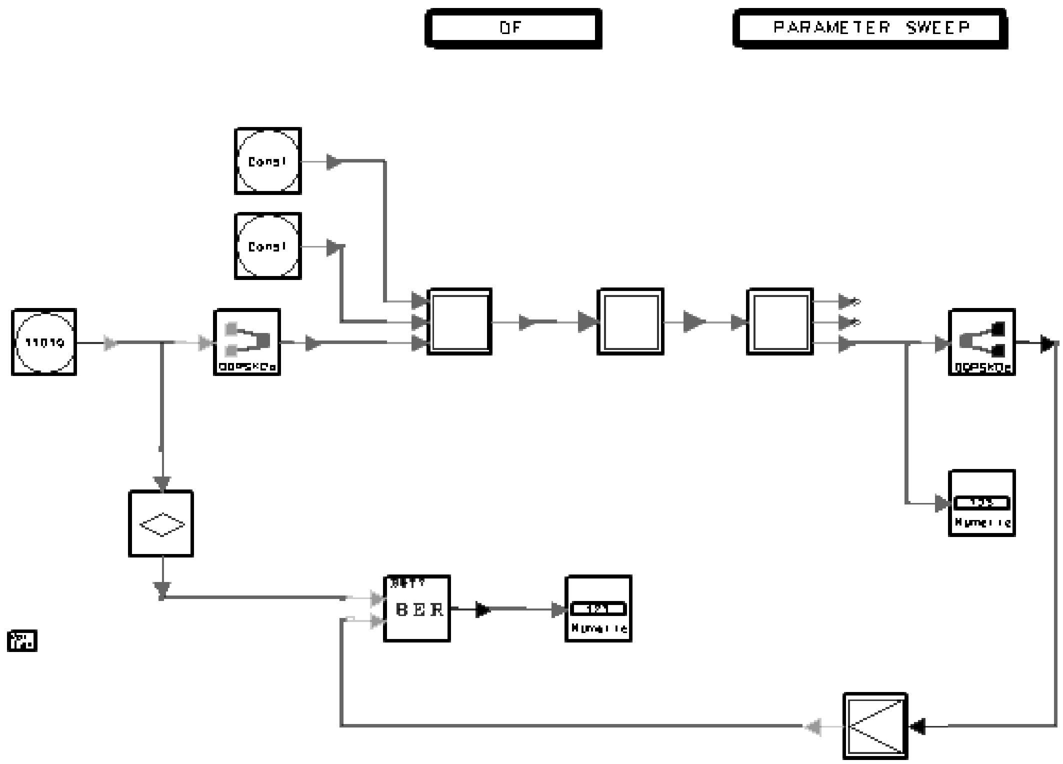
Description

This design example is an OFDM adaptation for ISDB-T to test the BER of an ISDB-T system without channel coding. In mode 1, the guard interval ratio is 1/8; modulation mode is DQPSK.
Simulation results are compared to those of *DsnDTV_ISDBOneLay_DQPSK*, which tests the BER with channel coding and interleaving.

Schematics

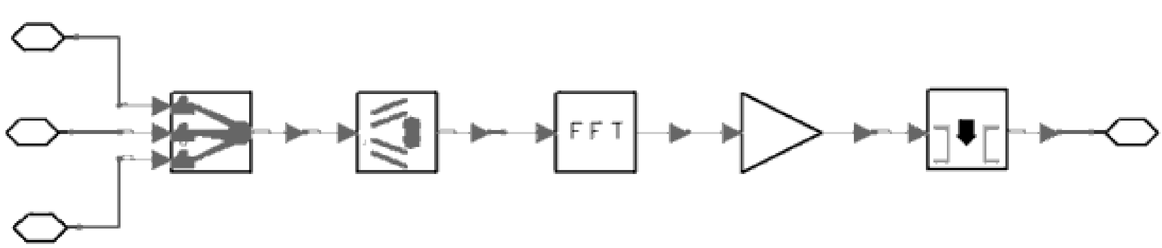
The figure below shows the schematic for this design.

DsnDTV_ISDBOFDM_DQPSK_BER

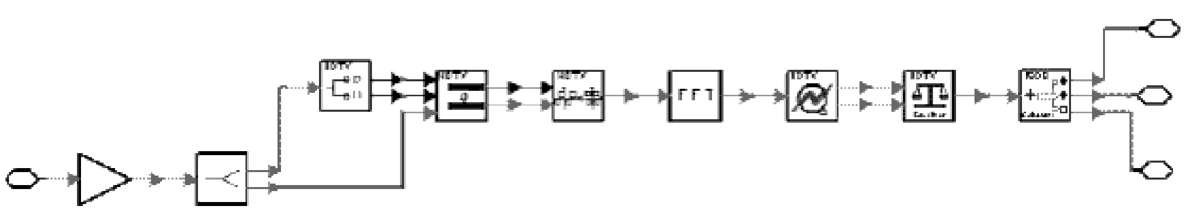


Subnetwork designs are shown in th figures below.

sub_ISDBOFDM_CohMod



sub_ISDBOFDM_CohDemod



Specifications

Specification (Parameter)	Simulation Type	Value
Carriers	ADS Ptolemy	108
IFFTSize	ADS Ptolemy	2048
FFTSize	ADS Ptolemy	2048
Guard	ADS Ptolemy	256
IFFTOrder	ADS Ptolemy	11
FFTOrder	ADS Ptolemy	11
MaxDelay	ADS Ptolemy	2047

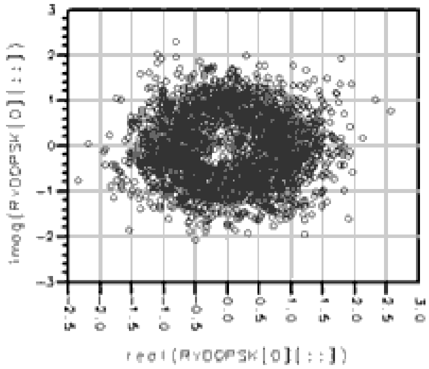
Notes

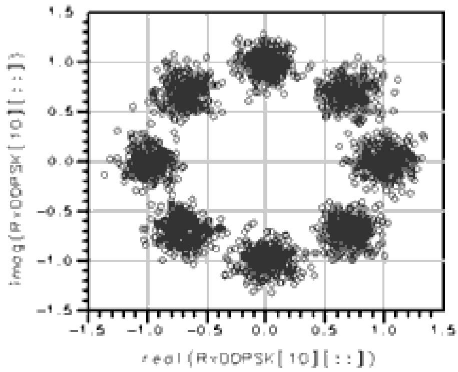
1. The modification of the guard interval is according to the ISDB-T. In mode 1, the value of the guard interval is 64, 128, 256, and 512 corresponding to the 1/32, 1/16, 1/8, and 1/4 guard interval ratio, respectively. In this example, the guard interval ratio is 1/8, so the guard interval is 256.
2. This design will work in AWGN channel. The DsnDTV_ISDBOFDM_DQPSK_BER_AWGN.ds is the simulation of Gaussian channel (AWGN).

Simulation Results

The figure below shows the received constellation after OFDM demodulation when the CN is 15dB and 25dB, respectively in the Gaussian channel simulation. The results show the result of higher CN is better than that of lower CN.

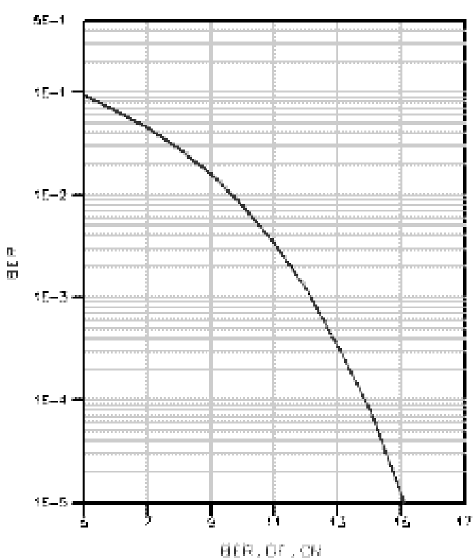
Constellation of the OFDM Demodulation Signal at Different CN





The figure below shows the BER of different CN when the simulation channel is Gaussian channel.

Gaussian Channel BER



Benchmark

- Hardware Platform: Pentium II 200 MHz, 128 MB memory

- Software Platform: WindowsNT 4.0 Workstation, ADS 1.3
- Data Points: 400 OFDM symbols
- Simulation Time: 2 hours

References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.

1-Layer 64-QAM Mapping ISDB-T System Design

DTV_ISDBSystem_wrk Design Name

DsnDTV_ISDBOneLay_64QAM

Features

- 1-layer full ISDB system with channel coding/decoding and OFDM modulation/demodulation
- OFDM modulation mode 1, 96 carriers per OFDM segment
- 64-QAM mapping
- 3/4 rate punctured convolutional coding and Viterbi decoding
- Reed-Solomon coding and decoding
- Bytewise interleaving, time and frequency interleaving
- Carrier rotation and scrambling
- AWGN and multipath channel simulation

Description

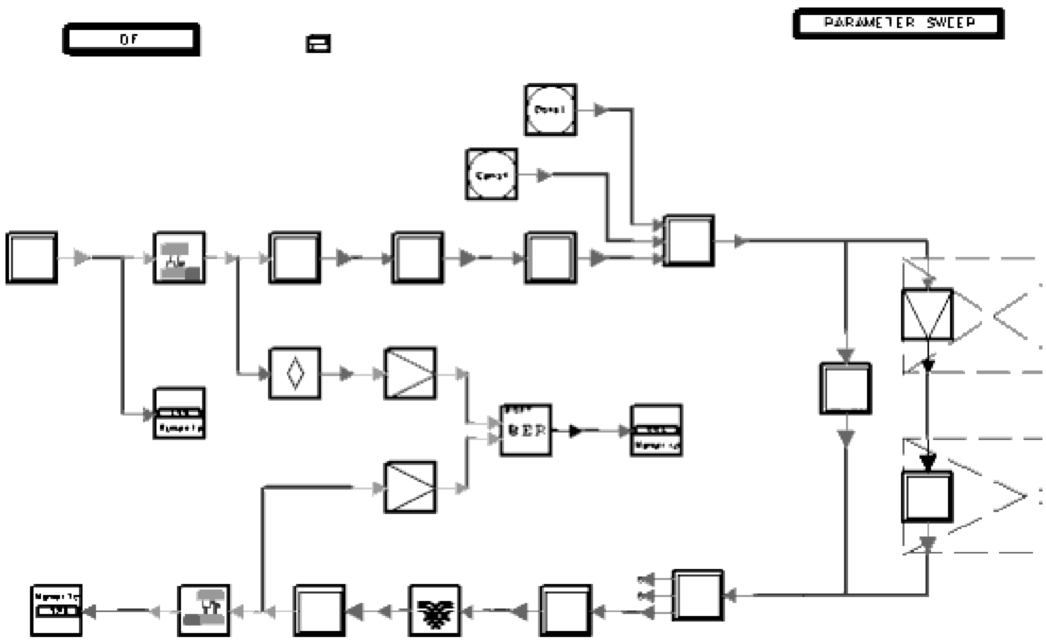
This example demonstrates the functionality of a full 1-layer ISDB system, including channel coding/decoding and OFDM modulation/demodulation models.

This design is simulated under AWGN and multipath channels. The bit error rates of these channels are shown in the simulation results. In the AWGN channel, the BER is compared to that of *DsnDTV_ISDBOFDM_64QAM_BER* without channel coding and interleaving.

Schematics

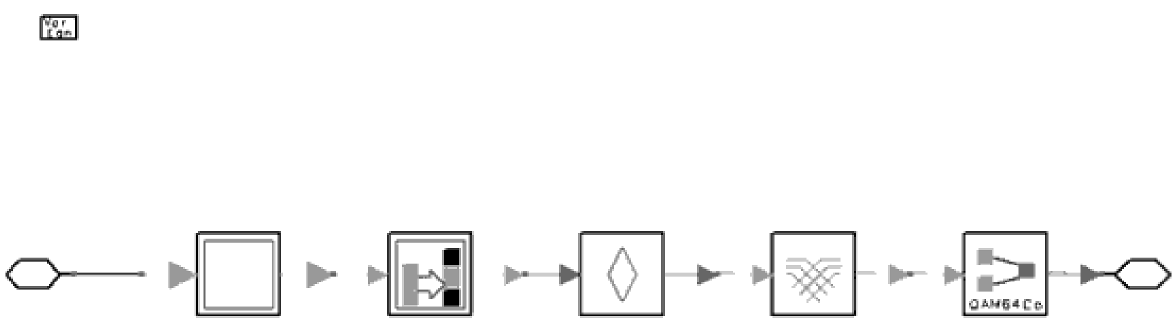
The figure below shows the schematic for this design.

DsnDTV_ISDBOneLay_64QAM

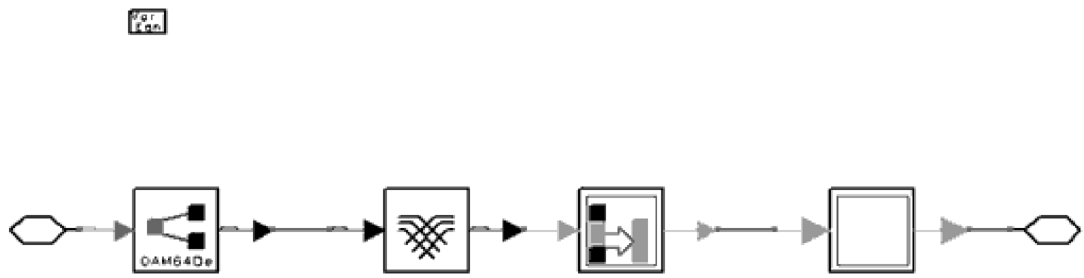


The coding and decoding subnetwork designs are shown in the figures below.

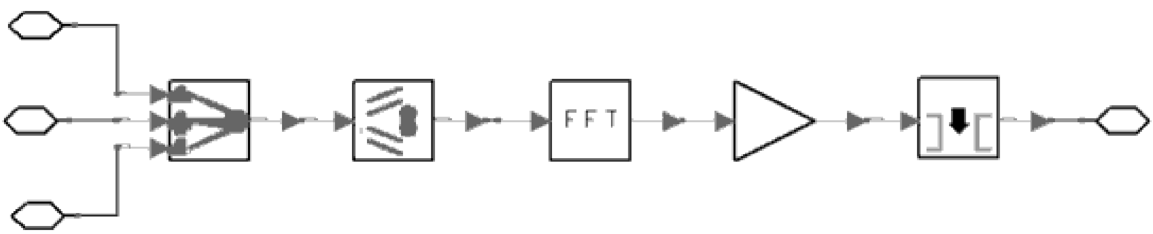
sub_ISDBChCoder_64QAM_3_4



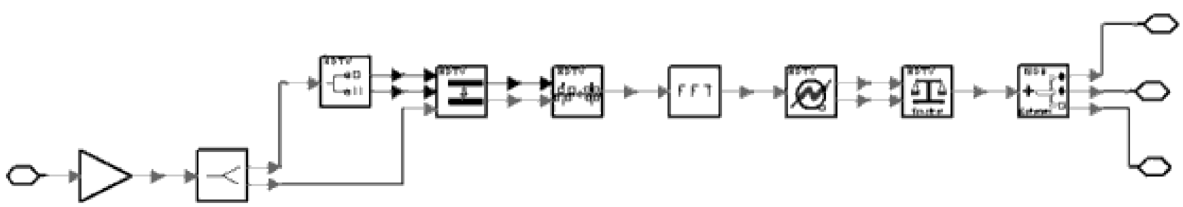
sub_ISDBChDecoder_64QAM_3_4



sub_ISDBOFDM_CohMod



sub_ISDBOFDM_CohDemod



Specifications

Specification	Simulation Type	Value
Number of carriers in each OFDM segment (mode 1)	ADS Ptolemy	96
Number of OFDM segments in this layer	ADS Ptolemy	13
Punctured convolutional code rate	ADS Ptolemy	3/4
Constellation mapping	ADS Ptolemy	64QAM

Notes

1. In this design, some system parameters are represented by global variables in order to adapt the system to different modulation modes. These variables are listed in *Global Variables*.
2. Delay is introduced in the system in several places as listed in *Delay Adjustments*. The following parameter settings are important because they relate to the delays in *Delay Adjustments*.
    - In the *DTV_PuncConvDecoder* (dtv) model, OFDM symbol and Viterbi decoding delays are summed and adjusted to a multiple of 204 bytes in order to correctly

align the data packet for Reed-Solomon decoding.

- In the sub_ISDBDerandomize subnetwork, delay parameters must be set correctly for the pseudo-random sequence to be reset at the right timing.
- The sink of the ultimate output of the system must take into account all delays for correct output data that corresponds to system input.

Global Variables

Variables	Description
Carriers	Number of carriers per segment in different OFDM modes:
Segments	Number of OFDM segments belonging to this layer; in this 1-layer application, it is always 13.
NumberTSP	Number of TSPs transmitted on all carriers of each OFDM segment. It is also determined by the data rate of punctured convolutional code type and constellation mapping.
FrameDelays	Number of TSPs delayed in the entire system caused by byte interleaving (1 OFDM frame delay) and time interleaving (several OFDM frame delays, dependent on the I parameter of time interleaving. In this example, I=4; therefore, FrameDelays is 2 OFDM frames).
SymDelays	Number of bytes delayed in the entire system caused by bit interleaving (2 OFDM symbols) and OFDM demodulation (1 OFDM symbol).
CN	Carrier/noise ratio of the channel.

Delay Adjustments

Delay Type	Delay Length
Byte interleaving and delay adjustment	1 OFDM frame
Bit interleaving and delay adjustment	2 OFDM symbols
Time interleaving and delay adjustment	Several OFDM frames (depending on the time interleaving mode)
OFDM demodulation	1 OFDM symbol
Viterbi decoding	several bytes determined by PathLen

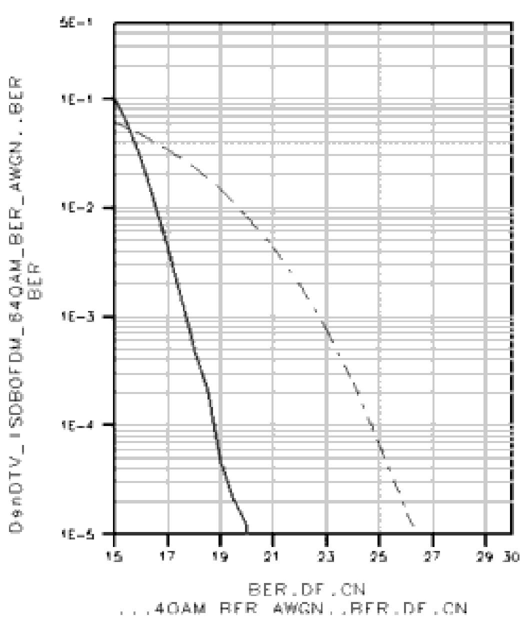
Simulation Results

- AWGN channel
  Additive white Gaussian noise was added to set the carrier-to-noise ratio (CN) at the input of the receiver. Compare RxByte with TxByte with different CN show the transmitted and the received byte data when CN is 15dB and 20dB in the Gaussian channel simulation. The second column is the received byte of CN=15dB; the third column is the received Byte of CN=20dB. Compared to TxByte, the second column has more errors than the third column.
  The BERs of the full system before RS decoding and OFDM system without channel coding (in DsnDTV_ISDBOFDM_64QAM_BER) are shown in BER for AWGN solid line = full system; dash line = OFDM system without channel coding. Channel coding gain is approximately 6.0dB at 0.0001 BER.

Compare RxByte with TxByte with different CN

Index	...[::]	Index	...[::]	...[::]
0	71.000	397996	71.000	71.000
1	192.000	397997	29.000	192.000
2	104.000	397998	48.000	104.000
3	3.000	397999	3.000	3.000
4	160.000	398000	118.000	160.000
5	132.000	398001	8.000	132.000
6	56.000	398002	77.000	56.000
7	160.000	398003	160.000	160.000
8	63.000	398004	63.000	63.000
9	28.000	398005	28.000	28.000
10	52.000	398006	52.000	52.000
11	14.000	398007	14.000	14.000
12	251.000	398008	251.000	251.000
13	204.000	398009	69.000	204.000
14	4.000	398010	6.000	4.000
15	113.000	398011	98.000	113.000
16	226.000	398012	226.000	226.000
17	200.000	398013	183.000	200.000
18	122.000	398014	122.000	122.000
19	170.000	398015	170.000	170.000
20	38.000	398016	150.000	38.000
21	182.000	398017	182.000	182.000
22	232.000	398018	183.000	232.000
23	32.000	398019	32.000	32.000
24	67.000	398020	67.000	67.000
25	151.000	398021	23.000	151.000
26	220.000	398022	227.000	220.000
27	7.000	398023	20.000	7.000
28	88.000	398024	88.000	88.000
29	87.000	398025	93.000	87.000
30	103.000	398026	103.000	103.000
31	251.000	398027	251.000	251.000
32	163.000	398028	163.000	163.000
33	91.000	398029	91.000	91.000
34	175.000	398030	175.000	175.000
35	38.000	398031	89.000	38.000
36	216.000	398032	216.000	216.000
37	187.000	398033	116.000	187.000
38	18.000	398034	66.000	18.000
39	27.000	398035	8.000	27.000

BER for AWGN - solid line = full system; dash line = OFDM system without channel coding



- Multipath channel (3dB)

Measurements of BER vs. CN were made using a fading channel simulator. The DU ratios of a main signal and a delayed signal were set to 3 dB. Delay time of a delayed signal from a main signal was set to 1.5 μsec. This multipath channel has no fading frequency. In the ADS simulation system, this multipath channel is simulated by UserDefChannel model; parameters were set as follows:

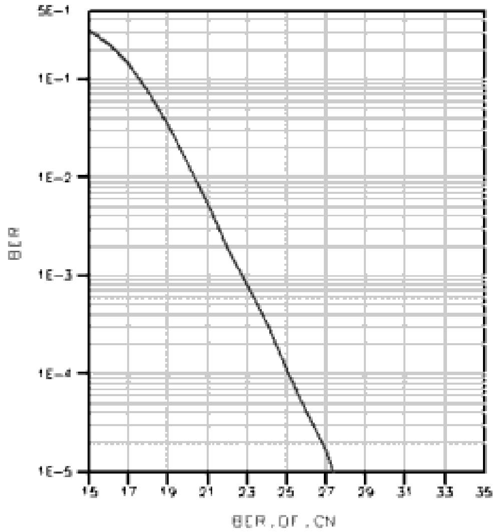
Symbol	Specification	Simulation Type	Value
UserDefChannel	PathNumber	ADS Ptolemy	2
UserDefChannel	AmpArray	ADS Ptolemy	"0.8165 0.5773"
UserDefChannel	DelayArray	ADS Ptolemy	"0.0 1.5"
AntMobile	Vx	ADS Ptolemy	0

This simulation result was not included into this DTV package because of the limitation of DTV package size. To prove the BER performance of this channel, set the parameters above and run this design example. The simulation time is very long.
Compare RxByte with TxByte with different CN shows the transmitted and received Byte data when carrier-to-noise ratio (CN) is 15dB and 25dB in the multipath channel simulation. In Compare RxByte with TxByte with different CN, the second column is the received Byte of the CN=15dB, the third column is the received Byte of 25dB . Compared to TxByte, the second column has more error than the third column.
The BER of the full system before RS decoding is shown in Multipath Channel BER. CN is 25.0dB when BER is 0.0001.

Compare RxByte with TxByte with different CN

Index	...][::]	Index	...][::]	...][::]
0	71.000	397996	81.000	71.000
1	195.000	397997	195.000	195.000
2	162.000	397998	162.000	162.000
3	169.000	397999	25.000	169.000
4	46.000	398000	102.000	46.000
5	27.000	398001	27.000	27.000
6	211.000	398002	4.000	211.000
7	233.000	398003	233.000	233.000
8	80.000	398004	80.000	80.000
9	122.000	398005	132.000	122.000
10	193.000	398006	216.000	193.000
11	187.000	398007	187.000	187.000
12	171.000	398008	218.000	171.000
13	245.000	398009	168.000	245.000
14	31.000	398010	97.000	31.000
15	188.000	398011	112.000	188.000
16	190.000	398012	9.000	190.000
17	154.000	398013	61.000	154.000
18	236.000	398014	157.000	236.000
19	111.000	398015	181.000	111.000
20	36.000	398016	36.000	36.000
21	167.000	398017	99.000	167.000
22	55.000	398018	120.000	55.000
23	68.000	398019	54.000	68.000
24	180.000	398020	52.000	180.000
25	196.000	398021	11.000	196.000
26	19.000	398022	19.000	19.000
27	217.000	398023	217.000	217.000
28	152.000	398024	4.000	152.000
29	66.000	398025	66.000	66.000
30	12.000	398026	32.000	12.000
31	209.000	398027	218.000	209.000
32	161.000	398028	249.000	161.000
33	14.000	398029	8.000	14.000
34	13.000	398030	25.000	13.000
35	25.000	398031	25.000	25.000
36	215.000	398032	241.000	215.000
37	52.000	398033	52.000	52.000
38	242.000	398034	242.000	242.000

Multipath Channel BER



- Multipath channel (10dB)
  Measurements of BER vs. CN were made using a fading channel simulator. The DU ratios of a main signal and a delayed signal were set to 10 dB. Delay time of a delayed signal from a main signal was set to 1.5 us. This multipath channel has no fading frequency. In the ADS simulation system, this multipath channel is simulated by UserDefChannel model, its parameters were set as follows:

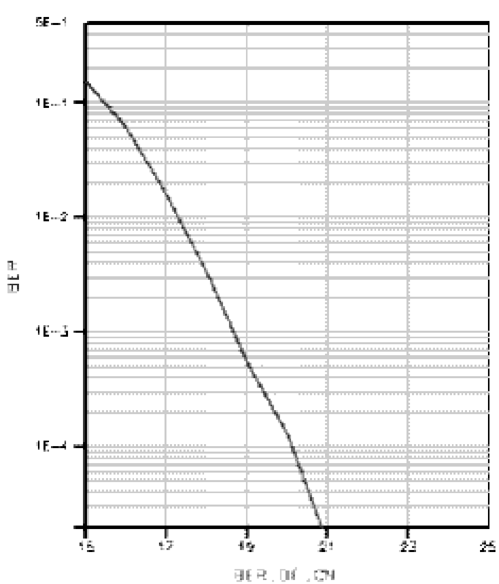
Symbol	Specification	Simulation Type	Value
UserDefChannel	PathNumber	ADS Ptolemy	2
UserDefChannel	AmpArray	ADS Ptolemy	"0.9535 0.3015"
UserDefChannel	DelayArray	ADS Ptolemy	"0.0 1.5"
AntMobile	Vx	ADS Ptolemy	0

  This simulation result was not included into this DTV package because of the limitation of DTV package size. If users want to prove the BER performance of this channel, users can set the parameters above and run this design example. The simulation time is very long.
  Compare RxByte with TxByte with different CN show the transmitted Byte data and the received Byte data when carrier-to-noise ratio (CN) is 15dB and 20dB in the multipath channel simulation. In Compare RxByte with TxByte with different CN, the second column is the received Byte of the CN=15dB, the third column is the received Byte of 20dB. Compared to TxByte, the second column has more errors than the the third column.
  The BER of the full system before RS decoding is shown in Multipath Channel BER. The CN is 20.0dB when BER is 0.0001.

Compare RxByte with TxByte with different CN

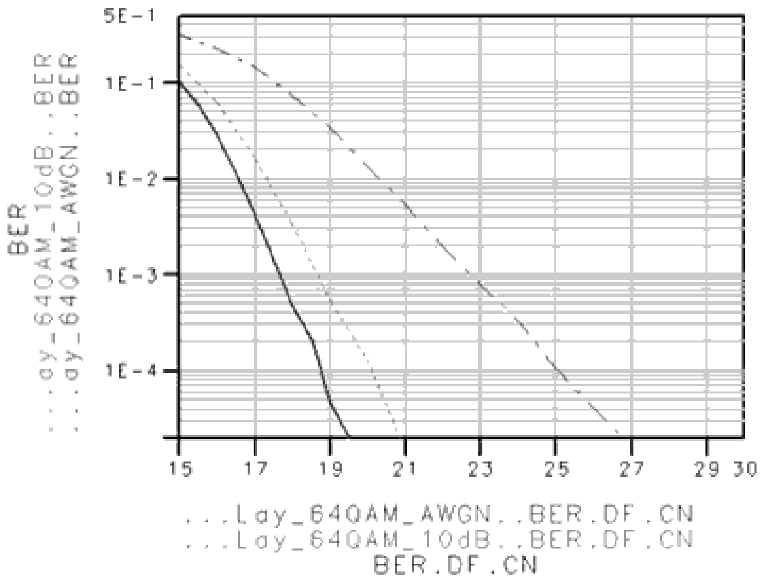
Index	...[::]	Index	...[::]	...[::]
0	71.000	397996	71.000	71.000
1	195.000	397997	164.000	195.000
2	162.000	397998	50.000	162.000
3	169.000	397999	253.000	169.000
4	46.000	398000	104.000	46.000
5	27.000	398001	27.000	27.000
6	211.000	398002	147.000	211.000
7	233.000	398003	233.000	233.000
8	80.000	398004	80.000	80.000
9	122.000	398005	111.000	122.000
10	193.000	398006	191.000	193.000
11	187.000	398007	187.000	187.000
12	171.000	398008	115.000	171.000
13	245.000	398009	245.000	245.000
14	31.000	398010	113.000	31.000
15	188.000	398011	189.000	188.000
16	190.000	398012	190.000	190.000
17	154.000	398013	200.000	154.000
18	236.000	398014	49.000	236.000
19	111.000	398015	171.000	111.000
20	36.000	398016	36.000	36.000
21	167.000	398017	167.000	167.000
22	55.000	398018	55.000	55.000
23	68.000	398019	68.000	68.000
24	180.000	398020	180.000	180.000
25	196.000	398021	196.000	196.000
26	19.000	398022	19.000	19.000
27	217.000	398023	217.000	217.000
28	152.000	398024	152.000	152.000
29	66.000	398025	66.000	66.000
30	12.000	398026	27.000	12.000
31	209.000	398027	143.000	209.000
32	161.000	398028	190.000	161.000
33	14.000	398029	46.000	14.000
34	13.000	398030	13.000	13.000
35	25.000	398031	77.000	25.000
36	215.000	398032	215.000	215.000
37	52.000	398033	52.000	52.000
38	242.000	398034	54.000	242.000
39	16.000	398035	115.000	16.000

Multipath Channel BER



The figure below shows the BERs of the three different simulation results. The performance of AWGN channel is better than the multipath channels (DU ratios are 3dB and 10dB); the performance of the 10dB multipath channel is better than the 3dB multipath channel.

BERs of Different Channels - solid line = AWGN; dotted line =10dB multipath channel; dot-dash line = 3dB multipath channel



Benchmark

- Hardware Platform: Pentium II 200 MHz, 128 MB memory
- Software Platform: WindowsNT 4.0 Workstation, ADS 1.3
- Data Points: 188 × 5-1
- Simulation Time: 16 hours for AWGN channel, 20 hours for DU=3dB and DU=10 dB multipath channel.

References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.

1-Layer DQPSK-Mapping ISDB-T System Design

DTV_ISDBSystem_wrk Design Name

DsnDTV_ISDBOneLay_DQPSK

Features

- 1-layer full ISDB system with channel coding/decoding and OFDM

modulation/demodulation
- OFDM modulation mode 1, 96 carriers per OFDM segment
- DQPSK mapping
- 1/2 rate punctured convolutional coding
- Reed-Solomon coding and decoding
- Bytewise interleaving, time and frequency interleaving
- Carrier rotation and scrambling
- AWGN, multipath, and Rayleigh fading channel simulations

Description

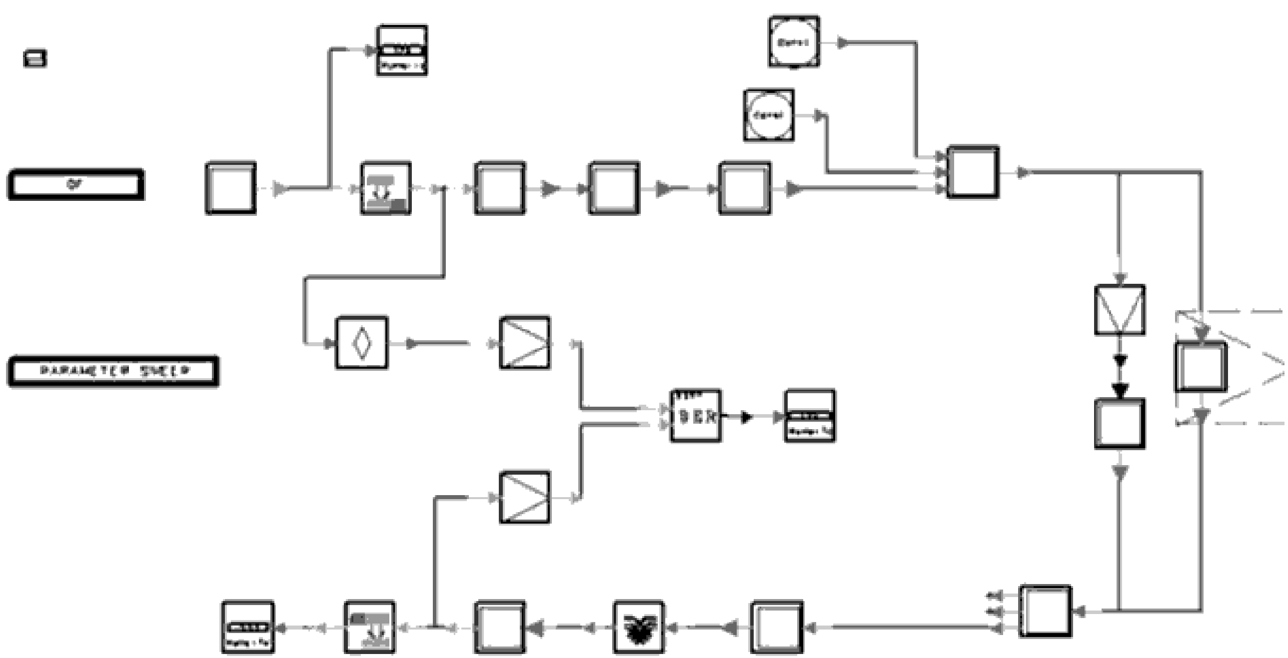
This design demonstrates the performance of a full 1-layer ISDB system, including channel coding/decoding and OFDM modulation/demodulation models. It uses OFDM mode 1 and OFDM modulation, DQPSK mapping, 1/2 rate punctured convolutional coding, interleaving and delay adjustments.

This design is simulated under AWGN, multipath, and Rayleigh fading channels. The bit error rates of these channels are shown in the simulation results. In the AWGN channel, the BER is compared to the *DsnDTV_ISDBOFDM_DQPSK_BER* design without channel coding and interleaving.

Schematics

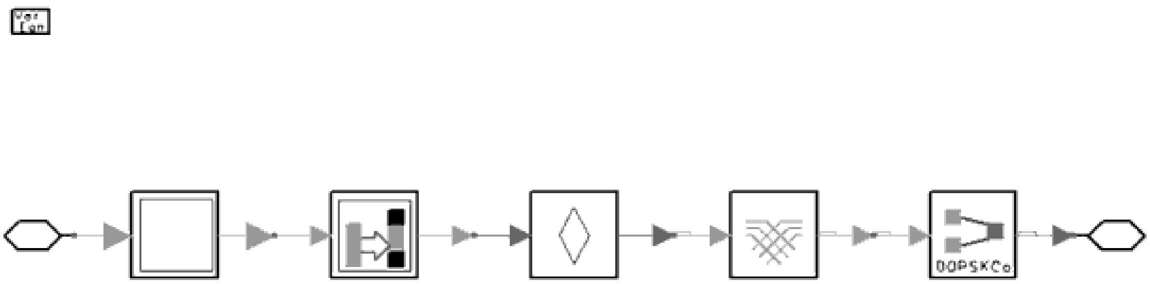
The figure below shows the schematic for this design.

DsnDTV_ISDBOneLay_DQPSK

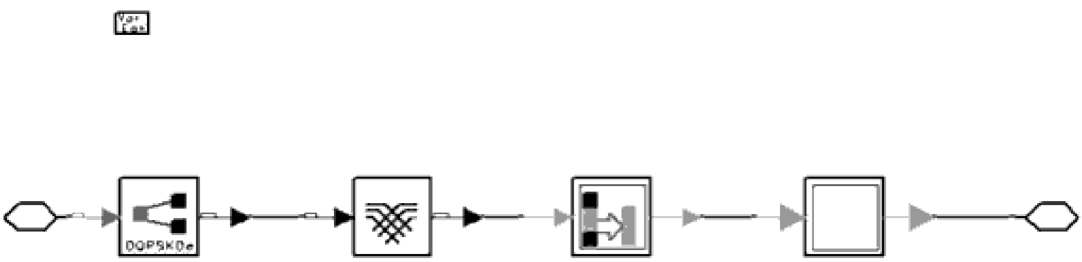


The coding and decoding subnetwork designs are shown in the figures below.

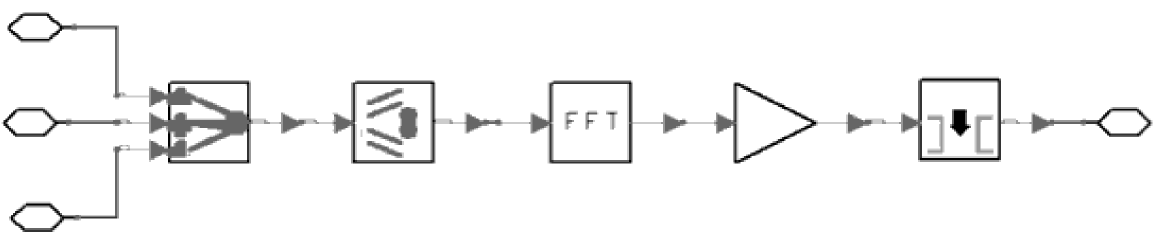
sub_ISDBChCoder_DQPSK_1_2



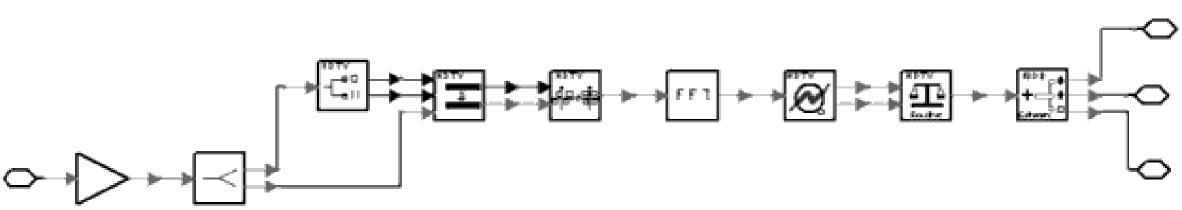
sub_ISDBChDecoder_DQPSK_1_2



sub_ISDBOFDM_CohMod



sub_ISDBOFDM_CohDemod



Specifications

Symbol	Specification	Simulation Type	Value
Number of carriers in each OFDM segment (mode 1)	ADS Ptolemy	96	
Number of OFDM segments in this layer	ADS Ptolemy	13	
Punctured convolutional code rate	ADS Ptolemy	1/2	
Constellation mapping	ADS Ptolemy	DQPSK	
Vx	Vehicle speed	ADS Ptolemy	124 km/hr

Notes

1. In this design, some system parameters are represented by global variables in order to adapt the system to different modulation modes. These variables are listed in *Global Variables*.
2. Delay is introduced in the system in several places as listed in *Delay*.
   The following parameter settings are important as they relate to the delays in *Delay*.
   - In the *DTV_PuncConvDecoder* (dtv) model, OFDM symbol and Viterbi decoding delays are summed and adjusted to a multiple of 204 bytes in order to correctly align the data packet for Reed-Solomon decoding.
   - In the sub_ISDBDerandomize subnetwork, delay parameters must be set correctly for the pseudo-random sequence to be reset at the right timing.
   - The sink of the ultimate output of the system must take into account all delays for correct output data that corresponds to system input.

Global Variables

Variables	Description
Carriers	Number of carriers per segment in different OFDM modes:
Segments	Number of OFDM segments belonging to this layer; in this 1-layer application, it is always 13.
NumberTSP	Number of TSPs transmitted on all carriers of each OFDM segment. It is also determined by the data rate of punctured convolutional code type and constellation mapping.
FrameDelays	Number of TSPs delayed in the entire system caused by byte interleaving (1 OFDM frame delay) and time interleaving (several OFDM frame delays, dependent on the I parameter of time interleaving. In this example, I=4; therefore, FrameDelays is 2 OFDM frames).
SymDelays	Number of bytes delayed in the entire system caused by bit interleaving (2 OFDM symbols) and OFDM demodulation (1 OFDM symbol).
CN	Carrier/noise ratio of the channel.

Delay

Delay Type	Delay Length
Byte interleaving and delay adjustment	1 OFDM frame
Bit interleaving and delay adjustment	2 OFDM symbols
Time interleaving and delay adjustment	Several OFDM frames (depending on the time interleaving mode)
OFDM demodulation	1 OFDM symbol
Viterbi decoding	several bytes determined by PathLen

Simulation Results

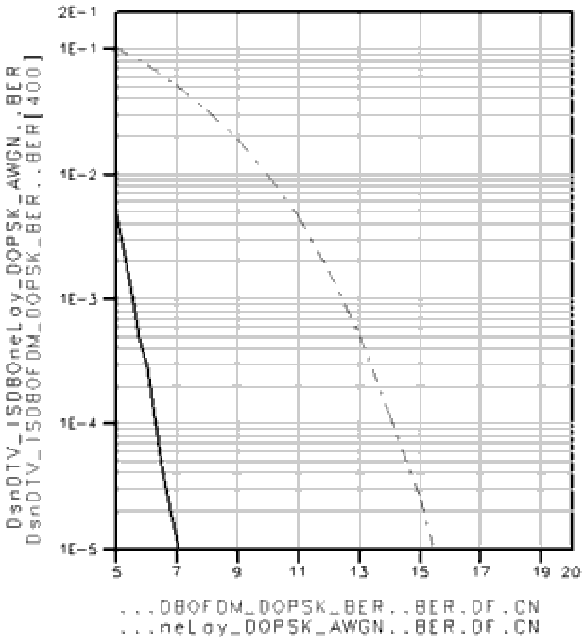
AWGN Channel
Additive white Gaussian noise was added to set the carrier-to-noise ratio (CN) at the input of the receiver. The figure below shows the transmitted and the received byte data when carrier-to-noise ratio (CN) is 5dB and 7dB in the Gaussian channel simulation.

Compare RxByte with TxByte with different CN

Index	...[::]	Index	...[::]	...[::]
280	111.000	88828	111.000	111.000
281	11.000	88829	11.000	11.000
282	58.000	88830	58.000	58.000
283	254.000	88831	254.000	254.000
284	250.000	88832	250.000	250.000
285	104.000	88833	104.000	104.000
286	57.000	88834	57.000	57.000
287	122.000	88835	122.000	122.000
288	192.000	88836	192.000	192.000
289	172.000	88837	172.000	172.000
290	136.000	88838	136.000	136.000
291	159.000	88839	159.000	159.000
292	224.000	88840	224.000	224.000
293	98.000	88841	98.000	98.000
294	94.000	88842	94.000	94.000
295	0.000	88843	0.000	0.000
296	67.000	88844	67.000	67.000
297	29.000	88845	29.000	29.000
298	229.000	88846	229.000	229.000
299	172.000	88847	172.000	172.000
300	3.000	88848	3.000	3.000
301	238.000	88849	238.000	238.000
302	251.000	88850	251.000	251.000
303	148.000	88851	148.000	148.000
304	28.000	88852	28.000	28.000
305	49.000	88853	49.000	49.000
306	91.000	88854	91.000	91.000
307	22.000	88855	22.000	22.000
308	4.000	88856	4.000	4.000
309	235.000	88857	235.000	235.000
310	180.000	88858	180.000	180.000
311	90.000	88859	90.000	90.000
312	245.000	88860	245.000	245.000
313	133.000	88861	133.000	133.000
314	107.000	88862	107.000	107.000
315	129.000	88863	129.000	129.000

The BERs of the full system before RS decoding and OFDM system without channel coding (in DsnDTV_ISDBOFDM_DQPSK_BER) are shown below. From the figure below, we can know the channel coding gain is about 8.0dB at 0.0001 BER.

BER for AWGN Full System and OFDM System without Channel Coding



Multipath Channel

Measurements of BER vs. CN were made using a fading channel simulator. The DU ratios of a main signal and a delayed signal were set to 3 dB. Delay time of a delayed signal from a main signal was set to 1.5 μsec. This multipath channel has no fading frequency. In the ADS simulation system, this multipath channel is simulated by UserDefChannel model; parameters were set as follows.

Symbol	**Specification**	**Simulation Type**	**Value**
UserDefChannel	PathNumber	ADS Ptolemy	2
UserDefChannel	AmpArray	ADS Ptolemy	"0.8165 0.5773"
UserDefChannel	DelayArray	ADS Ptolemy	"0.0 1.5"
AntMobile	Vx	ADS Ptolemy	0

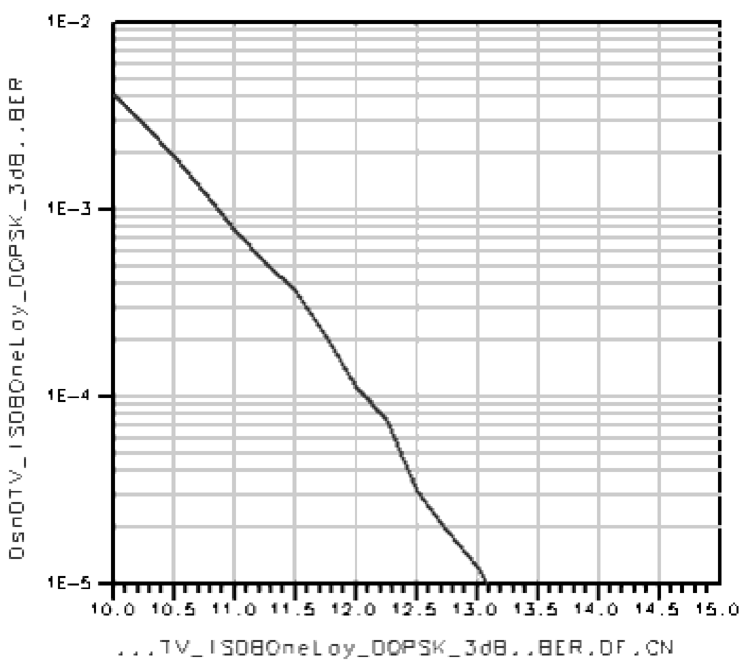
The figure below shows the transmitted Byte data and the received Byte data when carrier-to-noise ratio (CN) is 10dB and 13dB in the multipath channel simulation.

Compare RxByte with TxByte with different CN

Index	...[::]	Index	...[::]	...[::]
185	90.000	88733	90.000	90.000
186	108.000	88734	108.000	108.000
187	15.000	88735	15.000	15.000
188	71.000	88736	71.000	71.000
189	109.000	88737	109.000	109.000
190	65.000	88738	65.000	65.000
191	91.000	88739	91.000	91.000
192	186.000	88740	186.000	186.000
193	156.000	88741	156.000	156.000
194	112.000	88742	112.000	112.000
195	10.000	88743	10.000	10.000
196	35.000	88744	35.000	35.000
197	47.000	88745	47.000	47.000
198	113.000	88746	113.000	113.000
199	161.000	88747	161.000	161.000
200	157.000	88748	157.000	157.000
201	198.000	88749	198.000	198.000
202	65.000	88750	65.000	65.000
203	221.000	88751	221.000	221.000
204	10.000	88752	10.000	10.000
205	246.000	88753	246.000	246.000
206	119.000	88754	119.000	119.000
207	193.000	88755	193.000	193.000
208	221.000	88756	221.000	221.000
209	163.000	88757	163.000	163.000
210	210.000	88758	210.000	210.000
211	190.000	88759	190.000	190.000
212	170.000	88760	170.000	170.000
213	237.000	88761	237.000	237.000
214	157.000	88762	157.000	157.000
215	166.000	88763	166.000	166.000
216	118.000	88764	118.000	118.000
217	205.000	88765	205.000	205.000
218	41.000	88766	41.000	41.000
219	86.000	88767	86.000	86.000
220	84.000	88768	84.000	84.000
221	100.000	88769	100.000	100.000
222	73.000	88770	73.000	73.000

The BER of the full system before RS decoding is shown below. The CN is 11.8dB when BER is 0.0002.

Multipath Channel BER



Rayleigh Channel

Measurements of BER vs. CN were made using a fading channel simulator. 2-path Rayleigh fading was used and the DU ratio was set to 0 dB. Delay time of a delayed signal from a main signal was set to 1.5 msec. This multipath channel has a 70-Hz fading frequency. In the ADS simulation system, this multipath channel is simulated by UserDefChannel model; parameters were set as follows:

Symbol	Specification	Simulation Type	Value
UserDefChannel	PathNumber	ADS Ptolemy	2
UserDefChannel	AmpArray	ADS Ptolemy	"0.707 0.707"
UserDefChannel	DelayArray	ADS Ptolemy	"0.0 1.5"
AntMobile	Vx	ADS Ptolemy	124.0

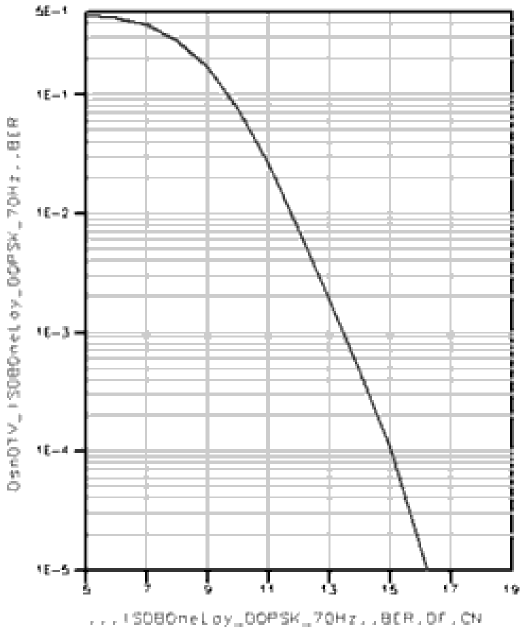
The figure below shows the transmitted and received Byte data when carrier-to-noise ratio (CN) is 5dB and 15dB in the Rayleigh channel simulation. In the figure below, the second column is the received Byte of the CN=5dB, the third column is the received Byte of 15dB . Compared to TxByte, the second column has more errors than the third.

Compare RxByte with TxByte with different CN

Index	...][::]	Index	...][::]	...][::]
0	71.000	88548	165.000	71.000
1	183.000	88549	252.000	183.000
2	87.000	88550	172.000	87.000
3	191.000	88551	204.000	191.000
4	201.000	88552	102.000	201.000
5	229.000	88553	184.000	229.000
6	107.000	88554	236.000	107.000
7	39.000	88555	150.000	39.000
8	119.000	88556	16.000	119.000
9	17.000	88557	17.000	17.000
10	203.000	88558	126.000	203.000
11	81.000	88559	179.000	81.000
12	152.000	88560	59.000	152.000
13	63.000	88561	180.000	63.000
14	2.000	88562	69.000	2.000
15	98.000	88563	121.000	98.000
16	235.000	88564	235.000	235.000
17	208.000	88565	91.000	208.000
18	44.000	88566	44.000	44.000
19	165.000	88567	156.000	165.000
20	138.000	88568	63.000	138.000
21	221.000	88569	168.000	221.000
22	239.000	88570	19.000	239.000
23	84.000	88571	238.000	84.000
24	64.000	88572	114.000	64.000
25	120.000	88573	160.000	120.000
26	232.000	88574	174.000	232.000
27	184.000	88575	55.000	184.000
28	166.000	88576	166.000	166.000
29	137.000	88577	185.000	137.000
30	97.000	88578	147.000	97.000
31	109.000	88579	107.000	109.000
32	226.000	88580	16.000	226.000
33	119.000	88581	128.000	119.000
34	64.000	88582	176.000	64.000
35	114.000	88583	170.000	114.000
36	171.000	88584	106.000	171.000

The BER of the full system before RS decoding is shown below. The CN is 14.5dB when BER is 0.0002.

Rayleigh Channel BER



Benchmark

- Hardware Platform: Pentium II 200 MHz, 128 MB memory
- Software Platform: WindowsNT 4.0 Workstation, ADS 1.3
- Data Points: 2 × 188-1 Bytes
- Simulation Time: 16 hours for AWGN channel, 22 hours for multipath channel, 40 hours for Rayleigh channel

References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.

3-Layer ISDB-T System Design

DTV_ISDBSystem_wrk Design Name

DsnDTV_ISDBThrLay_System

Features

- 3-layer system design
- Different modulation mode and code rate for each layer

- Reed-Solomon coding and decoding
- Punctured convolutional coding and decoding
- Mode 1 OFDM adaptation
- Byte-wise interleaving and deinterleaving
- Time interleaving and deinterleaving
- Frequency interleaving and deinterleaving

Description

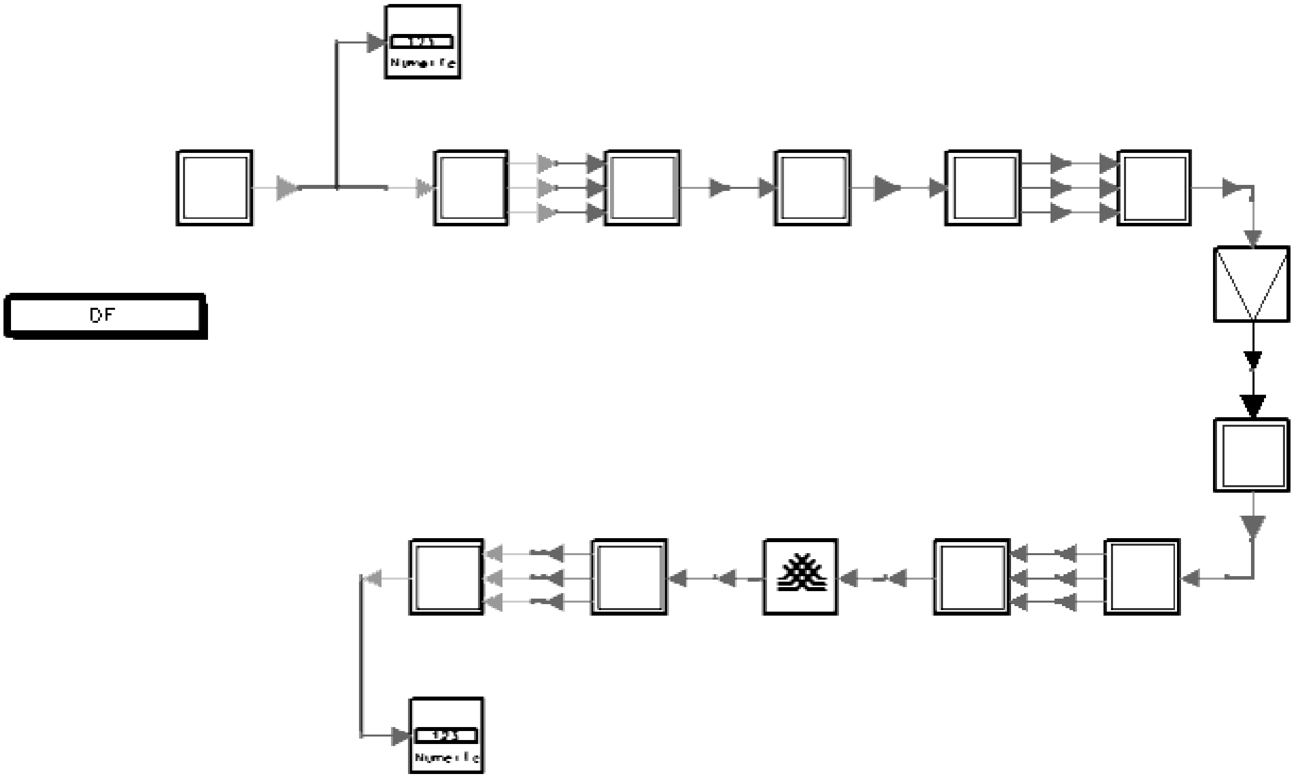
This design is a 3-layer system design example of ISDB-T. It includes 13 segments (1 segment for Layer A, 5 segments for Layer B, and 7 segments for Layer C). The modulation modes and code rates are 64-QAM, 2/3, and DQPSK, 1/2, and 16-QAM, 3/4 in Layer A, Layer B, and Layer C, respectively.

In the OFDM adaptation, the 3-layer full system design works in mode 1. The IFFT/ FFT size is 2048; the guard interval is 1/16 of IFFT size. The simulation channel is the TDMA channel. The byte in transmitter and receiver, the received 64-QAM, DQPSK, and 16-QAM constellations are shown in the simulation results.

Schematics

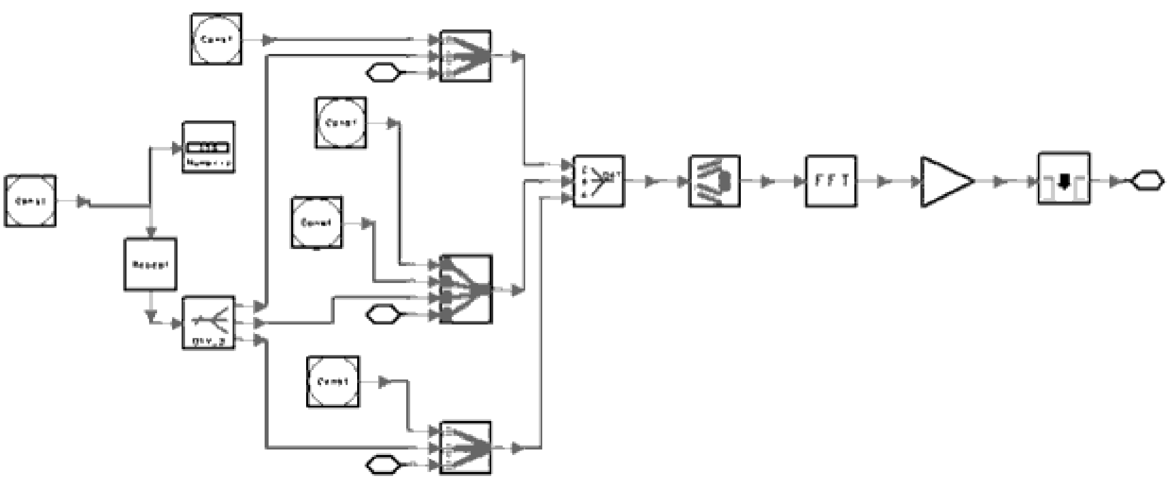
The figure below shows the schematic for this design.

DsnDTV_ISDBThrLay_System

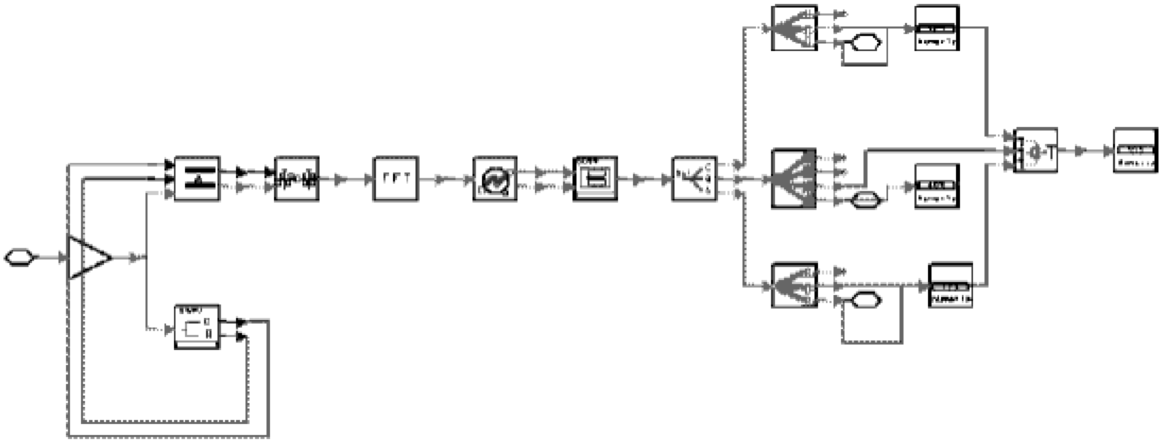


The subnetwork designs are shown in the figures below.

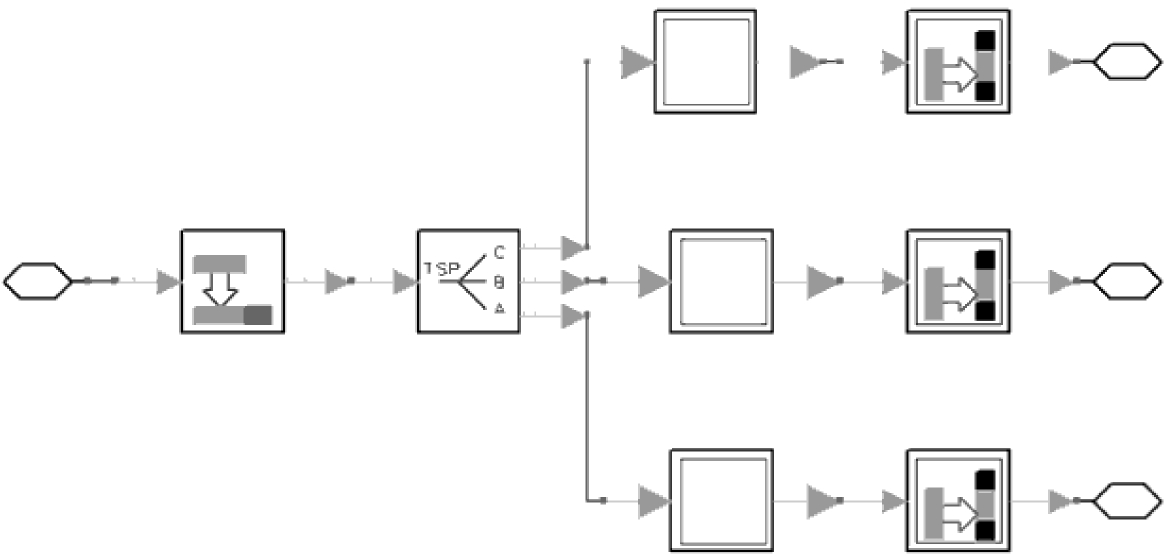
sub_ISDBOFDM_ThrLayMod



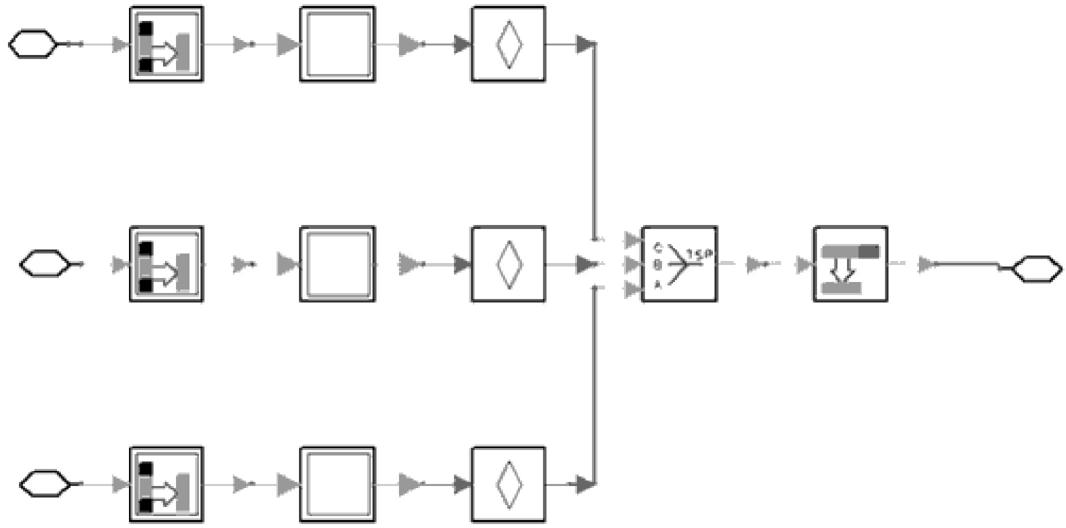
sub_ISDBOFDM_ThrLayDemod



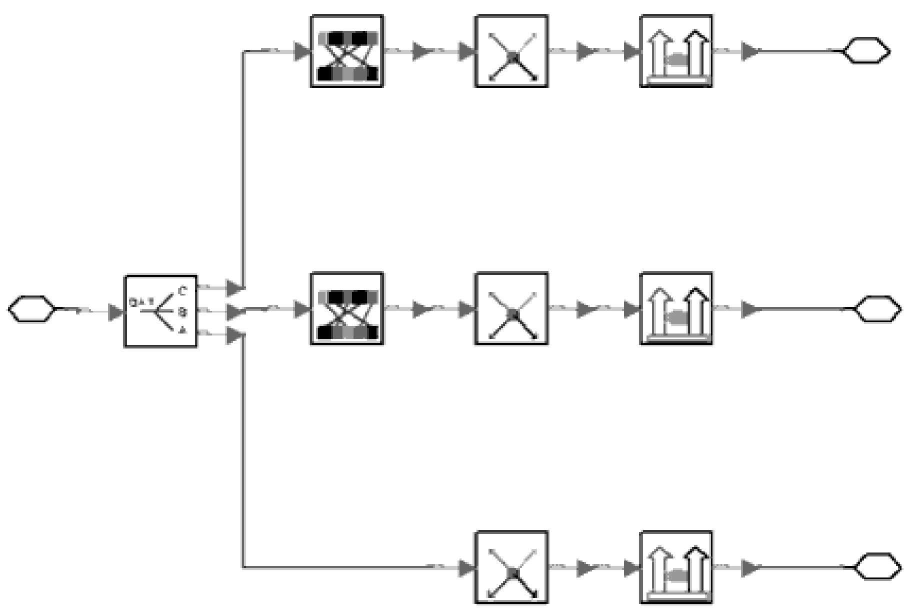
sub_ISDBThrLay_ChCoder



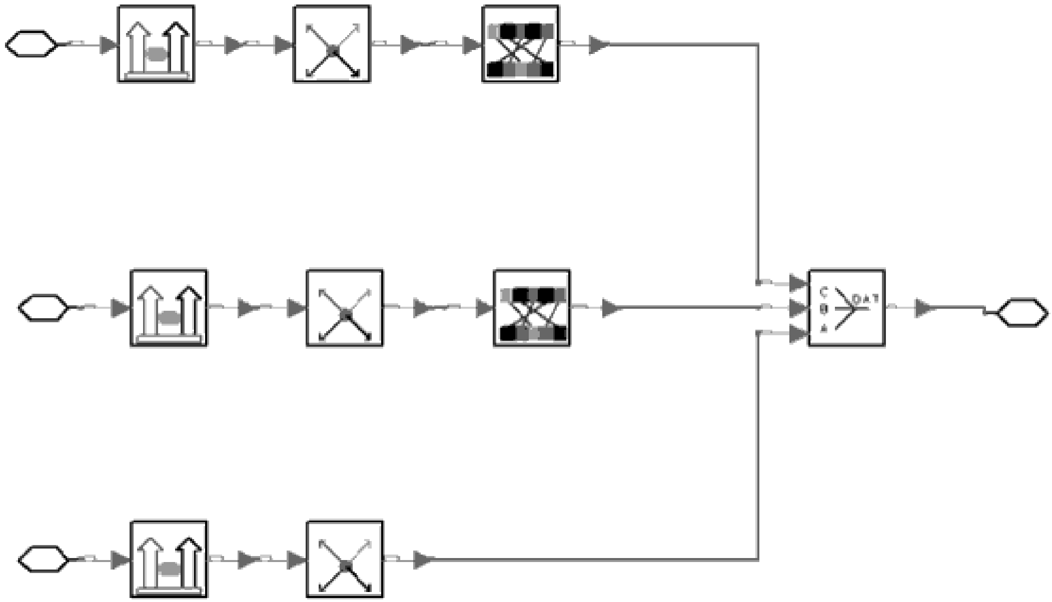
sub_ISDBThrLay_ChDecoder



sub_ISDBThrLay_FreqInterlv



sub_ISDBThrLay_FreqDeinterlv



Specifications

Specification (Parameter)	Simulation Type	Value
Carriers	ADS Ptolemy	96
Segments	ADS Ptolemy	13
IFFTSize	ADS Ptolemy	2048
FFTSize	ADS Ptolemy	2048
Guard	ADS Ptolemy	128
IFFTOrder	ADS Ptolemy	11
FFTOrder	ADS Ptolemy	11
MaxDelay	ADS Ptolemy	2047
SegmentsA	ADS Ptolemy	1
SegmentsB	ADS Ptolemy	5
SegmentsC	ADS Ptolemy	7
Ru	ADS Ptolemy	0.9

Notes

1. The propagation channel model used in this example is a standard TDMA channel.
2. The DelayByte parameter of the punctured convolutional decoder model (DTV_PunConvDecoder) is used to adjust delays caused by OFDM demodulation (which is one OFDM symbol) and two additional OFDM symbol delays, which correspond to the bit interleaving procedure because delay adjustment for bit interleaving is 2 OFDM symbols.
3. Total delay caused by byte-wise interleaving and deinterleaving is 17 × 11 × 12 bytes (corresponding to 11 TSPs). Because the OFDM symbol is transmitted as an OFDM frame, delay of the TSPs is adjusted to one OFDM frame.
4. Total delay caused by time interleaving and deinterleaving is adjusted in accordance with an integer I as shown in table 4-3 in ISDB-T. Because I=4 in this 3-layer design,

the number of OFDM frames to be delayed by the delay adjustment and time interleaving is 2.

5. The last delay adjusted in this design generates the number of total null TSP bytes which is needed per operation in DTV_SynThreeLayTSP model.

Simulation Results

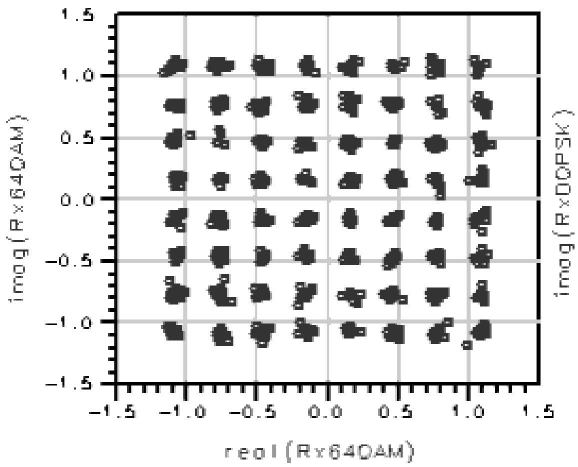
The figure below shows the transmitted and received TSP data.

Compare RxTSP with TxTSP

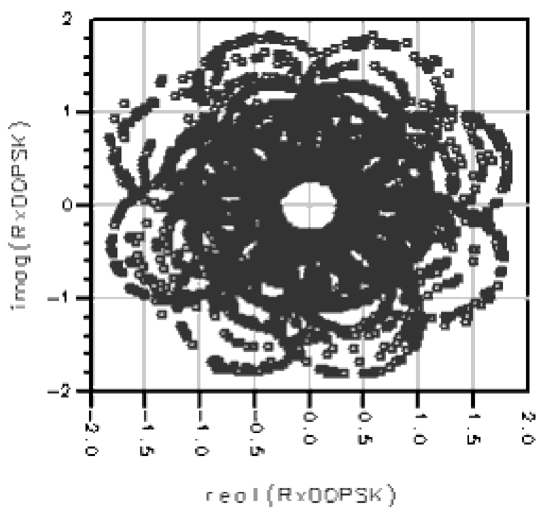
Index	TxByte ...4.000	Index	RxByte ...4.000
0	71.000	208680	71.000
1	218.000	208681	218.000
2	50.000	208682	50.000
3	141.000	208683	141.000
4	17.000	208684	17.000
5	156.000	208685	156.000
6	29.000	208686	29.000
7	142.000	208687	142.000
8	56.000	208688	56.000
9	58.000	208689	58.000
10	136.000	208690	136.000
11	213.000	208691	213.000
12	147.000	208692	147.000
13	189.000	208693	189.000
14	106.000	208694	106.000
15	159.000	208695	159.000
16	219.000	208696	219.000
17	207.000	208697	207.000
18	131.000	208698	131.000
19	187.000	208699	187.000
20	143.000	208700	143.000
21	212.000	208701	212.000
22	4.000	208702	4.000
23	7.000	208703	7.000
24	27.000	208704	27.000
25	158.000	208705	158.000
26	45.000	208706	45.000
27	10.000	208707	10.000
28	67.000	208708	67.000
29	211.000	208709	211.000
30	15.000	208710	15.000
31	150.000	208711	150.000
32	164.000	208712	164.000
33	241.000	208713	241.000
34	151.000	208714	151.000
35	7.000	208715	7.000

The three figures below show the received constellations for Layers A, B, and C.

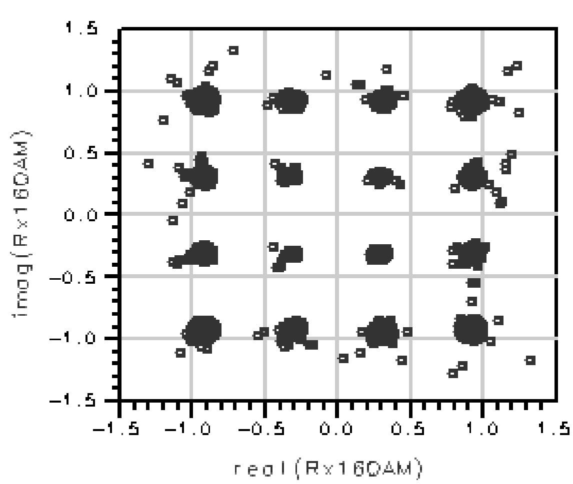
Received Constellation for Layer A



Received Constellation for Layer B



Received Constellation for Layer C



Benchmark

- Hardware Platform: Pentium II 200 MHz, 128 MB memory
- Software Platform: WindowsNT 4.0 Workstation, ADS 1.3
- Data Points: 188 × ((12 × 5 + 36 × 7 + 48 × 1) × 3 + 40) Bytes
- Simulation Time: 1 hour and 8 minutes

References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.

2-Layer ISDB-T System Design

DTV_ISDBSystem_wrk Design Name

DsnDTV_ISDBTwoLay_System

Features

- 2- layer system design
- Different modulation mode and code rate for each layer
- Reed-Solomon coding and decoding
- Punctured convolutional coding and decoding
- Mode 1 OFDM adaptation
- Byte-wise interleaving and deinterleaving
- Time interleaving and deinterleaving
- Frequency interleaving and deinterleaving

Description

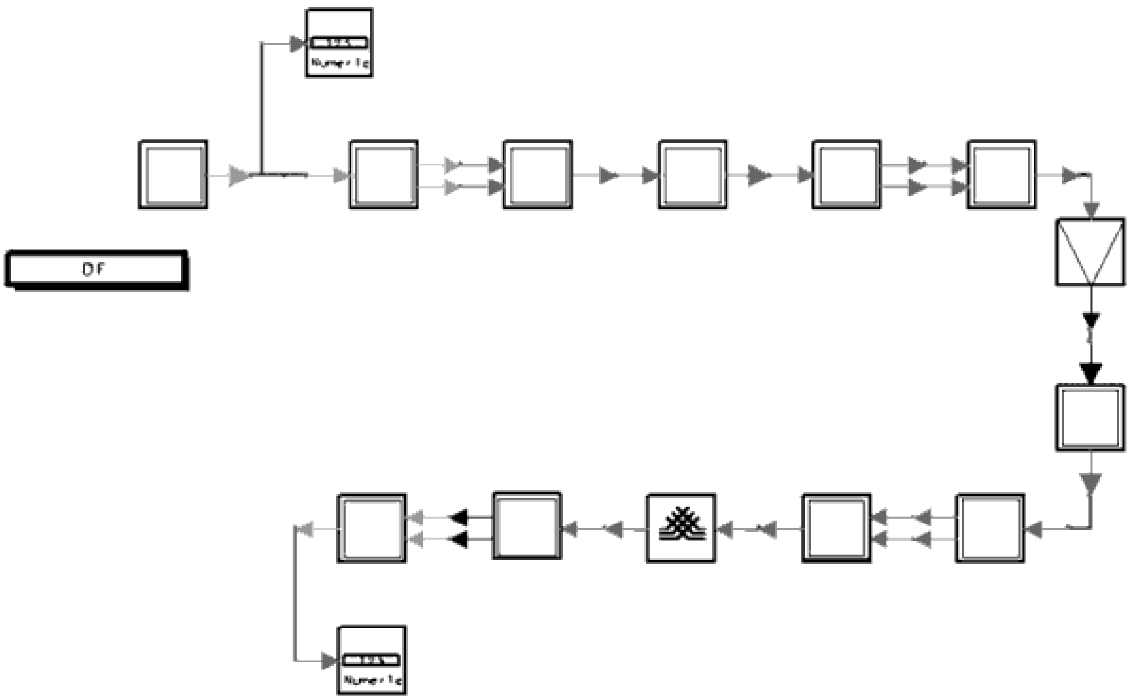
This design is a 2-layer system example of ISDB-T. It includes 13 segments (5 segments for Layer A, 8 segments for Layer B). Modulation modes and code rates are DQPSK, 1/2, and 64-QAM, 7/8 in Layer A and Layer B, respectively.

In the OFDM adaptation, the 2-layer full system design works in mode 1. The IFFT/ FFT size is 2048; the guard interval is 1/8 of IFFT size. The simulation channel is the TDMA channel. The byte in transmitter and receiver, the received DQPSK and 64-QAM constellations are shown in the simulation results.

Schematics

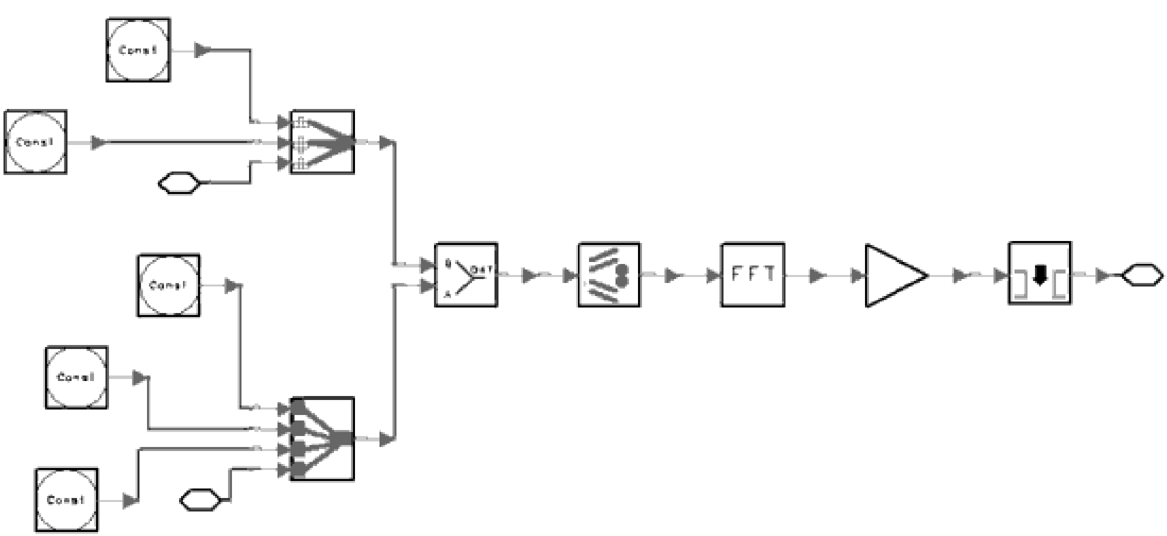
The figure below shows the schematic for this design.

DsnDTV_ISDBTwoLay_System

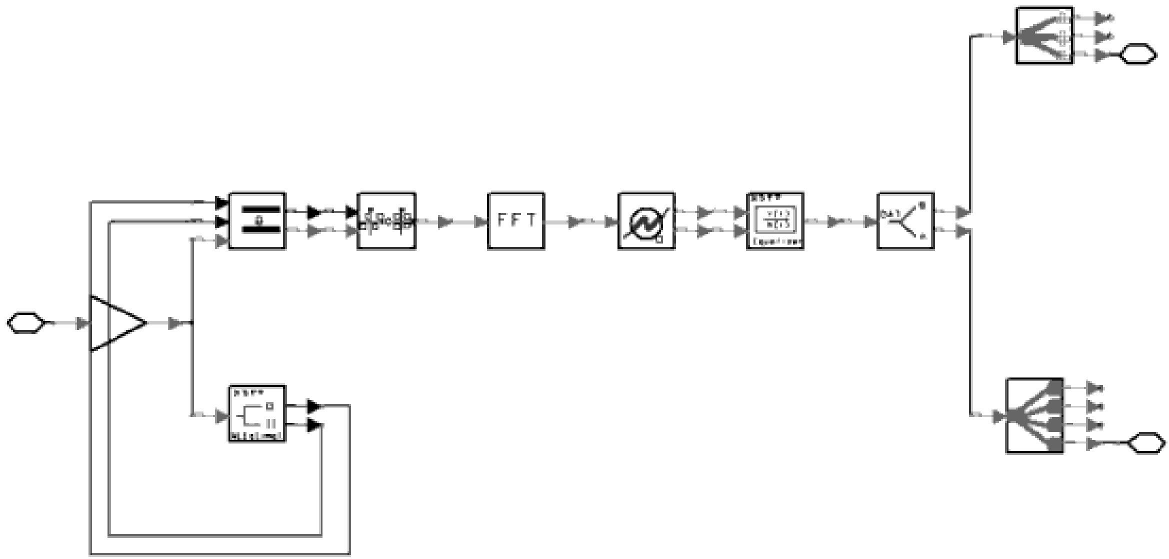


The coding and decoding subnetwork designs are shown in the figures below.

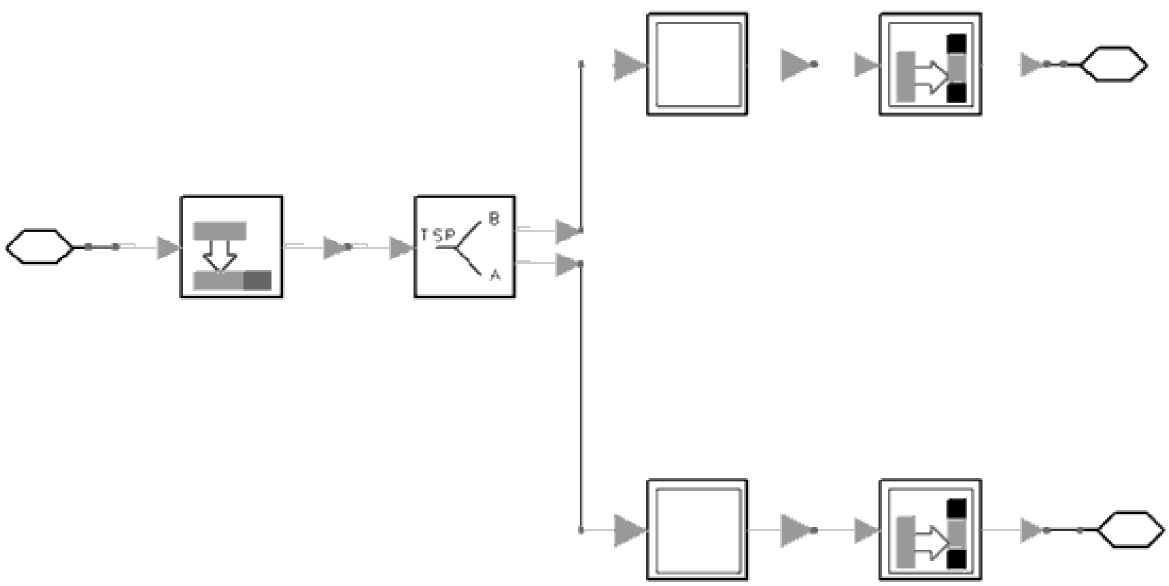
sub_ISDBOFDM_TwoLayMod



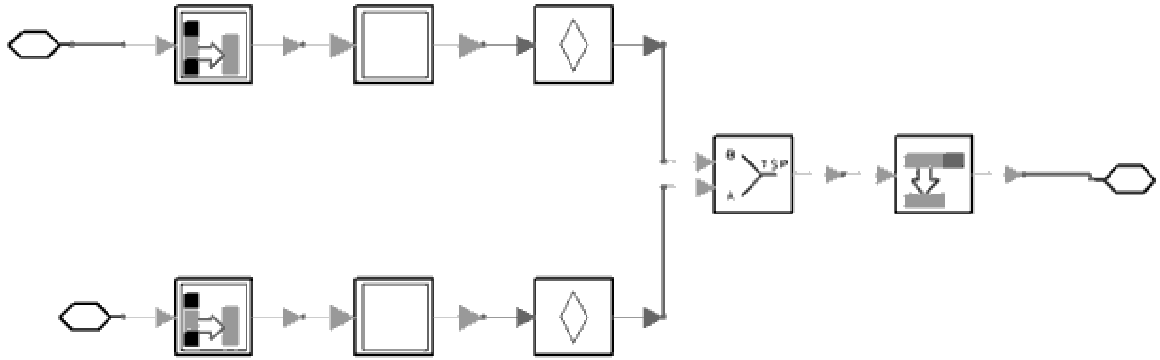
sub_ISDBOFDM_TwoLayDemod



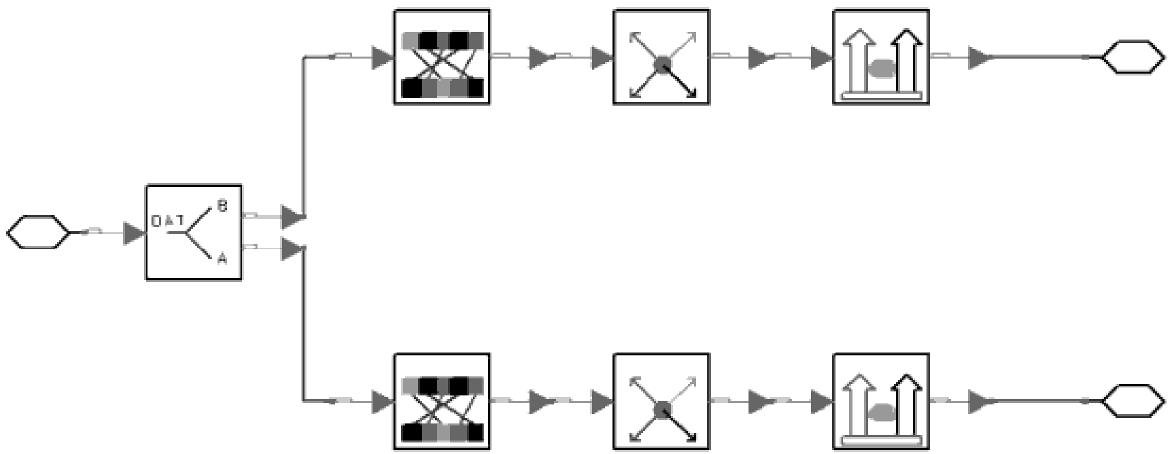
sub_ISDBTwoLay_ChCoder



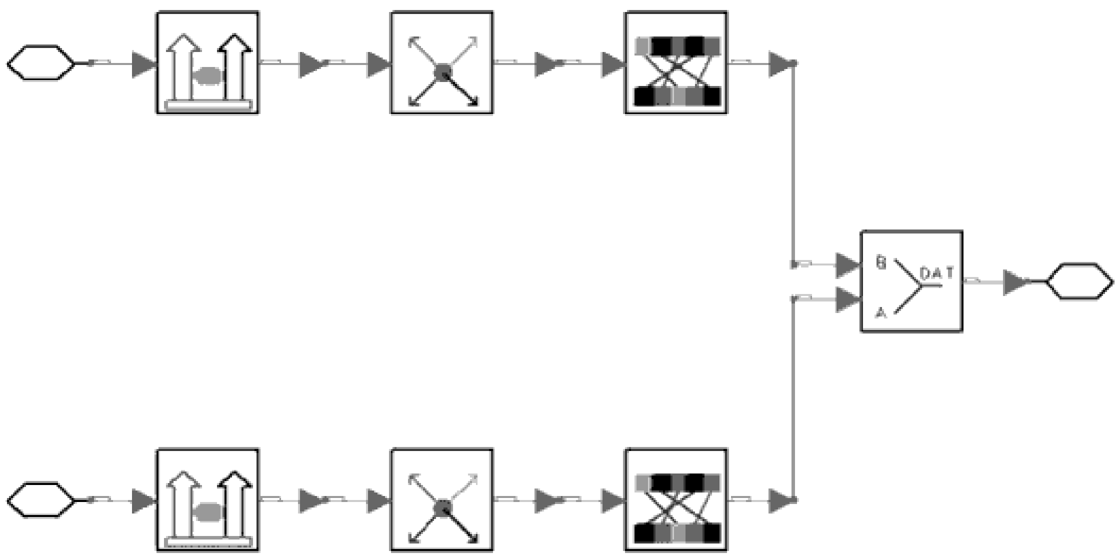
sub_ISDBTwoLay_ChDecoder



sub_ISDBTwoLay_FreqInterlv



sub_ISDBTwoLay_FreqDeinterlv



Specifications

Specification (Parameter)	Simulation Type	Value
Carriers	ADS Ptolemy	96
Segments	ADS Ptolemy	13
IFFTSize	ADS Ptolemy	2048
FFTSize	ADS Ptolemy	2048
Guard	ADS Ptolemy	256
IFFTOrder	ADS Ptolemy	11
FFTOrder	ADS Ptolemy	11
MaxDelay	ADS Ptolemy	2047
SegmentsA	ADS Ptolemy	5
SegmentsB	ADS Ptolemy	8
Ru	ADS Ptolemy	0.9

Notes

1. The propagation channel model used in this example is a standard TDMA channel.
2. The DelayByte parameter of the punctured convolutional decoder model (*DTV_PuncConvDecoder* (dtv)) is used to adjust delays caused by OFDM demodulation (which is one OFDM symbol) and two additional OFDM symbols delay which is corresponding to the bit interleaving procedure because delay adjustment for bit interleaving is 2 OFDM symbols.
3. Total delay caused by byte-wise interleaving and deinterleaving is 17 × 11 × 12 bytes (corresponding to 11 TSPs). Because the OFDM symbol is transmitted as an OFDM frame, in this design the delay of the TSPs is adjusted to one OFDM frame.
4. Total delay caused by time interleaving and deinterleaving is adjusted in accordance with an integer I as shown in table 4-3 in ISDB-T. Because I=4 in this 2-layer design, the number of OFDM frames to be delayed by delay adjustment and time interleaving is 2.
5. The last delay adjusted in this design generates the number of total null TSP bytes which is needed per operation in DTV_SynTwoLayTSP model.

Simulation Results

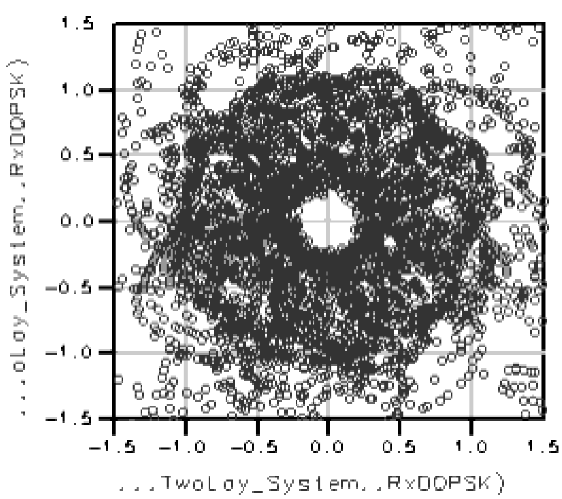
Compare RxTSP with TxTSP shows the transmitted and received TSP data.

Received Constellation for Layer A and Received Constellation for Layer B show the received constellation of Layer A and B.

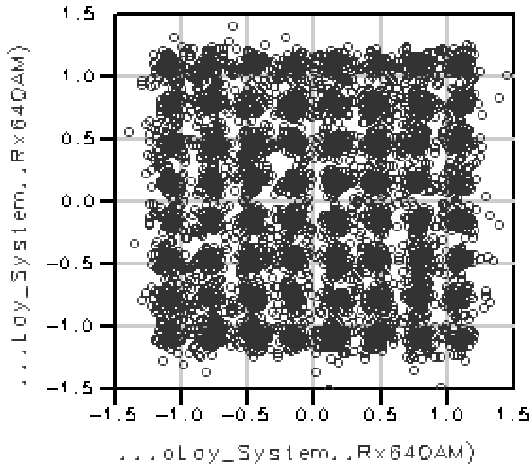
Compare RxTSP with TxTSP

Index	RxByte	Index	TxByte
208680	71.000	0	71.000
208681	218.000	1	218.000
208682	50.000	2	50.000
208683	141.000	3	141.000
208684	17.000	4	17.000
208685	156.000	5	156.000
208686	29.000	6	29.000
208687	142.000	7	142.000
208688	56.000	8	56.000
208689	58.000	9	58.000
208690	136.000	10	136.000
208691	213.000	11	213.000
208692	147.000	12	147.000
208693	189.000	13	189.000
208694	106.000	14	106.000
208695	159.000	15	159.000
208696	219.000	16	219.000
208697	207.000	17	207.000
208698	131.000	18	131.000
208699	187.000	19	187.000
208700	143.000	20	143.000
208701	212.000	21	212.000
208702	4.000	22	4.000
208703	7.000	23	7.000
208704	27.000	24	27.000
208705	158.000	25	158.000
208706	45.000	26	45.000
208707	10.000	27	10.000
208708	67.000	28	67.000
208709	211.000	29	211.000
208710	15.000	30	15.000
208711	150.000	31	150.000
208712	164.000	32	164.000
208713	241.000	33	241.000
208714	151.000	34	151.000
208715	7.000	35	7.000
208716	178.000	36	178.000
208717	56.000	37	56.000
208718	34.000	38	34.000
208719	175.000	39	175.000
208720	240.000	40	240.000

Received Constellation for Layer A



Received Constellation for Layer B



Benchmark

- Hardware Platform: Pentium II 200 MHz, 128 MB memory
- Software Platform: WindowsNT 4.0 Workstation, ADS 1.3
- Data Points: 188 × ((12 × 5 + 63 × 8) × 3 + 47 + 47) Bytes
- Simulation Time: 1 hour and 26 minutes

References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.

TMCC in ISDB-T 1-Layer System Design

DTV_ISDBSystem_wrk Design Name

DsnDTV_TMCCMod

Features

Displays include:

- TMCCInfoT (102 TMCC information bits in the transmitter)
- TMCCT (204 TMCC bits in the transmitter after channel coding)
- TMCCInfoR (102 TMCC information bits in the receiver after channel decoding)
- TMCCR (204 TMCC bits in the receiver after TMCC modulation, AWGN channel, and demodulation)

Description

This design example illustrates how to use TMCC models in ISDB-T 1-layer systems. It includes TMCC information multiplexing and de-multiplexing, channel coding and decoding, and modulation and demodulation of TMCC carriers.

If the 1-layer ISDB-T system works in mode 3 and uses 13 segments, its modulation scheme of OFDM carrier is DQPSK, coding rate of inner code is 1/2, length of time interleaving is 2, then the first 122 TMCC bits should be:

```
0
0 0 1 1 0 1 0 1 1 1 1 0 1 1 1 0
1 1 1
0 0
1 1 1 1
0
0
0 0 0
0 0 0
0 1 0
1 1 0 1
1 1 1
1 1 1
1 1 1
1 1 1 1
1 1 1
1 1 1
1 1 1
1 1 1 1
1
1 1 1
1 1 1
1 1 1
1 1 1 1
1 1 1
1 1 1
1 1 1
1 1 1 1
1 1 1
1 1 1
1 1 1
1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
```

or

```
0
1 1 0 0 1 0 1 0 0 0 0 1 0 0 0 1
1 1 1
0 0
1 1 1 1
0
0
0 0 0
0 0 0
0 1 0
```

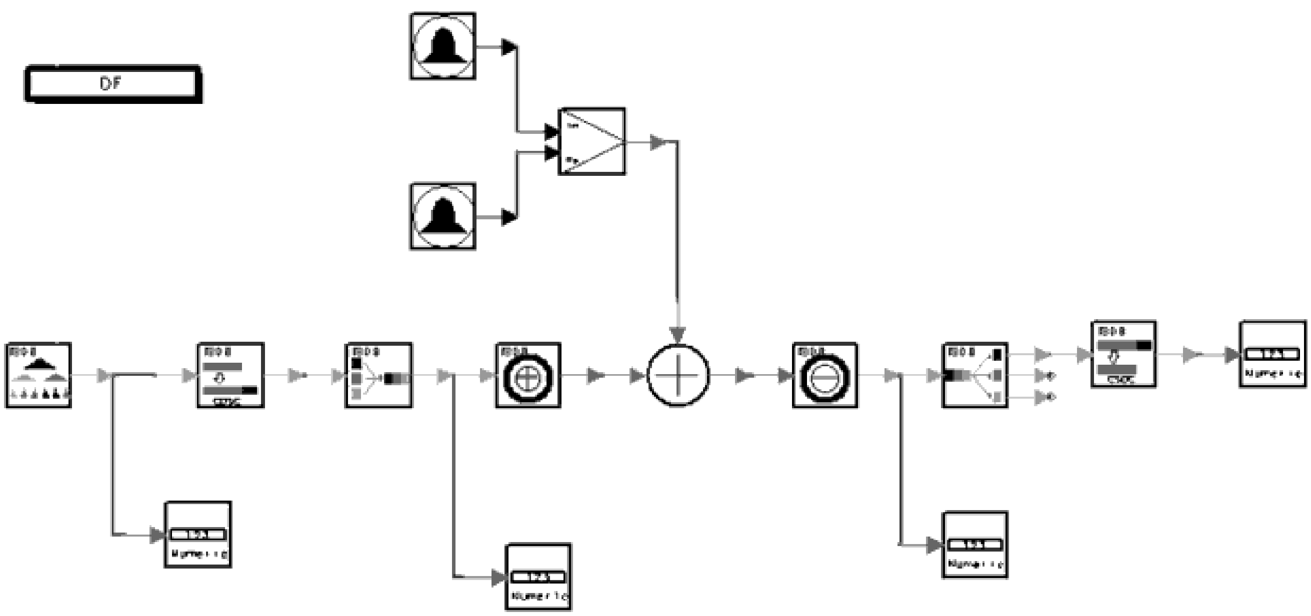
```
1 1 0 1
1 1 1
1 1 1
1 1 1
1 1 1 1
1 1 1
1 1 1
1 1 1
1 1 1 1
1
1 1 1
1 1 1
1 1 1
1 1 1 1
1 1 1
1 1 1
1 1 1
1 1 1 1
1 1 1
1 1 1
1 1 1
1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
```

We can compare the results of this design with the previous 122 TMCC bits in the dds file.

Schematics

The figure below shows the schematic for this design.

DsnDTV_TMCCMod



Simulation Results

The figure below shows the 102 TMCC information bits in the transmitter before channel coding and in the receiver after channel docoding. The first column is the information bits in the transmitter; the second column is the information bits in the receiver; the third column is the error between the information bits.

102 TMCC information Bits in the Transmitter and Receiver

Index	...nfoT	...nfoR	errI
0	0.000	0.000	0.000
1	0.000	0.000	0.000
2	1.000	1.000	0.000
3	1.000	1.000	0.000
4	1.000	1.000	0.000
5	1.000	1.000	0.000
6	0.000	0.000	0.000
7	0.000	0.000	0.000
8	0.000	0.000	0.000
9	0.000	0.000	0.000
10	0.000	0.000	0.000
11	0.000	0.000	0.000
12	0.000	0.000	0.000
13	0.000	0.000	0.000
14	0.000	0.000	0.000
15	1.000	1.000	0.000
16	0.000	0.000	0.000
17	1.000	1.000	0.000
18	1.000	1.000	0.000
19	0.000	0.000	0.000
20	1.000	1.000	0.000
21	1.000	1.000	0.000
22	1.000	1.000	0.000
23	1.000	1.000	0.000
24	1.000	1.000	0.000
25	1.000	1.000	0.000
26	1.000	1.000	0.000
27	1.000	1.000	0.000
28	1.000	1.000	0.000
29	1.000	1.000	0.000
30	1.000	1.000	0.000
31	1.000	1.000	0.000
32	1.000	1.000	0.000

The figure below shows the 204 TMCC bits in the transmitter before modulation and in the receiver after de-modulation. The first column is the transmitter bits; the second column is the receiver bits; the third column is the error between the information bits.

204 TMCC bits in the Transmitter and Receiver

Index	TMCCT	TMCCR	errT
0	0.000	0.000	0.000
1	0.000	0.000	0.000
2	0.000	0.000	0.000
3	1.000	1.000	0.000
4	1.000	1.000	0.000
5	0.000	0.000	0.000
6	1.000	1.000	0.000
7	0.000	0.000	0.000
8	1.000	1.000	0.000
9	1.000	1.000	0.000
10	1.000	1.000	0.000
11	1.000	1.000	0.000
12	0.000	0.000	0.000
13	1.000	1.000	0.000
14	1.000	1.000	0.000
15	1.000	1.000	0.000
16	0.000	0.000	0.000
17	1.000	1.000	0.000
18	1.000	1.000	0.000
19	1.000	1.000	0.000
20	0.000	0.000	0.000
21	0.000	0.000	0.000
22	1.000	1.000	0.000
23	1.000	1.000	0.000
24	1.000	1.000	0.000
25	1.000	1.000	0.000
26	0.000	0.000	0.000
27	0.000	0.000	0.000
28	0.000	0.000	0.000
29	0.000	0.000	0.000
30	0.000	0.000	0.000
31	0.000	0.000	0.000
32	0.000	0.000	0.000

Benchmark

- Hardware Platform: Pentium III 450 MHz, 512 MB memory
- Software Platform: Windows NT 4.0 Workstation, ADS 1.3
- Data Points: 408
- Simulation Time: 5 seconds

References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.

TMCC in ISDB-T 3-Layer System Design

DTV_ISDBSystem_wrk Design Name

DsnDTV_TMCCThrLay

Features

Displays include:

- TMCCInfoT (102 TMCC information bits in the transmitter)
- TMCCT 204 TMCC bits in the transmitter after channel coding)
- TMCCInfoR (102 TMCC information bits in the receiver after channel decoding)
- TMCCR (204 TMCC bits in the receiver after TMCC modulation, AWGN channel, and demodulation)

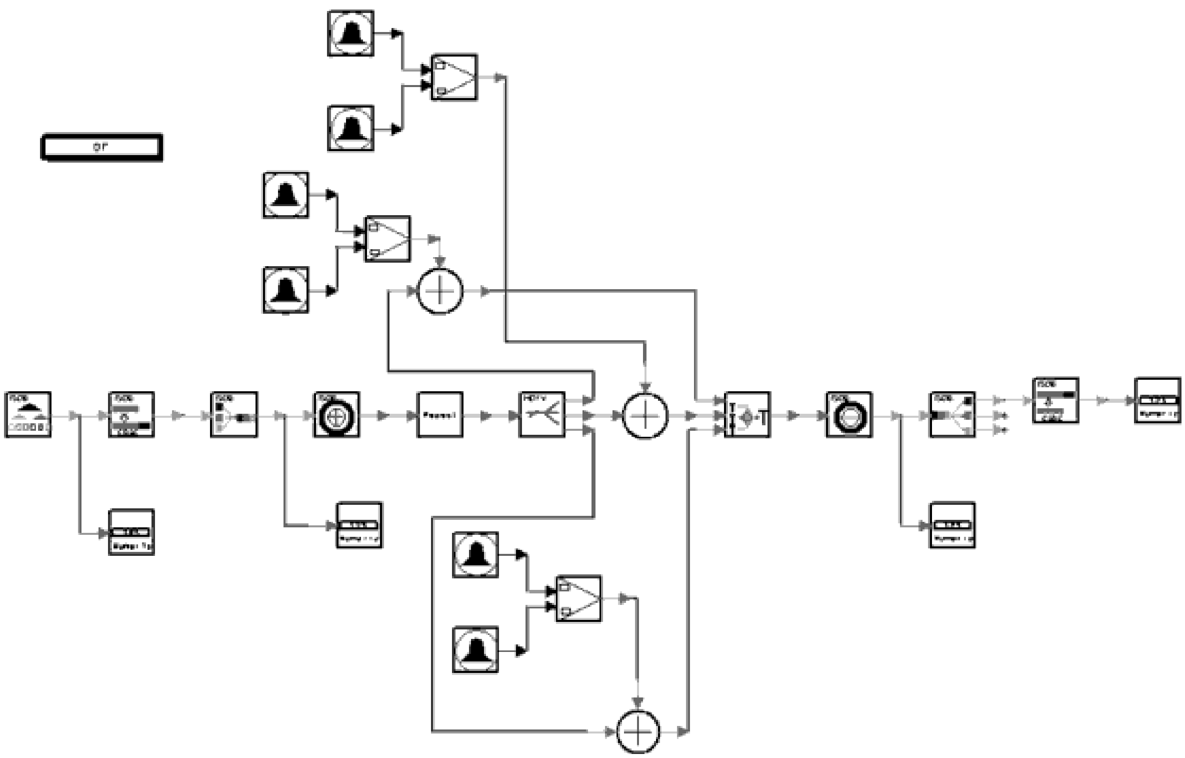
Description

This design example illustrates how to use TMCC models in ISDB-T 3-layer systems. It includes TMCC information multiplexing and de-multiplexing, channel coding and decoding, and modulation and demodulation of TMCC carriers.

Schematics

The figure below shows the schematic for this design.

DsnDTV_TMCCThrLay



Simulation Results

102 Bits TMCC Information in Transmitter and Receiver lists the 102 bits TMCC information bits in the transmitter before channel coding and in the receiver after channel docoding. The first column is the 102 TMCC information bits in the transmitter; the second column is the 102 information bits in the receiver; the third column is the error between both 102 TMCC information bits.

204 TMCC Bits in Transmitter and Receiver shows the 204 bits TMCC bits in the transmitter before modulator and in the receiver after de-modulator. The first column is the 204 TMCC bits in the transmitter, the second column is the 204 TMCC bits in the receiver, and the third column is the error between both 204 TMCC information bits.

102 Bits TMCC Information in Transmitter and Receiver

Index	TMCCInfoT	TMCCInfoR	errI
0	0.000	0.000	0.000
1	0.000	0.000	0.000
2	1.000	1.000	0.000
3	1.000	1.000	0.000
4	1.000	1.000	0.000
5	1.000	1.000	0.000
6	0.000	0.000	0.000
7	0.000	0.000	0.000
8	0.000	0.000	0.000
9	0.000	0.000	0.000
10	0.000	0.000	0.000
11	0.000	0.000	0.000
12	0.000	0.000	0.000
13	0.000	0.000	0.000
14	0.000	0.000	0.000
15	1.000	1.000	0.000
16	0.000	0.000	0.000
17	0.000	0.000	0.000
18	0.000	0.000	0.000
19	0.000	0.000	0.000
20	1.000	1.000	0.000
21	0.000	0.000	0.000
22	1.000	1.000	0.000
23	0.000	0.000	0.000
24	0.000	0.000	0.000
25	1.000	1.000	0.000
26	0.000	0.000	0.000
27	0.000	0.000	0.000
28	1.000	1.000	0.000
29	0.000	0.000	0.000
30	0.000	0.000	0.000
31	1.000	1.000	0.000
32	0.000	0.000	0.000
33	1.000	1.000	0.000
34	0.000	0.000	0.000
35	1.000	1.000	0.000
36	1.000	1.000	0.000
37	0.000	0.000	0.000
38	0.000	0.000	0.000

204 TMCC Bits in Transmitter and Receiver

Index	TMCCT	TMCCR	errR
0	0.000	0.000	0.000
1	0.000	0.000	0.000
2	0.000	0.000	0.000
3	1.000	1.000	0.000
4	1.000	1.000	0.000
5	0.000	0.000	0.000
6	1.000	1.000	0.000
7	0.000	0.000	0.000
8	1.000	1.000	0.000
9	1.000	1.000	0.000
10	1.000	1.000	0.000
11	1.000	1.000	0.000
12	0.000	0.000	0.000
13	1.000	1.000	0.000
14	1.000	1.000	0.000
15	1.000	1.000	0.000
16	0.000	0.000	0.000
17	1.000	1.000	0.000
18	1.000	1.000	0.000
19	1.000	1.000	0.000
20	0.000	0.000	0.000
21	0.000	0.000	0.000
22	1.000	1.000	0.000
23	1.000	1.000	0.000
24	1.000	1.000	0.000
25	1.000	1.000	0.000
26	0.000	0.000	0.000
27	0.000	0.000	0.000
28	0.000	0.000	0.000
29	0.000	0.000	0.000
30	0.000	0.000	0.000
31	0.000	0.000	0.000
32	0.000	0.000	0.000
33	0.000	0.000	0.000
34	0.000	0.000	0.000
35	1.000	1.000	0.000
36	0.000	0.000	0.000
37	0.000	0.000	0.000
38	0.000	0.000	0.000

Benchmark

- Hardware Platform: Pentium III 450 MHz, 512 MB memory
- Software Platform: Windows NT 4.0 Workstation, ADS 1.3
- Data Points: 408
- Simulation Time: 5 seconds

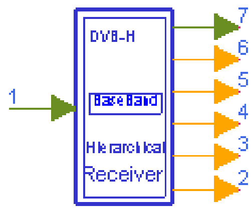
References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.

DVB-H Components

- *DTV DVBHHierReceiver* (dtv)
- *DTV DVBHHierReceiver RF* (dtv)
- *DTV DVBHHierSignalSrc* (dtv)
- *DTV DVBHHierSignalSrc RF* (dtv)
- *DTV DVBHInnerDeinterlv* (dtv)
- *DTV DVBHInnerInterlv* (dtv)
- *DTV DVBHReceiver* (dtv)
- *DTV DVBHReceiver RF* (dtv)
- *DTV DVBHSignalSrc* (dtv)
- *DTV DVBHSignalSrc RF* (dtv)
- *DTV DVBHTPS* (dtv)

DTV_DVBHHierReceiver



Description: DVB-H baseband hierarchical receiver
Library: DTV, DVB-H
Class: SDFDTV_DVBHHierReceiver

Parameters

Name	Description	Default	Unit	Type	Range
Mode	Transmission mode: Mode 2K, Mode 8K, Mode 4K	Mode 4K		enum	
OversamplingOption	Oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	
GuardInterval	Guard interval (frac FFT size)	1/32		int	[0, 1]
CodeRateHP	High priority stream current convolutional code rate: HP 1/2, HP 2/3, HP 3/4, HP 5/6, HP 7/8	HP 1/2		enum	
CodeRateLP	Low priority stream current convolutional code rate: LP 1/2, LP 2/3, LP 3/4, LP 5/6, LP 7/8	LP 1/2		enum	
MappingMode	Signal constellations and mapping: QAM-16, QAM-64	QAM-16		enum	
Alpha	Non-uniform factor for DVB-H	1		int	[1, ∞)
InnerInterlv	Inner interleaving type: Native, In-depth	In-depth		enum	
SoftDecision	Soft decision viterbi decoding type: Soft, Hard, Cochannel	Soft		enum	
TrunLen	Path memory truncation length of viterbi decoding algorithm, in bytes	10		int	[5, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	Rx_Signal	received OFDM signal to be demodulated	complex

Pin Outputs

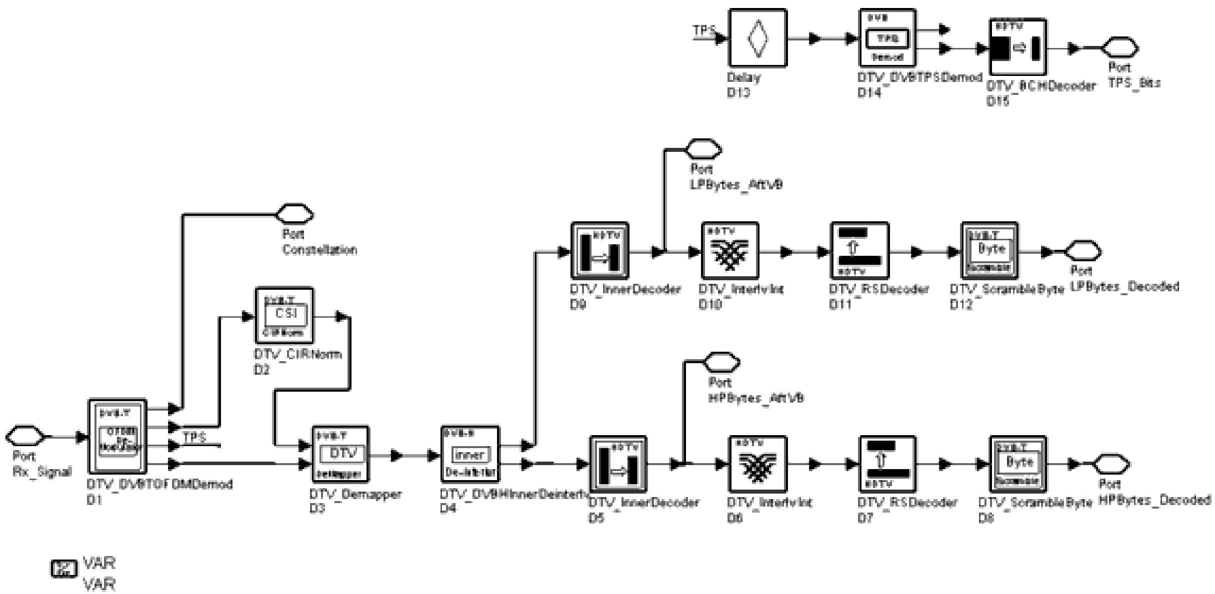
Pin	Name	Description	Signal Type
2	HPBytes_Decoded	decoded bytes after Reed Solomon decoder of high priority layer	int
3	LPBytes_Decoded	decoded bytes after Reed Solomon decoder of low priority layer	int
4	HPBytes_AftVB	decoded bytes after viterbi decoder of high priority layer	int
5	LPBytes_AftVB	decoded bytes after viterbi decoder of low priority layer	int
6	TPS_Bits	decoded TPS information bits	int
7	Constellation	constellation signal after OFDM demodulation	complex

Notes/Equations

Notes/Equations

1. This subnetwork model implements a DVB-H baseband hierarchical receiver. The schematic for this subnetwork is shown below.

DTV_DVBHHierReceiver Schematic



2. Implementation
   - Start of OFDM symbol is detected. In the DTV_DVBTOFDMDemod subnetwork:
     - DTV_MLEstimator calculates the correlation based on guard interval; DTV_LoadFFTBuff selects the index with the maximum correlation value as the start of FFT.
     - Complex channel impulse responses are estimated on continual and scattered pilot subcarriers. Channel impulse responses of data subcarriers are interpolated based on the estimated CIR. This function is implemented by DTV_DVB2DChEstimator.
     - Each subcarrier value is divided by a complex estimated channel response coefficient. This simple one-tap frequency domain channel response compensation is implemented by DTV_OFDMEqualizer.
     - After equalization, DTV_DVBDemuxOFDMSym demultiplexes 1705, 3409, or 6817 subcarriers into 1512 (2K mode), 3024 (4K mode), or 6048 (8K mode) data subcarriers and 1 demodulated TPS.
   - The demodulated data subcarriers (16- or 64-QAM modulated) are demapped by DTV_Demapper.
   - Demodulated soft bits are deinterleaved by DTV_DVBHInnerDeinterlv.
   - De-interleaved bits are inner decoded (DTV_InnerDecoder), outer de-interleaved (DTV_InterlvInt), outer decoded (DTV_RSDecoder), and descrambled (DTV_ScrambleByte).
   - Fully decoded stream bytes are output as HPBytes_Decoded and LPBytes_Decoded. Partially decoded stream bytes after inner decoding are output as HPBytes_AftVB and LPBytes_AftVB.
   - The TPS signal is demodulated by DTV_DVBTPSDemod and the demodulated bits are decoded by DTV_BCHDecoder.
   - Output pins of this receiver correspond to DTV_DVBHSignalSrc pins.

- The number of samples of each OFDM symbol (Rx_Signal input pin) is:
  - (1+GuardInterval)×2048×OversamplingOption (2K mode)
  - (1+GuardInterval)×4096×OversamplingOption (4K mode)
  - (1+GuardInterval)×8192×OversamplingOption (8K mode)
- Output at the Constellation pin is 1705 (2K mode), 3409 (4K mode), or 6817 (8K mode) per OFDM symbol.

3. Parameter Details
   - Mode specifies the 2K, 4K, or 8K transmission mode.
   - OversamplingOption specifies oversampling ratio 1, 2, 4, 8, 16, or 32 of the transmission signal. If OversamplingOption=Ratio 2, the IFFT size is 4096 (2K mode), 8192 (4K mode), or 16384 (8K mode).
   - GuardInterval specifies guard interval (also called cyclic extension) 1/32, 1/16, 1/8, or 1/4 for DVB-H for each symbol, as a fraction of the FFT time period. For proper demodulation, the value of the corresponding receiver must match the guard interval length actually used in the input signal.
   - CodeRateHP specifies the high priority stream convolutional code rate: 1/2, 2/3, 3/4, 5/6, or 7/8.
   - CodeRateLP specifies the low priority stream convolutional code rate: 1/2, 2/3, 3/4, 5/6, or 7/8.
   - MappingMode specifies signal constellation and mapping mode: 16- or 64-QAM.
   - Alpha is used for signal constellation and mapping as defined in DVB-H specifications.
     - If Alpha=1, uniform mapping of 16- or 64-QAM is used.
     - If Alpha=2 or 4, non-uniform mapping of 16- or 64-QAM is used.
   - SoftDecision specifies the Viterbi decoding algorithm mode.
     - If SoftDecision=Soft, the Viterbi decoding algorithm is a soft decision decoder and uses channel status information.
     - If SoftDecision=Hard, the Viterbi decoding algorithm is a hard decision decoder and does not use channel status information.
     - If SoftDecision=Cochannel, the Viterbi decoding algorithm is for co-channel measurement with PAL analog TV and digital DVB-T.
   - TrunLen sets truncation length (in bytes) in the Viterbi decoding algorithm. The path memory is 8×TrunLen bits in the Viterbi decoding algorithm.
4. Output Pin Delay Adjustment
   - There are different delays in different output pins.
   - The Constellation pin has 8 OFDM symbol delays. The 8 × 1705 (2K mode), 8 × 3409 (4K mode) or 8 × 6817 (8K mode) constellation output signals are not used for EVM calculation.
   - DTV_BCHDecoder uses a 68-bit block. So a Delay component with N=60 is inserted before DTV_DVBTPSDemod. Pin TPS_Bits has one DVB-H frame (68 OFDM symbols) delay. The first 53 bits at TPS_Bits are not used.
   - Viterbi decoding introduces different delays for different path memory truncation lengths (TrunLen parameter). For synchronization in BER measurements, the delay between byte-interleaver and byte de-interleaver must be adjusted to a multiple of 12 bytes and the delay between randomizer and de-randomizer must be adjusted to a multiple of 204 bytes; both delays in the model have been adjusted to a multiple of 204 bytes.
   - The information bytes per one OFDM symbol in HPBytes_AftVB is calculated as follows:
     - DataPerOFDMSymbol=1512 (2K mode), 3024 (4K mode), or 6048 (8K mode)
     - CodedBlockSize=204
     - CR = 1/2, 2/3, 3/4, 5/6, or 7/8

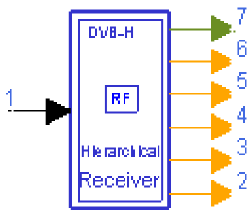
  - DVB_DelayOFDMSymbols=8
  - InfoBytes_HP=2×DataPerOFDMSymbol×CR/8
- The delay of HPBytes_AftVB is Delay_AftVB_HP, calculated as follows:
  - DelayBytes_HP=DVB_DelayOFDMSymbols × InfoBytes_HP-(int(DVB_DelayOFDMSymbols × InfoBytes_HP/CodedBlockSize))×CodedBlockSize
  - N_HP=int((TrunLen+DelayBytes_HP)/CodedBlockSize)
  - Delay_AftVB_HP=(1+int((DVB_DelayOFDMSymbols × InfoBytes_HP) / CodedBlockSize)+N_HP)×CodedBlockSize.
- The information bytes per one OFDM symbol in LPBytes_AftVB is calculated as follows:
  - DataPerOFDMSymbol=1512 (2K mode), 3024 (4K mode), or 6048 (8K mode)
  - CodedBlockSize=204
  - MapRateLP=2 for 16-QAM or 4 for 64-QAM
  - CR = 1/2, 2/3, 3/4, 5/6 or 7/8
  - InfoBytes_LP=MapRateLP×DataPerOFDMSymbol×CR/8
- The delay of LPBytes_AftVB is Delay_AftVB_LP, calculated as follows:
  - DelayBytes_LP=DVB_DelayOFDMSymbols × InfoBytes_LP-(int(DVB_DelayOFDMSymbols × InfoBytes_LP/CodedBlockSize))×CodedBlockSize
  - N_LP=int((TrunLen+DelayBytes_LP)/CodedBlockSize)
  - Delay_AftVB_LP=(1+int((DVB_DelayOFDMSymbols×InfoBytes_LP) / CodedBlockSize)+N_LP)×CodedBlockSize.
- HPBytes_Decoded and LPBytes_Decoded each have 8 OFDM symbol and 11 transport MUX packets delays.
- The delay of HPBytes_Decoded is
  - Delay_AftDescramble_HP=(11+1+int(DVB_DelayOFDMSymbols×InfoBytes_HP / CodedBlockSize)+N_HP)×188.
- The delay of LPBytes_Decoded is
  - Delay_AftDescramble_LP=(11+1+int(DVB_DelayOFDMSymbols×InfoBytes_LP / CodedBlockSize)+N_LP)×188.

5. When connecting the receiver to the signal source in MER and BER measurements, the reference signal from the signal generator should be delayed according to the formula above.

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.5.1, European Telecommunication Standard, November 2004.

DTV_DVBHHierReceiver_RF



Description: DVB-H RF hierarchical receiver
Library: DTV, DVB-H
Class: TSDFDTV_DVBHHierReceiver_RF

Parameters

Name	Description	Default	Unit	Type	Range
RIn	Input resistance	DefaultRIn	Ohm	real	(0, ∞)
RTemp	Physical temperature, in degrees C	DefaultRTemp	Celsius	real	[-273.15, ∞)
GainImbalance	Gain imbalance, Q vs I	0.0	dB	real	(-∞, ∞)
PhaseImbalance	Phase imbalance, Q vs I	0.0	deg	real	(-∞, ∞)
FCarrier	Carrier frequency	474.0MHz	Hz	real	(0, ∞)
Sensitivity	Voltage output sensitivity, Vout/Vin	1		real	(-∞, ∞)
Phase	Reference phase in degrees	0.0	deg	real	(-∞, ∞)
Mode	Transmission mode: Mode 2K, Mode 8K, Mode 4K	Mode 4K		enum	
OversamplingOption	Oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	
GuardInterval	Guard interval (frac FFT size)	1/32		int	[0, 1]
CodeRateHP	High priority stream current convolutional code rate: HP 1/2, HP 2/3, HP 3/4, HP 5/6, HP 7/8	HP 1/2		enum	
CodeRateLP	Low priority stream current convolutional code rate: LP 1/2, LP 2/3, LP 3/4, LP 5/6, LP 7/8	LP 1/2		enum	
MappingMode	Signal constellations and mapping: QAM-16, QAM-64	QAM-16		enum	
Alpha	Non-uniform factor for DVB-H	1		int	[1, ∞)
InnerInterlv	Inner interleaving type: Native, In-depth	In-depth		enum	
SoftDecision	Soft decision viterbi decoding type: Soft, Hard, Cochannel	Soft		enum	
TrunLen	Path memory truncation length of viterbi decoding algorithm, in bytes	10		int	[5, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	RF	received RF signal	timed

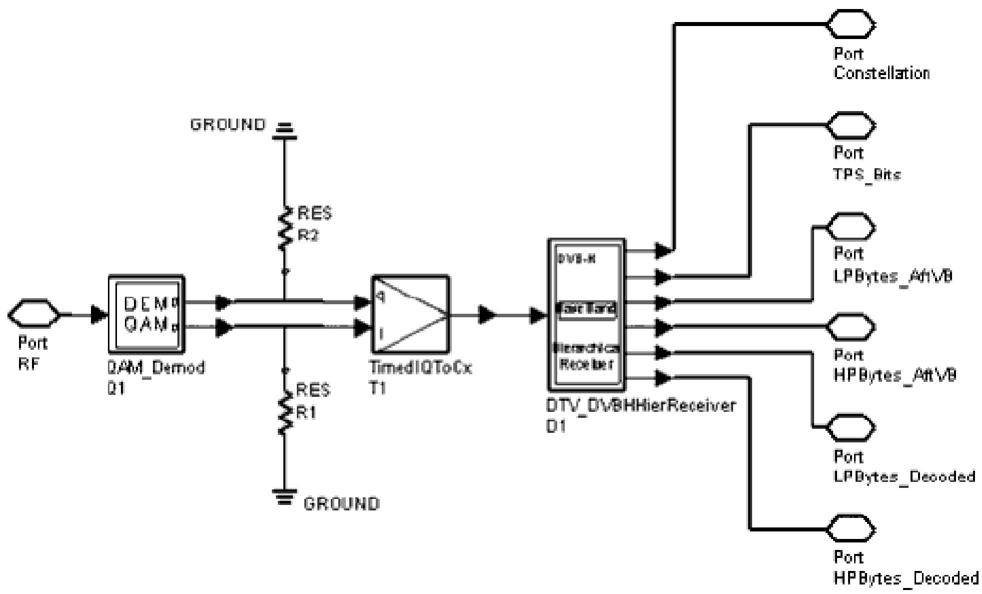
Pin Outputs

Pin	Name	Description	Signal Type
2	HPBytes_Decoded	decoded bytes after Reed Solomon decoder of high priority layer	int
3	LPBytes_Decoded	decoded bytes after Reed Solomon decoder of low priority layer	int
4	HPBytes_AftVB	decoded bytes after Viterbi decoder of high priority layer	int
5	LPBytes_AftVB	decoded bytes after Viterbi decoder of low priority layer	int
6	TPS_Bits	decoded TPS information bits	int
7	Constellation	constellation signal after OFDM demodulation	complex

Notes/Equations

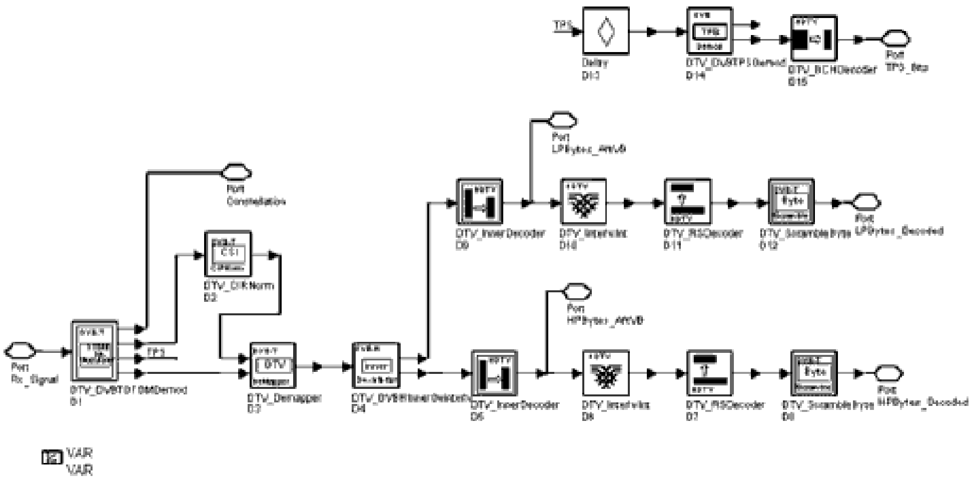
1. This subnetwork model implements RF hierarchical receiver functions according to the DVB-H standard. The schematic for this subnetwork is shown below.
   The received RF signal is demodulated and the demodulated signal is fed to the baseband receiver.

   DTV_DVBHHierReceiver_RF Schematic

2. The schematic for the baseband receiver is shown below.

   DTV_DVBHHierReceiver Schematic



3. Implementation
    - Start of OFDM symbol is detected. In the DTV_DVBTOFDMDemod subnetwork:
        - DTV_MLEstimator calculates the correlation based on guard interval; DTV_LoadFFTBuff selects the index with the maximum correlation value as the start of FFT.
        - Complex channel impulse response are estimated on continual and scattered pilot subcarriers. Channel impulse responses of the data subcarriers are interpolated based on the estimated CIR. DTV_DVB2DChEstimator implements these functions.
        - Each subcarrier value is divided by a complex estimated channel response coefficient. This simple one-tap frequency domain channel response compensation is implemented by DTV_OFDMEqualizer.
        - After equalization, DTV_DVBDemuxOFDMSym demultiplexes 1705, 3409, or 6817 subcarriers into 1512 (2K mode), 3024 (4K mode), or 6048 (8K mode) data subcarriers and 1 demodulated TPS.
    - The demodulated data subcarriers (16- or 64-QAM modulated) are demapped by DTV_Demapper.
    - Demodulated soft bits are deinterleaved by DTV_DVBHInnerDeinterlv.
    - De-interleaved bits are inner decoded (DTV_InnerDecoder), outer de-interleaved (DTV_InterlvInt), outer decoded (DTV_RSDecoder), and descrambled (DTV_ScrambleByte).
    - Fully decoded stream bytes are output as HPBytes_Decoded and LPBytes_Decoded.
    - Partially decoded stream bytes after inner decoding are output as HPBytes_AftVB and LPBytes_AftVB.
    - The TPS signal is demodulated by DTV_DVBTPSDemod and the demodulated bits are decoded by DTV_BCHDecoder.
    - The output pins of this receiver correspond to DTV_DVBHSignalSrc pins.
    - The number of samples of each OFDM symbol (Rx_Signal input pin) are:
        - (1+GuardInterval)×2048×OversamplingOption (2K mode)
        - (1+GuardInterval)×4096×OversamplingOption (4K mode)
        - (1+GuardInterval)×8192×OversamplingOption (8K mode)
    - The number of Constellation output pin is 1705 (2K mode), 3409 (4K mode), or 6817 (8K mode) per OFDM symbol.
4. Parameter Details
    - GainImbalance and PhaseImbalance add certain impairments to the ideal output RF signal. Impairments are added in the order described here.
    - The unimpaired RF I and Q envelope voltages have gain and phase imbalance applied. The RF is given by:

$$V_3(t) = A\left(V_1(t)\cos(\omega_c t) - gV_2(t)\sin\left(\omega_c t + \frac{\phi\pi}{180}\right)\right)$$

where $V_1(t)$ is the in-phase RF envelope, $V_2(t)$ is the quadrature phase RF envelope, g is the gain imbalance

$$g = 10^{\frac{GainImbalance}{20}}$$

and, Φ (in degrees) is the phase imbalance.

- FCarrier defines the RF frequency for the DVB signal.
- Mode specifies the 2K, 4K, or 8K transmission mode.
- OversamplingOption specifies oversampling ratio 1, 2, 4, 8, 16, or 32 of the transmission signal. If OversamplingOption=Ratio 2, the IFFT size is 4096 (2K mode), 8192 (4K mode), or 16384 (8K mode).
- GuardInterval specifies guard interval (also called cyclic extension) 1/32, 1/16, 1/8, or 1/4 for DVB-H for each symbol, as a fraction of the FFT time period. For proper demodulation, the value of the corresponding receiver must match the guard interval length actually used in the input signal.
- CodeRateHP specifies the high priority stream convolutional code rate: 1/2, 2/3, 3/4, 5/6, or 7/8.
- CodeRateLP specifies the low priority stream convolutional code rate: 1/2, 2/3, 3/4, 5/6, or 7/8.
- MappingMode specifies signal constellations and mapping: 16- or 64-QAM.
- Alpha is used for signal constellation and mapping as defined in DVB-H specifications.
  - If Alpha=1, uniform mapping of 16- or 64-QAM is used.
  - If Alpha=2 or 4, non-uniform mapping of 16- or 64-QAM is used.
- SoftDecision specifies the Viterbi decoding algorithm mode.
  - If SoftDecision=Soft, the Viterbi decoding algorithm is a soft decision decoder and uses channel status information.
  - If SoftDecision=Hard, the Viterbi decoding algorithm is a hard decision decoder and does not use channel status information.
  - If SoftDecision=Cochannel, the Viterbi decoding algorithm is for co-channel measurement with PAL analog TV and digital DVB-T.
- TrunLen sets truncation length (in bytes) in the Viterbi decoding algorithm. The path memory is 8×TrunLen bits in the Viterbi decoding algorithm.

5. Output Pin Delay Adjustment
   - The Constellation pin has 8 OFDM symbol delays. The 8 × 1705 (2K mode), 8 × 3409 (4K mode) or 8 × 6817 (8K mode) constellation output signals are not used for EVM calculation.
   - DTV_BCHDecoder uses a 68-bit block. So a Delay component with N=60 is inserted before DTV_DVBTPSDemod. Pin TPS_Bits has one DVB-H frame (68 OFDM symbols) delay. The first 53 bits at TPS_Bits are not used.
   - Viterbi decoding introduces different delays for different path memory truncation lengths (TrunLen parameter). For synchronization in BER measurements, the delay between byte-interleaver and byte de-interleaver must be adjusted to a multiple of 12 bytes and the delay between randomizer and de-randomizer must be adjusted to a multiple of 204 bytes; both delays in the model have been adjusted to a multiple of 204 bytes.
   - The information bytes per one OFDM symbol in HPBytes_AftVB is calculated as follows:
     - DataPerOFDMSymbol=1512 (2K mode), 3024 (4K mode), or 6048 (8K mode)

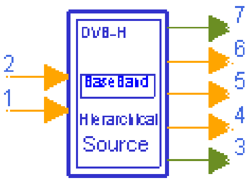
    - CodedBlockSize=204
    - CR = 1/2, 2/3, 3/4, 5/6, or 7/8
    - DVB_DelayOFDMSymbols=8
    - InfoBytes_HP=2×DataPerOFDMSymbol×CR/8
  - The delay of HPBytes_AftVB is Delay_AftVB_HP, calculated as follows:
    - DelayBytes_HP=DVB_DelayOFDMSymbols × InfoBytes_HP-(int(DVB_DelayOFDMSymbols × InfoBytes_HP/CodedBlockSize))×CodedBlockSize
    - N_HP=int((TrunLen+DelayBytes_HP)/CodedBlockSize)
    - Delay_AftVB_HP=(1+int((DVB_DelayOFDMSymbols × InfoBytes_HP) / CodedBlockSize)+N_HP)×CodedBlockSize.
  - The information bytes per one OFDM symbol in LPBytes_AftVB is calculated as follows:
    - DataPerOFDMSymbol=1512 (2K mode), 3024 (4K mode), or 6048 (8K mode)
    - CodedBlockSize=204
    - MapRateLP=2 for 16-QAM or 4 for 64-QAM
    - CR = 1/2, 2/3, 3/4, 5/6 or 7/8
    - InfoBytes_LP=MapRateLP×DataPerOFDMSymbol×CR/8
  - The delay of LPBytes_AftVB is Delay_AftVB_LP, calculated as follows:
    - DelayBytes_LP=DVB_DelayOFDMSymbols × InfoBytes_LP-(int(DVB_DelayOFDMSymbols × InfoBytes_LP/CodedBlockSize))×CodedBlockSize
    - N_LP=int((TrunLen+DelayBytes_LP)/CodedBlockSize)
    - Delay_AftVB_LP=(1+int((DVB_DelayOFDMSymbols×InfoBytes_LP) / CodedBlockSize)+N_LP)×CodedBlockSize.
  - HPBytes_Decoded and LPBytes_Decoded each have 8 OFDM symbol and 11 transport MUX packets delays.
  - The delay of HPBytes_Decoded is
    - Delay_AftDescramble_HP=(11+1+int(DVB_DelayOFDMSymbols×InfoBytes_HP / CodedBlockSize)+N_HP)×188.
  - The delay of LPBytes_Decoded is
    - Delay_AftDescramble_LP=(11+1+int(DVB_DelayOFDMSymbols×InfoBytes_LP / CodedBlockSize)+N_LP)×188.

6. When connecting the receiver to the signal source in MER and BER measurements, the reference signal from the signal generator should be delayed according to the formula above.

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.5.1, European Telecommunication Standard, November 2004.

DTV_DVBHHierSignalSrc



Description: DVB-H base-band hierarchical signal source
Library: DTV, DVB-H
Class: SDFDTV_DVBHHierSignalSrc

Parameters

Name	Description	Default	Unit	Type	Range
Mode	Transmission mode: Mode 2K, Mode 8K, Mode 4K	Mode 4K		enum	
OversamplingOption	Oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	
GuardInterval	Guard interval (frac FFT size)	1/32		real	[0, 1]
CodeRateHP	High priority stream convolutional code rate: HP 1/2, HP 2/3, HP 3/4, HP 5/6, HP 7/8	HP 1/2		enum	
CodeRateLP	Low priority stream convolutional code rate: LP 1/2, LP 2/3, LP 3/4, LP 5/6, LP 7/8	LP 1/2		enum	
MappingMode	Signal constellations and mapping: QAM-16, QAM-64	QAM-16		enum	
Alpha	Non-uniform factor for DVB-H	1		int	[1, ∞)
InnerInterlv	Inner interleaving type: Native, In-depth	In-depth		enum	
Cell_ID	Cell identifier	0		int	[0, 65535]
TimeSlicing	Time slicing for DVB-H signalling: TimeSlicing Not-used, TimeSlicing Used	TimeSlicing Not-used		enum	
MPE_FEC	MPE-FEC for DVB-H signalling: MPE_FEC Not-used, MPE_FEC used	MPE_FEC Not-used		enum	
TPSLength	TPS length indicator (23 for version 1.2.1, 31 for version 1.5.1, 33 for DVB-H)	33		int	[23, 37]

Pin Inputs

Pin	Name	Description	Signal Type
1	DataHP	Data input of high priority	int
2	DataLP	Data input of low priority	int

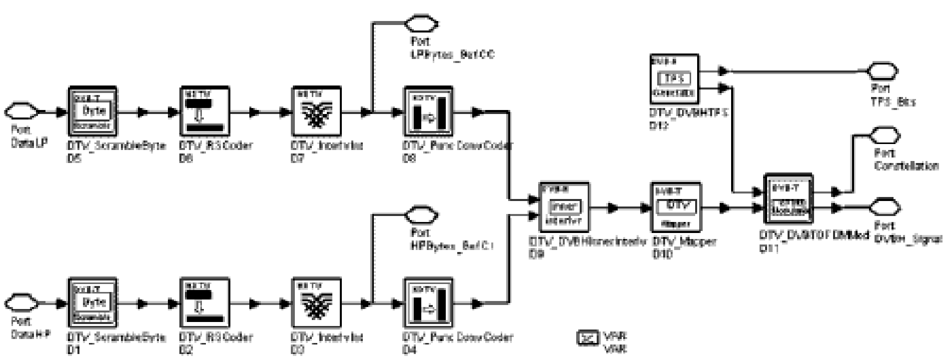
Pin Outputs

Pin	Name	Description	Signal Type
3	DVBH_Signal	DVBH base-band hierarchical signal	complex
4	HPBytes_BefCC	high priority information bytes before convolutional encoder	int
5	LPBytes_BefCC	low priority information bytes before convolutional encoder	int
6	TPS_Bits	TPS information bits	int
7	Constellation	constellation signal before IFFT	complex

Notes/Equations

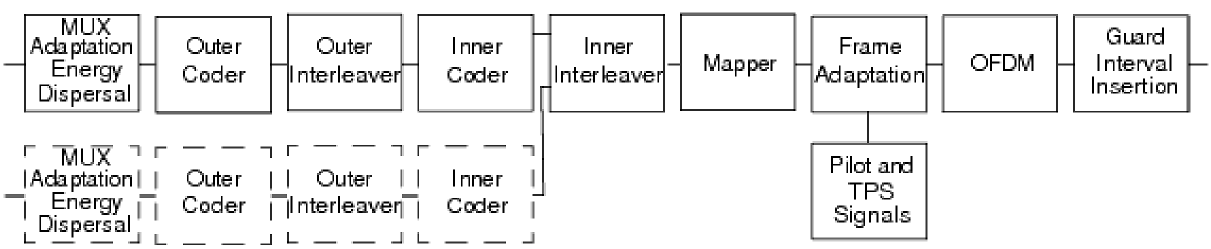
1. This subnetwork model generates a DVB-H hierarchical baseband signal. The schematic for this subnetwork, shown below, includes: scrambler (DTV_ScrambleByte); outer coder (DTV_RSCoder); outer interleaver (DTV_InterlvInt); inner coder (DTV_PuncConvCoder); inner interleaver (DTV_DVBHInnerInterlv); mapper (DTV_Mapper); frame adaptation, OFDM, and guard interval insertion (DTV_DVBTOFDMMod subnetwork); and, TPS generator (DTV_DVBHTPS).

DTV_DVBHHierSignalSrc Schematic



2. The DVB-H signal source format follows the DVB specification. The figure below shows the functional block diagram of the DVB-H baseband system.

DVB-H Baseband System Block Diagram



3. When native inner interleaving is selected, the signal source generates one OFDM symbol each firing.
When InnerInterlv=In-depth inner interleaving, the signal source generates 1 OFDM symbol in the 8K mode (in-depth inner interleaving does not affect the 8K mode), 2 OFDM symbols in the 4K mode, and 4 OFDM symbols in the 2K mode.
For each OFDM symbol, the Constellation pin exports 1705 (2K mode), 3409 (4K

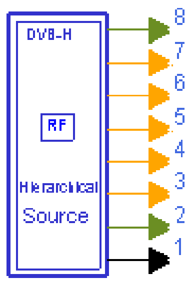
mode), or 6817 (8K mode) particles.
The number of samples of each OFDM symbol (DVBH_signal pin) is:
- (1+GuardInterval)×2048×OversamplingOption (2K mode)
- (1+GuardInterval)×4096×OversamplingOption (4K mode)
- (1+GuardInterval)×8192×OversamplingOption (8K mode)

4. Input of the subnetwork is a transport stream (TS) defined in *MPEG-2 Systems*.
5. Parameter Details
    - Mode specifies a 2K, 4K, or 8K transmission mode as defined in DVB-H specification.
    - OversamplingOption specifies the oversampling ratio of the transmission signal. Oversampling ratios 1, 2, 4, 8, 16, 32 are supported in this source. If OversamplingOption = Ratio 2, the IFFT size is 4096 (2K mode), 8192 (4K mode), or 16384 (8K mode).
    - GuardInterval specifies the guard interval (also called cyclic extension) length for each symbol, as a fraction of the FFT time period. Guard interval value of the corresponding receiver must match the guard interval length actually used in the input signal in order for the demodulation to work properly. It takes the value of 1/32, 1/16, 1/8 or 1/4 for DVB-H.
    - CodeRateHP is defined as convolutional code rate for the high priority stream. Code rates 1/2, 2/3, 3/4, 5/6 and 7/8 are available in this source. CodeRateLP is defined as convolutional code rate for the low priority stream. Code rates 1/2, 2/3, 3/4, 5/6 and 7/8 are available in this source.
    - MappingMode specifies signal constellations and mapping: 16- or 64-QAM.
    - Alpha is used for signal constellation and mapping (based on MappingMode).
        - If Alpha=1, uniform mapping of 16- or 64-QAM is used.
        - If Alpha=2 or 4, non-uniform mapping of 16- or 64-QAM is used as defined in DVB-H specification.
    - Cell_ID specifies the cell from which the signal comes from, it should belong to [0, 65535]. If not used, it should be set zero.
    - TPS_Length specifies the number of TPS information bits based on ETSI EN 300744 specification:
        - 23 (when cell identification information is not transmitted, MPE-FEC and Time Slicing information are not transmitted, DVB-T version 1.2.1).
        - 31 (when cell identification information is transmitted, MPE-FEC and Time Slicing information are not transmitted, DVB-T version 1.5.1).
        - 33 (when cell identification information is transmitted, MPE-FEC and Time Slicing information are transmitted, DVB-T version 1.5.1).

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.5.1, European Telecommunication Standard, November 2004.

DTV_DVBHHierSignalSrc_RF



Description: DVB-H RF hierarchical signal source
Library: DTV, DVB-H
Class: TSDFDTV_DVBHHierSignalSrc_RF

Parameters

Name	Description	Default	Unit	Type	Range
ROut	Output resistance	DefaultROut	Ohm	real	(0, ∞)
RTemp	Physical temperature, in degrees C	DefaultRTemp	Celsius	real	[-273.15, ∞)
FCarrier	Carrier frequency	474.0MHz	Hz	real	(0, ∞)
Power	Modulator output power	40mW	W	real	(0, ∞)
BasicSamplingRate	Basic sampling rate	(2048/224.0)MHz	Hz	real	(0, ∞)
MirrorSpectrum	Mirror spectrum about carrier?: NO, YES	NO		enum	
GainImbalance	Gain imbalance, Q vs I	0.0	dB	real	(-∞, ∞)
PhaseImbalance	Phase imbalance, Q vs I	0.0	deg	real	(-∞, ∞)
I_OriginOffset	I origin offset (percent)	0.0		real	(-∞, ∞)
Q_OriginOffset	Q origin offset (percent)	0.0		real	(-∞, ∞)
IQ_Rotation	IQ rotation	0.0	deg	real	(-∞, ∞)
Mode	Transmission mode: Mode 2K, Mode 8K, Mode 4K	Mode 4K		enum	
OversamplingOption	Oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	
GuardInterval	Guard interval (frac FFT size)	1/32		real	[0, 1]
CodeRateHP	High priority stream convolutional code rate: HP 1/2, HP 2/3, HP 3/4, HP 5/6, HP 7/8	HP 1/2		enum	
CodeRateLP	Low priority stream convolutional code rate: LP 1/2, LP 2/3, LP 3/4, LP 5/6, LP 7/8	LP 1/2		enum	
MappingMode	Signal constellations and mapping: QAM-16, QAM-64	QAM-16		enum	
Alpha	Non-uniform factor for DVB-H	1		int	[1, ∞)
InnerInterlv	Inner interleaving type: Native, In-depth	In-depth		enum	
Cell_ID	Cell identifier	0		int	[0, 65535]
TimeSlicing	Time slicing for DVB-H signalling: TimeSlicing Not-used, TimeSlicing Used	TimeSlicing Not-used		enum	
MPE_FEC	MPE-FEC for DVB-H signalling: MPE_FEC Not-used, MPE_FEC used	MPE_FEC Not-used		enum	
TPSLength	TPS length indicator (23 for version 1.2.1, 31 for version 1.5.1, 33 for DVB-H)	33		int	[23, 37]
DataTypeHP	Payload data type with high priority: PN9 HP, PN15 HP, FIX4 HP, _4_1_4_0 HP, _8_1_8_0 HP, _16_1_16_0 HP, _32_1_32_0 HP, _64_1_64_0 HP	PN9 HP		enum	
DataTypeLP	Payload data type with low priority: PN9 LP, PN15 LP, FIX4 LP, _4_1_4_0 LP, _8_1_8_0 LP, _16_1_16_0 LP, _32_1_32_0 LP, _64_1_64_0 LP	PN15 LP		enum	

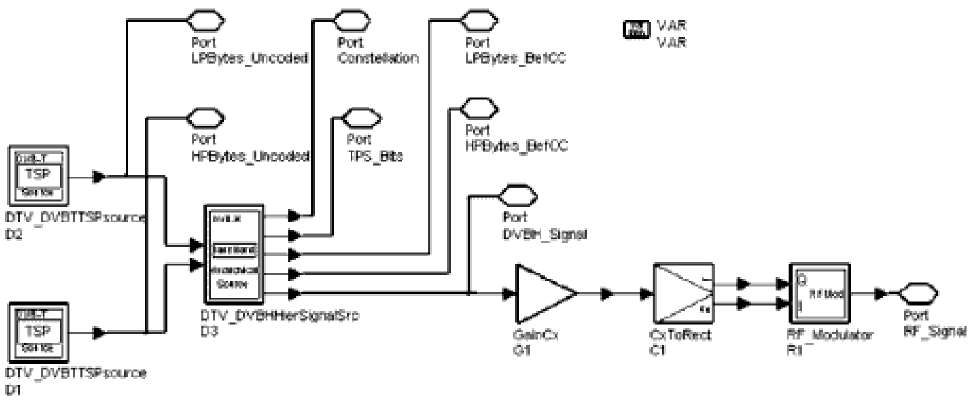
Pin Outputs

Pin	Name	Description	Signal Type
1	RF	RF hierarchical signal	timed
2	DVBH_Signal	DVB-H hierarchical base-band signal	complex
3	HPBytes_Uncoded	high priority information bytes of transport packet	int
4	LPBytes_Uncoded	low priority information bytes of transport packet	int
5	HPBytes_BefCC	high priority information bytes before convolutional coder	int
6	LPBytes_BefCC	low priority information bytes before convolutional coder	int
7	TPS_Bits	TPS bits	int
8	Constellation	constellation signal before IFFT	complex

Notes/Equations

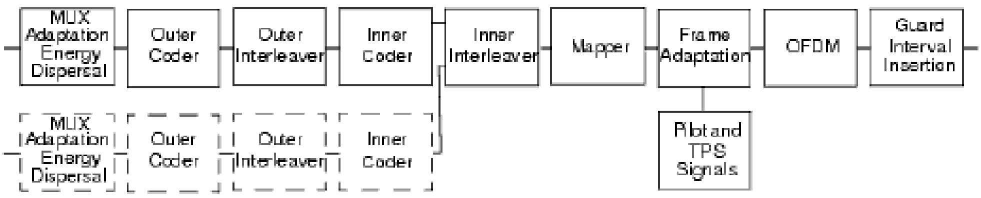
1. This subnetwork model integrates an RF modulator and a DVB-H hierarchical baseband signal source. The baseband signal is fed to the RF modulator; after RF modulation the timed signal is output. The schematic for this subnetwork is shown below.

DTV_DVBHHierSignalSrc_RF Schematic



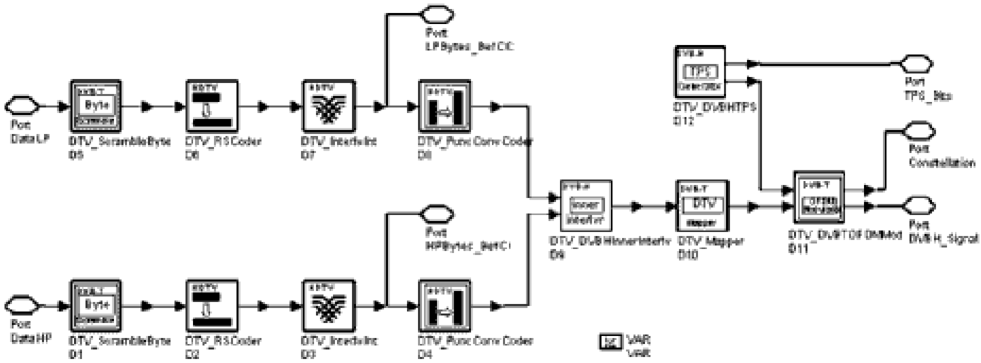
2. The DVB-H signal source format follows the DVB specification. The figure below shows the functional block diagram of the DVB-H baseband system.

DVB-H Baseband System Block Diagram



3. The schematic for baseband signal source DTV_DVBHHierSignalSrc is shown below, it includes: scrambler (DTV_ScrambleByte); outer coder (DTV_RSCoder); outer interleaver (DTV_InterlvInt); inner coder (DTV_PuncConvCoder); inner interleaver (DTV_DVBHInnerInterlv); mapper (DTV_Mapper); frame adaptation, OFDM, and guard interval insertion (DTV_DVBTOFDMMod subnetwork); and, TPS generator (DTV_DVBHTPS).

DTV_DVBHHierSignalSrc Schematic



When native inner interleaving is selected, the signal source generates one OFDM symbol each firing.
When in-depth inner interleaving is selected, the signal source generates 1 OFDM symbol in the 8K mode (in-depth inner interleaving does not affect 8K mode), 2 OFDM symbols in the 4K mode, and 4 OFDM symbols in the 2K mode.
Each OFDM symbol, the Constellation pin outputs 1705 (2K mode), 3409 (4K mode), or 6817 (8K mode) particles.
The number of samples of each OFDM symbol (DVBH_signal pin) is:

- (1+GuardInterval)×2048×OversamplingOption (2K mode)
- (1+GuardInterval)×4096×OversamplingOption (4K mode)
- (1+GuardInterval)×8192×OversamplingOption (8K mode)

4. Baseband Parameter Details
   - Mode is used to select a 2K, 4K, or 8K transmission mode as defined in DVB-H specification.
   - OversamplingOption specifies the oversampling ratio of the transmission signal. Oversampling ratios 1, 2, 4, 8, 16, 32 are supported in this source. If OversamplingOption = Ratio 2, the IFFT size is 4096 (2K mode), 8192 (4K mode), or 16384 (8K mode).
   - GuardInterval specifies the guard interval (also called cyclic extension) length for each symbol, as a fraction of the FFT time period. Guard interval value of the corresponding receiver must match the guard interval length actually used in the input signal in order for the demodulation to work properly. It takes the value of 1/32, 1/16, 1/8 or 1/4 for DVB-H.
   - CodeRateHP is defined as convolutional code rate for the high priority stream. Code rates 1/2, 2/3, 3/4, 5/6, and 7/8 are available in this source.
   - CodeRateLP is defined as convolutional code rate for the low priority stream. Code rates 1/2, 2/3, 3/4, 5/6, and 7/8 are available in this source.
   - MappingMode specifies signal constellations and mapping: 16- or 64-QAM.
   - Alpha is used for signal constellation and mapping (based on MappingMode).
     - If Alpha=1, uniform mapping of 16- or 64-QAM is used.
     - If Alpha=2 or 4, non-uniform mapping of 16- or 64-QAM is used as defined in DVB-H specification.
   - Cell_ID specifies the cell from which the signal comes from, it should belong to [0, 65535]. If not used, it should be set zero.
   - TPS_Length specifies the number of TPS information bits based on ETSI EN 300744 specification:
     - 23 (when cell identification information is not transmitted, MPE-FEC and

Time Slicing information are not transmitted, DVB-T version 1.2.1).
    - 31 (when cell identification information is transmitted, MPE-FEC and Time Slicing information are not transmitted, DVB-T version 1.5.1).
    - 33 (when cell identification information is transmitted, MPE-FEC and Time Slicing information are transmitted, DVB-T version 1.5.1).
- For DataTypeHP and DataTypeLP:
    - if PN9 is selected, a 511-bit pseudo-random test pattern is generated according to CCITT Recommendation O.153
    - if PN15 is selected, a 32767-bit pseudo-random test pattern is generated according to CCITT Recommendation O.151
    - if FIX4 is selected, a zero-stream is generated
    - if x_1_x_0 is selected, where x equals 4, 8, 16, 32, or 64, a periodic bit stream is generated, with the period being 2x. In one period, the first x bits are 1s and the second x bits are 0s.

5. RF Parameter Details
FCarrier defines the RF frequency for the DVB signal.
Power defines the power level for FCarrier.
BasicSamplingRate indicates the sampling rate of baseband signal, the corresponding bandwidth of the RF signal is:

    BasicSamplingRate×1705/2048 (2K mode)
    BasicSamplingRate×3409/4096 (4K mode)
    BasicSamplingRate×6817/8192 (8K mode)

The MirrorSpectrum (when set to YES) conjugates the input signal before any other processing is done.
The GainImbalance, PhaseImbalance, I_OriginOffset, Q_OriginOffset, and IQ_Rotation parameters add certain impairments to the ideal output RF signal. Impairments are added in the order described here.
The unimpaired RF I and Q envelope voltages have gain and phase imbalance applied. The RF is given by:

$$V_3(t) = A\left(V_1(t)\cos(\omega_c t) - gV_2(t)\sin\left(\omega_c t + \frac{\phi\pi}{180}\right)\right)$$

where *A* is a scaling factor that depends on the Power and ROut parameters specified by the user, $V_1(t)$ is the in-phase RF envelope, $V_2(t)$ is the quadrature phase RF envelope, *g* is the gain imbalance

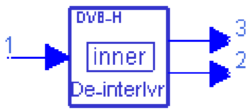
$$g = 10^{\frac{GainImbalance}{20}}$$

and, Φ (in degrees) is the phase imbalance.
The signal $V_3(t)$ is rotated by IQ_Rotation degrees; I_OriginOffset and Q_OriginOffset are then applied to the rotated signal. Note that the amounts specified are percentages with respect to the output rms voltage. The output rms voltage is given by sqrt(2×ROut×Power).

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.5.1, European Telecommunication Standard, November 2004.

DTV_DVBHInnerDeinterlv



Description: DVB-H inner deinterleaver
Library: DTV, DVB-H
Class: SDFDTV_DVBHInnerDeinterlv

Parameters

Name	Description	Default	Unit	Type	Range
Mode	Transmission mode: DVB 2k mode, DVB 8k mode, DVB 4k mode	DVB 4k mode		enum	
MappingMode	Signal constellation and mapping: QPSK, QAM-16, QAM-64	QPSK		enum	
Hierarchy	Hierarchical transmission flag: Non-Hierarchical, Hierarchical	Non-Hierarchical		enum	
InterlvType	Symbol interleaving type for 2K and 4K mode: Native, In-depth	In-depth		enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	BitsIn	bits to be de-interleaved	real

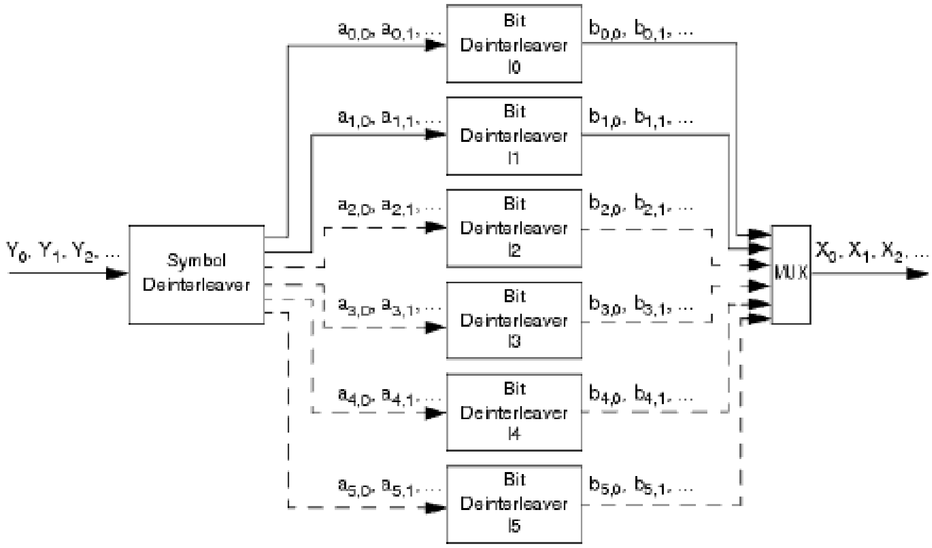
Pin Outputs

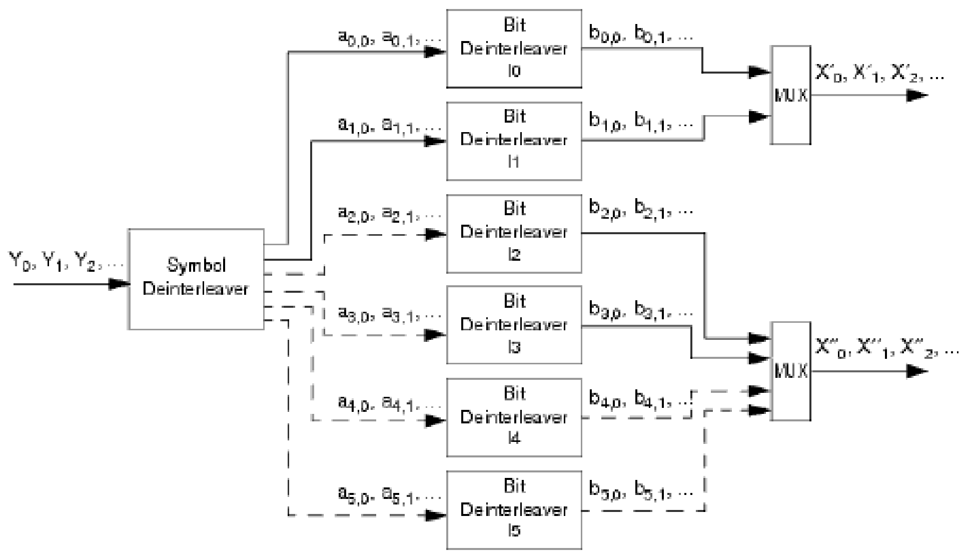
Pin	Name	Description	Signal Type
2	BitsHP	high priority bit stream (no output in non-hierarchical transmission)	real
3	BitsLP	low priority bit stream or non-hierarchical bit stream	real

Notes/Equations

1. This model performs inner de-interleaving functions in DVB-H systems for non-hierarchical and hierarchical transmission.
   Inner de-interleaver functions (symbol de-interleaving, bit de-interleaving, and multiplexing) are shown below.

DTV_DVBHInnerDeinterlv Functional Block Diagram





2. Symbol de-interleaving
   The symbol de-interleaver de-maps v bit words from the active carriers of every one (all three modes with native inner interleaving), 2 (4K mode with in-depth inner interleaving) or 4 (2K mode with in-depth inner interleaving) consecutive OFDM symbols. The symbol de-interleaver acts on blocks of 1512 (2K mode with native inner interleaving), 3024 (4K mode with native inner interleaving), or 6048 (8K mode, 2K mode with in-depth inner interleaving and 4K mode with in-depth inner interleaving) data symbols.
   The input v bit words { yq } is defined as:

   $$y_q = (y_{0,q}, y_{1,q}, \dots , y_{v-1,q})$$

   where v = 2 for QPSK, v = 4 for 16-QAM, and v = 6 for 64-QAM.
   For native symbol de-interleaving:

   In the 2K mode, vector $Y = (y_0, y_1, y_2, \dots , y_{1511})$ from one OFDM symbol of v bit words is read into the symbol de-interleaver.

   In the 4K mode, vector $Y = (y_0, y_1, y_2, \dots , y_{3023})$ is read in.

In the 8K mode, vector $Y = (y_0, y_1, y_2, \ldots, y_{6047})$ is read in.

The de-interleaved vector $Y' = (y'_0, y'_1, y'_2, \ldots, y'_{Nmax-1})$ is defined by:
$y'_q = y_{H(q)}$ for even symbols for q = 0, ... , N_{max} -1
$y'_{H(q)} = y_q$ for odd symbols for q = 0, ... , N_{max} -1
where N_{max} = 1512 (2K mode), N_{max} = 3024 (4K mode), and N_{max} = 6048 (8K mode). The symbol index is 0 to 67 in each frame.

For in-depth symbol de-interleaving:

When in-depth inner de-interleaver is selected, the symbol de-interleaver acts on blocks of 6048 data symbols.

In the 2K mode, vector $Y = (y_0, y_1, y_2, \ldots, y_{6047})$ is read in from four consecutive OFDM symbols. For even vectors these start with symbols 0, 8, 16, 24, etc.; for odd vectors these start with symbols 4, 12, 20, 28, etc. in every super-frame.

In the 4K mode, vector $Y = (y_0, y_1, y_2, \ldots, y_{6047})$ is read in from two consecutive OFDM symbols. For even vectors these start with symbols 0, 4, 8, 12, etc.; for odd vectors these start with symbols 2, 6, 10, 14, etc. in every super-frame.

The de-interleaved vector $Y' = (y'_0, y'_1, y'_2, \ldots, y'_{Nmax-1})$ is defined by:
$y'_q = y_{H(q)}$ for even vectors for q = 0, ... , N_{max} -1
$y'_{H(q)} = y_q$ for odd vectors for q = 0, ... , N_{max} -1
where N_{max} = 6048, for 2K ,4K, or 8K modes.
In the 8K mode, the native and in-depth inner de-interleaving is the same.

The permutation function represented by *H(q)* is defined by:

An (N_r - 1) bit binary word R'_i is defined, with N_r = log2 M_{max}, where M_{max} = 2048 when N_{max} = 1512, M_{max} = 8192 when N_{max} = 6048, and M_{max} = 4096 when N_{max} = 3024, where R'_i takes the following values:

i = 0,1: R'_i [N_r - 2, N_r - 3, ... , 1, 0] = 0, 0, ... , 0, 0
i = 2: R'_i [N_r - 2, N_r - 3, ... , 1, 0] = 0, 0, ... , 0, 1
2 < i < M_{max}: { R'_i [N_r - 3, N_r - 4, ... , 1, 0] = R'_i - 1 [N_r - 2, N_r - 3, ... , 2, 1];
if M_{max} = 2048: R'_i [N_r - 2] = (R'_{i-1} [0] + R'_{i-1} [3]) mod 2
if M_{max} = 8192: R'_i [N_r - 2] = (R'_{i-1} [0] + R'_{i-1} [1] + R'_{i-1} [4] + R'_{i-1} [6]) mod 2
if M = 4096: R' [N - 2] = (R' [0] + R' [2]) mod 2 }

max i r i-1 i-1

A vector R_i is derived from the vector R'_i by the bit permutations, that is:

M_{max} = 2048	$R'_{[9..0]}$	= {R'_9, R'_8, R'_7, R'_6, R'_5, R'_4, R'_3, R'_2, R'_1, R'_0}
	$R_{[9..0]}$	= {R'_2, R'_5, R'_8, R'_3, R'_7, R'_0, R'_1, R'_4, R'_6, R'_9} = {R_9, R_8, R_7, R_6, R_5, R_4, R_3, R_2, R_1, R_0}
M_{max} = 8192	$R'_{[11..0]}$	= {R'_{11}, R'_{10}, R'_9, R'_8, R'_7, R'_6, R'_5, R'_4, R'_3, R'_2, R'_1, R'_0}
	$R_{[11..0]}$	= {R'_{10}, R'_7, R'_4, R'_6, R'_0, R'_5, R'_{11}, R'_2, R'_9, R'_3, R'_1, R'_8} = {R_{11}, R_{10}, R_9, R_8, R_7, R_6, R_5, R_4, R_3, R_2, R_1, R_0}
M_{max} = 4096	$R'_{[10..0]}$	= {R'_{10}, R'_9, R'_8, R'_7, R'_6, R'_5, R'_4, R'_3, R'_2, R'_1, R'_0}
	$R_{[10..0]}$	= {R'_9, R'_3, R'_7, R'_{10}, R'_0, R'_8, R'_4, R'_1, R'_5, R'_6, R'_2} = {R_{10}, R_9, R_8, R_7, R_6, R_5, R_4, R_3, R_2, R_1, R_0}

Thus we get the permutation function *H(q)* by the following algorithm:
$q = 0$;
for ($i = 0$; $i < M_{max}$; $i = i + 1$)

$$\{H(q) = (i \mod 2) \times 2^{N_r - 1} + \sum_{j=0}^{N_r - 2} R_i(j) \times 2^j;$$
$$\text{if } (H(q) < N_{max})\ q = q + 1;\ \}$$

Similar to *y*, *y*' is made up of v bits:
$y'_{q'} = (y'_{0,q'}, y'_{1,q'}, \ldots, y'_{v-1,q'})$
where *q*' is the symbol number at the output of the symbol de-interleaver.
The vector $Y' = (y'_0, y'_1, y'_2, \ldots, y'_{Nmax-1})$ are divided into v sub-streams and fed into the bit de-interleaver.

3. Bit de-interleaving
Each sub-stream from the symbol de-interleaver is processed by a separate bit de-interleaver. There are up to six de-interleavers depending on v, labelled I0 to I5: I0 and I1 are used for QPSK; I0 through I3 are used for 16-QAM; and I0 through I5 are used for 64-QAM.
The block size is the same for each de-interleaver, but the de-interleaving sequence is different in each case. The bit de-interleaving block size is 126 bits.
For each bit de-interleaver, the input bit vector is defined by:
$$A(e) = (a_{e,0}, a_{e,1}, a_{e,2}, \ldots, a_{e,125})$$
where *e* ranges from 0 to v-1.
The de-interleaved output vector $B(e) = (b_{e,0}, b_{e,1}, b_{e,2}, \ldots, b_{e,125})$ is defined by:
$$b_{e,w} = a_{e,He(w)}$$
where *He(w)* is a permutation function that is different for each de-interleaver.
He(w) is defined as follows for each de-interleaver:

I0: $H_0(w) = w$

I1: $H_1(w) = (w+63) \bmod 126$

I2: $H_2\ (w) = (w+21) \bmod 126$

I3: $H_3\ (w) = (w+84) \bmod 126$

I4: $H_4\ (w) = (w+105) \bmod 126$

I5: $H_5\ (w) = (w+42) \bmod 126$

4. Multiplexing
The input, which consists of v sub-streams, is multiplexed into up to two bit streams: in non-hierarchical mode, the v sub-streams are multiplexed into a single output stream; in hierarchical mode, the first two sub-streams are multiplexed into a high-priority stream, and the other v-2 sub-streams are multiplexed into a low-priority stream. This applies to uniform and non-uniform QAM modes.
QPSK:

$b_{0,0}$ maps to x_0

$b_{1,0}$ maps to x_1

16-QAM non-hierarchical transmission:

$b_{0,0}$ maps to x_0

$b_{2,0}$ maps to x_1

$b_{1,0}$ maps to x_2

$b_{3,0}$ maps to x_3

16-QAM non-hierarchical transmission:

$b_{0,0}$ maps to x'_0

$b_{1,0}$ maps to x'_1

$b_{2,0}$ maps to x''_0

$b_{3,0}$ maps to x''_1

64-QAM non-hierarchical transmission:

$b_{0,0}$ maps to x_0

$b_{2,0}$ maps to x_1

$b_{4,0}$ maps to x_2

$b_{1,0}$ maps to x_3

$b_{3,0}$ maps to x_4

$b_{5,0}$ maps to x_5

64-QAM non-hierarchical transmission:

$b_{0,0}$ maps to x'_0

b maps to x'

1,0 1

$b_{2,0}$ maps to $x"_0$

$b_{4,0}$ maps to $x"_1$

$b_{3,0}$ maps to $x"_2$

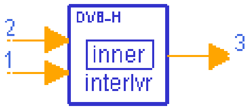
$b_{5,0}$ maps to $x"_3$

QPSK does not have hierarchical transmission.

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.5.1, European Telecommunication Standard, November 2004.

DTV_DVBHInnerInterlv



Description: DVB-H inner interleaver
Library: DTV, DVB-H
Class: SDFDTV_DVBHInnerInterlv

Parameters

Name	Description	Default	Unit	Type	Range
Mode	Transmission mode: DVB 2k mode, DVB 8k mode, DVB 4k mode	DVB 4k mode		enum	
MappingMode	Signal constellation and mapping: QPSK, QAM-16, QAM-64	QPSK		enum	
Hierarchy	Hierarchical transmission flag: Non-Hierarchical, Hierarchical	Non-Hierarchical		enum	
InterlvType	Symbol interleaving type for 2K and 4K mode: Native, In-depth	In-depth		enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	BitsHP	high priority bit stream (connection is not needed in non-hierarchical transmission	int
2	BitsLP	low priority bit stream or non-hierarchical bit stream	int

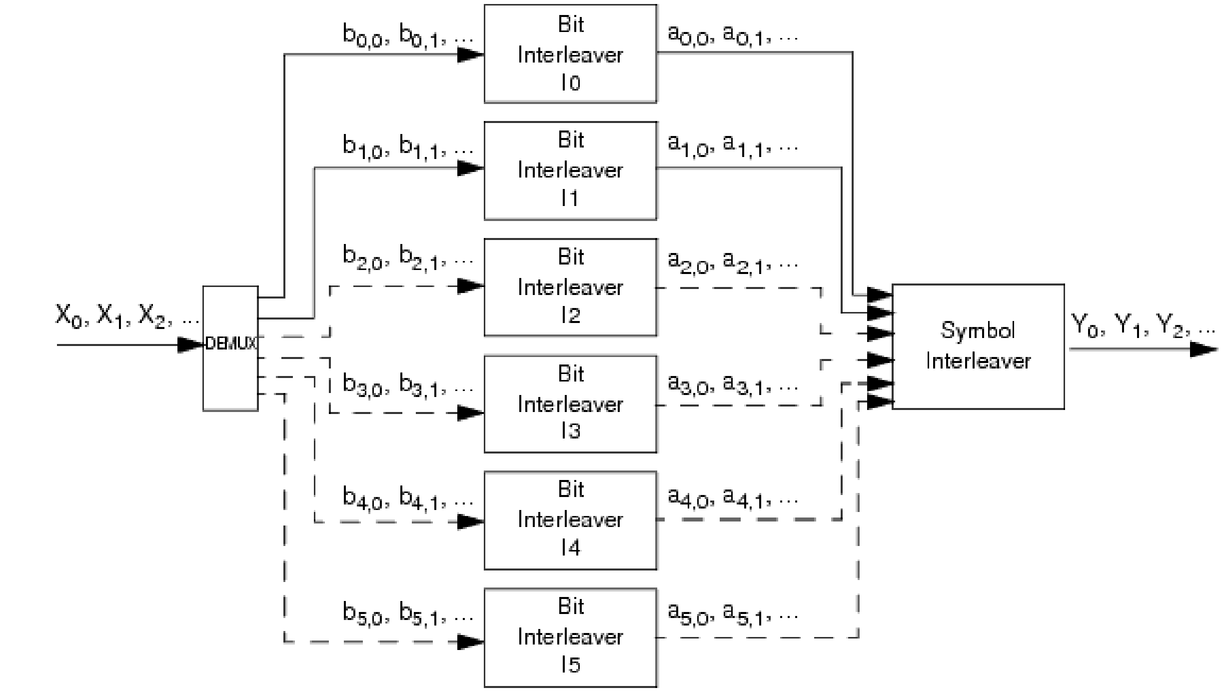
Pin Outputs

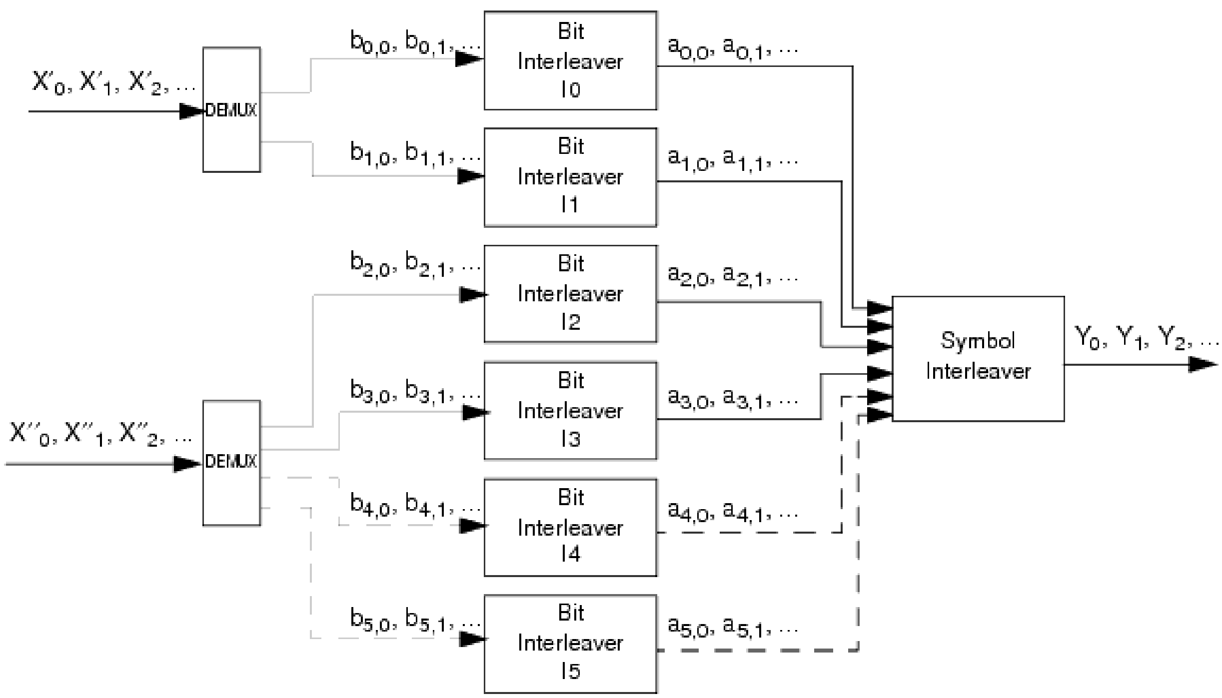
Pin	Name	Description	Signal Type
3	BitsOut	inner interleaved bits	int

Notes/Equations

1. This model performs inner-interleaving functions in DVB-H systems for non-hierarchical and hierarchical transmission.
2. Inner interleaving functions (demultiplexing, bit interleaving, and symbol interleaving) are shown below.

DTV_DVBHInnerInterlv Functional Block Diagram





3. Demultiplexing
   The input, which consists of up to two bit streams, is demultiplexed into v sub-streams, where v = 2 for QPSK, v = 4 for 16-QAM, and v = 6 for 64-QAM. In non-hierarchical mode, the single input stream is demultiplexed into v sub-streams. In hierarchical mode the high priority stream is demultiplexed into two sub-streams and the low priority stream is demultiplexed into v-2 sub-streams. This applies in both uniform and non-uniform QAM modes.
   QPSK:

   x_0 maps to $b_{0,0}$

   x_1 maps to $b_{1,0}$

16-QAM non-hierarchical transmission:

x_0 maps to $b_{0,0}$
x_1 maps to $b_{2,0}$
x_2 maps to $b_{1,0}$
x_3 maps to $b_{3,0}$

16-QAM non-hierarchical transmission:

x'_0 maps to $b_{0,0}$
x'_1 maps to $b_{1,0}$
x''_0 maps to $b_{2,0}$
x''_1 maps to $b_{3,0}$

64-QAM non-hierarchical transmission:

x_0 maps to $b_{0,0}$
x_1 maps to $b_{2,0}$
x_2 maps to $b_{4,0}$
x_3 maps to $b_{1,0}$
x_4 maps to $b_{3,0}$
x_5 maps to $b_{5,0}$

64-QAM non-hierarchical transmission:

x'_0 maps to $b_{0,0}$
x'_1 maps to $b_{1,0}$
x''_0 maps to $b_{2,0}$
x''_1 maps to $b_{4,0}$
x''_2 maps to $b_{3,0}$
x''_3 maps to $b_{5,0}$

4. Bit Interleaving
Each sub-stream from the demultiplexer is processed by a separate bit interleaver. There are therefore up to six interleavers depending on v, labelled I0 to I5: I0 and I1 are used for QPSK; I0 through I3 are used for 16-QAM; I0 through I5 are used for 64-QAM.
Bit interleaving is performed only on the useful data. The block size is the same for each interleaver, but the interleaving sequence is different in each case. The bit interleaving block size is 126 bits.
for each bit interleaver, the input bit vector is defined by:
$B(e) = (b_{e,0}, b_{e,1}, b_{e,2}, \ldots, b_{e,125})$

where e ranges from 0 to v-1.
The interleaved output vector $A(e) = (a_{e,0}, a_{e,1}, a_{e,2}, \dots , a_{e,125})$ is defined by:

$$a_{e,w} = b_{e,He(w)}$$

where $He(w)$ is a permutation function that is different for each interleaver and is defined as:

I0: $H_0(w) = w$

I1: $H_1(w) = (w+63) \bmod 126$

I2: $H_2(w) = (w+105) \bmod 126$

I3: $H_3(w) = (w+42) \bmod 126$

I4: $H_4(w) = (w+21) \bmod 126$

I5: $H_5(w) = (w+84) \bmod 126$

The outputs of the v bit interleavers are grouped to form the digital data symbols, such that each symbol of v bits will consist of exactly one bit from each of the v interleavers. Therefore, the output from the bit-wise interleaver is a v bit word y' that has the output of I0 as its most significant bit; that is,

$$y' = (a_{0,w}, a_{1,w}, \dots, a_{v-1,w})$$

5. Symbol Interleaving
   - The symbol interleaver maps v bit words onto the active carriers of:
     - one OFDM symbol (all modes with native inner interleaving)
     - two OFDM symbols (4K mode with in-depth inner interleaving)
     - four OFDM symbols (2K mode with in-depth inner interleaving)
   - The symbol interleaver acts on blocks of:
     - 1512 data symbols (2K mode with native inner interleaving)
     - 3024 data symbols (4K mode with native inner interleaving)
     - 6048 data symbols (8K mode, 2K mode with in-depth inner interleaving, 4K mode with in-depth inner interleaving)
   - Native symbol interleaving:
     - In 2K mode, 12 groups of 126 data words from the bit interleaver are read sequentially into a vector $Y' = (y'_0, y'_1, y'_2, \dots , y'_{1511})$.
     - In 4K mode, a vector $Y' = (y'_0, y'_1, y'_2, \dots , y'_{3023})$ is assembled from 24 groups of 126 data words.
     - In 8K mode, a vector $Y' = (y'_0, y'_1, y'_2, \dots , y'_{6047})$ is assembled from 48 groups of 126 data words.
   - The interleaved vector $Y = (y_0, y_1, y_2, \dots , y_{\text{Nmax-1}})$ is defined by:

     $y_{H(q)} = y'_q$ for even symbols for $q = 0, \dots , N_{max} - 1$

     $y_q = y'_{H(q)}$ for odd symbols for $q = 0, \dots , N_{max} - 1$

     where N_{max} = 1512 (2K mode), N_{max} = 6048 (8K mode), and N_{max} = 3024 (4K mode). The symbol index is from 0 to 67 in each frame.
   - In-depth symbol interleaving:

- When in-depth inner interleaver is selected, the symbol interleaver acts on blocks of 6048 data symbols, thus 48 groups of 126 data words from the bit interleaver are read sequentially into a vector $Y' = (y'_0, y'_1, y'_2, \ldots , y'_{6047})$.
- The interleaved vector $Y = (y_0, y_1, y_2, \ldots , y_{Nmax} - 1)$ is defined by:

  $y_{H(q)} = y'_q$ for even interleaved vectors for $q = 0, \ldots , N_{max} - 1$

  $y_q = y'_{H(q)}$ for odd interleaved vectors for $q = 0, \ldots , N_{max} - 1$

  where $N_{max} = 6048$, for mode 2K ,4K, or 8K.
- In the 2K mode, interleaved vectors are mapped onto four consecutive OFDM symbols. For even interleaved vectors these start with symbols 0, 8, 16, 24, etc.; for odd interleaved vectors these start with symbols 4, 12, 20, 28, etc. in every super-frame.
- In the 4K mode, interleaved vectors are mapped onto two consecutive OFDM symbols. For even interleaved vectors these start with symbols 0, 4, 8, 12, etc.; for odd interleaved vectors these start with symbols 2, 6, 10, 14, etc. in every super-frame.
- For 8K mode, the native and in-depth inner de-interleaving is the same.

* The permutation function represented by *H(q)* is defined by:

  $(N_r - 1)$ bit binary word R'_i is defined with $N_r = \log2 M_{max}$,

  where

  $M_{max} = 2048$ when $N_{max} = 1512$

  $M_{max} = 8192$ when $N_{max} = 6048$

  $M_{max} = 4096$ when $N_{max} = 3024$

  where R'_i takes the following values:

  i = 0,1: $R'_i [N_r - 2, N_r - 3, \ldots , 1, 0] = 0, 0, \ldots , 0, 0$

  i = 2: $R'_i [N_r - 2, N_r - 3, \ldots , 1, 0] = 0, 0, \ldots , 0, 1$

  $2 < i < M_{max}$: $\{R'_i [N_r - 3, N_r - 4, \ldots , 1, 0] = R'_i -1 [N_r -2, N_r -3, \ldots , 2, 1]$
  if $M_{max} = 2048$: $R'_i [N_r - 2] = (R'_{i-1} [0] + R'_{i-1} [3]) \bmod 2$

  if $M_{max} = 8192$: $R'_i [N_r - 2] = (R'_{i-1} [0] + \_R'_{i-1} [1] + R'_{i-1} [4] + R'_{i-1} [6]) \bmod 2$

  if $M_{max} = 4096$: $R'_i [N_r - 2] = (R'_{i-1} [0] + R'_{i-1} [2]) \bmod 2 \}$
* A vector R_i is derived from a vector R'_i by the bit permutations.

M_{max} = 2048	$R'_{[9..0]}$	= {R'_9, R'_8, R'_7, R'_6, R'_5, R'_4, R'_3, R'_2, R'_1, R'_0}
	$R_{[9..0]}$	= {R'_2, R'_5, R'_8, R'_3, R'_7, R'_0, R'_1, R'_4, R'_6, R'_9} = {R_9, R_8, R_7, R_6, R_5, R_4, R_3, R_2, R_1, R_0}
M_{max} = 8192	$R'_{[11..0]}$	= {R'_{11}, R'_{10}, R'_9, R'_8, R'_7, R'_6, R'_5, R'_4, R'_3, R'_2, R'_1, R'_0}
	$R_{[11..0]}$	= {R'_{10}, R'_7, R'_4, R'_6, R'_0, R'_5, R'_{11}, R'_2, R'_9, R'_3, R'_1, R'_8} = {R_{11}, R_{10}, R_9, R_8, R_7, R_6, R_5, R_4, R_3, R_2, R_1, R_0}
M_{max} = 4096	$R'_{[10..0]}$	= {R'_{10}, R'_9, R'_8, R'_7, R'_6, R'_5, R'_4, R'_3, R'_2, R'_1, R'_0}
	$R_{[10..0]}$	= {R'_9, R'_3, R'_7, R'_{10}, R'_0, R'_8, R'_4, R'_1, R'_5, R'_6, R'_2} = {R_{10}, R_9, R_8, R_7, R_6, R_5, R_4, R_3, R_2, R_1, R_0}

- The permutation function *H(q)* is determined by the algorithm:

  $q = 0;$
  for ($i = 0$; i < M_{max}; $i = i + 1$)

  $$\{H(q) = (i \mod 2) \times 2^{N_r - 1} + \sum_{i=0}^{N_r - 2} R_i(j) \times 2^j;$$

  $$\text{if } (H(q) < N_{max})\ q = q + 1; \}$$

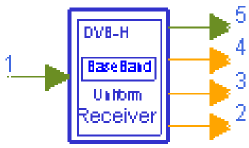
- Similar to *y*, *y*' is made up of v bits:
  $y'_{q'} = (y'_{0,q'}, y'_{1,q'}, \ldots, y'_{v-1,q'})$
  where *q*' is the symbol number at the output of the symbol interleaver.
  These y values are used to map data into the signal constellation.

6. For non-hierarchical transmission, pin 1 must not be connected.

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.5.1, European Telecommunication Standard, November 2004.

DTV_DVBHReceiver



Description: DVB-H baseband receiver
Library: DTV, DVB-H
Class: SDFDTV_DVBHReceiver

Parameters

Name	Description	Default	Unit	Type	Range
Mode	Transmission mode: Mode 2K, Mode 8K, Mode 4K	Mode 4K		enum	
OversamplingOption	Oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	
GuardInterval	Guard interval (frac FFT size)	1/32		int	[0, 1]
CodeRate	Convolutional code rate: DTV 1/2, DTV 2/3, DTV 3/4, DTV 5/6, DTV 7/8	DTV 1/2		enum	
MappingMode	Signal constellations and mapping: QPSK, QAM-16, QAM-64	QPSK		enum	
InnerInterlv	Inner interleaving type: Native, In-depth	In-depth		enum	
SoftDecision	Soft decision viterbi decoding type: Soft, Hard, Cochannel	Soft		enum	
TrunLen	Path memory truncation length of viterbi decoding algorithm, in bytes	10		int	[5, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	Rx_Signal	received OFDM signal to be demodulated	complex

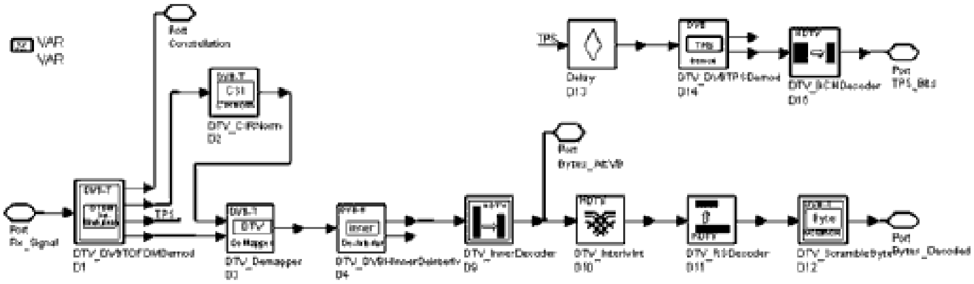
Pin Outputs

Pin	Name	Description	Signal Type
2	Bytes_Decoded	decoded bytes after Reed Solomon decoder	int
3	Bytes_AftVB	decoded bytes after Viterbi decoder	int
4	TPS_Bits	decoded TPS information bits	int
5	Constellation	constellation signal after OFDM demodulation	complex

Notes/Equations

1. This subnetwork model implements a DVB-H baseband receiver function based on the DVB-H Standard. The schematic is shown below.

DTV_DVBHReceiver Schematic



2. Implementation
    - Start of OFDM symbol is detected. In the DTV_DVBTOFDMDemod subnetwork:
        - DTV_MLEstimator calculates the correlation based on guard interval, and DTV_LoadFFTBuff selects the index with the maximum correlation value as the start of FFT.
        - Complex channel impulse response are estimated on continual and scattered pilot subcarriers. The channel impulse responses of data subcarriers are interpolated based on the estimated CIR. This function is implemented by DTV_DVB2DChEstimator.
        - Each subcarrier value is divided by a complex estimated channel response coefficient. This simple one-tap frequency domain channel response compensation is implemented by DTV_OFDMEqualizer.
        - After equalization, DTV_DVBDemuxOFDMSym demultiplexes 1705, 3409, or 6817 subcarriers into 1512 (2K mode), 3024 (4K mode), or 6048 (8K mode) data subcarriers and 1 demodulated TPS.
    - The demodulated data subcarriers (QPSK, 16-QAM or 64-QAM modulated) are demapped by DTV_Demapper.
    - Demodulated soft bits are deinterleaved by DTV_DVBHInnerDeinterlv.
    - De-interleaved bits are inner decoded (DTV_InnerDecoder), outer de-interleaved (DTV_InterlvInt), outer decoded (DTV_RSDecoder), and descrambled (DTV_ScrambleByte).
    - Fully decoded stream bytes are output as Bytes_Decoded; partially decoded stream bytes after inner decoding are output as Bytes_AftVB.
    - The TPS signal is demodulated by DTV_DVBTPSDemod and the demodulated bits are decoded by DTV_BCHDecoder.
    - The output pins of this receiver correspond to those of DTV_DVBHSignalSrc.
    - The number of samples of each OFDM symbol (Rx_Signal input pin) is:
        - (1+GuardInterval)×2048×OversamplingOption for 2K mode
        - (1+GuardInterval)×4096×OversamplingOption for 4K mode
        - (1+GuardInterval)×8192×OversamplingOption for 8K mode
    - The number of Constellation output pin is 1705 (2K mode), 3409 (4K mode), or 6817 (8K mode) per OFDM symbol.
3. Parameter Details
   Mode is used to select transmission mode of 2K, 4K, or 8K as defined in DVB-H.
   OversamplingOption specifies the oversampling ratio of the transmission signal. Oversampling ratios 1, 2, 4, 8, 16, 32 are supported in this source. If OversamplingOption = Ratio 2, the IFFT size is 4096 (2K mode), 8192 (4K mode), or 16384 (8K mode).
   GuardInterval specifies the guard interval (also called cyclic extension) length for each symbol, as a fraction of the FFT time period. Guard interval value of the corresponding receiver must match the guard interval length actually used in the input signal in order for the demodulation to work properly. It takes the value of 1/32, 1/16, 1/8 or 1/4 for DVB-H.
   CodeRate is defined as convolutional code rate. Code rates 1/2, 2/3, 3/4, 5/6 and 7/8

are available in this source.
MappingMode specifies signal constellations and mapping: QPSK, 16-QAM or 64-QAM.
SoftDecision specifies the Viterbi decoding algorithm mode.

If SoftDecision=Soft, the Viterbi decoding algorithm is a soft decision decoder and uses channel status information.

If SoftDecision=Hard, the Viterbi decoding algorithm is a hard decision decoder and does not use channel status information.

If SoftDecision=Cochannel, the Viterbi decoding algorithm is for co-channel measurement with PAL analog TV and digital DVB-T.

TrunLen sets truncation length (in bytes) in the Viterbi decoding algorithm. The path memory is 8 × TrunLen bits in the Viterbi decoding algorithm.

4. Output Pin Delay Adjustment
There are different delays in different output pins.
The Constellation pin has 8 OFDM symbol delay. The 8 × 1705 (2K mode), 8 × 3409 (4K mode) or 8 × 6817 (8K mode) constellation output signals are not used for EVM calculation.
DTV_BCHDecoder uses a 68-bit block. So a Delay component with N=60 is inserted before DTV_DVBTPSDemod. Pin TPS_Bits has one DVB-H frame (68 OFDM symbols) delay. The first 53 bits at TPS_Bits are not used.
Viterbi decoding introduces different delays for different path memory truncation lengths (TrunLen parameter). For synchronization in BER measurements, the delay between byte-interleaver and byte de-interleaver must be adjusted to a multiple of 12 bytes, the delay between randomizer and de-randomizer must be adjusted to a multiple of 204 bytes; both delays in this model are adjusted to a multiple of 204 bytes.
The information bytes per one OFDM symbol in Bytes_AftVB is calculated as follows:

DataPerOFDMSymbol=1512 (2K mode), 3024 (4K mode), or 6048 (8K mode)
CodedBlockSize=204
CR = 1/2, 2/3, 3/4, 5/6 or 7/8
InfoBytes=MapRate×CR×DataPerOFDMSymbol/8
DTV_DelayOFDMSymbols=8

The delay of Bytes_AftVB is Delay_AftVB, calculated as follows:

DelayBytes=DTV_DelayOFDMSymbols× InfoBytes-(int(DelayOFDMSymbols×InfoBytes/CodedBlockSize))×CodedBlockSize,
N=int((TrunLen+DelayBytes)/CodedBlockSize)
Delay_AftVB=(1+int(DelayOFDMSymbols×InfoBytes/CodedBlockSize)+N) × CodedBlockSize.

N is used to deal with the situation in which sum of TrunLen and DelayBytes is over one block length.
The pin Bytes_Decoded has extra 11 transport MUX packets delays.
The delay of Bytes_Decoded is

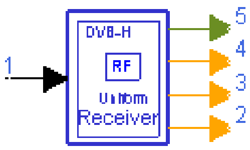
Delay_AftDescramble = (1+int(DelayOFDMSymbols×InfoBytes/CodedBlockSize)+N+11)×188.

5. When connecting the receiver to the signal source in MER and BER measurements, reference signal from the signal generator should be delayed according to the formula above.

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.5.1, European Telecommunication Standard, November 2004.

DTV_DVBHReceiver_RF



Description: DVB-H RF receiver
Library: DTV, DVB-H
Class: TSDFDTV_DVBHReceiver_RF

Parameters

Name	Description	Default	Unit	Type	Range
RIn	Input resistance	DefaultRIn	Ohm	real	(0, ∞)
RTemp	Physical temperature, in degrees C	DefaultRTemp	Celsius	real	[-273.15, ∞)
GainImbalance	Gain imbalance, Q vs I	0.0	dB	real	(-∞, ∞)
PhaseImbalance	Phase imbalance, Q vs I	0.0	deg	real	(-∞, ∞)
FCarrier	Carrier frequency	474.0MHz	Hz	real	(0, ∞)
Sensitivity	Voltage output sensitivity, Vout/Vin	1		real	(-∞, ∞)
Phase	Reference phase in degrees	0.0	deg	real	(-∞, ∞)
Mode	Transmission mode: Mode 2K, Mode 8K, Mode 4K	Mode 4K		enum	
OversamplingOption	Oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	
GuardInterval	Guard interval (frac FFT size)	1/32		int	[0, 1]
CodeRate	Convolutional code rate: DTV 1/2, DTV 2/3, DTV 3/4, DTV 5/6, DTV 7/8	DTV 1/2		enum	
MappingMode	Signal constellations and mapping: QPSK, QAM-16, QAM-64	QPSK		enum	
InnerInterlv	Inner interleaving type: Native, In-depth	In-depth		enum	
SoftDecision	Soft decision viterbi decoding type: Soft, Hard, Cochannel	Soft		enum	
TrunLen	Path memory truncation length of viterbi decoding algorithm, in bytes	10		int	[5, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	RF	received OFDM signal to be demodulated	timed

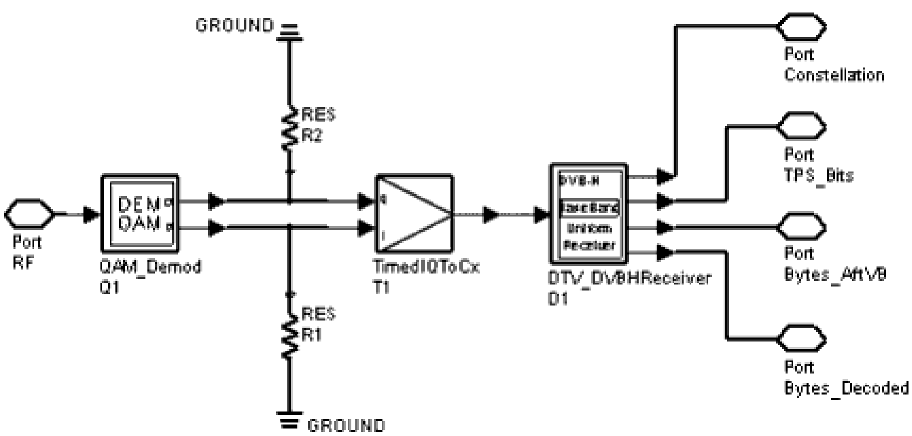
Pin Outputs

Pin	Name	Description	Signal Type
2	Bytes_Decoded	decoded bytes after Reed Solomon decoder	int
3	Bytes_AftVB	decoded bytes after Viterbi decoder	int
4	TPS_Bits	decoded TPS information bits	int
5	Constellation	constellation signal after OFDM demodulation	complex

Notes/Equations

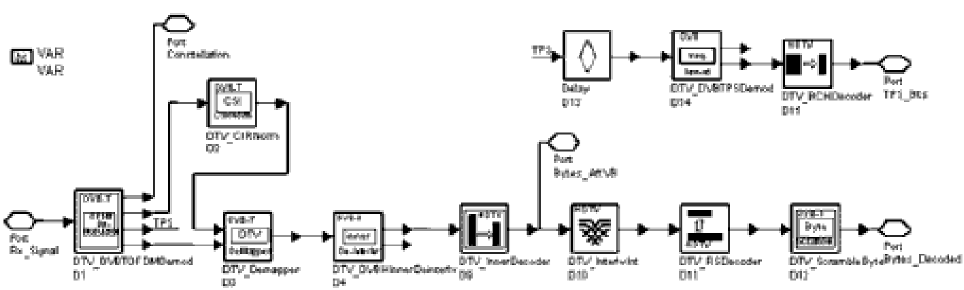
1. This subnetwork model implements a DVB-H RF non-hierarchical receiver function. The received RF signal is demodulated and the demodulated signal is fed into baseband receiver.
   The schematic for this subnetwork is shown below.

DTV_DVBHReceiver_RF Schematic



2. The schematic for the baseband receiver is shown below.

DTV_DVBHReceiver Schematic



3. Receiver functions, implemented according to the DVB-H Standard, are described here.
   - Start of OFDM symbol is detected. In the DTV_DVBTOFDMDemod subnetwork:
     - DTV_MLEstimator calculates the correlation based on guard interval, and DTV_LoadFFTBuff selects the index with the maximum correlation value as the start of FFT.
     - Complex channel impulse response are estimated on continual and scattered pilot subcarriers. The channel impulse responses of data subcarriers are interpolated based on the estimated CIR. This function is implemented by DTV_DVB2DChEstimator.
     - Each subcarrier value is divided by a complex estimated channel response coefficient. This simple one-tap frequency domain channel response compensation is implemented by DTV_OFDMEqualizer.
     - After equalization, DTV_DVBDemuxOFDMSym demultiplexes 1705, 3409,

or 6817 subcarriers into 1512 (2K mode), 3024 (4K mode), or 6048 (8K mode) data subcarriers and 1 demodulated TPS.

- The demodulated data subcarriers (16- or 64-QAM modulated) are demapped by DTV_Demapper.
- The demodulated soft bits are deinterleaved by DTV_DVBHInnerDeinterlv.
- De-interleaved bits are inner decoded (DTV_InnerDecoder), outer de-interleaved (DTV_InterlvInt), outer decoded (DTV_RSDecoder), and descrambled (DTV_ScrambleByte).
- Fully decoded stream bytes are output as Bytes_Decoded; partially decoded stream bytes after inner decoding are output as Bytes_AftVB.
- The TPS signal is demodulated by DTV_DVBTPSDemod and the demodulated bits are decoded by DTV_BCHDecoder.
- The output pins of this receiver correspond to DTV_DVBHSignalSrc.
- The number of samples of each OFDM symbol (Rx_Signal input pin) is:
  - (1+GuardInterval)×2048×OversamplingOption for 2K mode
  - (1+GuardInterval)×4096×OversamplingOption for 4K mode
  - (1+GuardInterval)×8192×OversamplingOption for 8K mode
- The number of Constellation output pin is 1705 (2K mode), 3409 (4K mode), or 6817 (8K mode) per OFDM symbol.

4. Parameter Details

GainImbalance and PhaseImbalance add certain impairments to the ideal output RF signal. Impairments are added in the order described here.

The unimpaired RF I and Q envelope voltages have gain and phase imbalance applied. The RF is given by:

$$V_3(t) = A\left(V_1(t)\cos(\omega_c t) - gV_2(t)\sin\left(\omega_c t + \frac{\phi\pi}{180}\right)\right)$$

where V_1 (t) is the in-phase RF envelope, V_2 (t) is the quadrature phase RF envelope, g is the gain imbalance

$$g = 10^{\frac{GainImbalance}{20}}$$

and, Φ (in degrees) is the phase imbalance.

FCarrier defines the RF frequency for the DVB signal.

Mode is used to select transmission mode of 2K, 4K, or 8K as defined in DVB-H.

OversamplingOption indicates the oversampling ratio of the transmission signal. Oversampling ratios 1, 2, 4, 8, 16, 32 are supported in this source. If OversamplingOption = Ratio 2, the IFFT size is 4096 (2K mode), 8192 (4K mode), or 16384 (8K mode).

GuardInterval specifies the guard interval (also called cyclic extension) length for each symbol, as a fraction of the FFT time period. Guard interval value of the corresponding receiver must match the guard interval length actually used in the input signal in order for the demodulation to work properly. It takes the value of 1/32, 1/16, 1/8 or 1/4 for DVB-H.

CodeRate is defined as convolutional code rate. Code rates 1/2, 2/3, 3/4, 5/6, and 7/8 are available in this source.

MappingMode specifies signal constellations and mapping: QPSK, 16-QAM or 64-QAM.

SoftDecision specifies the Viterbi decoding algorithm mode.

If SoftDecision=Soft, the Viterbi decoding algorithm is a soft decision decoder and uses channel status information.

If SoftDecision=Hard, the Viterbi decoding algorithm is a hard decision decoder and does not use channel status information.

If SoftDecision=Cochannel, the Viterbi decoding algorithm is for co-channel measurement with PAL analog TV and digital DVB-T.

TrunLen sets truncation length (in bytes) in the Viterbi decoding algorithm. The path memory is 8×TrunLen bits in the Viterbi decoding algorithm.

5. Output Pin Delay Adjustment
There are different delays in different output pins.
The Constellation pin has 8 OFDM symbol delay. The 8 × 1705 (2K mode), 8 × 3409 (4K mode) or 8 × 6817 (8K mode) constellation output signals are not used for EVM calculation.
DTV_BCHDecoder uses a 68-bit block. So a Delay component with N=60 is inserted before DTV_DVBTPSDemod. Pin TPS_Bits has one DVB-H frame (68 OFDM symbols) delay. The first 53 bits at TPS_Bits are not used.
Viterbi decoding introduces different delay for different path memory truncation length (TrunLen parameter). For synchronization in BER measurements, the delay between byte-interleaver and byte de-interleaver must be adjusted to a multiple of 12 bytes, the delay between randomizer and de-randomizer must be adjusted to a multiple of 204 bytes; both delays in this model are adjusted to a multiple of 204 bytes.
The information bytes per one OFDM symbol in Bytes_AftVB is calculated as follows:

    DataPerOFDMSymbol=1512 (2K mode), 3024 (4K mode), or 6048 (8K mode)
    CodedBlockSize=204
    CR = 1/2, 2/3, 3/4, 5/6 or 7/8,
    InfoBytes=MapRate×CR×DataPerOFDMSymbol/8
    DTV_DelayOFDMSymbols=8

The delay of Bytes_AftVB is Delay_AftVB, calculated as follows:

    DelayBytes=DTV_DelayOFDMSymbols× InfoBytes-(int(DelayOFDMSymbols×InfoBytes/CodedBlockSize))×CodedBlockSize,
    N=int((TrunLen+DelayBytes)/CodedBlockSize),
    Delay_AftVB=(1+int(DelayOFDMSymbols× InfoBytes/CodedBlockSize)+N) × CodedBlockSize.

N is used to deal with the situation in which sum of TrunLen and DelayBytes is over one block length.
The pin Bytes_Decoded has extra 11 transport MUX packets delays.
The delay of Bytes_Decoded is

    Delay_AftDescramble = (1+int(DelayOFDMSymbols×InfoBytes/CodedBlockSize)+N+11)×188.

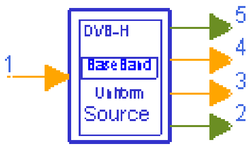
6. When connecting the receiver to the signal source in MER and BER measurements, reference signal from the signal generator should be delayed according to the formula above.

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and*

modulation for digital terrestrial television. EN300 744 v1.5.1, European Telecommunication Standard, November 2004.

DTV_DVBHSignalSrc



Description: DVB-H base-band non-hierarchical signal source
Library: DTV, DVB-H
Class: SDFDTV_DVBHSignalSrc

Parameters

Name	Description	Default	Unit	Type	Range
Mode	Transmission mode: Mode 2K, Mode 8K, Mode 4K	Mode 4K		enum	
OversamplingOption	Oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	
GuardInterval	Guard interval (frac FFT size)	1/32		real	[0, 1]
CodeRate	Convolutional code rate: DTV 1/2, DTV 2/3, DTV 3/4, DTV 5/6, DTV 7/8	DTV 1/2		enum	
MappingMode	Signal constellations and mapping: QPSK, QAM-16, QAM-64	QPSK		enum	
InnerInterlv	Inner interleaving type: Native, In-depth	In-depth		enum	
Cell_ID	Cell identifier	0		int	[0, 65535]
TimeSlicing	Time slicing for DVB-H signalling: TimeSlicing Not-used, TimeSlicing Used	TimeSlicing Not-used		enum	
MPE_FEC	MPE-FEC for DVB-H signalling: MPE_FEC Not-used, MPE_FEC used	MPE_FEC Not-used		enum	
TPSLength	TPS length indicator (23 for version 1.2.1, 31 for version 1.5.1, 33 for DVB-H)	33		int	[23, 37]

Pin Inputs

Pin	Name	Description	Signal Type
1	Data	Data input in byte	int

Pin Outputs

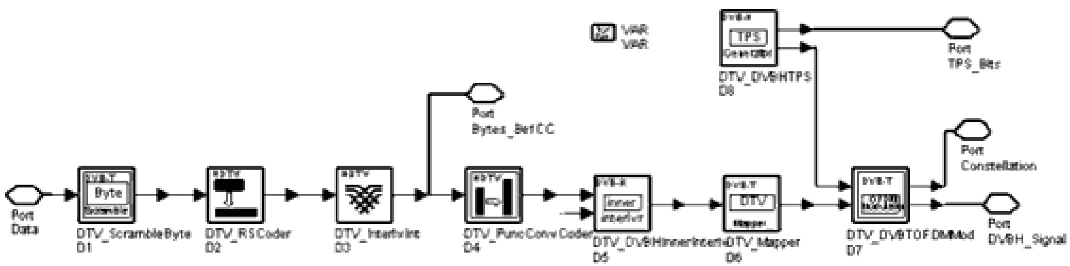
Pin	Name	Description	Signal Type
2	DVBH_Signal	DVBH base-band hierarchical signal	complex
3	Bytes_BefCC	bytes before convolutional encoder	int
4	TPS_Bits	TPS information bits	int
5	Constellation	constellation signal before IFFT	complex

Notes/Equations

1. This subnetwork model generates a DVB-H non-hierarchical baseband signal. The

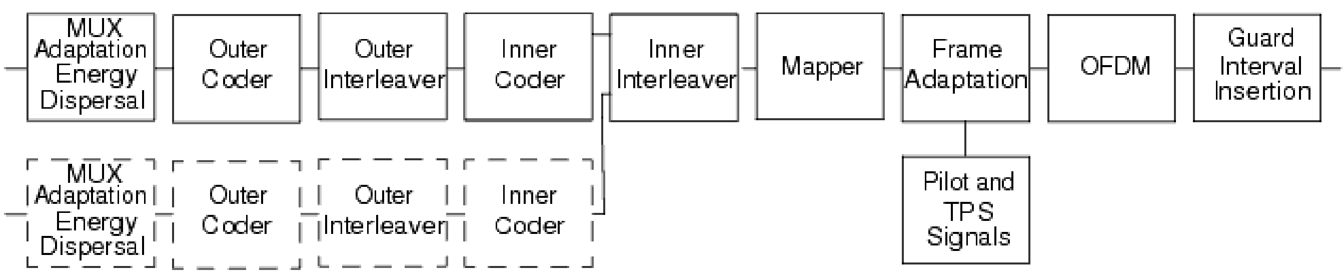
schematic for this subnetwork, shown below, includes: scrambler (DTV_ScrambleByte); outer coder (DTV_RSCoder); outer interleaver (DTV_InterlvInt); inner coder (DTV_PuncConvCoder); inner interleaver (DTV_DVBHInnerInterlv); mapper (DTV_Mapper); frame adaptation, OFDM, and guard interval insertion (DTV_DVBTOFDMMod subnetwork); and, TPS generator (DTV_DVBHTPS).

DTV_DVBHSignalSrc Schematic



2. The DVB-H signal source format follows the DVB specification. The figure below shows the functional block diagram of the DVB-H baseband system.

DVB-H Baseband System Block Diagram



When native inner interleaving is selected, the signal source generates one OFDM symbol each firing.
When in-depth inner interleaving is selected, the signal source generates 1 OFDM symbol in the 8K mode (that means in-depth inner interleaving does not affect 8K mode), 2 OFDM symbols in the 4K mode, and 4 OFDM symbols in the 2K mode.
Each OFDM symbol, the Constellation pin exports 1705 (2K mode), 3409 (4K mode), or 6817 (8K mode) particles.
The number of samples of each OFDM symbol (DVBH_Signal pin) is:

- (1+GuardInterval)×2048×OversamplingOption for 2K mode
- (1+GuardInterval)×4096×OversamplingOption for 4K mode
- (1+GuardInterval)×8192×OversamplingOption for 8K mode

3. Input of the subnetwork is transport stream (TS) defined in *MPEG-2 Systems*.
4. Parameter Details
Mode specifies a 2K, 4K or 8K transmission mode as defined in DVB-H specification.
OversamplingOption specifies the oversampling ratio of the transmission signal. Oversampling ratios 1, 2, 4, 8, 16, 32 are supported in this source. If OversamplingOption = Ratio 2, the IFFT size is 4096 (2K mode), 8192 (4K mode), or 16384 (8K mode).
GuardInterval specifies the guard interval (also called cyclic extension) length for

each symbol, as a fraction of the FFT time period. Guard interval value of the corresponding receiver must match the guard interval length actually used in the input signal in order for the demodulation to work properly. It takes the value of 1/32, 1/16, 1/8 or 1/4 for DVB-H.
CodeRate is defined as convolutional code rate. Code rates 1/2, 2/3, 3/4, 5/6 and 7/8 are available in this source.
MappingMode specifies signal constellations and mapping: QPSK, 16-QAM or 64-QAM.
Cell_ID specifies the cell from which the signal comes from, it should belong to [0, 65535]. If not used, it should be set zero.
TPS_Length specifies the number of TPS information bits based on ETSI EN 300744 specification:

23 (when cell identification information is not transmitted, MPE-FEC and Time Slicing information are not transmitted, DVB-T version 1.2.1).

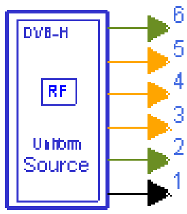
31 (when cell identification information is transmitted, MPE-FEC and Time Slicing information are not transmitted, DVB-T version 1.5.1).

33 (when cell identification information is transmitted, MPE-FEC and Time Slicing information are transmitted, DVB-T version 1.5.1).

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.5.1, European Telecommunication Standard, November 2004.

DTV_DVBHSignalSrc_RF



Description: DVB-H RF signal source
Library: DTV, DVB-H
Class: TSDFDTV_DVBHSignalSrc_RF

Parameters

Name	Description	Default	Unit	Type	Range
ROut	Output resistance	DefaultROut	Ohm	real	(0, ∞)
RTemp	Physical temperature, in degrees C	DefaultRTemp	Celsius	real	[-273.15, ∞)
FCarrier	Carrier frequency	474.0MHz	Hz	real	(0, ∞)
Power	Modulator output power	40mW	W	real	(0, ∞)
BasicSamplingRate	Basic sampling rate	(2048/224.0)MHz	Hz	real	(0, ∞)
MirrorSpectrum	Mirror spectrum about carrier?: NO, YES	NO		enum	
GainImbalance	Gain imbalance, Q vs I	0.0	dB	real	(-∞, ∞)
PhaseImbalance	Phase imbalance, Q vs I	0.0	deg	real	(-∞, ∞)
I_OriginOffset	I origin offset (percent)	0.0		real	(-∞, ∞)
Q_OriginOffset	Q origin offset (percent)	0.0		real	(-∞, ∞)
IQ_Rotation	IQ rotation	0.0	deg	real	(-∞, ∞)
Mode	Transmission mode: Mode 2K, Mode 8K, Mode 4K	Mode 4K		enum	
OversamplingOption	Oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	
GuardInterval	Guard interval (frac FFT size)	1/32		real	[0, 1]
CodeRate	Convolutional code rate: DTV 1/2, DTV 2/3, DTV 3/4, DTV 5/6, DTV 7/8	DTV 1/2		enum	
MappingMode	Signal constellations and mapping: QPSK, QAM-16, QAM-64	QPSK		enum	
InnerInterlv	Inner interleaving type: Native, In-depth	In-depth		enum	
Cell_ID	Cell identifier	0		int	[0, 65535]
TimeSlicing	Time slicing for DVB-H signalling: TimeSlicing Not-used, TimeSlicing Used	TimeSlicing Not-used		enum	
MPE_FEC	MPE-FEC for DVB-H signalling: MPE_FEC Not-used, MPE_FEC used	MPE_FEC Not-used		enum	
TPSLength	TPS length indicator (23 for version 1.2.1, 31 for version 1.5.1, 33 for DVB-H)	33		int	[23, 37]
DataType	Payload data type: PN9, PN15, FIX4, _4_1_4_0, _8_1_8_0, _16_1_16_0, _32_1_32_0, _64_1_64_0	PN9		enum	

Pin Outputs

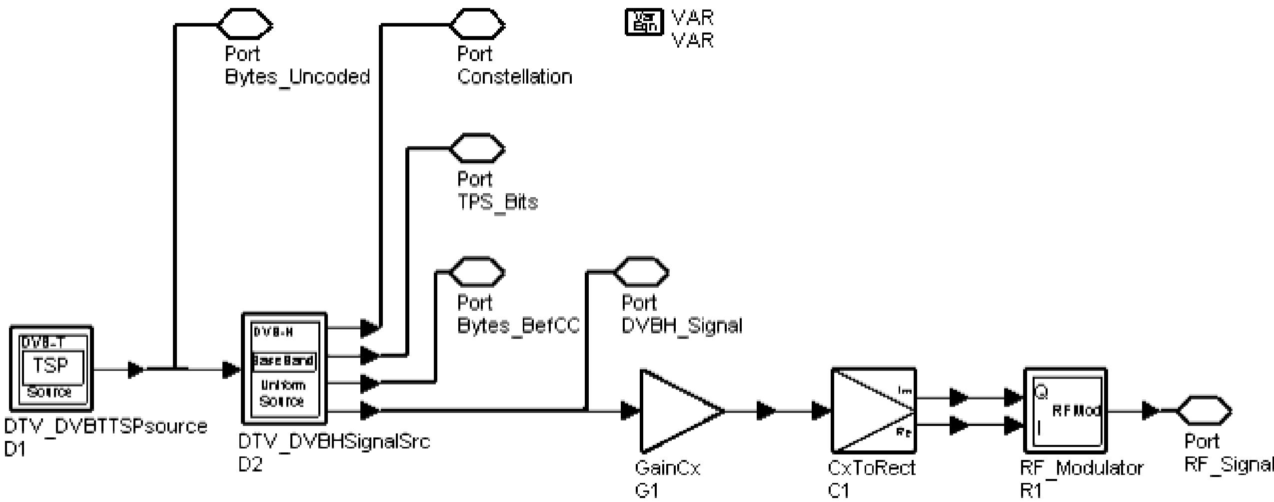
Pin	Name	Description	Signal Type
1	RF	RF signal	timed
2	DVBH_Signal	DVB-H base-band signal	complex
3	Bytes_Uncoded	information bytes of transport packet	int
4	Bytes_BefCC	information bytes before convolutional coder	int
5	TPS_Bits	TPS bits	int
6	Constellation	constellation signal before IFFT	complex

Notes/Equations

1. This subnetwork model integrates an RF modulator and a DVB-H non-hierarchical baseband signal source. The schematic for this subnetwork is shown below. The baseband signal is fed to the RF modulator; after RF modulation the timed signal is

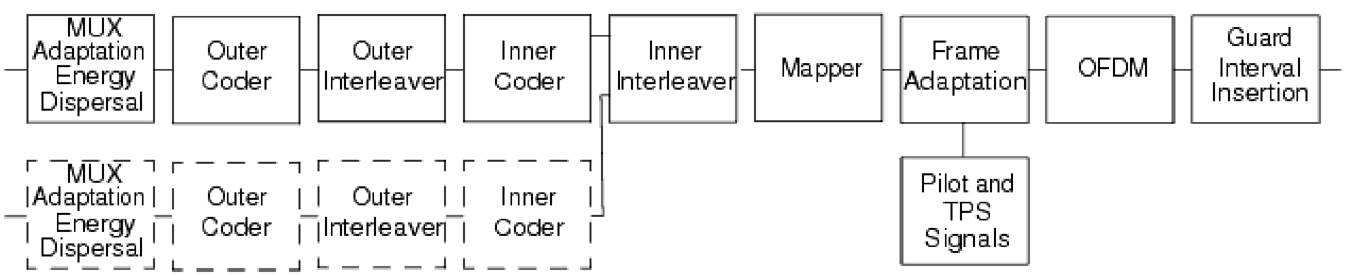
exported.

DTV_DVBHSignalSrc_RF Schematic



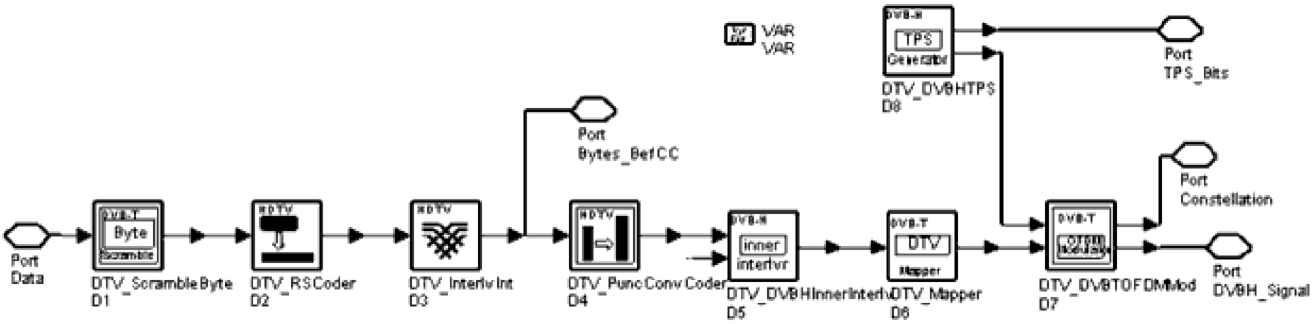
2. The DVB-H signal source format follows the DVB specification. The figure below shows the functional block diagram of the DVB-H baseband system.

DVB-H Baseband System Block Diagram



3. The schematic for baseband signal source DTV_DVBHSignalSrc is shown below; it includes: scrambler (DTV_ScrambleByte); outer coder (DTV_RSCoder); outer interleaver (DTV_InterlvInt); inner coder (DTV_PuncConvCoder); inner interleaver (DTV_DVBHInnerInterlv); mapper (DTV_Mapper); frame adaptation, OFDM, and guard interval insertion (DTV_DVBTOFDMMod subnetwork); and, TPS generator (DTV_DVBHTPS).

DTV_DVBHSignalSrc Schematic



When native inner interleaving is selected, the signal source generates one OFDM symbol each firing.
When in-depth inner interleaving is selected, the signal source generates 1 OFDM symbol in the 8K mode (that means in-depth inner interleaving does not affect 8K mode), 2 OFDM symbols in the 4K mode, and 4 OFDM symbols in the 2K mode.
Each OFDM symbol, the *Constellation* pin outputs 1705 (2K mode), 3409 (4K mode), or 6817 (8K mode) particles.
The number of samples of each OFDM symbol (*DVBH_signal* pin) is:

- (1+GuardInterval)×2048×OversamplingOption for 2K mode
- (1+GuardInterval)×4096×OversamplingOption for 4K mode
- (1+GuardInterval)×8192×OversamplingOption for 8K mode

4. Baseband Parameter Details
Mode specifies a 2K, 4K, or 8K transmission mode as defined in DVB-H specification.
OversamplingOption specifies the oversampling ratio of the transmission signal. Oversampling ratios 1, 2, 4, 8, 16, 32 are supported in this source. If OversamplingOption = Ratio 2, the IFFT size is 4096 (2K mode), 8192 (4K mode), or 16384 (8K mode).
GuardInterval specifies the guard interval (also called cyclic extension) length for each symbol, as a fraction of the FFT time period. Guard interval value of the corresponding receiver must match the guard interval length actually used in the input signal in order for the demodulation to work properly. It takes the value of 1/32, 1/16, 1/8 or 1/4 for DVB-H.
CodeRate is defined as convolutional code rate. Code rates 1/2, 2/3, 3/4, 5/6 and 7/8 are available in this source.
MappingMode specifies signal constellations and mapping: QPSK, 16-QAM or 64-QAM.
Cell_ID specifies the cell from which the signal comes from, it should belong to [0, 65535]. If not used, it should be set zero.
TPS_Length specifies the number of TPS information bits based on ETSI EN 300744 specification:

23 (when cell identification information is not transmitted, MPE-FEC and Time Slicing information are not transmitted, DVB-T version 1.2.1).

31 (when cell identification information is transmitted, MPE-FEC and Time Slicing information are not transmitted, DVB-T version 1.5.1).

33 (when cell identification information is transmitted, MPE-FEC and Time Slicing information are transmitted, DVB-T version 1.5.1).

For the *DataType* parameter:

- if PN9 is selected, a 511-bit pseudo-random test pattern is generated according

to CCITT Recommendation O.153
- if PN15 is selected, a 32767-bit pseudo-random test pattern is generated according to CCITT Recommendation O.151
- if FIX4 is selected, a zero-stream is generated
- if x_1_x_0 is selected, where x equals 4, 8, 16, 32, or 64, a periodic bit stream is generated, with the period being 2x. In one period, the first x bits are 1s and the second x bits are 0s.

5. RF parameter details
FCarrier defines the RF frequency for the DVB signal.
Power defines the power level for FCarrier.
BasicSamplingRate indicates the sampling rate of baseband signal, the corresponding bandwidth of the RF signal is: BasicSamplingRate×1705/2048 (2K mode), BasicSamplingRate×3409/4096 (4K mode), or BasicSamplingRate×6817/8192 (8K mode).
The MirrorSpectrum (when set to YES) conjugates the input signal before any other processing is done.
The GainImbalance, PhaseImbalance, I_OriginOffset, Q_OriginOffset, and IQ_Rotation parameters add certain impairments to the ideal output RF signal. Impairments are added in the order described here.
The unimpaired RF I and Q envelope voltages have gain and phase imbalance applied. The RF is given by:

$$V_3(t) = A\left(V_1(t)\cos(\omega_c t) - gV_2(t)\sin\left(\omega_c t + \frac{\phi\pi}{180}\right)\right)$$

where *A* is a scaling factor that depends on the Power and ROut parameters specified by the user, $V_1(t)$ is the in-phase RF envelope, $V_2(t)$ is the quadrature phase RF envelope, *g* is the gain imbalance

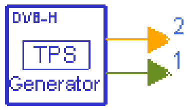
$$g = 10^{\frac{GainImbalance}{20}}$$

and, Φ (in degrees) is the phase imbalance.
The signal $V_3(t)$ is rotated by IQ_Rotation degrees; I_OriginOffset and Q_OriginOffset are then applied to the rotated signal. Note that the amounts specified are percentages with respect to the output rms voltage. The output rms voltage is given by sqrt(2×ROut×Power).

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.5.1, European Telecommunication Standard, November 2004.

DTV_DVBHTPS



Description: Modulated transmission parameter signal information
Library: DTV, DVB-H
Class: SDFDTV_DVBHTPS

Parameters

Name	Description	Default	Unit	Type	Range
LengthIndicator	TPS length indicator (23 for version 1.2.1, 31 for version 1.5.1, 33 for DVB-H, 6 bits)	33		int	[23, 37]
Constellation	Modulation scheme in DVB-H (2 bits): QPSK, QAM-16, QAM-64, Reserved Con	QPSK		enum	
InnerInterlv	Inner interleave type (1 bit): Native, In-depth	In-depth		enum	
Hierarchy	Signalling format for alpha values (2 bits): Non-hierarchical, Alpha 1, Alpha 2, Alpha 4	Non-hierarchical		enum	
CodeRateHP	High priority stream current convolutional code rate (3 bits): HP 1/2, HP 2/3, HP 3/4, HP 5/6, HP 7/8, Reserved C1 HP, Reserved C2 HP, Reserved C3 HP	HP 1/2		enum	
CodeRateLP	Low priority stream current convolutional code rate (3 bits): LP 1/2, LP 2/3, LP 3/4, LP 5/6, LP 7/8, Reserved C1 LP, Reserved C2 LP, Reserved C3 LP	LP 1/2		enum	
GuardInterval	Guard interval (frac FFT size, 2 bits): G 1/32, G 1/16, G 1/8, G 1/4	G 1/32		enum	
Mode	Transmission mode (2 bits): DVB 2k mode, DVB 8k mode, DVB 4k mode, Reserved M	DVB 4k mode		enum	
Cell_ID	Cell identifier (between 0 and 65535, 8 bits x2)	0		int	[0, 65535]
TimeSlicing	Time slicing for DVB-H signalling (1 bit): TimeSlicing Not-used, TimeSlicing Used	TimeSlicing Not-used		enum	
MPE_FEC	MPE-FEC for DVB-H signalling (1 bit): MPE_FEC Not-used, MPE_FEC used	MPE_FEC Not-used		enum	
FutureUse	reserved for future use (by default, all 4 bits are set to 0)	0 0 0 0		int array	
TPS_BitsOption	Select output type for pin TPS_Bits: Info 53Bits, Info 54Bits, Info 53 and Parity 14, Info 54 and Parity 14	Info 53Bits		enum	

Pin Outputs

Pin	Name	Description	Signal Type
1	TPS	TPS after BPSK modulation (68 particles per frame)	complex
2	TPS_Bits	TPS information bits	int

Notes/Equations

1. This model generates modulated transmission parameter signaling information used in TPS carriers in DVB-H OFDM symbols.
2. The TPS is defined over 68 consecutive OFDM symbols (referred to as one OFDM frame). Four consecutive frames correspond to one OFDM super-frame.
   The reference sequence corresponding to the TPS carriers of the first symbol of each OFDM frame is used to initialize the TPS modulation on each TPS carrier.
   Each OFDM symbol conveys one TPS bit. Each TPS block (corresponding to one OFDM frame) contains 68 bits, defined as:
   - 1 initialization bit
   - 16 synchronization bits
   - 37 information bits
     Only 33 of the 37 information bits are used, the remaining 4 bits are reserved for future use and are set to 0 by default.
   - 14 redundancy bits for error protection
3. TPS data generated is described here.
   The 53 original information bits (16 synchronization bits and 37 information bits) are appended 14 parity bits by BCH (67, 53, t=2) coder; therefore, a 67-bit sequence generated.
   The 67-bit sequence is then DBPSK modulated with an initialization bit 0.
   Each firing, 53 (see Parameter details section) original binary data is exported through the TPS_Bits pin, and the initialization bit 0 with the corresponding 67 DBPSK modulated bits are exported through the TPS pin (modulated data is converted to non-return-to-zero data before export, i.e. 0 to 1 and 1 to -1).
4. TPS bit assignments are listed in the table below.

TPS Signalling Information and Format

Bit Number	Format	Purpose/Content
S 0	0	Initialization bit for differential BPSK modulation
$S_1 - S_{16}$	0011010111101110 or 1100101000010001	Synchronization word (even frame and odd frame)
$S_{17} - S_{22}$	See TPS Length Indicator	Length indicator (starting from and including bit s17)
$S_{23} - S_{24}$	See Signalling Format for Frame Number	Frame number
$S_{25} - S_{26}$	See Signalling Format for the Possible Constellation Patterns	Constellation
S_{27}	See Signal Format for Inner Interleaving and Values	Inner interleaving information
$S_{28} - S_{29}$	See Signal Format for Inner Interleaving and Values	Hierarchy information
$S_{30} - S_{32}$	See Signal Format for Each Code Rate	Code rate, HP stream
$S_{33} - S_{35}$	See Signal Format for Each Code Rate	Code rate, LP stream
$S_{36} - S_{37}$	See Signal Format for Each Guard Interval	Guard interval
$S_{38} - S_{39}$	See Signal Format for Transmission Mode	Transmission mode
$S_{40} - S_{47}$	See Mapping of cell_id on TPS Bits	Cell identifier
$S_{48} - S_{49}$	See DVB-H Service Indication	DVB-H service indication
$S_{50} - S_{53}$	all set to 0 by default	Reserved for future use
$S_{54} - S_{66}$	BCH code	Error protection

TPS Length Indicator

Bits S_{17} - S_{22}	TPS Length Indicator
010111	when Cell Identification information is not transmitted (23 TPS bits in use)
011111	when Cell Identification information is transmitted (31 TPS bits in use)
100001	when Cell identification and DVB-H signalling (MPE-FEC and Time Slicing information) is transmitted (33 TPS bits in use)

Signalling Format for Frame Number

Bits S_{23} - S_{24}	Frame Number
00	Frame number 1 in the super-frame
01	Frame number 2 in the super-frame
10	Frame number 3 in the super-frame
11	Frame number 4 in the super-frame

Signalling Format for the Possible Constellation Patterns

Signalling Format for the Possible Constellation Patterns

Bits S_{25} - S_{26}	**Constellation Characteristics**
00	QPSK
01	16-QAM
10	64-QAM
11	reserved

Signal Format for Inner Interleaving and α Values

Bits S_{27} - S_{29}	**In-depth Interleaver Information**	**α Value**
0xx	native interleaver	
1xx	in-depth interleaver	
x00		Non-hierarchical
x01		α = 1
x10		α = 2
x11		α = 3
NOTE: "x" means whatever bit state.		

Signal Format for Each Code Rate

Bits, S_{30} - S_{32} HP Stream, S_{33} - S_{35} LP Stream	**Code Rate**
000	1/2
001	2/3
010	3/4
011	5/6
100	7/8
101	reserved
110	reserved
111	reserved

Signal Format for Each Guard Interval

Bits S_{36} - S_{37}	**Guard Interval Values**
00	1/32
01	1/16
10	1/8
11	1/4

Signal Format for Transmission Mode

Bits S_{38} - S_{39}	Transmission Mode
00	2K mode
01	8K mode
10	4K mode
11	reserved

Mapping of cell_id on TPS Bits

TPS Bit Number	Frame Number 1 or 3	Frame Number 2 or 4
S_{40}	cell_id b_{15}	cell_id b_7
S_{41}	cell_id b_{14}	cell_id b_6
S_{42}	cell_id b_{13}	cell_id b_5
S_{43}	cell_id b_{12}	cell_id b_4
S_{44}	cell_id b_{11}	cell_id b_3
S_{45}	cell_id b_{10}	cell_id b_2
S_{46}	cell_id b_9	cell_id b_1
S_{47}	cell_id b_8	cell_id b_0

DVB-H Service Indication

S_{48}	S_{49}	Transmission Mode
0 1	x x	Time Slicing is not used At least one elementary stream uses Time Slicing
x x	0 1	MPE-FEC not used At least one elementary stream uses MPE-FEC
x = any bit state		

5. Error Protection of TPS
   The 53 bits containing TPS synchronization and information (bits s_1 - s_{53}) are extended with 14 parity bits of the BCH (67, 53, t=2) shortened code, derived from the original systematic BCH (127, 113, t=2) code.
   The code generator polynomial is:
   $$h(x) = x^{14} + x^9 + x^8 + x^6 + x^5 + x^4 + x^2 + x + 1$$
   The shortened BCH code is implemented by adding 60 bits (all set to 0) before the information bits input of a BCH (127, 113, t=2) encoder. After BCH encoding these null bits are discarded, leaving a BCH code word of 67 bits.
6. TPS Modulation
   - TPS cells are transmitted at the *normal* power level, that is, they are transmitted with energy equal to that of the mean of all data cells, $E[c \times c^*] = 1$.

- Each TPS carrier is DBPSK modulated and conveys the same message. The DBPSK is initialized at the beginning of each TPS block.
- The following rule applies for the differential modulation of carrier k of symbol l (l > 0) in frame m:
    - if s_1 = 0, then
      $Re\{c_{m,l,k}\} = Re\{c_{m,l-1,k}\}$; $Im\{c_{m,l,k}\} = 0$
    - if s_1 = 1, then
      $Re\{c_{m,l,k}\} = -Re\{c_{m,l-1,k}\}$; $Im\{c_{m,l,k}\} = 0$
- Absolute modulation of TPS carriers in the first symbol in a frame is derived from the reference sequence w_k as follows:

$$Re\{c_{m,l,k}\} = 2\left(\frac{1}{2} - w_k\right)$$

$$Im\{c_{m,l,k}\} = 0$$

7. Parameter Details
   TPS_Length indicates the number of TPS information bits based on ETSI EN 300744 specification:

   23 (when cell identification information is not transmitted, MPE-FEC and Time Slicing information are not transmitted, DVB-T version 1.2.1).

   31 (when cell identification information is transmitted, MPE-FEC and Time Slicing information are not transmitted, DVB-T version 1.5.1).

   33 (when cell identification information is transmitted, MPE-FEC and Time Slicing information are transmitted, DVB-T version 1.5.1).

   TPS_BitsOption is used for the output type selection of pin *TPS_Bits*. "Info_53bits" means this pin will export s_1's_{53}, "Info 54bits" export s_0's_{53}, "Info 53 and Parity 14" export s_1's_{67}, and "Info 54 and Parity 14" export s_0's_{67}.

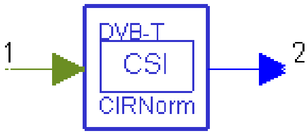
References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.5.1, European Telecommunication Standard, November 2004.

DVB-T Components

- *DTV CIRNorm* (dtv)
- *DTV DVB2DChEstimator* (dtv)
- *DTV DVBBitBlockInterlv* (dtv)
- *DTV DVBChannel* (dtv)
- *DTV DVBChEstimator* (dtv)
- *DTV DVBDemuxOFDMSym* (dtv)
- *DTV DVBLoadIFFTBuff* (dtv)
- *DTV DVBMuxOFDMSym* (dtv)
- *DTV DVBSymDeinterlv2b* (dtv)
- *DTV DVBSymDeinterlv4b* (dtv)
- *DTV DVBSymDeinterlv6b* (dtv)
- *DTV DVBSymInterlv2b* (dtv)
- *DTV DVBSymInterlv4b* (dtv)
- *DTV DVBSymInterlv6b* (dtv)
- *DTV DVBSymInterlvCx* (dtv)
- *DTV DVBTHierInnerDeInterlv* (dtv)
- *DTV DVBTHierInnerInterlv* (dtv)
- *DTV DVBTHierReceiver* (dtv)
- *DTV DVBTHierReceiver RF* (dtv)
- *DTV DVBTHierSignalSrc* (dtv)
- *DTV DVBTHierSignalSrc RF* (dtv)
- *DTV DVBTImpulseNoise* (dtv)
- *DTV DVBTInnerDeInterlv* (dtv)
- *DTV DVBTInnerInterlv* (dtv)
- *DTV DVBTOFDMDemod* (dtv)
- *DTV DVBTOFDMMod* (dtv)
- *DTV DVBTPS* (dtv)
- *DTV DVBTPSDemod* (dtv)
- *DTV DVBTPSMod* (dtv)
- *DTV DVBTReceiver* (dtv)
- *DTV DVBTReceiver RF* (dtv)
- *DTV DVBTSignalSrc* (dtv)
- *DTV DVBTSignalSrc RF* (dtv)
- *DTV DVBTTPSGen* (dtv)
- *DTV DVBTTSPsource* (dtv)
- *DTV PALSource* (dtv)

DTV_CIRNorm



Description: Soft output for soft decision decoder
Library: DTV, DVB-T
Class: SDFDTV_CIRNorm

Parameters

Name	Description	Default	Unit	Type	Range
Mode	transmission mode: DVB 2k mode, DVB 8k mode, DVB 4k mode	DVB 2k mode		enum	
SoftDecision	soft decision viterbi decoding type: Soft, Hard, Cochannel	Soft		enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	input	channel coefficient in active subcarriers	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	output	channel status information	real

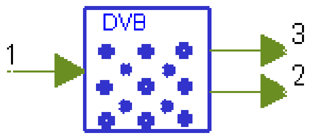
Notes/Equations

1. This model outputs soft information for a soft decision decoder. The input signal is the channel coefficient in active subcarriers (= H(i)).
   - When SoftDecision=Hard, the output signal is 1.0 in all active subcarriers.
   - When SoftDecision=Soft, the output signal is CSI (= $|H(i)|^2$ / Max ($|H(i)|^2$)) which is limited to [0, 1].
   - When SoftDecision=Cochannel, the 1.0 output in the subcarrier signal is slightly affected by the PAL co-channel analog signal; 0.0 in other subcarriers is severely affected by the PAL co-channel analog signal.
     The PAL analog signal bandwidth is 8 MHz.
     Each firing, 1512 (2K mode), 3024 (4K mode), or 6048 (8K mode) tokens are produced.

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.5.1, European Telecommunication Standard, November 2004.

DTV_DVB2DChEstimator



Description: Channel estimator and two-dimension channel interpolator for DVB-T
Library: DTV, DVB-T
Class: SDFDTV_DVB2DChEstimator

Parameters

Name	Description	Default	Unit	Type	Range
Carriers	number of carriers in one OFDM symbol	1705		int	1705 for 2k mode, 6817 for 8k mode, 3409 for 4k mode
Order	FFT points=2^Order	11		int	(0, ∞)†
SPperiod	distance in carriers between nearby scattered pilots	12		int	[0, ∞)††
SPstart	start position of scattered pilots in carriers	0		int	[0, ∞)††
SPoffset	offset value of scattered pilots in each symbol	3		int	[0, ∞)††
SPphase	initial phase of scattered pilots	0		int	[0, SPperiod/ SPoffset-1]
GuardInterval	guard interval (fractional FFT size)	1/4		real	[0, 1]

† Order is the order of FFT; it must satisfy $2^{Order} \geq$ Carriers
†† In DVB-T systems: SPperiod=12, SPstart=0, SPoffset=3

Pin Inputs

Pin	Name	Description	Signal Type
1	input	output signals from FFT	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	output	signals in active subcarriers	complex
3	Coef	channel coefficient in active subcarriers	complex

Notes/Equations

1. This model provides linear channel estimation and 2D channel interpolation using collected scattered pilots; data from the active subcarriers is output.
2. The number of IntState of Length determines the number of CP (continual pilot) and TPS in each symbol; the position of CP and TPS are determined according to Carrier Indices for Continual Pilot Carriers and Carrier Indices for TPS Carriers, respectively. PRBS sequences in each segment are generated according to Generation of PRBS Sequence; the initial sets of PRBS register is 11111111111. The PRBS is initialized so

that the first output bit from the PRBS coincides with the first active carrier. A new value is generated by the PRBS on every used carrier in each segment (whether or not it is a pilot).
Positions of the corresponding scattered pilots are generated as follows. For the symbol of index *l* (ranging from 0 to 67), carriers for which index *k* belongs to subset

$$\{k = K_{min} + 3 \times l \ mod \ 4 + 12p | p \ integer, p \geq 0, k \in [K_{min}, K_{max}]\}$$

are scattered pilot positions.
where *p* is an integer that takes all possible values ≥ 0, provided the resulting value for k does not exceed the valid range [K_{min}, K_{max}]; K_{min} = 0, and K_{max} = 1704 (2K mode), K_{max} = 3408 (4K mode), or 6816 (8K mode). SPperiod, SPstart, SPoffset and SPphase parameters control the scattered pilots positions.

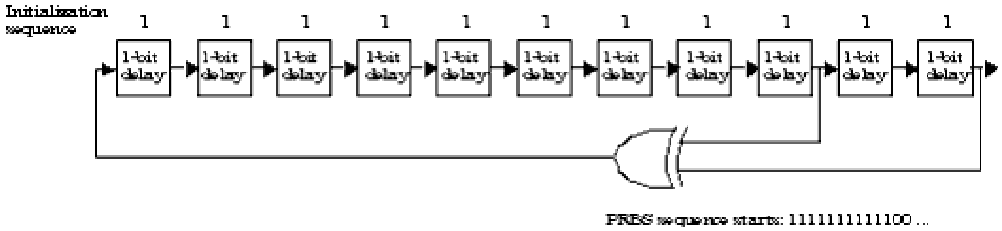
Carrier Indices for Continual Pilot Carriers

Continual pilot carrier positions (index number k)		
2K mode	**4K mode**	**8K mode**
0 48 54 87 141 156 192 201 255 279 282 333 432 450 483 525 531 618 636 714 759 765 780 804 873 888 918 939 942 969 984 1050 1101 1107 1110 1137 1140 1146 1206 1269 1323 1377 1491 1683 1704	0 48 54 87 141 156 192 201 255 279 282 333 432 450 483 525 531 618 636 714 759 765 780 804 873 888 918 939 942 969 984 1050 1101 1107 1110 1137 1140 1146 1206 1269 1323 1377 1491 1683 1704 1752 1758 1791 1845 1860 1896 1905 1959 1983 1986 2037 2136 2154 2187 2229 2235 2322 2340 2418 2463 2469 2484 2508 2577 2592 2622 2643 2646 2673 2688 2754 2805 2811 2814 28412844 2850 2910 2973 3027 3081 3195 3387 3408	0 48 54 87 141 156 192 201 255 279 282 333 432 450 483 525 531 618 636 714 759 765 780 804 873 888 918 939 942 969 984 1050 1101 1107 1110 1137 1140 1146 1206 1269 1323 1377 1491 1683 1704 1752 1758 1791 1845 1860 1896 1905 1959 1983 1986 2037 2136 2154 2187 2229 2235 2322 2340 2418 2463 2469 2484 2508 2577 2592 2622 2643 2646 2673 2688 2754 2805 2811 2814 28412844 2850 2910 2973 3027 3081 3195 3387 3408 3456 3462 3495 3549 3564 3600 3609 3663 3687 3690 3741 3840 3858 3891 3933 3939 4026 4044 4122 4167 4173 4188 4212 4281 4296 4326 4347 4350 4377 4392 4458 4509 4515 4518 4545 4548 4554 4614 4677 4731 4785 4899 5091 5112 5160 5166 5199 5253 5268 5304 5313 5367 5391 5394 5445 5544 5562 5595 5637 5643 5730 5748 5826 5871 5877 5892 5916 5985 6000 6030 6051 6054 6081 6096 6162 6213 6219 6222 6249 6252 6258 6318 6381 6435 6489 6603 6795 6816

Carrier Indices for TPS Carriers

2K mode	4K mode	8K mode
34 50 209 346 413 569 595 688 790 901 1073 1219 1262 1286 1469 1594 1687	34 50 209 346 413 569 595 688 790 901 1073 1219 1262 1286 1469 1594 1687 1738 1754 1913 2050 2117 2273 2299 2392 2494 2605 2777 2923 2966 2990 3173 3298 3391	34 50 209 346 413 569 595 688 790 901 1073 1219 1262 1286 1469 1594 1687 1738 1754 1913 2050 2117 2273 2299 2392 2494 2605 2777 2923 2966 2990 3173 3298 3391 3442 3458 3617 3754 3821 3977 4003 4096 4198 4309 4481 4627 4670 4694 4877 5002 5095 5146 5162 5321 5458 5525 5681 5707 5800 5902 6013 6185 6331 6374 6398 6581 6706 6799

Generation of PRBS Sequence



After determining all CP, TPS, and SP positions in each symbol and the value of the PRBS sequence in all active carriers in symbol, this model demultiplexes input data into TPS and TSP data. According to the TPS position and the PRBS sequence, one TPS bit in each TPS position is output.

The channel on current symbol is estimated by utilizing four symbols which are current symbol and previous three symbols. So, after determining all scattered pilots positions in four OFDM symbols, we get the pilot values from the PRBS sequence; channel estimation in scattered pilots can be determined by:

$$h(i) = \frac{x(i)}{PilotValue(i)}$$

where *h(i)* is the channel estimation, *x(i)* is the received signal from channel after FFT, and *PilotValue(i)* is the PRBS value corresponding to CP and SP positions in OFDM symbol.

From the subchannel estimation in the scattered pilots positions, we can use the linear interpolation algorithm for active subchannel estimations as follows:

$$h(k) = \alpha h(i) + (1-\alpha)h(j)$$

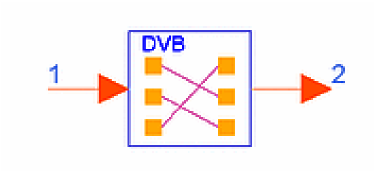
$$\alpha = \frac{j-k}{j-i}$$

where $i \le h \le j$, *h(i)*, and *h(j)* are the subchannel estimations of scattered pilots which are located in different OFDM symbols and dependent on SPphase parameter. The active carriers and corresponding subchannel carriers are output for use in the equalizer model. The inserted zeros in DTV_DVBLoadIFFTBuff are discarded.

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.5.1, European Telecommunication Standard, November 2004.

DTV_DVBBitBlockInterlv



Description: DVB bit interleaver
Library: DTV, DVB-T
Class: SDFDTV_DVBBitBlockInterlv

Parameters

Name	Description	Default	Unit	Type	Range
BlockSize	size of bit block to be interleaved	126		int	(0, ∞)
Offset	offset of permutation in interleaver	0		int	(0, BlockSize)
Option	operation option: Interleaving, De-interleaving	Interleaving		enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	input	input data bits	anytype

Pin Outputs

Pin	Name	Description	Signal Type
2	output	interleaved OFDM symbols	anytype

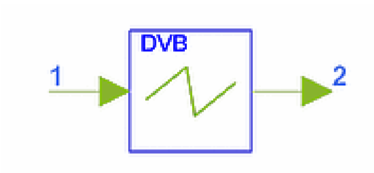
Notes/Equations

1. This model performs bit block interleaving in DVB-T systems. The bit interleaving block size is 126 bits in DVB-T systems. The block interleaving process is repeated 12 times per OFDM symbol of useful data in the 2K mode and 48 times per OFDM symbol in the 8K mode.
   Each firing, this model consumes BlockSize points of input data and produces the same amount of output data.

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.

DTV_DVBChannel



Description: DVB channel model for transmission
Library: DTV, DVB-T
Class: SDFDTV_DVBChannel

Parameters

Name	Description	Default	Unit	Type	Range
ChannelModel	test path environment: Fixed Reception F1, Portable Reception P1	Fixed Reception F1		enum	
SampleTime	time interval per symbol	0.123046875e-6	sec	real	(0, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	in	input signal to channel	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	out	output signal from channel	complex

Notes/Equations

1. This model is a multipath fading channel with 20 reflected paths to simulate the baseband. It is described in the DVB-T specification for performance evaluation.
2. The channel models were generated based on the following equations where *x(t)* and *y(t)* are input and output signals, respectively.
   Fixed Reception F1
   The relationship of the output signal *y(t)* and input signal *x(t)* is:

$$y(t) = \frac{\rho_0 x(t) + \sum_{i=1}^{N} \rho_i e^{-j2\pi\theta_i} x(t-\tau_i)}{\sqrt{\sum_{i=0}^{N} \rho_i^2}}$$

   where

   The first term before the sum represents the line of sight ray

   N is the number of echoes equal to 20

Θ_i is the phase shift from scattering of the *i* th path (listed in Attenuation, Phase, and Delay Values for F1 and P1)

P_i is the attenuation of the *i* th path (listed in Attenuation, Phase, and Delay Values for F1 and P1)

T_i is the relative delay of the *i* th path (listed in Attenuation, Phase, and Delay Values for F1 and P1)

The Rician factor K (ratio of line of sight ray to reflected paths) is:

$$K = \frac{\rho_0^2}{\sum_{i=1}^{N} \rho_i^2}$$

In simulations, a Rician factor *K* =10 dB has been used:

$$\rho_0 = \sqrt{10 \sum_{i=1}^{N} \rho_i^2}$$

Portable Reception P1, Rayleigh fading

$$y(t) = k \sum_{i=1}^{N} \rho_i e^{-j2\pi\theta_i} x(t-\tau_i)$$

where

$$k = \frac{1}{\sqrt{\sum_{i=1}^{N} \rho_i^2}}$$

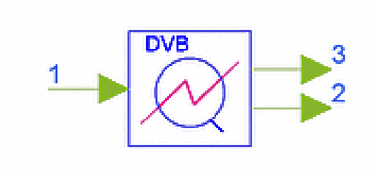
Attenuation, Phase, and Delay Values for F1 and P1

i	P_i	T_i[us]	Θ_i[rad]
1	0.057662	1.003019	4.855121
2	0.176809	5.422091	3.419109
3	0.407163	0.518650	5.864470
4	0.303585	2.751772	2.215894
5	0.258782	0.602895	3.758058
6	0.061831	1.016585	5.430202
7	0.150340	0.143556	3.952093
8	0.051534	0.153832	1.093586
9	0.185074	3.324866	5.775198
10	0.400967	1.935570	0.154459
11	0.295723	0.429948	5.928383
12	0.350825	3.228872	3.053023
13	0.262909	0.848831	0.628578
14	0.225894	0.073883	2.128544
15	0.170996	0.203952	1.099463
16	0.149723	0.194207	3.462951
17	0.240140	0.924450	3.664773
18	0.116587	1.381320	2.833799
19	0.221155	0.640512	3.334290
20	0.259730	1.368671	0.393889

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.

DTV_DVBChEstimator



Description: Linear channel estimator and channel interpolator for DVB-T
Library: DTV, DVB-T
Class: SDFDTV_DVBChEstimator

Parameters

Name	Description	Default	Unit	Type	Range
Carriers	number of carriers in one OFDM symbol	1705		int	1705 for 2k mode, 6817 for 8k mode
Order	FFT points=2^Order	11		int	(0, ∞)†
SPperiod	distance in carriers between nearby scattered pilots	12		int	[0, ∞)††
SPstart	start position of scattered pilots in carriers	0		int	[0, ∞)††
SPoffset	offset value of scattered pilots in each symbol	3		int	[0, ∞)††
SPphase	initial phase of scattered pilots	0		int	[0, SPperiod/ SPoffset-1]†††

† Order is the order of FFT; it must satisfy $2^{Order} \geq$ Carriers
†† In DVB-T systems: SPperiod=12, SPstart=0, SPoffset=3
††† SPphase=3 in OFDM receiver (because DTV_MLEstimator makes one OFDM symbol delay).

Pin Inputs

Pin	Name	Description	Signal Type
1	input	output signals from FFT	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	output	signals in active subcarriers	complex
3	Coef	channel coefficient in active subcarriers	complex

Notes/Equations

1. This model provides linear channel estimation and channel interpolation based on the pilot channel; data from the active subcarriers is output.
2. The number of IntState of Length determines the number of CP (continual pilot) and TPS in each symbol; the position of CP and TPS are determined according to Carrier Indices for Continual Pilot Carriers and Carrier Indices for TPS Carriers, respectively.

Carrier Indices for Continual Pilot Carriers

Continual Pilot Carrier Positions (index number k)	
2K mode	**8K mode**
0 48 54 87 141 156 192 201 255 279 282 333 432 450 483 525 531 618 636 714 759 765 780 804 873 888 918 939 942 969 984 1050 1101 1107 1110 1137 1140 1146 1206 1269 1323 1377 1491 1683 1704	0 48 54 87 141 156 192 201 255 279 282 333 432 450 483 525 531 618 636 714 759 765 780 804 873 888 918 939 942 969 984 1050 1101 1107 1110 1137 1140 1146 1206 1269 1323 1377 1491 1683 1704 1752 1758 1791 1845 1860 1896 1905 1959 1983 1986 2037 2136 2154 2187 2229 2235 2322 2340 2418 2463 2469 2484 2508 2577 2592 2622 2643 2646 2673 2688 2754 2805 2811 2814 2841 2844 2850 2910 2973 3027 3081 3195 3387 3408 3456 3462 3495 3549 3564 3600 3609 3663 3687 3690 3741 3840 3858 3891 3933 3939 4026 4044 4122 4167 4173 4188 4212 4281 4296 4326 4347 4350 4377 4392 4458 4509 4515 4518 4545 4548 4554 4614 4677 4731 4785 4899 5091 5112 5160 5166 5199 5253 5268 5304 5313 5367 5391 5394 5445 5544 5562 5595 5637 5643 5730 5748 5826 5871 5877 5892 5916 5985 6000 6030 6051 6054 6081 6096 6162 6213 6219 6222 6249 6252 6258 6318 6381 6435 6489 6603 6795 6816

Carrier Indices for TPS Carriers

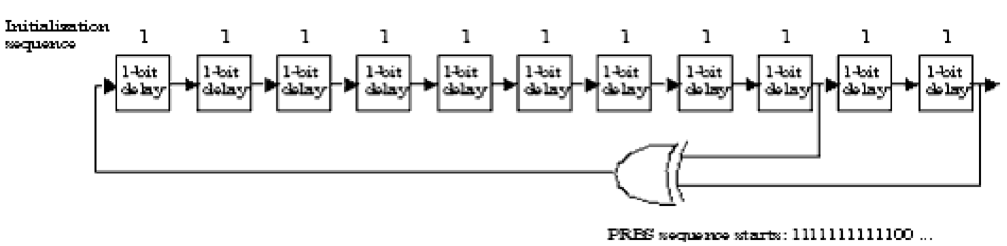
2K mode	8K mode
34 50 209 346 413 569 595 688 790 901 1073 1219 1262 1286 1469 1594 1687	34 50 209 346 413 569 595 688 790 901 1073 1219 1262 1286 1469 1594 1687 1738 1754 1913 2050 2117 2273 2299 2392 2494 2605 2777 2923 2966 2990 3173 3298 3391 3442 3458 3617 3754 3821 3977 4003 4096 4198 4309 4481 4627 4670 4694 4877 5002 5095 5146 5162 5321 5458 5525 5681 5707 5800 5902 6013 6185 6331 6374 6398 6581 6706 6799

PRBS sequences in each segment are generated according to Generation of PRBS Sequence; the initial sets of PRBS register is 11111111111. The PRBS is initialized so that the first output bit from the PRBS coincides with the first active carrier. A new value is generated by the PRBS on each carrier used in each segment (whether or not it is a pilot).
Positions of the corresponding scattered pilots are generated as follows. For the symbol of index *l* (ranging from 0 to 67), carriers for which index *k* belongs to subset

$$\{k = K_{min} + 3 \times l \ mod \ 4 + 12p \mid p \ \ integer, p \geq 0, k \in [K_{min}, K_{max}]\}$$

are scattered pilot positions.
where *p* is an integer that takes all possible values ≥ 0, provided the resulting value for k does not exceed the valid range $[K_{min}, K_{max}]$; $K_{min} = 0$, and $K_{max} = 1704$ (2K mode) or 6816 (8K mode). SPperiod, SPstart, SPoffset and SPphase parameters control the scattered pilots positions.

Generation of PRBS Sequence



After determining all CP, TPS, and SP positions in each symbol and the value of the PRBS sequence in all active carriers in symbol, this model demultiplexes input data into TPS and TSP data. According to the TPS position and the PRBS sequence, one TPS bit in each TPS position is output.

After determining all CP and SP positions in OFDM symbol, we get the pilot value from the PRBS sequence; channel estimation in CP and SP pilots can be determined:

$$h(i) = \frac{x(i)}{PilotValue(i)}$$

where *h(i)* is the channel estimation, *x(i)* is the received signal from channel after FFT, and *PilotValue(i)* is the PRBS value corresponding to CP and SP positions in OFDM symbol.

From the subchannel estimation in the CP and SP pilots position, we use the linear interpolation algorithm for active subchannel estimations as follows:

$$h(k) = \alpha h(i) + (1-\alpha)h(j)$$

$$\alpha = \frac{j-k}{j-i}$$

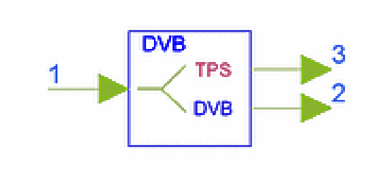
where $i \le h \le j$, *h(i)*, and *h(j)* are the subchannel estimations of CP or SP pilots.

The active carriers and corresponding subchannel carriers are output for use in the equalizer model. The inserted zeros in DTV_DVBLoadIFFTBuff are discarded.

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.

DTV_DVBDemuxOFDMSym



Description: Data and TPS demux for DVB-T symbol
Library: DTV, DVB-T
Class: SDFDTV_DVBDemuxOFDMSym

Parameters

Name	Description	Default	Unit	Type	Range
Carriers	number of carriers in one OFDM symbol	1705		int	1705 for 2k mode; 6817 for 8k mode; 3409 for 4k mode
Data	number of input data in one OFDM symbol	1512		int	1512 for 2k mode; 6048 for 8k mode; 3024 for 4k mode
SPperiod	distance in carriers between nearby scattered pilots	12		int	[0, ∞)†
SPstart	start position of scattered pilots in carriers	0		int	[0, ∞)†
SPoffset	offset value of scattered pilots in each symbol	3		int	[0, ∞)†
SPphase	initial phase of scattered pilots	0		int	[0, SPperiod/ SPoffset-1]††

† In DVB-T systems: SPperiod=12, SPstart=0, SPoffset=3
†† SPphase=3 in the OFDM receiver (because DTV_MLEstimator makes one OFDM symbol delay).

Pin Inputs

Pin	Name	Description	Signal Type
1	input	equalized signals before de-multiplexer	complex

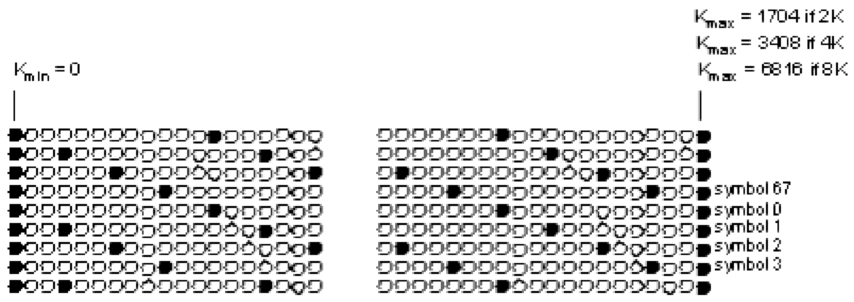
Pin Outputs

Pin	Name	Description	Signal Type
2	data	OFDM demodulation data	complex
3	TPS	OFDM demodulation TPS	complex

Notes/Equations

1. This model demultiplexes DVB-T OFDM symbols (such as QPSK, 16- QAM, and 64-QAM modulation) into TSP (transport stream packet) data, TPS (transmission parameter signal) data. The figure below shows the frame structure.

Frame Structure



2. The number of IntState of Length determines the number of CP (continual pilot) and TPS in each symbol; the position of CP and TPS are determined according to Carrier Indices for Continual Pilot Carriers and Carrier Indices for TPS Carriers, respectively. PRBS sequences in each segment are generated according to PRBS Sequence Generation; the initial sets of PRBS register is 11111111111. The PRBS in initialized so that the first output bit from the PRBS coincides with the first active carrier. A new value is generated by the PRBS on each carrier used in each segment (whether or not it is a pilot).
   Positions of the corresponding scattered pilots are generated as follows. For the symbol of index *l* (ranging from 0 to 67), carriers for which index *k* belongs to subset
   $$\{k = K_{min} + 3 \times l \ mod \ 4 + 12p | p \ integer, p \geq 0, k \in [K_{min}, K_{max}]\}$$
   are scattered pilots positions.
   where *p* is an integer that takes all possible values ≥ 0, provided the resulting value for k does not exceed the valid range [K_{min}, K_{max}]; K_{min} = 0, and K_{max} = 1704 (2K mode), K_{max} = 3408 (4K mode), or K_{max} = 6816 (8K mode). SPperiod, SPstart, SPoffset, and SPphase parameters control the scattered pilots positions.
   After determining the CP, TPS, and SP positions in each symbol and the value of the PRBS sequence in all active carriers in the symbol, the model demultiplexes the input data into TPS and TSP data. According to the TPS position and the PRBS sequence, one transmitted TPS bit is determined by the mean value of the TPS positions.
   $$TPS = \frac{1}{NTPS} \sum_{l=1}^{NTPS} \frac{x[TPSposition[l]]}{PilotValue[TPSposition[l]]}$$
   where *NTPS* is the number of TPS in one symbol; *PilotValue* is the PRBS sequence in symbol; *x[i]* is the input data.
   Except for TPS, CP, and SP positions, the remaining positions in one segment are the TSP data positions.

   Data[i] = x[i]

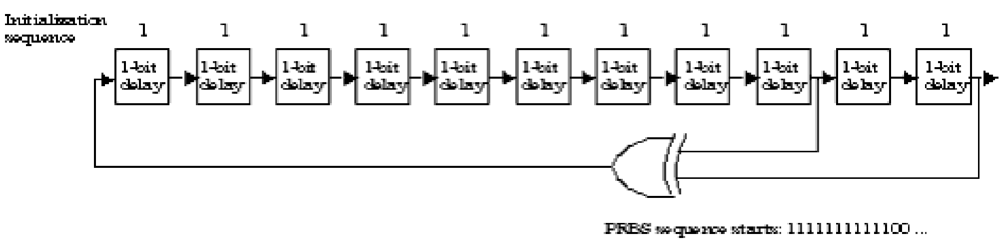
Carrier Indices for Continual Pilot Carriers

Continual Pilot Carrier Positions (index number k)		
2K mode	**4K mode**	**8K mode**
0 48 54 87 141 156 192 201 255 279 282 333 432 450 483 525 531 618 636 714 759 765 780 804 873 888 918 939 942 969 984 1050 1101 1107 1110 1137 1140 1146 1206 1269 1323 1377 1491 1683 1704	0 48 54 87 141 156 192 201 255 279 282 333 432 450 483 525 531 618 636 714 759 765 780 804 873 888 918 939 942 969 984 1050 1101 1107 1110 1137 1140 1146 1206 1269 1323 1377 1491 1683 1704 1752 1758 1791 1845 1860 1896 1905 1959 1983 1986 2037 2136 2154 2187 2229 2235 2322 2340 2418 2463 2469 2484 2508 2577 2592 2622 2643 2646 2673 2688 2754 2805 2811 2814 28412844 2850 2910 2973 3027 3081 3195 3387 3408	0 48 54 87 141 156 192 201 255 279 282 333 432 450 483 525 531 618 636 714 759 765 780 804 873 888 918 939 942 969 984 1050 1101 1107 1110 1137 1140 1146 1206 1269 1323 1377 1491 1683 1704 1752 1758 1791 1845 1860 1896 1905 1959 1983 1986 2037 2136 2154 2187 2229 2235 2322 2340 2418 2463 2469 2484 2508 2577 2592 2622 2643 2646 2673 2688 2754 2805 2811 2814 28412844 2850 2910 2973 3027 3081 3195 3387 3408 3456 3462 3495 3549 3564 3600 3609 3663 3687 3690 3741 3840 3858 3891 3933 3939 4026 4044 4122 4167 4173 4188 4212 4281 4296 4326 4347 4350 4377 4392 4458 4509 4515 4518 4545 4548 4554 4614 4677 4731 4785 4899 5091 5112 5160 5166 5199 5253 5268 5304 5313 5367 5391 5394 5445 5544 5562 5595 5637 5643 5730 5748 5826 5871 5877 5892 5916 5985 6000 6030 6051 6054 6081 6096 6162 6213 6219 6222 6249 6252 6258 6318 6381 6435 6489 6603 6795 6816

Carrier Indices for TPS Carriers

2K mode	4K mode	8K mode
34 50 209 346 413 569 595 688 790 901 1073 1219 1262 1286 1469 1594 1687	34 50 209 346 413 569 595 688 790 901 1073 1219 1262 1286 1469 1594 1687 1738 1754 1913 2050 2117 2273 2299 2392 2494 2605 2777 2923 2966 2990 3173 3298 3391	34 50 209 346 413 569 595 688 790 901 1073 1219 1262 1286 1469 1594 1687 1738 1754 1913 2050 2117 2273 2299 2392 2494 2605 2777 2923 2966 2990 3173 3298 3391 3442 3458 3617 3754 3821 3977 4003 4096 4198 4309 4481 4627 4670 4694 4877 5002 5095 5146 5162 5321 5458 5525 5681 5707 5800 5902 6013 6185 6331 6374 6398 6581 6706 6799

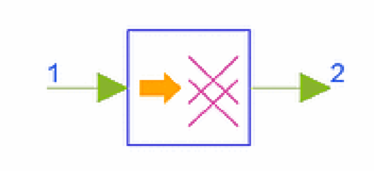
PRBS Sequence Generation



References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.5.1, European Telecommunication Standard, November 2004.

DTV_DVBLoadIFFTBuff



Description: Data stream loader into IFFT buffer for DVB-T
Library: DTV, DVB-T
Class: SDFDTV_DVBLoadIFFTBuff

Parameters

Name	Description	Default	Unit	Type	Range
Carriers	number of carriers in one OFDM symbol	1705		int	1705 for 2k mode; 6817 for 8k mode; 3409 for 4k mode
Order	IFFT points=2^Order	13		int	[1, ∞)†

† Order is the order of IFFT; it must satisfy $2^{Order} \geq Carriers+1$

Pin Inputs

Pin	Name	Description	Signal Type
1	input	transmitted signal before IFFT	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	output	IFFT input signal, zero padded	complex

Notes/Equations

1. This model loads transmission data into the IFFT buffer, which is used in DVB-T only.
2. Implementation
   Assume *x(0)*, *x(1)*, ... , *x(N-1)* are the changed signal segments,
   where

   $$N = Length \times Segments + 1$$

   $$M = 2^{Order}$$

   y(0), *y(1)*, ... , *y(M-1)* are the model outputs.

   Data loading is performed as follows:

$$y(i) = x\left(\frac{N}{2} + i\right) \qquad i = 0, \ldots, \frac{N+1}{2} - 1$$

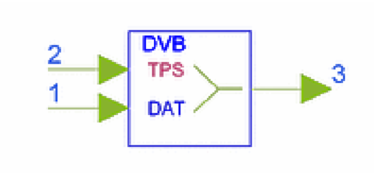
$$y(i) = 0 \qquad i = \frac{N+1}{2}, \ldots, M - \frac{N}{2} - 1$$

$$y(i) = x\left(i - M + \frac{N}{2}\right) \qquad i = M - \frac{N}{2}, \ldots, M$$

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.5.1, European Telecommunication Standard, November 2004.

DTV_DVBMuxOFDMSym



Description: OFDM symbol multiplexer for DVB-T
Library: DTV, DVB-T
Class: SDFDTV_DVBMuxOFDMSym

Parameters

Name	Description	Default	Unit	Type	Range
Carriers	number of carriers in one OFDM symbol(1705,3409 or 6817)	1705		int	1705 for 2k mode; 3409 for 4k mode; 6817 for 8k mode
Data	number of input data in one OFDM symbol(1512,3024 or 6048)	1512		int	1512 for 2k mode; 3024 for 4k mode; 6048 for 8k mode
SPperiod	distance in carriers between nearby scattered pilots	12		int	[0, ∞)†
SPstart	start position of scattered pilots in carriers	0		int	(0, ∞)†
SPoffset	offset value of SPstart in each symbol	3		int	(0, ∞)†

† In DVB-T systems: SPperiod=12, SPstart=0, SPoffset=3

Pin Inputs

Pin	Name	Description	Signal Type
1	data	data input	complex
2	TPS	TPS input	complex

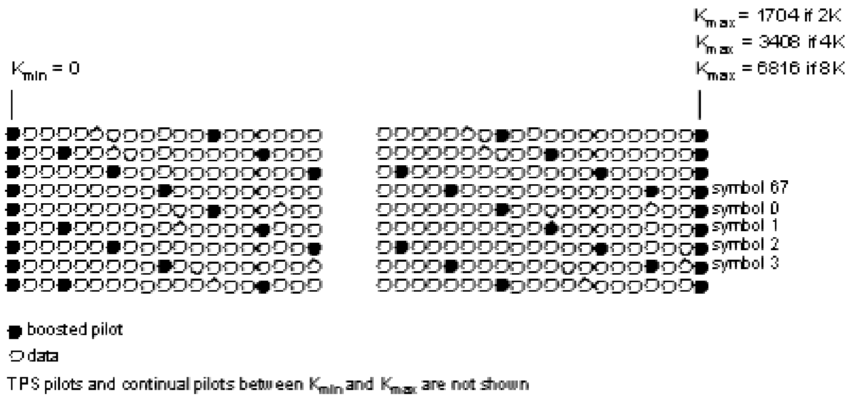
Pin Outputs

Pin	Name	Description	Signal Type
3	output	OFDM symbol data output	complex

Notes/Equations

1. This model multiplexes TSP (transport stream packet) and TPS (transmission parameter signal) data into the DVB-T OFDM symbol. The figure below shows the frame structure.

Frame Structure



2. The number of IntState of Length determines the number of CP (continual pilot) and TPS in each symbol; the position of CP and TPS are determined according to Carrier Indices for Continual Pilot Carriers and Carrier Indices for TPS Carriers, respectively. PRBS sequences in each segment are generated according to PRBS Sequence Generation; the initial sets of PRBS register is 11111111111. The PRBS in initialized so that the first output bit from the PRBS coincides with the first active carrier. A new value is generated by the PRBS on each carrier in each segment (whether or not it is a pilot).
   Positions of the corresponding scattered pilots are generated as follows. For the symbol of index *l* (ranging from 0 to 67), carriers for which index *k* belongs to subset
   $\{k = K_{min} + 3 \times l \ mod \ 4 + 12p \mid p \ \ integer, p \geq 0, k \in [K_{min}, K_{max}]\}$
   are scattered pilot positions.
   where *p* is an integer that takes all possible values ≥ 0, provided the resulting value for *k* does not exceed the valid range $[K_{min}, K_{max}]$; K_{min} = 0, and K_{max} = 1704 (2K mode), K_{max} = 3408 (4K mode), or K_{max} = 6816 (8K mode). SPperiod, SPstart, and SPoffset parameters control the scattered pilots positions.
   After determining the CP, TPS, and SP positions in each symbol and the value of the PRBS sequence in all active carriers in one symbol, the model demultiplexes the input data into TPS and TSP data. According to the TPS position and the PRBS sequence, one TPS bit is output in each TPS position.
   $x[TPSposition[l]] = PilotValue[TPSposition[l]] \times TPS$
   where *NTPS* is the number of TPS in one symbol; *PilotValue* is the PRBS sequence in symbol; *x[i]* is the OFDM symbol data.
   Except for TPS, CP, and SP positions, the remaining positions in one segment are the TSP data positions.
   $x[i] = Data[i]$

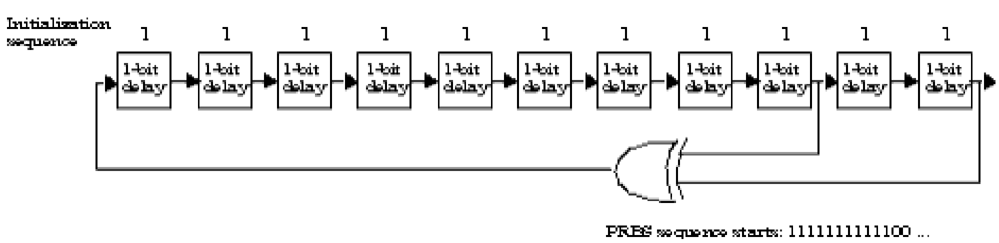
Carrier Indices for Continual Pilot Carriers

Continual pilot carrier positions (index number k)		
2K mode	**4K mode**	**8K mode**
0 48 54 87 141 156 192 201 255 279 282 333 432 450 483 525 531 618 636 714 759 765 780 804 873 888 918 939 942 969 984 1050 1101 1107 1110 1137 1140 1146 1206 1269 1323 1377 1491 1683 1704	0 48 54 87 141 156 192 201 255 279 282 333 432 450 483 525 531 618 636 714 759 765 780 804 873 888 918 939 942 969 984 1050 1101 1107 1110 1137 1140 1146 1206 1269 1323 1377 1491 1683 1704 1752 1758 1791 1845 1860 1896 1905 1959 1983 1986 2037 2136 2154 2187 2229 2235 2322 2340 2418 2463 2469 2484 2508 2577 2592 2622 2643 2646 2673 2688 2754 2805 2811 2814 28412844 2850 2910 2973 3027 3081 3195 3387 3408	0 48 54 87 141 156 192 201 255 279 282 333 432 450 483 525 531 618 636 714 759 765 780 804 873 888 918 939 942 969 984 1050 1101 1107 1110 1137 1140 1146 1206 1269 1323 1377 1491 1683 1704 1752 1758 1791 1845 1860 1896 1905 1959 1983 1986 2037 2136 2154 2187 2229 2235 2322 2340 2418 2463 2469 2484 2508 2577 2592 2622 2643 2646 2673 2688 2754 2805 2811 2814 28412844 2850 2910 2973 3027 3081 3195 3387 3408 3456 3462 3495 3549 3564 3600 3609 3663 3687 3690 3741 3840 3858 3891 3933 3939 4026 4044 4122 4167 4173 4188 4212 4281 4296 4326 4347 4350 4377 4392 4458 4509 4515 4518 4545 4548 4554 4614 4677 4731 4785 4899 5091 5112 5160 5166 5199 5253 5268 5304 5313 5367 5391 5394 5445 5544 5562 5595 5637 5643 5730 5748 5826 5871 5877 5892 5916 5985 6000 6030 6051 6054 6081 6096 6162 6213 6219 6222 6249 6252 6258 6318 6381 6435 6489 6603 6795 6816

Carrier Indices for TPS Carriers

2K mode	**4K mode**	**8K mode**
34 50 209 346 413 569 595 688 790 901 1073 1219 1262 1286 1469 1594 1687	34 50 209 346 413 569 595 688 790 901 1073 1219 1262 1286 1469 1594 1687 1738 1754 1913 2050 2117 2273 2299 2392 2494 2605 2777 2923 2966 2990 3173 3298 3391	34 50 209 346 413 569 595 688 790 901 1073 1219 1262 1286 1469 1594 1687 1738 1754 1913 2050 2117 2273 2299 2392 2494 2605 2777 2923 2966 2990 3173 3298 3391 3442 3458 3617 3754 3821 3977 4003 4096 4198 4309 4481 4627 4670 4694 4877 5002 5095 5146 5162 5321 5458 5525 5681 5707 5800 5902 6013 6185 6331 6374 6398 6581 6706 6799

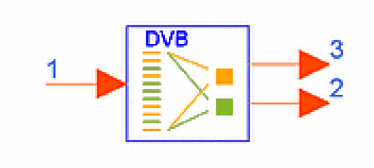
PRBS Sequence Generation



References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.5.1, European Telecommunication Standard, November 2004.DT

DTV_DVBSymDeinterlv2b



Description: Symbol de-interleaver with 2 branches
Library: DTV, DVB-T
Class: SDFDTV_DVBSymDeinterlv2b
Derived From: DTV_DVBSymInterlv

Parameters

Name	Description	Default	Unit	Type	Range
Mode	DVB OFDM mode: DVB 2k mode, DVB 8k mode	DVB 2k mode		enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	input	interleaved OFDM symbol bits	anytype

Pin Outputs

Pin	Name	Description	Signal Type
2	outb0	data symbol bit 0	anytype
3	outb1	data symbol bit 1	anytype

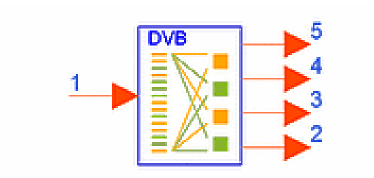
Notes/Equations

1. This model performs symbol de-interleaving in DVB-T systems. Each firing, it consumes 1512 (2K mode) or 6048 (8K mode) data symbols at the input and outputs them to each output pin after de-interleaving.
2. This model is the reverse of the process used for DTV_DVBSymInterlv2b. The interleaving algorithm is described in DTV_DVBSymInterlv2b.
3. This model is one of three symbol de-interleavers with data symbol bit output. 2-, 4-, and 6-bit data symbol de-interleavers are used for QPSK, 16-QAM, and 64-QAM, respectively; after constellation mapping de-mapping, a complex symbol interleaver is used before constellation de-mapping. These models use the same permutation sequence.

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.

DTV_DVBSymDeinterlv4b



Description: Symbol de-interleaver with 4 branches
Library: DTV, DVB-T
Class: SDFDTV_DVBSymDeinterlv4b
Derived From: DTV_DVBSymInterlv

Parameters

Name	Description	Default	Unit	Type	Range
Mode	DVB OFDM mode: DVB 2k mode, DVB 8k mode	DVB 2k mode		enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	input	interleaved OFDM symbol bits	anytype

Pin Outputs

Pin	Name	Description	Signal Type
2	outb0	data symbol bit 0	anytype
3	outb1	data symbol bit 1	anytype
4	outb2	data symbol bit 2	anytype
5	outb3	data symbol bit 3	anytype

Notes/Equations

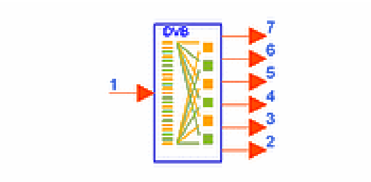
1. This model performs symbol de-interleaving in DVB-T systems. Each firing, it consumes 1512 (2K mode) or 6048 (8K mode) data symbols at the input and outputs them to each output pin after de-interleaving.
2. This model is the reverse of the process used for DTV_DVBSymInterlv4b. The interleaving algorithm is described in DTV_DVBSymInterlv4b.
3. This model is one of three symbol de-interleavers with data symbol bit output. 2-, 4-, and 6- data symbol de-interleavers are used for QPSK, 16-QAM, and 64-QAM, respectively; after constellation mapping de-mapping, a complex symbol interleaver is used before constellation de-mapping. These models use the same permutation sequence.

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European

Telecommunication Standard, July 1999.

DTV_DVBSymDeinterlv6b



Description: Symbol de-interleaver with 6 branches
Library: DTV, DVB-T
Class: SDFDTV_DVBSymDeinterlv6b
Derived From: DTV_DVBSymInterlv

Parameters

Name	Description	Default	Unit	Type	Range
Mode	DVB OFDM mode: DVB 2k mode, DVB 8k mode	DVB 2k mode		enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	input	interleaved OFDM symbol bits	anytype

Pin Outputs

Pin	Name	Description	Signal Type
2	outb0	data symbol bit 0	anytype
3	outb1	data symbol bit 1	anytype
4	outb2	data symbol bit 2	anytype
5	outb3	data symbol bit 3	anytype
6	outb4	data symbol bit 4	anytype
7	outb5	data symbol bit 5	anytype

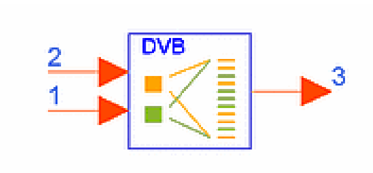
Notes/Equations

1. This model performs symbol de-interleaving in DVB-T systems. Each firing, it consumes 1512 (2K mode) or 6048 (8K mode) data symbols at the input and outputs them to each output pin after de-interleaving.
2. This model is the reverse of the process used for DTV_DVBSymInterlv6b. The interleaving algorithm is described in DTV_DVBSymInterlv6b.
3. This model is one of three symbol de-interleavers with data symbol bit output. 2-, 4-, and 6-bit data symbol de-interleavers are used for QPSK, 16-QAM, and 64-QAM, respectively; after constellation mapping de-mapping, a complex symbol interleaver is used before constellation de-mapping. These models use the same permutation sequence.

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.

DTV_DVBSymInterlv2b



Description: Symbol interleaver with 2 branches
Library: DTV, DVB-T
Class: SDFDTV_DVBSymInterlv2b
Derived From: DTV_DVBSymInterlv

Parameters

Name	Description	Default	Unit	Type	Range
Mode	DVB OFDM mode: DVB 2k mode, DVB 8k mode	DVB 2k mode		enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	inb0	data symbol bit 0	anytype
2	inb1	data symbol bit 1	anytype

Pin Outputs

Pin	Name	Description	Signal Type
3	output	interleaved OFDM symbol bits	anytype

Notes/Equations

1. This model performs symbol interleaving in DVB-T systems. Each firing, it consumes 1512 (2K mode) or 6048 (8K mode) bits data in each input pin, and outputs them after interleaving. The interleaving algorithm is described in note 2.

2. This model is one of the three symbol interleavers with data symbol bit inputs. 2-, 4-, and 6-bit data symbol interleavers are used for QPSK, 16-QAM, and 64-QAM, respectively, before constellation mapping; a complex symbol interleaver is used after constellation mapping. These models use the same permutation sequence.
Interleaving Algorithm
Define input vector *Y'* and interleaved vector *Y* as:
$$Y' = (y'_0, y'_1, y'_2, \dots, y'_{N_{max}-1})$$
$$Y = (y_0, y_1, y_2, \dots, y_{N_{max}-1})$$
$Y_{H(q)} = Y'_q$ for even symbols for $q = 0, \dots N_{max} - 1$
$Y_q = Y'_{H(q)}$ for odd symbols for $q = 0, \dots N_{max} - 1$
where $N_{max} = 1512$ in 2K mode and $N_{max} = 6048$ in 8K mode.
H(q) is a permutation function defined by the following:

An $(N_r - 1)$ bit binary word R'_i is defined, with $N_r = \log 2(M_{max})$, where $M_{max} = 1512$ in 2K mode and $M_{max} = 2048$ in the 8K mode, where R'_i takes the following values:

i = 0,1: $R'_i[N_r - 2, N_r - 3, \ldots, 1, 0] = (0, 0, \ldots, 0, 0)$

i = 2: $R'_i[N_r - 2, N_r - 3, \ldots, 1, 0] = (0, 0, \ldots, 0, 1)$

2 < *i* < M_{max}:

{ $R'_i[N_r - 3, N_r - 4, \ldots, 1, 0] = R'_{i-1}[N_r - 2, N_r - 3, \ldots, 1, 0]$;

in the 2K mode: $R'_i[9] = (R'_{i-1}[0] \oplus R'_{i-1}[3])$

in the 8K mode: $R'_i[9] = (R'_{i-1}[0] \oplus R'_{i-1}[1] \oplus R'_{i-1}[4] \oplus R'_{i-1}[6])$ }

A vector R_i is derived from vector R'_i by bit permutations given in 2K Mode Bit Permutations and 8K Mode Bit Permutations.

2K Mode Bit Permutations

R'_i	9	8	7	6	5	4	3	2	1	0
R_i	0	7	5	1	8	2	6	9	4	3

8K Mode Bit Permutations

R'_i	11	10	9	8	7	6	5	4	3	2	1	0
R_i	5	11	3	0	10	8	6	9	2	4	1	7

The permutation function *H(q)* is defined by the algorithm q = 0;
for (i = 0; i < M_{max}; i = i+1)

{

$$H(q) = (i MOD 2) \times 2^{N_r - 1} + \sum_{j=0}^{N_r - 2} R_i(j) \times 2^j$$

if (H(q) < N_{max}) q = q+1;

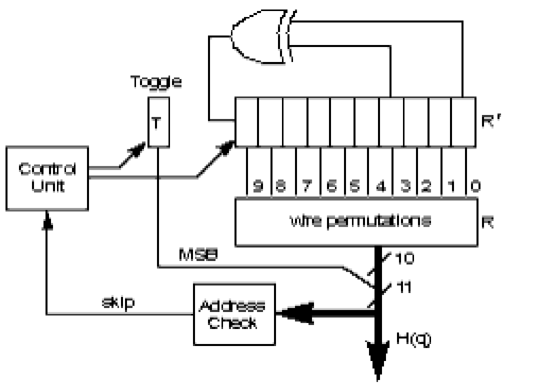
}

The algorithm used to generate the permutation function is shown in 2K Mode Symbol Interleaver Address Generation for the 2K mode and 8K Mode Symbol Interleaver Address Generation for the 8K mode.

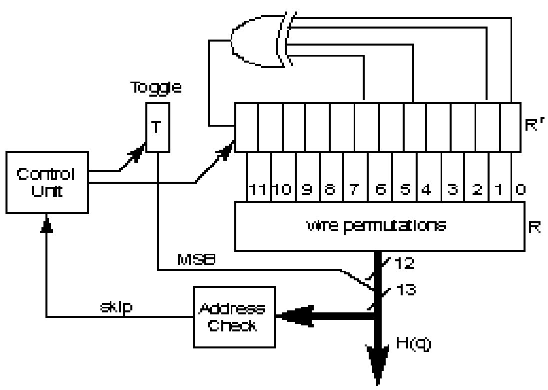
Each input signal generates its own input *Y'* vector and interleaved *Y* vector. All interleaved *Y* vectors are synthesized into the output signal.

2K Mode Symbol Interleaver Address Generation

2K Mode Symbol Interleaver Address Generation



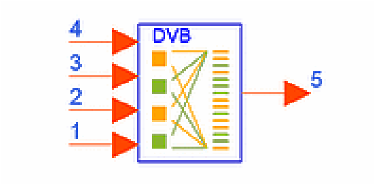
8K Mode Symbol Interleaver Address Generation



References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.

DTV_DVBSymInterlv4b



Description: Symbol interleaver with 4 branches
Library: DTV, DVB-T
Class: SDFDTV_DVBSymInterlv4b
Derived From: DTV_DVBSymInterlv

Parameters

Name	Description	Default	Unit	Type	Range
Mode	DVB OFDM mode: DVB 2k mode, DVB 8k mode	DVB 2k mode		enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	inb0	data symbol bit 0	anytype
2	inb1	data symbol bit 1	anytype
3	inb2	data symbol bit 2	anytype
4	inb3	data symbol bit 3	anytype

Pin Outputs

Pin	Name	Description	Signal Type
5	output	interleaved OFDM symbol bits	anytype

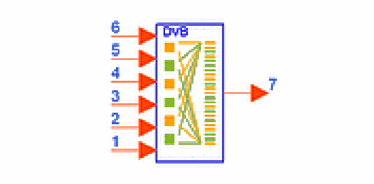
Notes/Equations

1. This model performs symbol interleaving in DVB-T systems. Each firing, it consumes 1512 (2K mode) or 6048 (8K mode) bits data in each input pin, and outputs them after interleaving. The interleaving algorithm is the same as that described for DTV_DVBSymInterlv2b except for the input bit streams.
2. This model is one of the three symbol interleavers with data symbol bit inputs. 2-, 4-, and 6-bit data symbol interleavers are used for QPSK, 16-QAM, and 64-QAM, respectively, before constellation mapping; a complex symbol interleaver is used after constellation mapping. These models use the same permutation sequence.

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.

DTV_DVBSymInterlv6b



Description: Symbol interleaver with 6 branches
Library: DTV, DVB-T
Class: SDFDTV_DVBSymInterlv6b
Derived From: DTV_DVBSymInterlv

Parameters

Name	Description	Default	Unit	Type	Range
Mode	DVB OFDM mode: DVB 2k mode, DVB 8k mode	DVB 2k mode		enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	inb0	data symbol bit 0	anytype
2	inb1	data symbol bit 1	anytype
3	inb2	data symbol bit 2	anytype
4	inb3	data symbol bit 3	anytype
5	inb4	data symbol bit 4	anytype
6	inb5	data symbol bit 5	anytype

Pin Outputs

Pin	Name	Description	Signal Type
7	output	interleaved OFDM symbol bits	anytype

Notes/Equations

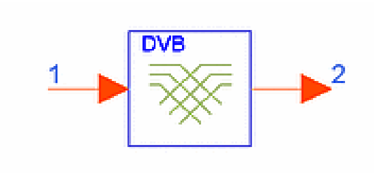
1. This model performs symbol interleaving in DVB-T systems. Each firing, it consumes 1512 (2K mode) or 6048 (8K mode) bits data in each input pin and outputs them after interleaving. The interleaving algorithm is the same as that described for DTV_DVBSymInterlv2b except for the input bit streams.
2. This model is one of the three symbol interleavers with data symbol bit inputs. 2-, 4-, and 6-bit data symbol interleavers are used for QPSK, 16-QAM, and 64-QAM, respectively, before constellation mapping; a complex symbol interleaver is used after constellation mapping. These models use the same permutation sequence.

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European

Telecommunication Standard, July 1999.

DTV_DVBSymInterlvCx



Description: Symbol interleaver
Library: DTV, DVB-T
Class: SDFDTV_DVBSymInterlvCx
Derived From: DTV_DVBSymInterlv

Parameters

Name	Description	Default	Unit	Type	Range
Mode	DVB OFDM mode: DVB 2k mode, DVB 8k mode	DVB 2k mode		enum	
Option	operation option: Interleaving, De-interleaving	Interleaving		enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	input	OFDM symbols after constellation mapping	anytype

Pin Outputs

Pin	Name	Description	Signal Type
2	output	interleaved OFDM symbols	anytype

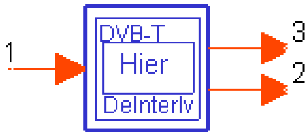
Notes/Equations

1. This model performs complex symbol interleaving in DVB-T systems. Each firing, it consumes 1512 (2K mode) or 6048 (8K mode) data bits at the input and outputs them after interleaving. The interleaving algorithm is the same as that described for DTV_DVBSymInterlv2b.
2. Besides this complex symbol interleaver, there are three symbol interleavers using data bits as input. The data symbol interleavers are used before constellation mapping; the complex symbol interleaver is used after constellation mapping. These models use the same permutation sequence.

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.

DTV_DVBTHierInnerDeInterlv



Description: Inner de-interleaver for 16QAM, 64QAM hierarchical transmission modes
Library: DTV, DVB-T
Class: SDFDTV_DVBTHierInnerDeInterlv

Parameters

Name	Description	Default	Unit	Type	Range
Mode	transmission mode: DVB 2k mode, DVB 8k mode	DVB 2k mode		enum	
MappingMode	signal constellations and mapping: QAM-16, QAM-64	QAM-16		enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	Symbols	input of inner de-interleaver	anytype

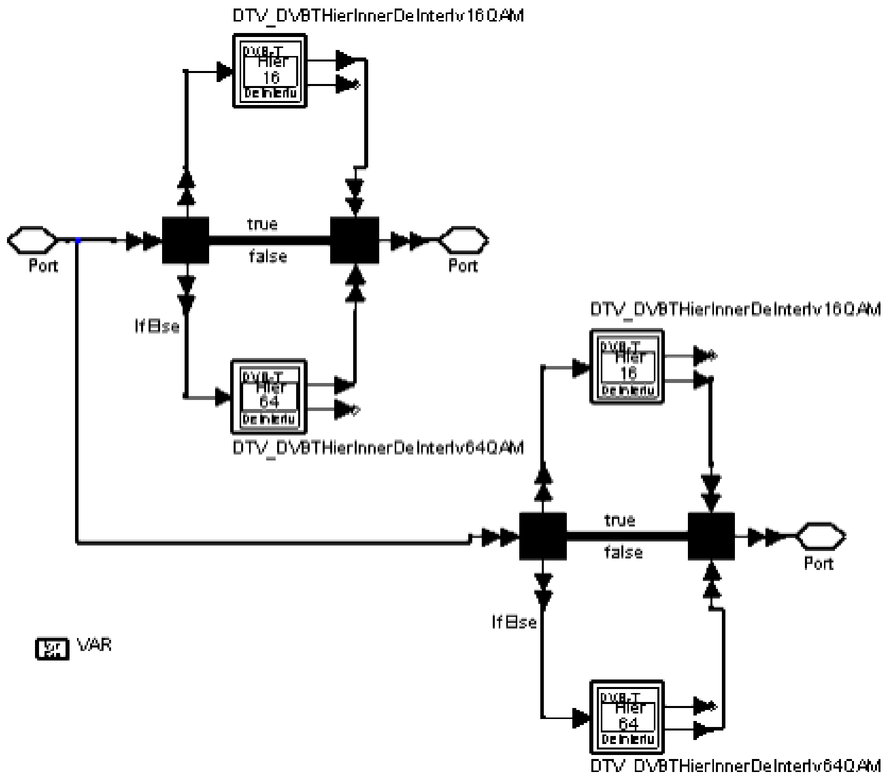
Pin Outputs

Pin	Name	Description	Signal Type
2	HP_Bits	The high priority bit stream for hierarchical modes	anytype
3	LP_Bitstream	The low priority bit stream for hierarchical modes	anytype

Notes/Equations

1. This subnetwork model performs inner de-interleaving for 16QAM and 64QAM for hierarchical transmission. 16QAM and 64QAM functions are performed by an if-else structure. The schematic for this subnetwork is shown below.

DTV_DVBTHierInnerDeInterlv Subnetwork

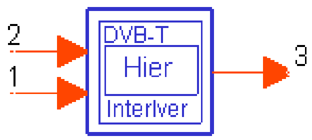


2. The Mode parameter specifies the 2K or 8K mode.
3. The MappingMode parameter specifies QAM-16 or QAM-64.

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.

DTV_DVBTHierInnerInterlv



Description: Inner interleaver for 16QAM, 64QAM hierarchical transmission mode
Library: DTV, DVB-T
Class: SDFDTV_DVBTHierInnerInterlv

Parameters

Name	Description	Default	Unit	Type	Range
Mode	transmission mode: DVB 2k mode, DVB 8k mode	DVB 2k mode		enum	
MappingMode	signal constellations and mapping: QAM-16, QAM-64	QAM-16		enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	HP_Bits	The high priority bit stream for hierarchical modes	anytype
2	LP_Bits	The low priority bit stream for hierarchical modes	anytype

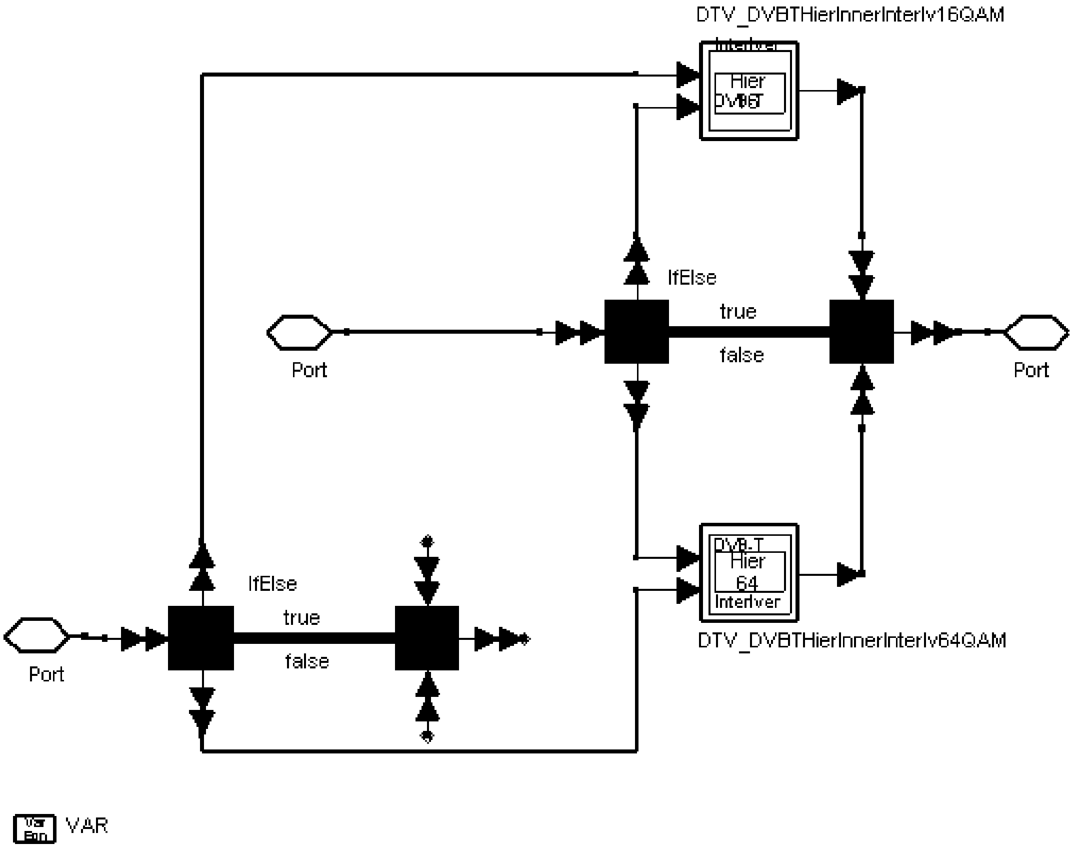
Pin Outputs

Pin	Name	Description	Signal Type
3	Symbols	output of inner interleaver	anytype

Notes/Equations

1. This subnetwork model performs 16QAM and 64QAM inner interleaving for hierarchical transmission. 16QAM and 64QAM inner interleaver is integrated; functions are performed by an if-else structure. The schematic for this subnetwork is shown below.

DTV_DVBTHierInnerInterlv Schematic

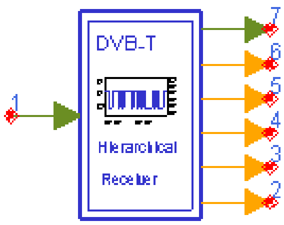


2. The Mode parameter specifies the 2K or 8K mode.
3. The MappingMode parameter specifies QAM-16 or QAM-64.

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.

DTV_DVBTHierReceiver



Description: DVB-T hierarchical receiver
Library: DTV, DVB-T
Class: SDFDTV_DVBTHierReceiver

Parameters

Name	Description	Default	Symbol	Unit	Type	Range
Mode	transmission mode: DVB 2k mode, DVB 8k mode	DVB 2k mode			enum	
OversamplingOption	oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1	S		enum	
GuardInterval	guard interval (frac FFT size)	0.125			real	[0, 1]
CodeRateHP	high priority stream current code rate: HP 1/2, HP 2/3, HP 3/4, HP 5/6, HP 7/8	HP 1/2			enum	
CodeRateLP	low priority stream current code rate: LP 1/2, LP 2/3, LP 3/4, LP 5/6, LP 7/8	LP 1/2			enum	
MappingMode	signal consetllaions and mapping: QAM-16, QAM-64	QAM-16			enum	
Alpha	non-uniform factor for DVB-T.	1			int	[1, ∞)
SoftDecision	soft decision viterbi decoding type: Soft, Hard, Cochannel	Soft			enum	
TrunLen	path memory truncation length of Viterbi decoding algorithm, in bytes	10			int	[5, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	Rx_signal	received OFDM signal to be demodulated	complex

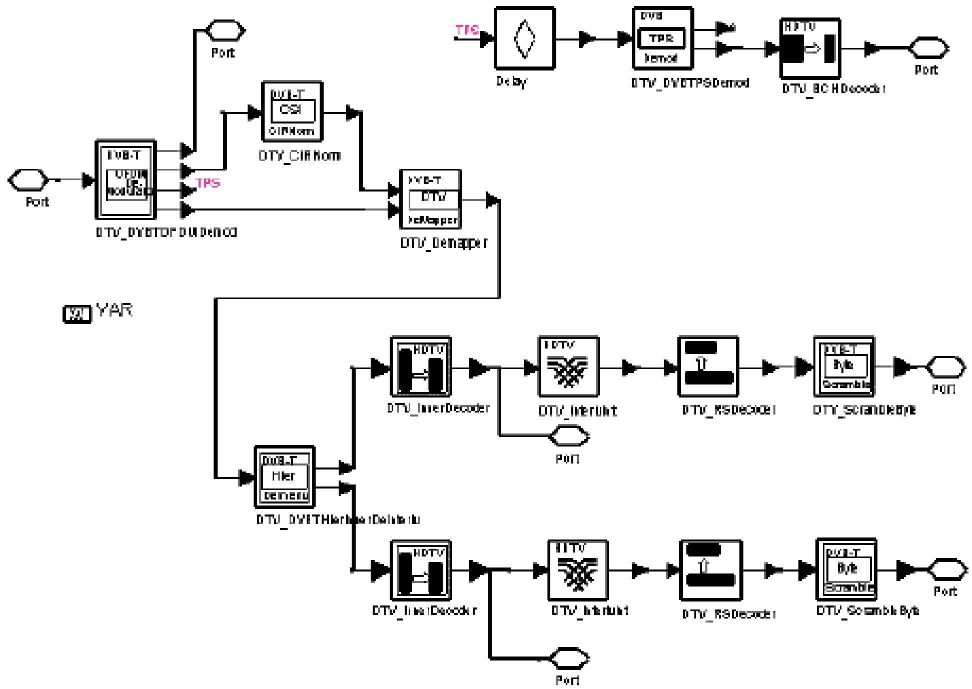
Pin Outputs

Pin	Name	Description	Signal Type
2	HPBytes_Decoded	decoded bytes after Reed Solomon decoder with high priority	int
3	LPBytes_Decoded	decoded bytes after Reed Solomon decoder with low priority	int
4	HPBytes_AfterViterbi	decoded bytes after Viterbi decoder with high priority	int
5	LPBytes_AfterViterbi	decoded bytes after Viterbi decoder with low priority	int
6	TPS_Bits	decoded TPS information bits	int
7	constellation	constellation signal after OFDM demodulation	complex

Notes/Equations

1. This subnetwork model implements the DVB-T hierarchical receiver function. The schematic for this subnetwork is shown below.

DTV_DVBTHierReceiver Schematic



2. Output Delays
The constellation pin has a delay of 8 OFDM symbols. The 8 × 1705 (2K mode) or 8 × 6817 (8K mode) constellation output signals are not used for EVM calculation.
DTV_BCHDecoder uses a 68-bit block; so, a Delay component with N=60 is inserted before DTV_DVBTPSDemod. Pin TPS_Bits has one DVB-T frame (68 OFDM symbols) delay; the first 53 bits at TPS_Bits are not used.
LPBytes_AfterViterbi and HPBytes_AfterViterbi each have 8 OFDM symbol delays.
The inner decoding (or convolutional decoding) is based on MPEG-2 transport MUX packet. So, the LPBytes_Decoded, HPBytes_Decoded, HPBytes_AfterViterbi, and LPBytes_AfterViterbi delays must be multiples of coded (204) and uncoded (188) transport MUX packet blocks.
The information bytes per one OFDM symbol in HPBytes_AfterViterbi is calculated as follows:

DataPerOFDMSymbol=1512 (2K mode) or 6048 (8K mode)

CodedBlockSize=204

HPCodeRate = 1/2, 2/3, 3/4, 5/6 or 7/8

DelayOFDMSymbols = 8

HPInfoBytes = DelayOFDMSymbols×DataPerOFDMSymbol×HPCodeRate/8

The block delay of HPBytes_AfterViterbi is Delay_HPAfterViterbi and calculated as follows:

HPDelayBytes= DelayOFDMSymbols×HPInfoBytes-(int(DelayOFDMSymbols×HPInfoBytes/CodedBlockSize))×CodedBlockSize

N_HP=int((TrunLen+LPDelayBytes)/CodedBlockSize)

Delay_HPAfterViterbi=1\ +int((DelayOFDMSymbols×HPInfoBytes)/CodedBlockSize)+N_HP.

Block size is 204 bytes.

The information bytes per one OFDM symbol in LPBytes_AfterViterbi is calculated as follows:

DataPerOFDMSymbol=1512 (2K mode) or 6048 (8K mode)

CodedBlockSize=204

BitsPerQAMmappingLP=2 for 16-QAM or 4 for 64-QAM,

LPCodeRate = 1/2, 2/3, 3/4, 5/6 or 7/8

LPInfoBytes=BitsPerQAMmappingLP×DataPerOFDMSymbol×LPCodeRate/8

The block delay of LPBytes_AfterViterbi is Delay_LPAfterViterbi is calculated as follows:

LPDelayBytes= DelayOFDMSymbols×LPInfoBytes-(int(DelayOFDMSymbols×LPInfoBytes/CodedBlockSize))×CodedBlockSize,

N_LP=int((TrunLen+LPDelayBytes)/CodedBlockSize),

Delay_LPAfterViterbi=1 +int((DelayOFDMSymbols×LPInfoBytes)/CodedBlockSize)+N_LP.

Block size is 204 bytes.

HPBytes_Decoded and LPBytes_Decoded each have 8 OFDM symbol and 11 transport MUX packet delays.
The block delay of HPBytes_Decoded is:

Delay_HPDecoded=11 +1+int((DelayOFDMSymbols×HPInfoBytes)/CodedBlockSize)+N_HP.

Block size is 188 bytes.

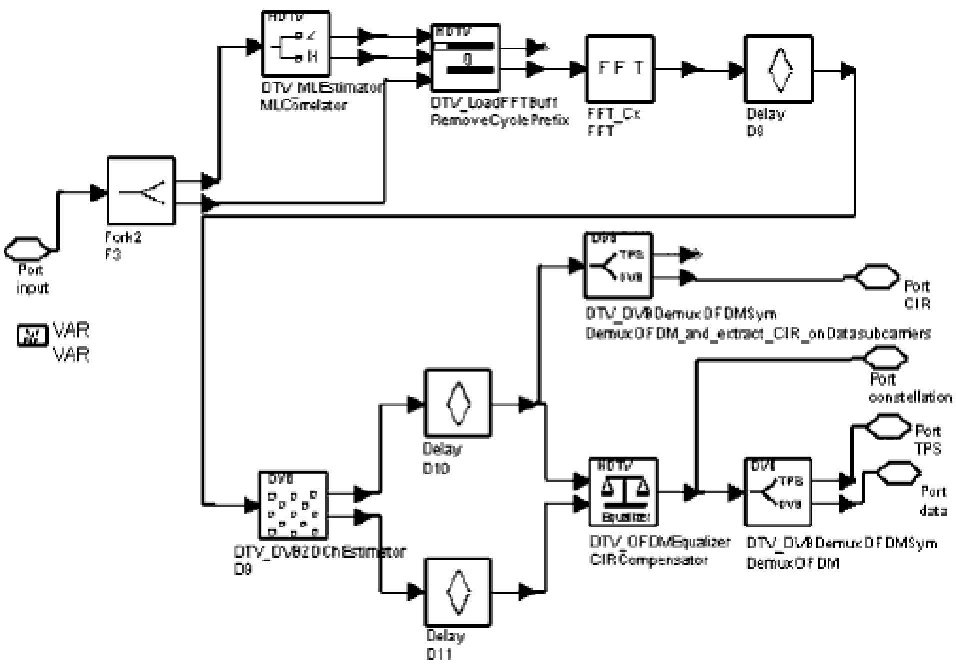
The block delay of LPBytes_Decoded is

Delay_LPDecoded=11 +1+int((DelayOFDMSymbols×LPInfoBytes)/CodedBlockSize)+N_LP.

Block size is 188 bytes.

3. Receiver functions are implemented according to the DVB-T Standard.
Start of OFDM symbol is detected by the DTV_DVBTOFDMDemod subnetwork (shown below).

DTV_DVBTOFDMDemod Schematic



DTV_MLEstimator calculates the correlation based on guard interval;
DTV_LoadFFTBuff selects the index with the maximum correlation value as the start of FFT.

DTV_DVBCh2DEstimator estimates the complex channel impulse responses for continual and scattered pilot subcarriers. The channel impulse responses of the data subcarriers are 2D interpolated based on the estimated CIR.
Each subcarrier value is divided with a complex estimated channel response coefficient (phase tracking, phase synchronization, and equalization). This simple one-tap frequency domain channel response compensation is implemented by DTV_OFDMEqualizer.
After equalization, DTV_DVBDemuxOFDMSym demultiplexes 1705 or 6817 subcarriers into 1512 (2K mode) or 6048 (8K mode) data subcarriers and 1 demodulated TPS.
The demodulated 1512 or 6048 data subcarriers (such as 16QAM, and 64QAM modulation) are demapped by DTV_Demapper.
The demodulated bits are deinterleaved by DTV_DVBTHierInnerDeinterlv and divided into high- and low-priority demodulated bits. The demodulated bits are inner decoded (DTV_InnerDecoder), outer de-interleaved (DTV_InterlvInt), outer decoded (DTV_RSDecoder) and descrambled (DTV_ScrambleByte). The fully-decoded high- and low-priority stream bytes are output as HPBytes_Decoded and LPBytes_Decoded.
After inner-decoding, the partially-decoded high- and low-priority stream bytes are output as HPBytes_AfterViterbi and LPBytes_AfterViterbi.
The TPS signal is demodulated by DTV_DVBTPSDemod; the demodulated bits are decoded by DTV_BCHDecoder.
Output pins of this DTV_DVBTHierReceiver subnetwork correspond to those of

DTV_DVBTHierSignalSrc.
This hierarchical receiver works per one OFDM symbol. The number of samples of each OFDM symbol (Rx_signal input pin) is:

(1+GuardInterval)×2048×OversamplingRatio (2K mode)

(1+GuardInterval)×8192×OversamplingRatio (8K mode)

The number of signals at the constellation output pin is 1705 (2K mode) or 6817 (8K mode) per one OFDM symbol.

4. Parameter Details
Mode specifies the 2K or 8K transmission mode as defined in DVB-T.
OversamplingOption specifies the transmission signal oversampling ratio 1, 2, 4, 8, 16, 32. If OversamplingOption=Ratio 2, the IFFT size is 4096 for 2K mode or 16384 for 8K mode.
GuardInterval specifies the guard interval (also called cyclic extension) length for each symbol time, as a fraction of the FFT time period. Guard interval types 1/4, 1/8, 1/16 and 1/32 are defined in the DVB-T specification. GuardInterval can be set to any value between 0.0 and 1.0 (not just 1/4, 1/8, 1/16 and 1/32). For proper demodulation, the value must match the guard interval length actually used in the input signal.
CodeRateHP specifies the high-priority stream code rate: 1/2, 2/3, 3/4, 5/6 or 7/8.
CodeRateLP specifies the low-priority stream code rate: 1/2, 2/3, 3/4, 5/6 or 7/8.
MappingMode specifies signal constellation and mapping modes: 16-QAM or 64-QAM.
Alpha is used for signal constellation and mapping as defined in DVB-T specifications.
If Alpha=1, 16-QAM or 64-QAM uniform mapping is performed; if Alpha=2 or 4, 16-QAM or 64-QAM in non-uniform mapping is performed.
SoftDecision specifies the Viterbi decoding algorithm mode.

If SoftDecision=Soft, the Viterbi decoding algorithm is a soft decision decoder and uses channel status information.

If SoftDecision=Hard, the Viterbi decoding algorithm is a hard decision decoder and does not use channel status information.

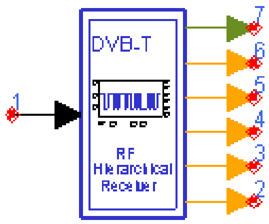
If SoftDecision=Cochannel, the Viterbi decoding algorithm is for co-channel measurement with PAL analog TV and digital DVB-T.

TrunLen sets the truncation length (in bytes) in the Viterbi decoding algorithm. The path memory is 8×TrunLen bits in the Viterbi decoding algorithm.

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.
2. W.C.Lee, H.M.Park, K.J.Kang, K.B.Kim, "Performance Analysis of Viterbi Decoder Using Channel State Information in COFDM System" *IEEE TRANSACTIONS ON BROADCASTING*, Vol.,44,NO.4, DECEMBER 1998.

DTV_DVBTHierReceiver_RF



Description: DVB-T RF hierarchical receiver
Library: DTV, DVB-T
Class: TSDFDTV_DVBTHierReceiver_RF

Parameters

Name	Description	Default	Symbol	Unit	Type	Range
RIn	input resistance	DefaultRIn		Ohm	real	(0, ∞)
ROut	output resistance	DefaultROut		Ohm	real	(0, ∞)
RTemp	physical temperature, in degrees C	DefaultRTemp		Celsius	real	[-273.15, ∞)
GainImbalance	Gain imbalance, Q vs I	0.0		dB	real	(-∞, ∞)
PhaseImbalance	Phase imbalance, Q vs I	0.0		deg	real	(-∞, ∞)
FCarrier	carrier frequency	474.0MHz		Hz	real	(0, ∞)
Sensitivity	voltage output sensitivity, Vout/Vin	1			real	(-∞, ∞)
Phase	reference phase in degrees	0.0		deg	real	(-∞, ∞)
Mode	transmission mode: DVB 2k mode, DVB 8k mode	DVB 2k mode			enum	
OversamplingOption	oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1	S		enum	
GuardInterval	guard interval (frac FFT size)	0.125			real	[0, 1]
CodeRateHP	high priority stream current code rate: HP 1/2, HP 2/3, HP 3/4, HP 5/6, HP 7/8	HP 1/2			enum	
CodeRateLP	low priority stream current code rate: LP 1/2, LP 2/3, LP 3/4, LP 5/6, LP 7/8	LP 1/2			enum	
MappingMode	signal consetllaions and mapping: QAM-16, QAM-64	QAM-16			enum	
Alpha	non-uniform factor for DVB-T.	1			int	[1, ∞)
SoftDecision	soft decision viterbi decoding type: Soft, Hard, Cochannel	Soft			enum	
TrunLen	path memory truncation length of Viterbi decoding algorithm, in bytes	10			int	[5, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	Rx_signal	received OFDM signal to be demodulated	timed

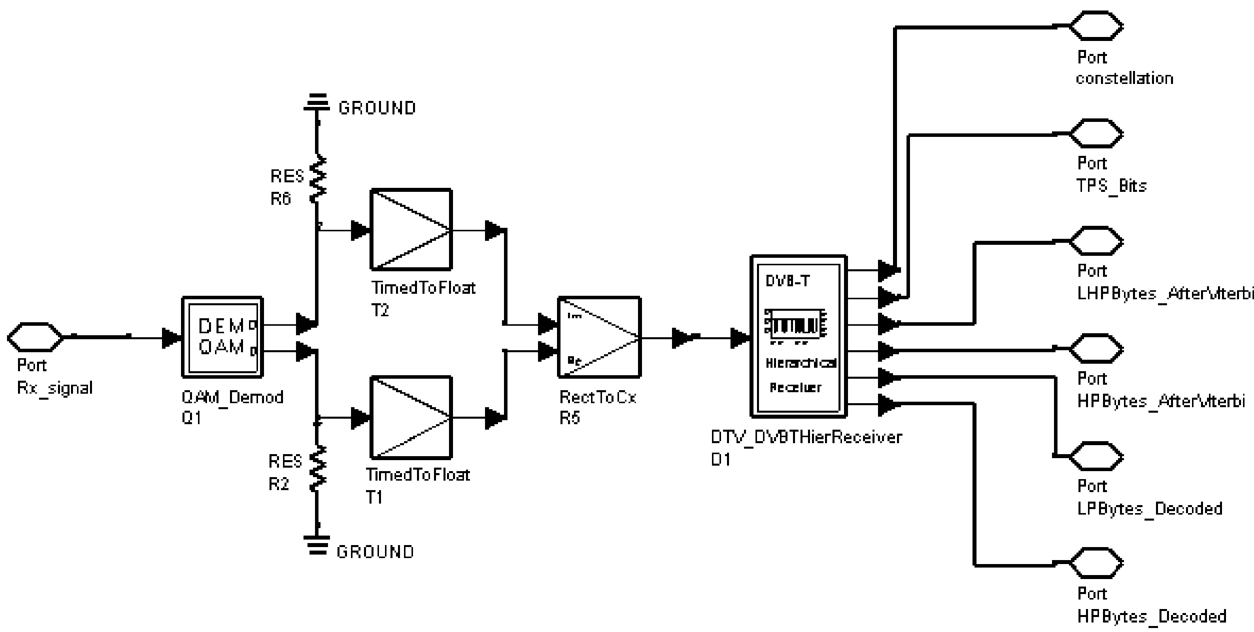
Pin Outputs

Pin	Name	Description	Signal Type
2	HPBytes_Decoded	decoded bytes after Reed Solomon decoder with high priority	int
3	LPBytes_Decoded	decoded bytes after Reed Solomon decoder with low priority	int
4	HPBytes_AfterViterbi	decoded bytes after Viterbi decoder with high priority	int
5	LPBytes_AfterViterbi	decoded bytes after Viterbi decoder with low priority	int
6	TPS_Bits	decoded TPS information bits	int
7	constellation	constellation signal after OFDM demodulation	complex

Notes/Equations

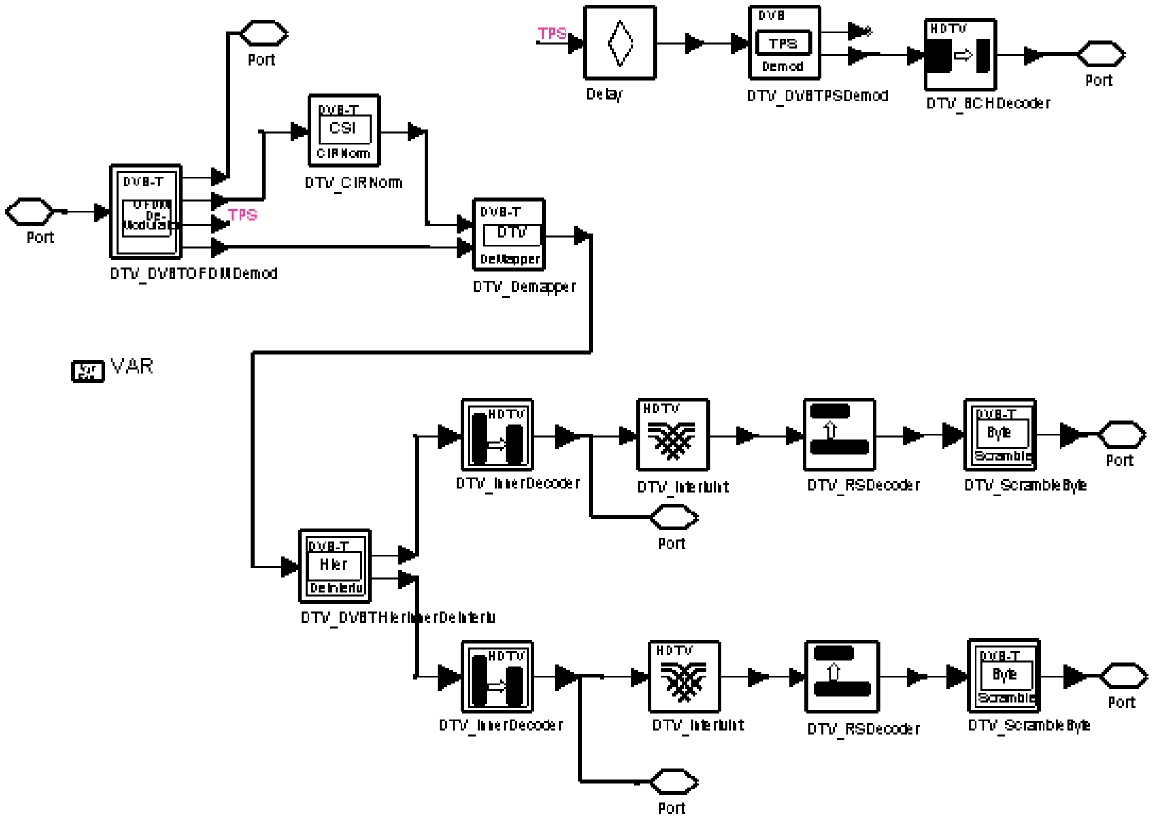
1. This subnetwork model implements the DVB-T RF hierarchical receiver function. The received RF signal is demodulated and fed to the baseband receiver.
   The schematic for this subnetwork is shown below.

   DTV_DVBTHierReceiver_RF schematic



   The baseband demodulator schematic is shown below.

   DTV_DVBTHierReceiver Schematic



2. Output Delays
   The constellation pin has a delay of 8 OFDM symbols. The first 8 × 1705 (2K mode) or 8 × 6817 (8K mode) constellation output signals are not used for EVM calculation.
   DTV_BCHDecoder uses a 68-bit block; so, a Delay component with N=60 is inserted before DTV_DVBTPSDemod.
   Pin TPS_Bits has one DVB-T frame (68 OFDM symbols) delay; the first 53 bits at TPS_Bits are not used.
   LPBytes_AfterViterbi and HPBytes_AfterViterbi each have 8 OFDM symbol delays.
   Inner (or convolutional) decoding is based on an MPEG-2 transport MUX packet. So, the LPBytes_Decoded, HPBytes_Decoded, HPBytes_AfterViterbi, and LPBytes_AfterViterbi delays must be multiples of coded (204) and uncoded (188) transport MUX packet blocks.
   The information bytes for one OFDM symbol in HPBytes_AfterViterbi is calculated as follows:

   DataPerOFDMSymbol=1512 (2K mode) or 6048 (8K mode)

   CodedBlockSize=204

   HPCodeRate = 1/2, 2/3, 3/4, 5/6 or 7/8

   DelayOFDMSymbols = 8

   HPInfoBytes=DelayOFDMSymbols×DataPerOFDMSymbol×HPCodeRate/8

   The block delay of HPBytes_AfterViterbi is Delay_HPAfterViterbi and calculated as follows:

   HPDelayBytes= DelayOFDMSymbols×HPInfoBytes-

(int(DelayOFDMSymbols×HPInfoBytes/CodedBlockSize))×CodedBlockSize

N_HP=int((TrunLen+LPDelayBytes)/CodedBlockSize)

Delay_HPAfterViterbi=1+int\

((DelayOFDMSymbols×HPInfoBytes)/CodedBlockSize)+N_HP.

Block size is 204 bytes.

The information bytes for one OFDM symbol in LPBytes_AfterViterbi is calculated as follows:

DataPerOFDMSymbol=1512 (2K mode) or 6048 (8K mode)

CodedBlockSize=204

BitsPerQAMmappingLP=2 for 16-QAM or 4 for 64-QAM,

LPCodeRate = 1/2, 2/3, 3/4, 5/6 or 7/8

LPInfoBytes=BitsPerQAMmappingLP×DataPerOFDMSymbol ×LPCodeRate/8

The block delay of LPBytes_AfterViterbi is Delay_LPAfterViterbi is calculated as follows:

LPDelayBytes= DelayOFDMSymbols×LPInfoBytes-(int(DelayOFDMSymbols×LPInfoBytes/CodedBlockSize))×CodedBlockSize,

N_LP=int((TrunLen+LPDelayBytes)/CodedBlockSize),

Delay_LPAfterViterbi= 1+int((DelayOFDMSymbols×LPInfoBytes)/CodedBlockSize)+N_LP.

Block size is 204 bytes.

HPBytes_Decoded and LPBytes_Decoded each have 8 OFDM symbols and 11 transport MUX packet delays.
The block delay of HPBytes_Decoded is:

Delay_HPDecoded= 11+1+int((DelayOFDMSymbols×HPInfoBytes)/CodedBlockSize)+N_HP.

Block size is 188 bytes.

The block delay of LPBytes_Decoded is

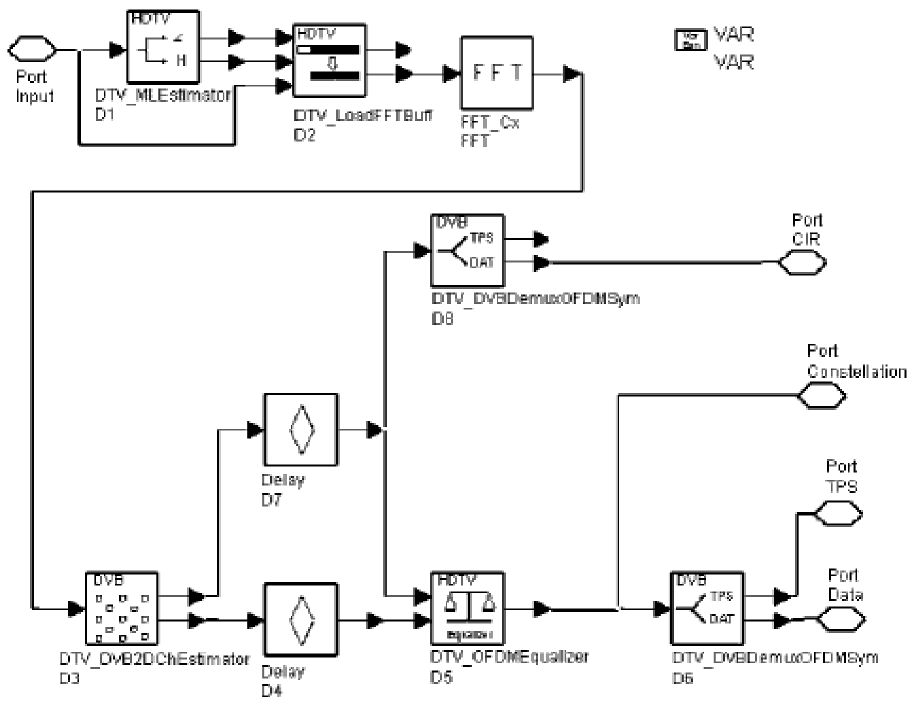
Delay_LPDecoded= 11+1+int((DelayOFDMSymbols×LPInfoBytes)/CodedBlockSize)+N_LP.

Block size is 188 bytes.

3. Receiver functions are implemented according to the DVB-T Standard.
Start of OFDM symbol is detected by the DTV_DVBTOFDMDemod subnetwork (see

below).

DTV_DVBTOFDMDemod Schematic



DTV_MLEstimator calculates the correlation based on guard interval;
DTV_LoadFFTBuff selects the index with the maximum correlation value as the start of FFT.

DTV_DVBCh2DEstimator estimates the complex channel impulse responses for continual and scattered pilot subcarriers. Channel impulse responses of the data subcarriers are 2D interpolated based on the estimated CIR.
Each subcarrier value is divided with a complex estimated channel response coefficient (phase tracking, phase synchronization, and equalization). This simple one-tap frequency domain channel response compensation is implemented by DTV_OFDMEqualizer.
After equalization, DTV_DVBDemuxOFDMSym demultiplexes 1705 or 6817 subcarriers into 1512 (2K mode) or 6048 (8K mode) data subcarriers and 1 demodulated TPS.
The demodulated 1512 or 6048 data subcarriers (16QAM, and 64QAM modulation) are demapped by DTV_Demapper.
The demodulated bits are deinterleaved by DTV_DVBTHierInnerDeinterlv and divided into high- and low-priority demodulated bits. The demodulated bits are inner decoded (DTV_InnerDecoder), outer de-interleaved (DTV_InterlvInt), outer decoded (DTV_RSDecoder) and descrambled (DTV_ScrambleByte). The fully-decoded high- and low-priority stream bytes are output as HPBytes_Decoded and LPBytes_Decoded.
After inner-decoding, the partially-decoded high- and low-priority stream bytes are output as HPBytes_AfterViterbi and LPBytes_AfterViterbi.
The TPS signal is demodulated by DTV_DVBTPSDemod; the demodulated bits are decoded by DTV_BCHDecoder.

Output pins of this DTV_DVBTHierReceiver subnetwork correspond to those of DTV_DVBTHierSignalSrc.
This hierarchical receiver works uses one OFDM symbol. The number of samples of each OFDM symbol (Rx_signal input pin) is:

(1+GuardInterval)×2048×OversamplingRatio for 2K mode

(1+GuardInterval)×8192×OversamplingRatio for 8K mode

The number of signals at the constellation output pin is 1705 (2K mode) or 6817 (8K mode) for one OFDM symbol.

4. Parameter Details
GainImbalance and PhaseImbalance add certain impairments to the ideal output RF signal. Impairments are added in the order described here.
The unimpaired RF I and Q envelope voltages have gain and phase imbalance applied. The RF is given by:

$$V_3(t) = A\left(V_1(t)\cos(\omega_c t) - gV_2(t)\sin\left(\omega_c t + \frac{\phi\pi}{180}\right)\right)$$

where $V_1(t)$ is the in-phase RF envelope, $V_2(t)$ is the quadrature phase RF envelope, g is the gain imbalance

$$g = 10^{\frac{GainImbalance}{20}}$$

and, Φ (in degrees) is the phase imbalance.
Mode specifies the 2K or 8K transmission mode as defined in DVB-T.
OversamplingOption specifies the transmission signal oversampling ratio 1, 2, 4, 8, 16, 32. If OversamplingOption=Ratio 2, the IFFT size is 4096 for 2K mode or 16384 for 8K mode.
GuardInterval specifies the guard interval (also called cyclic extension) length for each symbol time, as a fraction of the FFT time period. Guard interval types 1/4, 1/8, 1/16 and 1/32 are defined in the DVB-T specification. GuardInterval can be set to any value between 0.0 and 1.0 (not just 1/4, 1/8, 1/16 and 1/32). For proper demodulation, the value must match the guard interval length actually used in the input signal.
CodeRateHP specifies the high-priority stream code rate: 1/2, 2/3, 3/4, 5/6 or 7/8.
CodeRateLP specifies the low-priority stream code rate: 1/2, 2/3, 3/4, 5/6 or 7/8.
MappingMode specifies signal constellations and mapping for the DVB-T hierarchical signal source. Mapping modes 16-QAM and 64-QAM are available.
Alpha is used for signal constellation and mapping as defined in DVB-T specifications. If Alpha=1, 16-QAM or 64-QAM uniform mapping is performed; if Alpha=2 or 4, 16-QAM or 64-QAM in non-uniform mapping is performed.
SoftDecision specifies the Viterbi decoding algorithm mode.

If SoftDecision=Soft, the Viterbi decoding algorithm is a soft decision decoder and uses channel status information.

If SoftDecision=Hard, the Viterbi decoding algorithm is a hard decision decoder and does not use channel status information.

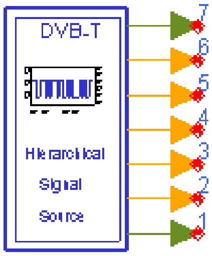
If SoftDecision=Cochannel, the Viterbi decoding algorithm is for co-channel measurement with PAL analog TV and digital DVB-T.

TrunLen sets the truncation length (in bytes) in the Viterbi decoding algorithm. The path memory is 8×TrunLen bits in Viterbi decoding algorithm.

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.
2. W.C.Lee, H.M.Park, K.J.Kang, K.B.Kim, "Performance Analysis of Viterbi Decoder Using Channel State Information in COFDM System" *IEEE TRANSACTIONS ON BROADCASTING*, Vol.,44,NO.4, DECEMBER 1998.

DTV_DVBTHierSignalSrc



Description: DVB-T hierarchical signal source
Library: DTV, DVB-T
Class: SDFDTV_DVBTHierSignalSrc

Parameters

Name	Description	Default	Symbol	Unit	Type	Range
Mode	transmission mode: DVB 2k mode, DVB 8k mode	DVB 2k mode			enum	
OversamplingOption	oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1	S		enum	
GuardInterval	guard interval (frac FFT size)	0.125			real	[0, 1]
CodeRateHP	high priority stream current code rate: HP 1/2, HP 2/3, HP 3/4, HP 5/6, HP 7/8	HP 1/2			enum	
CodeRateLP	low priority stream current code rate: LP 1/2, LP 2/3, LP 3/4, LP 5/6, LP 7/8	LP 1/2			enum	
MappingMode	signal consetllaions and mapping: QAM-16, QAM-64	QAM-16			enum	
Alpha	non-uniform factor for DVB-T.	1			int	[1, ∞)
DataTypeHP	Payload data type with high priority: PN9 HP, PN15 HP, FIX4 HP, _4_1_4_0 HP, _8_1_8_0 HP, _16_1_16_0 HP, _32_1_32_0 HP, _64_1_64_0 HP	PN9 HP			enum	
DataTypeLP	Payload data type with low priority: PN9 LP, PN15 LP, FIX4 LP, _4_1_4_0 LP, _8_1_8_0 LP, _16_1_16_0 LP, _32_1_32_0 LP, _64_1_64_0 LP	PN15 LP			enum	

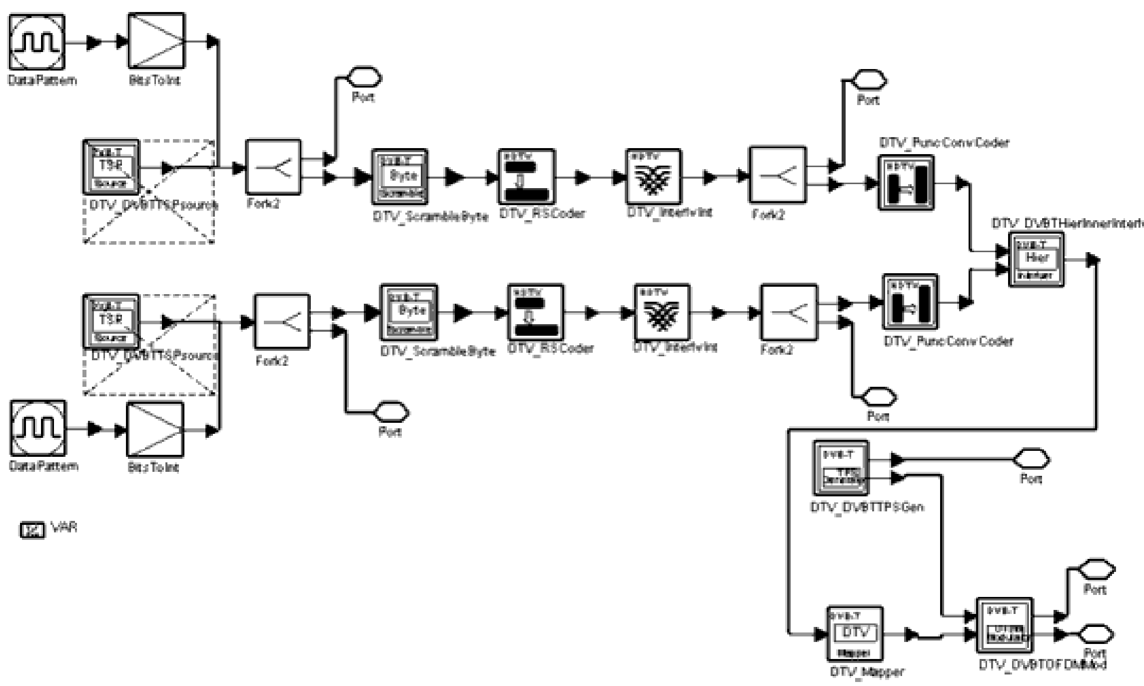
Pin Outputs

Pin	Name	Description	Signal Type
1	DVBT_signal	DVB-T signal	complex
2	HPBytes_Uncoded	information bytes of transport packet with high priority	int
3	LPBytes_Uncoded	information bytes of transport packet with low priority	int
4	HPBytes_BeforeCC	information bytes before convolutional coder with high priority	int
5	LPBytes_BeforeCC	information bytes before convolutional coder with low priority	int
6	TPS_Bits	TPS information bits	int
7	constellation	constellation signal before IFFT	complex

Notes/Equations

1. This subnetwork model is used to generate the DVB-T hierarchical signal source. Each firing, one OFDM symbol is generated.
   The schematic for this subnetwork is shown below.

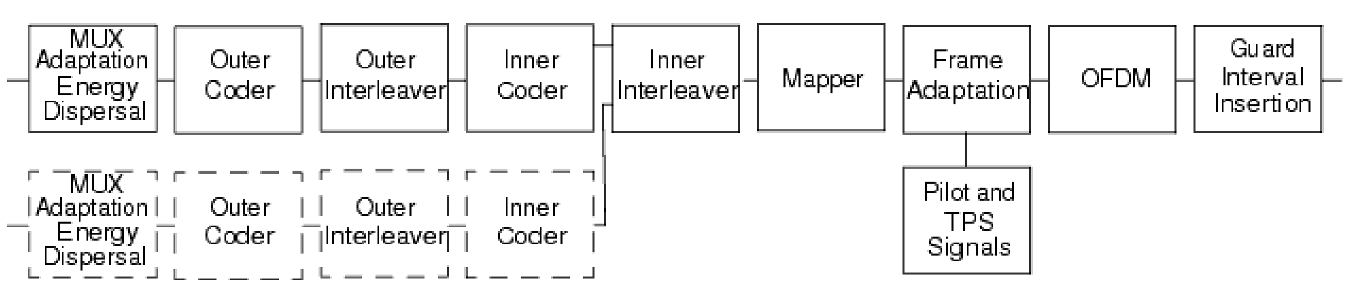
DTV_DVBTHierSignalSrc Schematic



> **Note**
> To use the 8 transport MUX packet structure according to the DVB-T standard, HP_stream and LP_stream with 8 transport MUX packets can be made active (HP_stream1, LP_stream1, B2 and B3 must be made inactive). However, the signal source with 8 transport MUX packets will consume much more memory during simulation.

2. The format of the hierarchical signal source follows the DVB-T specification. The figure below shows the functional block diagram of the DVB-T baseband system.

DVB-T Baseband System Functional Block Diagram



The DTV_DVBTHierSignalSrc includes: scrambler (DTV_ScrambleByte); outer coder (DTV_RSCoder); outer interleaver (DTV_InterlvInt); inner coder (DTV_PuncConvCoder); inner interleaver (DTV_DVBTHierInnerInterlv); mapper

(DTV_Mapper); and, frame adaptation, OFDM, and guard interval insertion (in DTV_DVBTOFDMMod subnetwork).
This hierarchical signal source works per one OFDM symbol: 1705 (2K mode) or 6817 (8K mode) constellations are output. The number of samples for each OFDM symbol (DVBT_signal output pin) is:

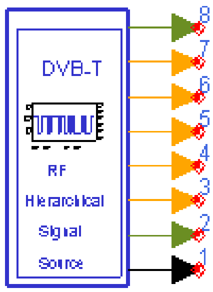
- (1+GuardInterval)×2048×OversamplingRatio (2K mode)
- (1+GuardInterval)×8192×OversamplingRatio (8K mode)

3. Parameter Details
    - Mode specifies the 2K or 8K transmission mode as defined in the DVB-T specification.
    - OversamplingOption specifies the transmission signal oversampling ratio 1, 2, 4, 8, 16, 32. If OversamplingOption=2, the IFFT size is 4096 (2K mode) or 16384 (8K mode).
    - GuardInterval specifies the guard interval (also called cyclic extension) length for each symbol time, as a fraction of the FFT time period. Guard interval types 1/4, 1/8, 1/16 and 1/32 are defined in the DVB-T specification. GuardInterval can be set to any value between 0.0 and 1.0 (not just 1/4, 1/8, 1/16 and 1/32). For proper demodulation, the value must match the guard interval length actually used in the input signal.
    - CodeRateHP specifies the high priority stream code rate: 1/2, 2/3, 3/4, 5/6 or 7/8.
    - CodeRateLP specifies the low priority stream code rate: 1/2, 2/3, 3/4, 5/6 or 7/8.
    - MappingMode specifies the DVB-T hierarchical signal source constellations: 16-QAM or 64-QAM.
    - Alpha is used for signal constellation and mapping (based on MappingMode).
        - If Alpha=1, uniform mapping of 16-QAM or 64-QAM is used.
        - If Alpha=2 or 4, non-uniform mapping of 16-QAM or 64-QAM is used as defined in DVB-T specification.
    - For the DataTypeHP parameter:
        - if PN9 HP is selected, a 511-bit pseudo-random test pattern is generated according to CCITT Recommendation O.153
        - if PN15 HP is selected, a 32767-bit pseudo-random test pattern is generated according to CCITT Recommendation O.151
        - if FIX4 HP is selected, a zero-stream is generated
        - if x_1_x_0 HP is selected (x equals 4, 8, 16, 32, or 64) a periodic bit stream is generated, with the period being 2x. In one period, the first x bits are 1s and the second x bits are 0s.
    - For the DataTypeLP parameter:
        - if PN9 LP is selected, a 511-bit pseudo-random test pattern is generated according to CCITT Recommendation O.153
        - if PN15 LP is selected, a 32767-bit pseudo-random test pattern is generated according to CCITT Recommendation O.151
        - if FIX4 LP is selected, a zero-stream is generated
        - if x_1_x_0 is selected (x equals 4, 8, 16, 32, or 64) a periodic bit stream is generated, with the period being 2x. In one period, the first x bits are 1s and the second x bits are 0s.

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.

DTV_DVBTHierSignalSrc_RF



Description: DVB-T RF hierarchical signal source
Library: DTV, DVB-T
Class: TSDFDTV_DVBTHierSignalSrc_RF

Parameters

Name	Description	Default	Symbol	Unit	Type	Range
ROut	output resistance	DefaultROut		Ohm	real	(0, ∞)
RTemp	physical temperature, in degrees C	DefaultRTemp		Celsius	real	[-273.15, ∞)
Noise	Enable thermal noise?: NO, YES	NO			enum	
FCarrier	carrier frequency	474.0MHz		Hz	real	(0, ∞)
Power	modulator output power	40mW		W	real	(0, ∞)
Bandwidth	bandwidth	(2048/224.0)MHz		Hz	real	(0, ∞)
MirrorSpectrum	Mirror spectrum about carrier?: NO, YES	NO			enum	
GainImbalance	Gain imbalance, Q vs I	0.0		dB	real	(-∞, ∞)
PhaseImbalance	Phase imbalance, Q vs I	0.0		deg	real	(-∞, ∞)
I_OriginOffset	I origin offset (percent)	0.0			real	(-∞, ∞)
Q_OriginOffset	Q origin offset (percent)	0.0			real	(-∞, ∞)
IQ_Rotation	IQ rotation	0.0		deg	real	(-∞, ∞)
Mode	transmission mode: DVB 2k mode, DVB 8k mode	DVB 2k mode			enum	
OversamplingOption	oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1	S		enum	
GuardInterval	guard interval (frac FFT size)	0.125			real	[0, 1]
CodeRateHP	high priority stream current code rate: HP 1/2, HP 2/3, HP 3/4, HP 5/6, HP 7/8	HP 1/2			enum	
CodeRateLP	low priority stream current code rate: LP 1/2, LP 2/3, LP 3/4, LP 5/6, LP 7/8	LP 1/2			enum	
MappingMode	signal consetllaions and mapping: QAM-16, QAM-64	QAM-16			enum	
Alpha	non-uniform factor for DVB-T.	1			int	[1, ∞)
DataTypeHP	Payload data type with high priority: PN9 HP, PN15 HP, FIX4 HP, _4_1_4_0 HP, _8_1_8_0 HP, _16_1_16_0 HP, _32_1_32_0 HP, _64_1_64_0 HP	PN9 HP			enum	
DataTypeLP	Payload data type with low priority: PN9 LP, PN15 LP, FIX4 LP, _4_1_4_0 LP, _8_1_8_0 LP, _16_1_16_0 LP, _32_1_32_0 LP, _64_1_64_0 LP	PN15 LP			enum	

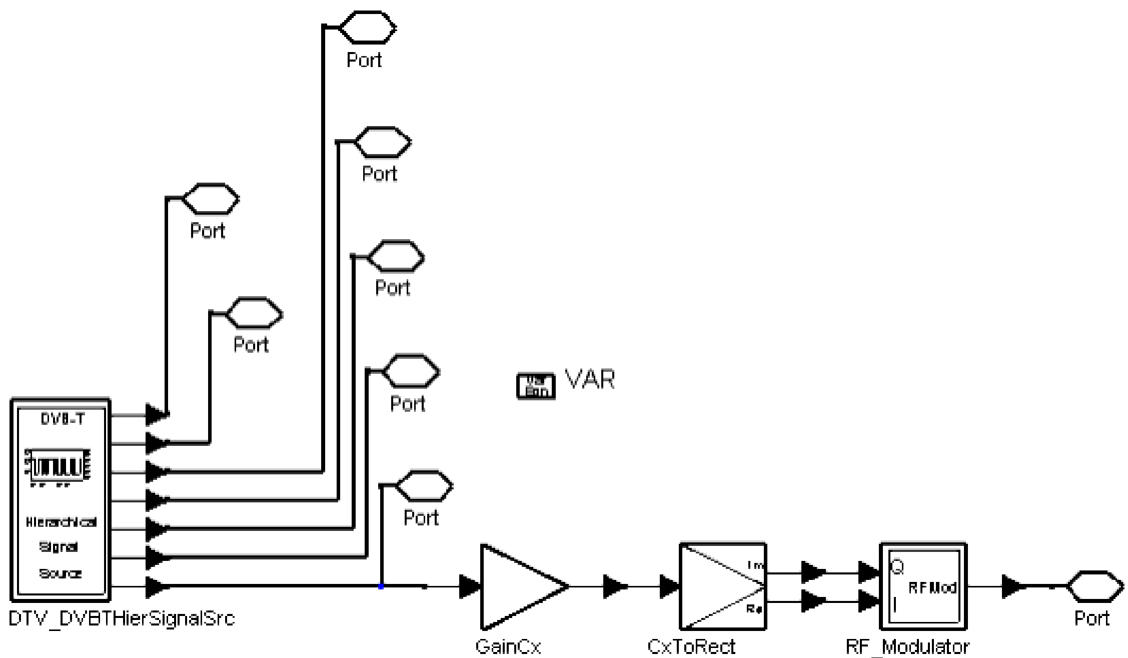
Pin Outputs

Pin	Name	Description	Signal Type
1	RF_signal	RF signal	timed
2	DVBT_signal	DVB-T signal	complex
3	HPBytes_Uncoded	information bytes of transport packet with high priority	int
4	LPBytes_Uncoded	information bytes of transport packet with low priority	int
5	HPBytes_BeforeCC	information bytes before convolutional coder with high priority	int
6	LPBytes_BeforeCC	information bytes before convolutional coder with low priority	int
7	TPS_Bits	TPS information bits	int
8	constellation	constellation signal before IFFT	complex

Notes/Equations

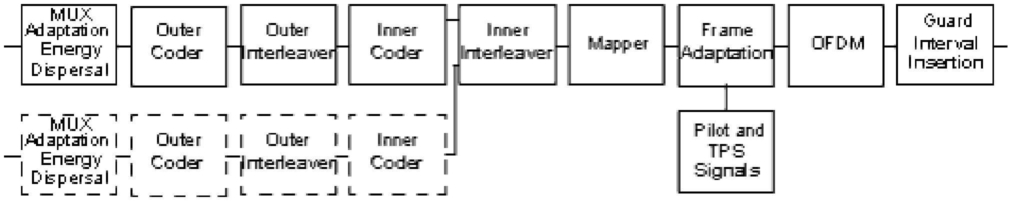
1. This subnetwork model integrates an RF modulator and a baseband hierarchical signal source based on the DVB-T specification. The baseband hierarchical signal is fed to the RF modulator; after RF modulation the timed signal is output.
   The schematic for this subnetwork is shown below.

   DTV_DVBTHierSignalSrc_RF Schematic



2. The format of DVB-T signal source follows the DVB-T specification. The figure below is a functional block diagram of a DVB-T baseband system.

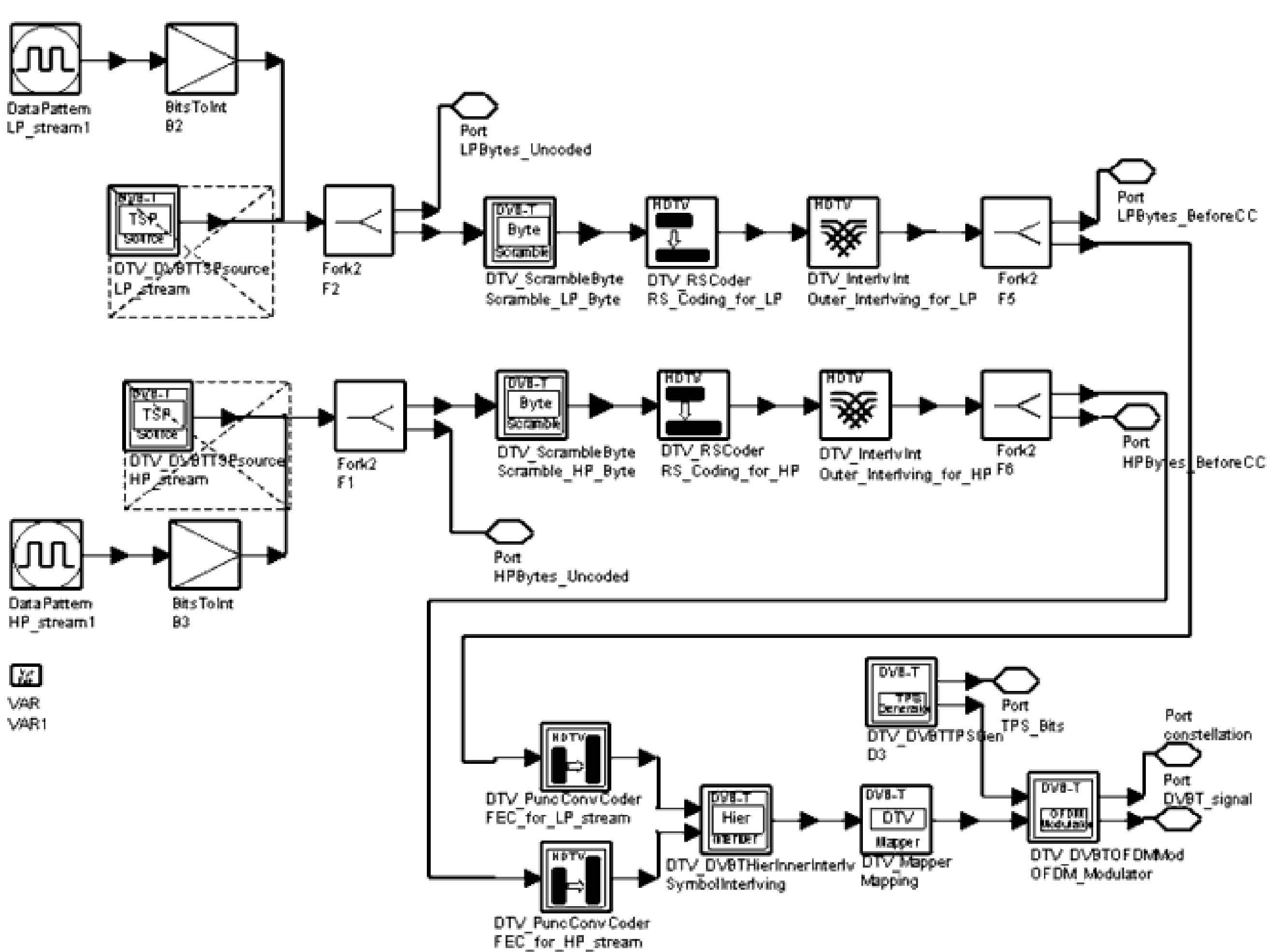
   DVB-T Baseband System Block Diagram



3. The schematic for the hierarchical signal source is shown in [DTV_DVBTHierSignalSrc Schematic](). The DTV_DVBTHierSignalSrc includes: scrambler (DTV_ScrambleByte); outer coder (DTV_RSCoder); outer interleaver (DTV_InterlvInt); inner coder (DTV_PuncConvCoder); inner interleaver (DTV_DVBTHierInnerInterlv); mapper (DTV_Mapper); and, frame adaptation, OFDM, and guard interval insertion (in DTV_DVBTOFDMMod subnetwork).

> **Note**
> To use the 8 transport MUX packet structure, HP_stream and LP_stream with 8 transport MUX packets must be active, and HP_stream1, LP_stream1, B2, and B3 must be inactive. A signal source with 8 transport MUX packets will consume more memory during simulation.

DTV_DVBTHierSignalSrc Schematic



This hierarchical signal source works per each OFDM symbol: 1705 (2K mode) or 6817 (8K mode) constellations are output. DVBT_signal pin outputs samples for each OFDM symbol:

- (1+GuardInterval)×2048×OversamplingRatio (2K mode)
- (1+GuardInterval)×8192×OversamplingRatio (8K mode)

4. Parameter Details
FCarrier defines the RF frequency for the DVB signal.
Power defines the power level for FCarrier.
Bandwidth indicates signal band width.
MirrorSpectrum (when set to YES) conjugates the input signal before any other processing is done.
The GainImbalance, PhaseImbalance, I_OriginOffset, Q_OriginOffset, and IQ_Rotation parameters add certain impairments to the ideal output RF signal. Impairments are added in the order described here.
The unimpaired RF I and Q envelope voltages have gain and phase imbalance applied. The RF is given by:

$$V_3(t) = A\left(V_1(t)\cos(\omega_c t) - gV_2(t)\sin\left(\omega_c t + \frac{\phi\pi}{180}\right)\right)$$

where *A* is a scaling factor that depends on the Power and ROut parameters specified by the user, $V_1(t)$ is the in-phase RF envelope, $V_2(t)$ is the quadrature phase RF envelope, *g* is the gain imbalance

$$g = 10^{\frac{GainImbalance}{20}}$$

and, Φ (in degrees) is the phase imbalance.
The signal $V_3(t)$ is rotated by IQ_Rotation degrees; I_OriginOffset and Q_OriginOffset are then applied to the rotated signal. Note that the amounts specified are percentages with respect to the output rms voltage. The output rms voltage is given by sqrt(2×ROut×Power).
Mode specifies the 2K or 8K transmission mode as defined in the DVB-T specification.
OversamplingOption specifies the transmission signal oversampling ratio 1, 2, 4, 8, 16, 32. If OversamplingOption=2, the IFFT size is 4096 (2K mode) or 16384 (8K mode).
GuardInterval specifies the guard interval (also called cyclic extension) length for each symbol time, as a fraction of the FFT time period. Guard interval types 1/4, 1/8, 1/16 and 1/32 are defined in the DVB-T specification. GuardInterval can be set to any value between 0.0 and 1.0 (not just 1/4, 1/8, 1/16 and 1/32). For proper demodulation, the value must match the guard interval length actually used in the input signal.
CodeRateHP specifies the high priority stream code rate: 1/2, 2/3, 3/4, 5/6 or 7/8.
CodeRateLP specifies the low priority stream code rate: 1/2, 2/3, 3/4, 5/6 or 7/8.
MappingMode specifies signal constellation and mapping modes: 16-QAM or 64-QAM.
Alpha is used for signal constellation and mapping as defined in DVB-T specifications. If Alpha=1, 16-QAM or 64-QAM uniform mapping is performed; if Alpha=2 or 4, 16-QAM or 64-QAM in non-uniform mapping is performed.
For the DataTypeHP parameter:

    if PN9 is selected, a 511-bit pseudo-random test pattern is generated according to CCITT Recommendation O.153.

    if PN15 is selected, a 32767-bit pseudo-random test pattern is generated according to CCITT Recommendation O.151.

    if FIX4 is selected, a zero-stream is generated.

if x_1_x_0 is selected, where x equals 4, 8, 16, 32, or 64, a periodic bit stream is generated, with the period being 2x. In one period, the first x bits are 1s and the second x bits are 0s.

For the DataTypeLP parameter:

if PN9 is selected, a 511-bit pseudo-random test pattern is generated according to CCITT Recommendation O.153.

if PN15 is selected, a 32767-bit pseudo-random test pattern is generated according to CCITT Recommendation O.151.

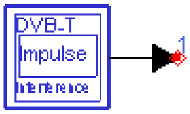
if FIX4 is selected, a zero-stream is generated.

if x_1_x_0 is selected, where x equals 4, 8, 16, 32, or 64, a periodic bit stream is generated, with the period being 2x. In one period, the first x bits are 1s and the second x bits are 0s.

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.

DTV_DVBTImpulseNoise



Description: Impulse interference Noise
Library: DTV, DVB-T
Class: TSDFDTV_DVBTImpulseNoise

Parameters

Name	Description	Default	Unit	Type	Range
Test_No	test mode: Test_No_1, Test_No_2, Test_No_3, Test_No_4, Test_No_5, Test_No_6	Test_No_3		enum	
NoisePower	power of impulse interference noise	1.0W	W	real	(-∞, ∞)
TStep	time step	0.19375usec	sec	real	(0, ∞)
FCarrier	carrier frequency	474.0MHz	Hz	real	(0, ∞)
RefR	resistance	50Ohm	Ohm	real	(0, ∞)

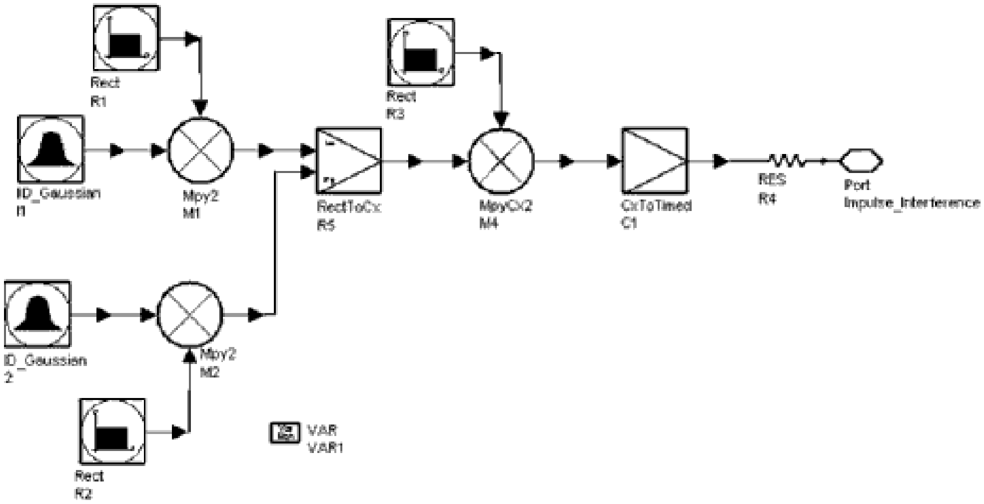
Pin Outputs

Pin	Name	Description	Signal Type
1	Impulse_Interfence	impulse interference noise	timed

Notes/Equations

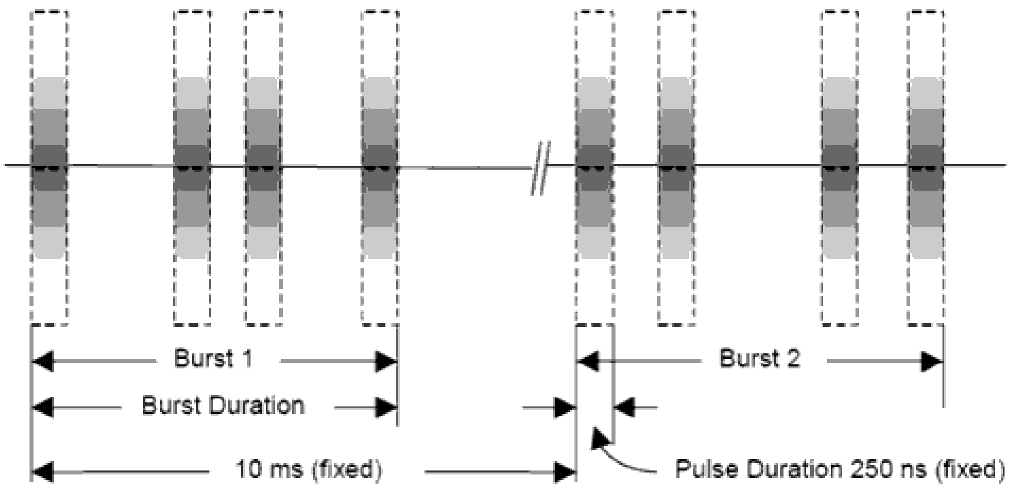
1. This model generates an impulse interference typically caused by automotive ignition systems, domestic appliance switches, and electric motors. The impulse interference consists of a number of bursts that are generated by gating a Gaussian noise source of power P.
   The schematic for this impulse noise generator is shown below.

DTV_DVBTImpulseNoise Schematic



2. The impulse noise test signal is shown below. In this figure, the separation of bursts is fixed at 10 msec and pulse duration is fixed at 250 nsec.

Impulse Noise Test Signal



> **Note**
> This model supports fixed spacing between pulses instead of variable spacing described in 11.13.3 of Reference [1]. Fixed spacing is dependent on test types detailed in note 3.

3. This model supports 6 tests in which the number of pulses per burst and pulse spacing vary according to Test_No as listed in the table below.

Impulse Noise Tests and Pulse Parameters

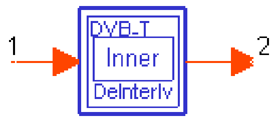
Test_No	Pulses per Burst	Pulse Spacing (μ sec)	Burst Duration (μ sec)
1	1	0.25	0.25
2	2	20	40
3	4	20	80
4	12	12	144
5	20	1.5	30
6	40	0.75	30

Noise power is the Gaussian noise power that is gated by pulses. It can be measured by closing the Rect pulse generators R1, R2, R3 in DTV_DVBTImpulseNoise Schematic.

References

1. DTG RF Sub-Group Document No.67, chapter 11.

DTV_DVBTInnerDeInterlv



Description: Inner de-interleaver for QPSK, 16QAM and 64QAM non-hierarchical transmission modes
Library: DTV, DVB-T
Class: SDFDTV_DVBTInnerDeInterlv

Parameters

Name	Description	Default	Unit	Type	Range
Mode	transmission mode: DVB 2k mode, DVB 8k mode	DVB 2k mode		enum	
MappingMode	signal constellations and mapping: QPSK, QAM-16, QAM-64	QAM-16		enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	Symbols	input of inner de-interleaver	anytype

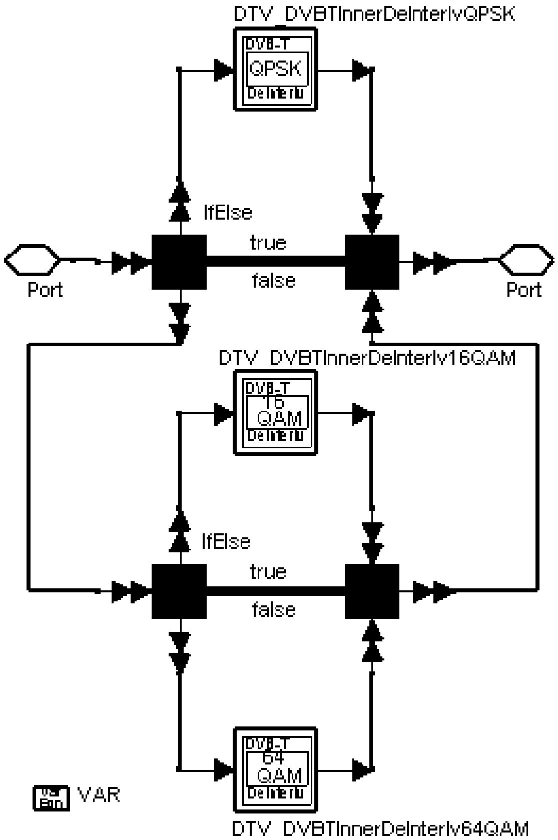
Pin Outputs

Pin	Name	Description	Signal Type
2	Bits	output bit stream of inner de-interleaver	anytype

Notes/Equations

1. This subnetwork model performs inner de-interleaving QPSK, 16QAM and 64QAM non-hierarchical transmission modes. Functions are performed by an if-else structure. The schematic for this subnetwork is shown below.

DTV_DVBTInnerDeInterlv Subnetwork

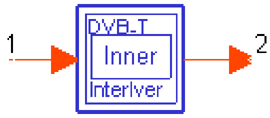


2. The Mode parameter is used to specify the 2K mode or the 8K mode.
3. The MappingMode parameter is used to specify QPSK, QAM-16 or QAM-64.

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.

DTV_DVBTInnerInterlv



Description: Inner interleaver for QPSK, 16QAM, 64QAM non-hierarchical transmission modes
Library: DTV, DVB-T
Class: SDFDTV_DVBTInnerInterlv

Parameters

Name	Description	Default	Unit	Type	Range
Mode	transmission mode: DVB 2k mode, DVB 8k mode	DVB 2k mode		enum	
MappingMode	signal constellations and mapping: QPSK, QAM-16, QAM-64	QAM-16		enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	Bits	Bit stream prior to inner interleaver	anytype

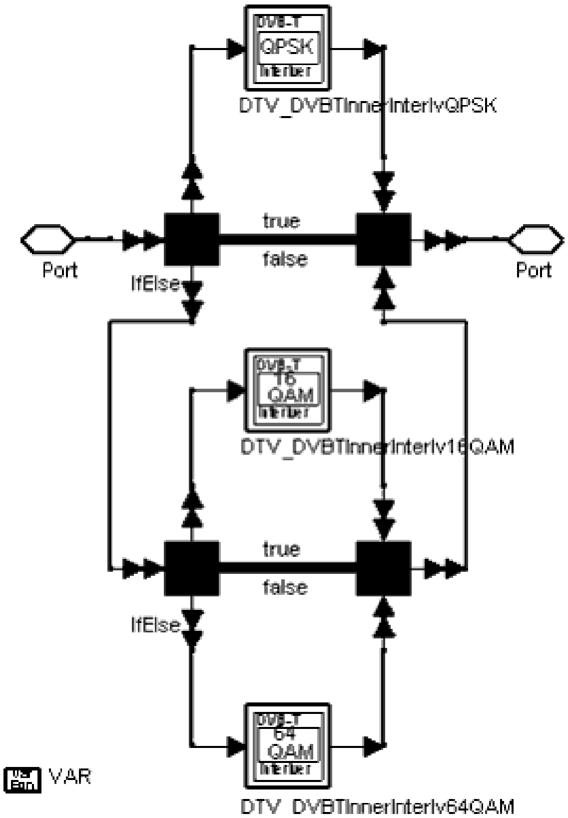
Pin Outputs

Pin	Name	Description	Signal Type
2	Symbols	output of inner interleaver	anytype

Notes/Equations

1. This subnetwork model performs inner interleaving QPSK, 16QAM and 64QAM. Functions are performed by an if-else structure.
   The schematic for this subnetwork is shown below.

DTV_DVBTInnerInterlv Schematic

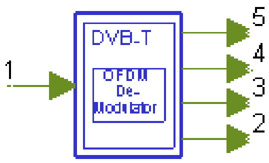


2. The Mode parameter is used to specify the 2K mode or the 8K mode.
3. The MappingMode parameter is used to specify QPSK, QAM-16 or QAM-64.

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.

DTV_DVBTOFDMDemod



Description: DVB-T OFDM de-modulator
Library: DTV, DVB-T
Class: SDFDTV_DVBTOFDMDemod

Parameters

Name	Description	Default	Symbol	Unit	Type	Range
Mode	transmission mode: DVB 2k mode, DVB 8k mode, DVB 4k mode	DVB 2k mode			enum	
OversamplingOption	oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1	S		enum	
GuardInterval	guard interval (frac FFT size)	1/32			real	[0, 1]

Pin Inputs

Pin	Name	Description	Signal Type
1	input	received OFDM symbol	complex

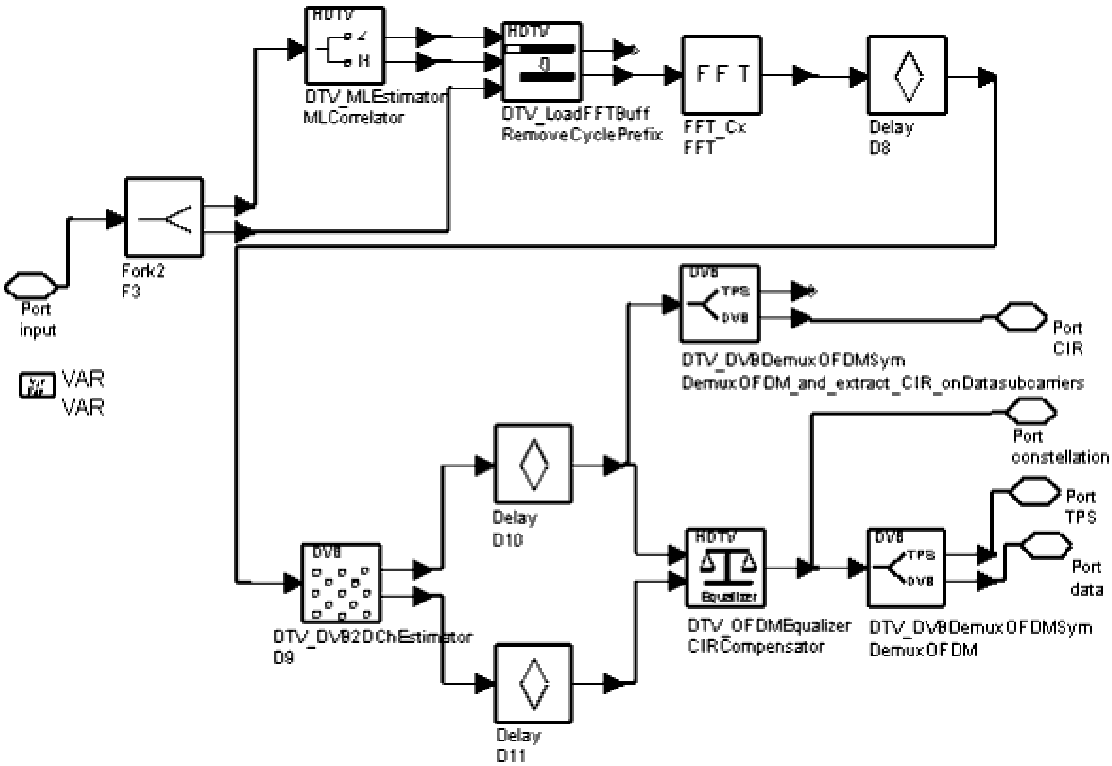
Pin Outputs

Pin	Name	Description	Signal Type
2	data	information on data subcarriers	complex
3	TPS	information on TPS subcarriers	complex
4	CIR	estimated channel impulse response on data subcarriers	complex
5	Constellation	demodulated constellation on all active subcarriers	complex

Notes/Equations

1. This subnetwork model implements OFDM demodulation for DVB-T. The schematic for this subnetwork is shown below.

DTV_DVBTOFDMDemod Schematic



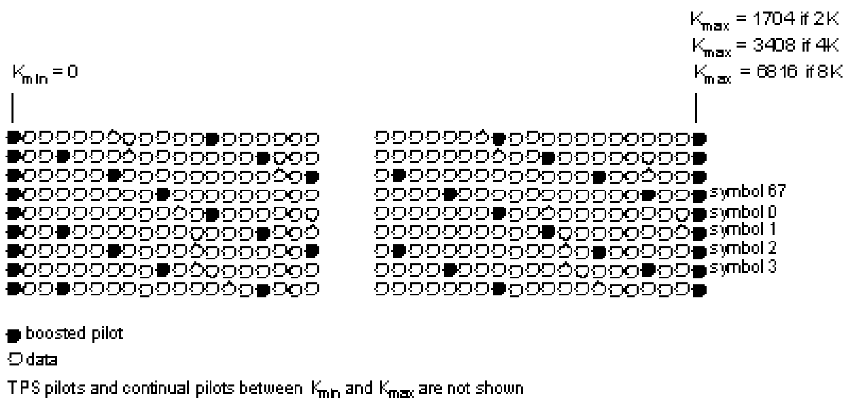
2. The data, TPS, and constellation output pins correspond to DTV_DVBTOFDMMod pins; the CIR pin outputs the estimated channel impulse response of each data subcarrier, which is used as channel status information in the soft Viterbi decoding algorithm. Each firing, the input pin consumes (1+GuardInterval)×2048×OversamplingRatio of 2K mode, (1+GuardInterval)×4096×OversamplingRatio of 4K mode, or (1+GuardInterval)×8192×OversamplingRatio of 8K mode tokens. The data and CIR pins output 1512 (2K mode), 3024 (4K mode), or 6048 (8K mode) complex signals; the constellation pin outputs 1705 (2K mode), 3049 (4K mode), or 6817 (8K mode) demodulated complex signals; the TPS pin outputs one received TPS signal. DTV_DVBTOFDMDemod has a delay of 8 OFDM symbols when the received OFDM signal is demodulated; so, the output tokens for the first 8 OFDM symbols in each output pin should be discarded.
3. De-multiplex demodulated subcarriers into TPS, data, and pilots (continual and scattered).
   Frame Structure shows the frame structure. IntState of Length determines the number of CP (continual pilot) and TPS in each symbol; CP and TPS positions are determined according to Carrier Indices for Continual Pilot Carriers and *Carrier Indices for TPS Carriers*, respectively.
   PRBS sequences in each segment are generated according to PRBS Sequence Generation; the initial PRBS register setting is 11111111111. The PRBS in initialized so that the first output bit from the PRBS coincides with the first active carrier. A new value is generated by the PRBS on each carrier in each segment (whether or not it is a pilot).
   Positions of the corresponding scattered pilots are generated as follows. For the symbol of index *l* (ranging from 0 to 67), carriers for which index *k* belongs to subset
   $$\{k = K_{min} + 3 \times l \ mod \ 4 + 12p \,|\, p \ \ integer, p \geq 0, k \in [K_{min}, K_{max}]\}$$
   are scattered pilots positions.
   where *p* is an integer that takes all possible values ≥ 0, provided the resulting value for *k* does not exceed the valid range [K_{min}, K_{max}]; K_{min} = 0, and K_{max} = 1705 (2K

mode), K_{max} = 3409 (4K mode), or 6817 (8K mode). SPperiod, SPstart, SPoffset, and SPphase parameters control the scattered pilots positions.
After determining the CP, TPS, and SP positions in each symbol and the value of the PRBS sequence in all active carriers in the symbol, this subnetwork demultiplexes input data into TPS and TSP data. According to the TPS position and the PRBS sequence, one transmitted TPS bit is determined by the mean value of the TPS positions.

$$TPS = \frac{1}{NTPS}\sum_{l=1}^{NTPS}\frac{x[TPSposition[l]]}{PilotValue[TPSposition[l]]}$$

where *NTPS* is the number of TPS in one symbol; *PilotValue* is the PRBS sequence in symbol; *x[i]* is the input data.
The other positions (other than TPS, CP, and SP) in one segment are the TSP data positions.

$$Data[i] = x[i]$$

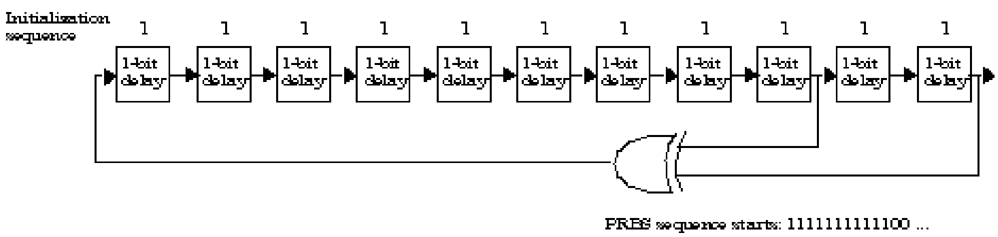


Frame Structure

Carrier Indices for Continual Pilot Carriers

Continual pilot carrier positions (index number k)		
2K mode	**4K mode**	**8K mode**
0 48 54 87 141 156 192 201 255 279 282 333 432 450 483 525 531 618 636 714 759 765 780 804 873 888 918 939 942 969 984 1050 1101 1107 1110 1137 1140 1146 1206 1269 1323 1377 1491 1683 1704	0 48 54 87 141 156 192 201 255 279 282 333 432 450 483 525 531 618 636 714 759 765 780 804 873 888 918 939 942 969 984 1050 1101 1107 1110 1137 1140 1146 1206 1269 1323 1377 1491 1683 1704 1752 1758 1791 1845 1860 1896 1905 1959 1983 1986 2037 2136 2154 2187 2229 2235 2322 2340 2418 2463 2469 2484 2508 2577 2592 2622 2643 2646 2673 2688 2754 2805 2811 2814 28412844 2850 2910 2973 3027 3081 3195 3387 3408	0 48 54 87 141 156 192 201 255 279 282 333 432 450 483 525 531 618 636 714 759 765 780 804 873 888 918 939 942 969 984 1050 1101 1107 1110 1137 1140 1146 1206 1269 1323 1377 1491 1683 1704 1752 1758 1791 1845 1860 1896 1905 1959 1983 1986 2037 2136 2154 2187 2229 2235 2322 2340 2418 2463 2469 2484 2508 2577 2592 2622 2643 2646 2673 2688 2754 2805 2811 2814 28412844 2850 2910 2973 3027 3081 3195 3387 3408 3456 3462 3495 3549 3564 3600 3609 3663 3687 3690 3741 3840 3858 3891 3933 3939 4026 4044 4122 4167 4173 4188 4212 4281 4296 4326 4347 4350 4377 4392 4458 4509 4515 4518 4545 4548 4554 4614 4677 4731 4785 4899 5091 5112 5160 5166 5199 5253 5268 5304 5313 5367 5391 5394 5445 5544 5562 5595 5637 5643 5730 5748 5826 5871 5877 5892 5916 5985 6000 6030 6051 6054 6081 6096 6162 6213 6219 6222 6249 6252 6258 6318 6381 6435 6489 6603 6795 6816

2K mode	4K mode	8K mode
34 50 209 346 413 569 595 688 790 901 1073 1219 1262 1286 1469 1594 1687	34 50 209 346 413 569 595 688 790 901 1073 1219 1262 1286 1469 1594 1687 1738 1754 1913 2050 2117 2273 2299 2392 2494 2605 2777 2923 2966 2990 3173 3298 3391	34 50 209 346 413 569 595 688 790 901 1073 1219 1262 1286 1469 1594 1687 1738 1754 1913 2050 2117 2273 2299 2392 2494 2605 2777 2923 2966 2990 3173 3298 3391 3442 3458 3617 3754 3821 3977 4003 4096 4198 4309 4481 4627 4670 4694 4877 5002 5095 5146 5162 5321 5458 5525 5681 5707 5800 5902 6013 6185 6331 6374 6398 6581 6706 6799



PRBS Sequence Generation

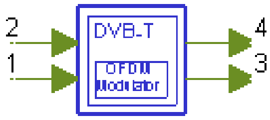
4. Parameter Details
   Mode is used to select transmission 2K, 4K, or 8K mode as defined in DVB-T.
   OversamplingOption indicates the oversampling ratio of transmission signal. Oversampling ratios 1, 2, 4, 8, 16, 32 are supported. If OversamplingOption=Ratio 2, the IFFT size is 4096 (2K mode), 8192 (4K mode), or 16384 (8K mode).
   GuardInterval specifies the guard interval (also called cyclic extension) length for each symbol time, as a fraction of the FFT time period. The value must match the guard interval length actually used in the input signal in order for the proper demodulation.

References

1. ETSI, *Digital Video Broadcasting (DVB)* ; *Framing structure, channel coding and modulation for digital terrestrial television* . EN300 744 v1.5.1, European

Telecommunication Standard, November 2004.

DTV_DVBTOFDMMod



Description: DVB-T OFDM modulator
Library: DTV, DVB-T
Class: SDFDTV_DVBTOFDMMod

Parameters

Name	Description	Default	Symbol	Unit	Type	Range
Mode	transmission mode: DVB 2k mode, DVB 8k mode, DVB 4k mode	DVB 2k mode			enum	
OversamplingOption	oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1	S		enum	
GuardInterval	guard interval (frac FFT size)	1/32			real	[0, 1]

Pin Inputs

Pin	Name	Description	Signal Type
1	Data	data subcarriers	complex
2	TPS	TPS signals	complex

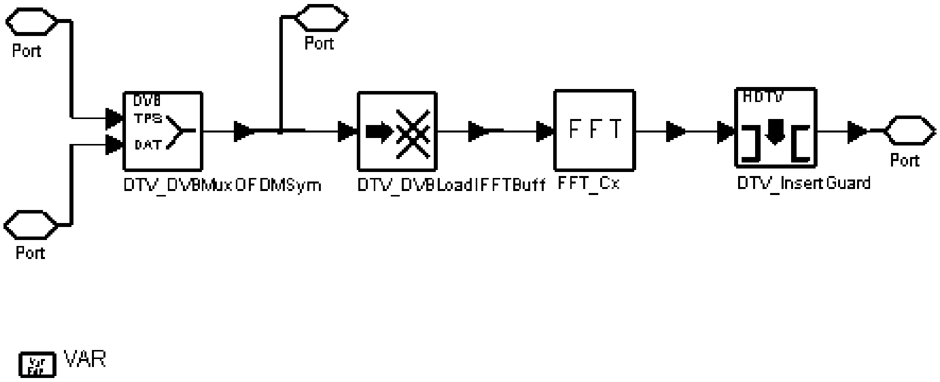
Pin Outputs

Pin	Name	Description	Signal Type
3	Signal	OFDM symbol	complex
4	Constellation	mapping signal before OFDM modulation	complex

Notes/Equations

1. This subnetwork model implements OFDM modulation for DVB-T.
   The schematic for this subnetwork is shown below.

DTV_DVBTOFDMMod Schematic



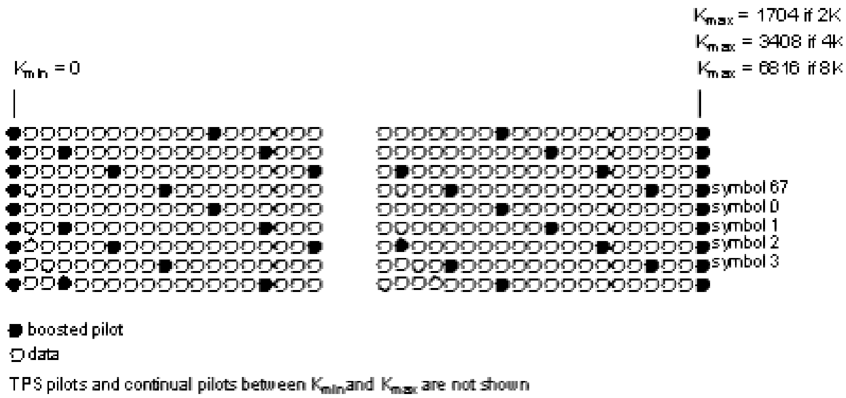
DTV_DVBMuxOFDMSym multiplexes TPS, data, and pilots (continual and scattered) into one OFDM symbol in the frequency domain and outputs (at the constellation pin) 1705 (2K mode), 3409 (4K mode), or 6817 (8K mode) subcarriers each firing.
DTV_DVBLoadIFFTBuff loads transmission data (1705, 3409, or 6817) into the IFFT buffer and inserts zeros into the other subcarriers. After IFFT, the frequency domain signals are converted into the time domain.
DTV_InsertGuard inserts a cyclic prefix as the guard interval before the IFFT signal. One OFDM symbol is then generated.
Each firing: TPS pin consumes one input token; the data pin fires 1512 (2K mode), 3024 (4K mode), or 6048 (8K mode) input tokens; constellation pin outputs (1705 or 6817) mapping signals and signal pin output
(1+GuardInterval)×2048×OversamplingRatio (2K mode),
(1+GuardInterval)×4096×OversamplingRatio (4K mode)
(1+GuardInterval)×8192×OversamplingRatio (8K mode) complex signals.

2. Multiplex TPS, data and pilots (continual pilots and scattered pilots)
The OFDM frame structure is shown in Frame Structure. The number of IntState of Length determines the number of CP (continual pilot) and TPS in each symbol; the CP and TPS positions are determined according to Carrier Indices for Continual Pilot Carriers and Carrier Indices for TPS Carriers, respectively.
PRBS sequences in each segment are generated according to PRBS Sequence Generation; the initial sets of PRBS register is 11111111111. The PRBS in initialized so that the first output bit from the PRBS coincides with the first active carrier. A new value is generated by the PRBS on each carrier in each segment (whether or not it is a pilot).
Positions of the corresponding scattered pilots are generated as follows. For the symbol of index *l* (ranging from 0 to 67), carriers for which index *k* belongs to subset
$$\{k = K_{min} + 3 \times l \;\; mod \;\; 4 + 12p \,|\, p \;\; integer, p \geq 0, k \in [K_{min}, K_{max}]\}$$
are scattered pilot positions
where *p* is an integer that takes all possible values ≥ 0, provided the resulting value for *k* does not exceed the valid range [K_{min}, K_{max}]; K_{min} = 0, and K_{max} = 1705 (2K mode), 3409 (4K mode), or 6817 (8K mode). SPperiod, SPstart, and SPoffset parameters control the scattered pilots positions.
After determining the CP, TPS, and SP positions in each symbol and the value of the PRBS sequence in all active carriers in one symbol, the model demultiplexes the input data into TPS and TSP data. According to the TPS position and the PRBS sequence, one TPS bit is output in each TPS position.
$$x[TPSposition[l]] = PilotValue[TPSposition[l]] \times TPS$$
where *NTPS* is the number of TPS in one symbol; *PilotValue* is the PRBS sequence in symbol; *x[i]* is the OFDM symbol data.
Except for TPS, CP, and SP positions, the remaining positions in one segment are the

TSP data positions.

$x[i] = Data[i]$

Frame Structure



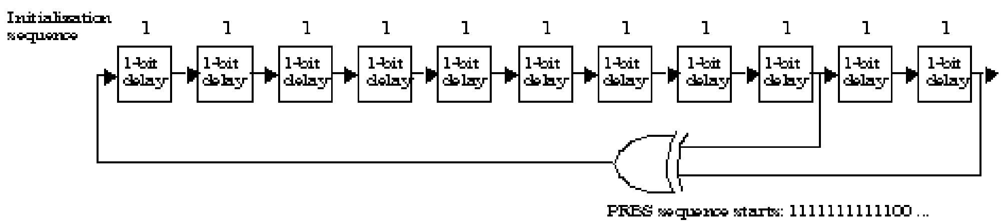
Carrier Indices for Continual Pilot Carriers

Continual pilot carrier positions (index number k)		
2K mode	**4K mode**	**8K mode**
0 48 54 87 141 156 192 201 255 279 282 333 432 450 483 525 531 618 636 714 759 765 780 804 873 888 918 939 942 969 984 1050 1101 1107 1110 1137 1140 1146 1206 1269 1323 1377 1491 1683 1704	0 48 54 87 141 156 192 201 255 279 282 333 432 450 483 525 531 618 636 714 759 765 780 804 873 888 918 939 942 969 984 1050 1101 1107 1110 1137 1140 1146 1206 1269 1323 1377 1491 1683 1704 1752 1758 1791 1845 1860 1896 1905 1959 1983 1986 2037 2136 2154 2187 2229 2235 2322 2340 2418 2463 2469 2484 2508 2577 2592 2622 2643 2646 2673 2688 2754 2805 2811 2814 28412844 2850 2910 2973 3027 3081 3195 3387 3408	0 48 54 87 141 156 192 201 255 279 282 333 432 450 483 525 531 618 636 714 759 765 780 804 873 888 918 939 942 969 984 1050 1101 1107 1110 1137 1140 1146 1206 1269 1323 1377 1491 1683 1704 1752 1758 1791 1845 1860 1896 1905 1959 1983 1986 2037 2136 2154 2187 2229 2235 2322 2340 2418 2463 2469 2484 2508 2577 2592 2622 2643 2646 2673 2688 2754 2805 2811 2814 28412844 2850 2910 2973 3027 3081 3195 3387 3408 3456 3462 3495 3549 3564 3600 3609 3663 3687 3690 3741 3840 3858 3891 3933 3939 4026 4044 4122 4167 4173 4188 4212 4281 4296 4326 4347 4350 4377 4392 4458 4509 4515 4518 4545 4548 4554 4614 4677 4731 4785 4899 5091 5112 5160 5166 5199 5253 5268 5304 5313 5367 5391 5394 5445 5544 5562 5595 5637 5643 5730 5748 5826 5871 5877 5892 5916 5985 6000 6030 6051 6054 6081 6096 6162 6213 6219 6222 6249 6252 6258 6318 6381 6435 6489 6603 6795 6816

Carrier Indices for TPS Carriers

2K mode	4K mode	8K mode
34 50 209 346 413 569 595 688 790 901 1073 1219 1262 1286 1469 1594 1687	34 50 209 346 413 569 595 688 790 901 1073 1219 1262 1286 1469 1594 1687 1738 1754 1913 2050 2117 2273 2299 2392 2494 2605 2777 2923 2966 2990 3173 3298 3391	34 50 209 346 413 569 595 688 790 901 1073 1219 1262 1286 1469 1594 1687 1738 1754 1913 2050 2117 2273 2299 2392 2494 2605 2777 2923 2966 2990 3173 3298 3391 3442 3458 3617 3754 3821 3977 4003 4096 4198 4309 4481 4627 4670 4694 4877 5002 5095 5146 5162 5321 5458 5525 5681 5707 5800 5902 6013 6185 6331 6374 6398 6581 6706 6799

PRBS Sequence Generation

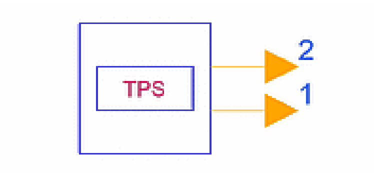


3. Parameter Details
   Mode specifies the 2K or 8K transmission mode as defined in DVB-T.
   OversamplingOption specifies the oversampling ratio of transmission signal: 1, 2, 4, 8, 16, or 32. For example, if OversamplingOption = Ratio 2, the IFFT size is 4096 (2K mode) or 16384 (8K mode).
   GuardInterval specifies the guard interval (also called cyclic extension) length for each symbol time, as a fraction of the FFT time period. For proper demodulation, the value must match the guard interval length that is actually used in the input signal.

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.

DTV_DVBTPS



Description: Transmission parameter signal information bits
Library: DTV, DVB-T
Class: SDFDTV_DVBTPS

Parameters

Name	Description	Default	Unit	Type	Range
Length	length of TPS information bits	54		int	{54}
InitiBit	initialization bit for DBPSK modulation (1 bit)	1		int	{0,1}
Sync	synchronization word (16 bits): W0, W1	W0		enum	
LengthIndicator	TPS length indicator (6 bits)	0 1 0 1 1 1		int array	"0 1 0 1 1 1"
FrameNumber	frame number in one super frame (2 bits): F1, F2, F3, F4	F1		enum	
Constellation	modulation scheme in DVB-T (2bits): QPSK, QAM 16, QAM 64, reserved M	QPSK		enum	
HierarchyInform	signaling format for alpha values (3 bits): Non hierarchical, alpha 1, alpha 2, alpha 4, reserved H1, reserved H2, reserved H3, reserved H4	Non hierarchical		enum	
CodeRateHP	high priority stream current code rate (3 bits): HP 1/2, HP 2/3, HP 3/4, HP 5/6, HP 7/8, Reserved C1 HP, Reserved C2 HP, Reserved C3 HP	HP 1/2		enum	
CodeRateLP	low priority stream current code rate (3 bits): LP 1/2, LP 2/3, LP 3/4, LP 5/6, LP 7/8, Reserved C1 LP, Reserved C2 LP, Reserved C3 LP	LP 1/2		enum	
GuardInterval	guard interval values (2 bits): G 1/32, G 1/16, G 1/8, G 1/4	G 1/32		enum	
TransmissionMode	transmission mode (2 bits): mode 2k, mode 8k, reserved T1, reserved T2	mode 2k		enum	
FutureUse	reserved for future use (currently, all 14 bits are set to 0)	0 0 0 0 0 0 0 0 0 0 0 0 0 0		int array	

Pin Outputs

Pin	Name	Description	Signal Type
1	output	TPS information bits	int
2	initial	initial bit for differential modulation	int

Notes/Equations

1. This model generates 54 bits of TPS information; refer to the table below for bit assignments.

PS Signal Information and Format

Bit No.	Format	Purpose/Content
S_0		Initialization bit for differential 2_PSK modulation
$S_1 - S_{16}$	0011010111101110 or 1100101000010001	Synchronization word
$S_{17} - S_{22}$	010 111	Length indicator
$S_{23} - S_{24}$	See Signal Format for Frame Number	Frame number
$S_{25} - S_{26}$	See Signal Format for Possible Constellation Patterns	Constellation
$S_{27} - S_{29}$	See Signal Format for α Values	Hierarchy information
$S_{30} - S_{32}$	See Signal Format for Each Code Rate	Code rate, HP stream
$S_{33} - S_{35}$	See Signal Format for Each Code Rate	Code rate, LP stream
$S_{36} - S_{37}$	See Signal Format for Each Guard Interval	Guard interval
$S_{38} - S_{39}$	See Signal Format for Transmission Mode	Transmission mode
$S_{40} - S_{52}$	all set to 0	Reserved for future use
$S_{54} - S_{66}$	BCH code	Error protection

Signal Format for Frame Number

Bits $S_{23} - S_{24}$	Frame Number
00	Frame number 1 in the super-frame
01	Frame number 2 in the super-frame
10	Frame number 3 in the super-frame
11	Frame number 4 in the super-frame

Signal Format for Possible Constellation Patterns

Bits $S_{25} - S_{26}$	Constellation Characteristics
00	QPSK
01	16-QAM
10	64-QAM
11	reserved

Signal Format for α Values

Bits $S_{27} - S_{29}$	α Value
000	Non-hierarchical
001	α = 1
010	α = 2
011	α = 3
100	reserved
101	reserved
110	reserved
111	reserved

Signal Format for Each Code Rate

Bits $S_{30} - S_{32}$ HP stream $S_{33} - S_{35}$ LP stream	Code Rate
000	1/2
001	2/3
010	3/4
011	5/6
100	7/8
101	reserved
110	reserved
111	reserved

Signal Format for Each Guard Interval

Bits $S_{36} - S_{37}$	Guard Interval Values
00	1/32
01	1/16
10	1/8
11	1/4

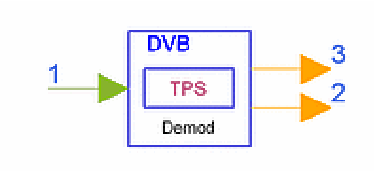
Signal Format for Transmission Model

Bits $S_{38} - S_{39}$	**Transmission Mode**
00	2K mode
01	8K mode
10	reserved
11	reserved

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.

DTV_DVBTPSDemod



Description: Transmission parameter signal differential demodulation
Library: DTV, DVB-T
Class: SDFDTV_DVBTPSDemod

Parameters

Name	Description	Default	Unit	Type	Range
Length	length of TPS bits per OFDM frame	68		int	68

Pin Inputs

Pin	Name	Description	Signal Type
1	input	TPS information (68 bits)	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	output	demodulated TPS information	int
3	init	demodulated initial bit for TPS DBPSK demodulation	int

Notes/Equations

1. The model performs DBPSK demodulation for 68 complex signals about the received transmission parameter signal.
2. A hard decision value is made on the real part of the complex input signal.

$$\begin{cases} B'[i] = 0 & if\ Re\{x[i]\} > 0 \\ B'[i] = 1 & if\ Re\{x[i]\} < 0 \end{cases}$$

where

$0 \le i < 68$.

Then set $B_0 = B'[0]$. DBPSK demodulation is:

$$B_i = B'[i] \oplus B'[i-1]$$

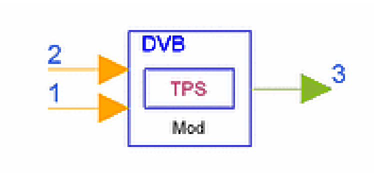
where

$i = 1, 2, \ldots, 67$.

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.

DTV_DVBTPSMod



Description: Transmission parameter signal differential modulation
Library: DTV, DVB-T
Class: SDFDTV_DVBTPSMod

Parameters

Name	Description	Default	Unit	Type	Range
Length	length of TPS bits per OFDM frame	68		int	68

Pin Inputs

Pin	Name	Description	Signal Type
1	input	TPS information (67 bits)	int
2	initial	initial bit for TPS DBPSK modulation	int

Pin Outputs

Pin	Name	Description	Signal Type
3	output	modulated TPS information	complex

Notes/Equations

1. The model performs DBPSK modulation for transmission parameter signal information.
2. Implementation
   First, set, $B'[0] = B_0$. DBPSK modulation is

   $$B'[i] = B_i \oplus B'[i-1]$$

   where i = 1, 2, ... , 67.
   Then

   $$\begin{cases} x[i] = 1 + j0 & if\ (B'[i] = 0) \\ x[i] = -1 + j0 & if\ (B'[i] = 1) \end{cases}$$

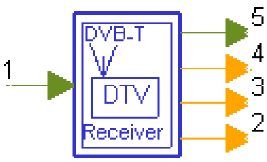
   coded bits $B'[0]$" $B'[67]$ are converted to (1,0), (-1,0)
   where

   i = 0, 1, ... , 67.

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.

DTV_DVBTReceiver



Description: DVB-T receiver
Library: DTV, DVB-T
Class: SDFDTV_DVBTReceiver

Parameters

Name	Description	Default	Symbol	Unit	Type	Range
Mode	transmission mode: DVB 2k mode, DVB 8k mode	DVB 2k mode			enum	
OversamplingOption	oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1	S		enum	
GuardInterval	guard interval (frac FFT size)	0.125			real	[0, 1]
CodeRate	code rate: DTV 1/2, DTV 2/3, DTV 3/4, DTV 5/6, DTV 7/8	DTV 1/2			enum	
MappingMode	signal constellations and mapping: QPSK, QAM-16, QAM-64	QAM-16			enum	
SoftDecision	soft decision viterbi decoding type: Soft, Hard, Cochannel	Soft			enum	
TrunLen	path memory truncation length of Viterbi decoding algorithm, in bytes	10			int	[5, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	Rx_signal	received OFDM signal to be demodulated	complex

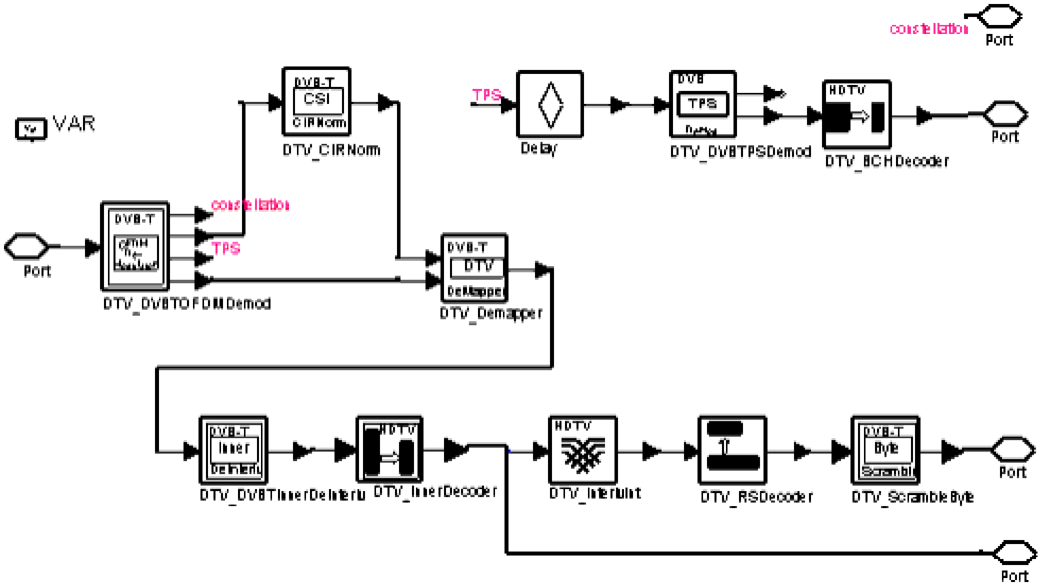
Pin Outputs

Pin	Name	Description	Signal Type
2	Bytes_Decoded	decoded bytes after Reed Solomon decoder	int
3	Bytes_AfterViterbi	decoded bytes after Viterbi decoder	int
4	TPS_Bits	decoded TPS information bits	int
5	constellation	constellation signal after OFDM demodulation	complex

Notes/Equations

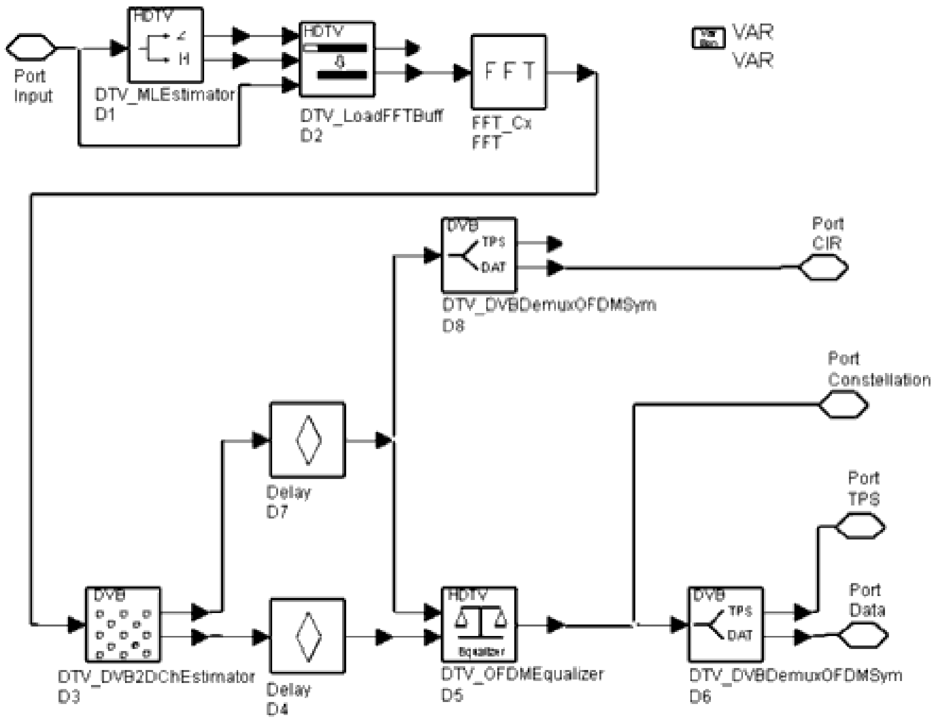
1. This subnetwork model implements the DVB-T receiver function. The schematic for this subnetwork is shown below.

DTV_DVBTReceiver Schematic



2. Output Delays
   - The constellation pin has one OFDM symbol delay. The first 8 × 1705 (2K mode) or 8 × 6817 (8K mode) constellation output signals not used for EVM calculation.
   - DTV_BCHDecoder works a 68-bit block; so, a Delay component with N=60 is inserted before DTV_DVBTPSDemod. TPS_Bits has a one DVB-T frame (68 OFDM symbols) delay; the first 53 bits are not used.
   - The information bytes per one OFDM symbol in Bytes_AfterViterbi can be calculated as follows:
     - CodedBlockSize=204
     - CodeRate = 1/2, 2/3, 3/4, 5/6 or 7/8,
     - InfoBytes=DelayOFDMSymbols×DataPerOFDMSymbol×CodeRate/8
     - DelayOFDMSymbols = 8
   - The block delay of Bytes_AfterViterbi is BlockDelay_AfterViterbi and can be calculated, as follows:
     - DelayBytes=DelayOFDMSymbols×InfoBytes-(int(DelayOFDMSymbols ×InfoBytes/CodedBlockSize))×CodedBlockSize,
     - N=int((TrunLen+DelayBytes)/CodedBlockSize),
     - BlockDelay_AfterViterbi= 1+int((DelayOFDMSymbols×InfoBytes)/CodedBlockSize)+N.
   - The block size is 204 bytes, N is used when the sum of TrunLen and DelayBytes is more than one block length.
   - The Bytes_Decoded pin has 11 extra transport MUX packet delays.
   - The block delay of Bytes_Decoded is
     - BlockDelay_Decoded= 1+int((DelayOFDMSymbols×InfoBytes)/CodedBlockSize)+N.
     - The block size is 188 bytes.
3. Receiver functions are implemented according to the DVB-T Standard.
   Start of OFDM symbol is detected by the DTV_DVBTOFDMDemod subnetwork (shown in below).

DTV_DVBTOFDMDemod Schematic



DTV_MLEstimator calculates the correlation based on guard interval;
DTV_LoadFFTBuff selects the index with the maximum correlation value as the start of FFT.

DTV_DVBCh2DEstimator estimates the complex channel impulse responses for continual and scattered pilot subcarriers. The channel impulse responses of the data subcarriers are 2D interpolated based on the estimated CIR.
Each subcarrier value is divided with a complex estimated channel response coefficient (phase tracking, phase synchronization, and equalization). This simple one-tap frequency domain channel response compensation is implemented by DTV_OFDMEqualizer.
After equalization, DTV_DVBDemuxOFDMSym demultiplexes 1705 or 6817 subcarriers into 1512 (2K mode) or 6048 (8K mode) data subcarriers and 1 demodulated TPS.
The demodulated 1512 or 6048 data subcarriers (such as 16-QAM and 64-QAM modulation) are demapped by DTV_Demapper.
Demodulated soft bits are de-interleaved by DTV_DVBTInnerDeinterlv.
De-interleaved bits are then inner decoded (DTV_InnerDecoder), outer de-interleaved (DTV_InterlvInt), outer decoded (DTV_RSDecoder) and descrambled (DTV_ScrambleByte).
The fully decoded stream bytes are then output as Bytes_Decoded.
The partially decoded stream bytes after inner decoding are output as Bytes_AfterViterbi.
The TPS signal is demodulated by DTV_DVBTPSDemod; the demodulated bits are decoded by DTV_BCHDecoder.
The output pins of this DTV_DVBTReceiver subnetwork correspond to those of DTV_DVBTSignalSrc.
This receiver is triggered per one OFDM symbol. The number of samples of each OFDM symbol (Rx_signal input pin) is:

$$(1+\text{GuardInterval})\times 2048\times \text{OversamplingRatio (2K mode)}$$

(1+GuardInterval)×8192×OversamplingRatio (8K mode)

The number of signals at the constellation output pin is 1705 (2K mode) or 6817 (8K mode) per one OFDM symbol.

4. Parameter Details
Mode specifies the 2K or 8K transmission mode as defined in DVB-T.
OversamplingOption specifies the transmission signal oversampling ratio 1, 2, 4, 8, 16, 32. If OversamplingOption = Ratio 2, the IFFT size is 4096 (2K mode) or 16384 (8K mode).
GuardInterval specifies the guard interval (also called cyclic extension) length for each symbol time, as a fraction of the FFT time period. Guard interval types 1/4, 1/8, 1/16 and 1/32 are defined in the DVB-T specification. GuardInterval can be set to any value between 0.0 and 1.0 (not just 1/4, 1/8, 1/16 and 1/32). For proper demodulation, the value must match the guard interval length actually used in the input signal.
CodeRate specifies the DTV code rate: 1/2, 2/3, 3/4, 5/6 or 7/8.
MappingMode specifies signal constellation and mapping modes: QPSK, QAM-16, or QAM-64.
SoftDecision specifies the Viterbi decoding algorithm mode.

    If SoftDecision=Soft, the Viterbi decoding algorithm is a soft decision decoder and uses channel status information.

    If SoftDecision=Hard, the Viterbi decoding algorithm is a hard decision decoder and does not use channel status information.

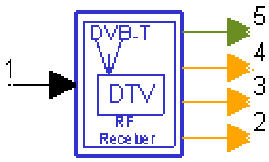
    If SoftDecision=Cochannel, the Viterbi decoding algorithm is for co-channel measurement with PAL analog TV and digital DVB-T.

TrunLen sets the truncation length (in bytes) in the Viterbi decoding algorithm. The path memory is 8×TrunLen bits in Viterbi decoding algorithm.

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.
2. W.C.Lee, H.M.Park, K.J.Kang, K.B.Kim, "*Performance Analysis of Viterbi Decoder Using Channel State Information in COFDM System*" IEEE TRANSACTIONS ON BROADCASTING, Vol.,44, NO.4, DECEMBER 1998.

DTV_DVBTReceiver_RF



Description: DVB-T RF receiver
Library: DTV, DVB-T
Class: TSDFDTV_DVBTReceiver_RF

Parameters

Name	Description	Default	Symbol	Unit	Type	Range
RIn	input resistance	DefaultRIn		Ohm	real	(0, ∞)
ROut	output resistance	DefaultROut		Ohm	real	(0, ∞)
RTemp	physical temperature, in degrees C	DefaultRTemp		Celsius	real	[-273.15, ∞)
GainImbalance	Gain imbalance, Q vs I	0.0		dB	real	(-∞, ∞)
PhaseImbalance	Phase imbalance, Q vs I	0.0		deg	real	(-∞, ∞)
FCarrier	carrier frequency	474.0MHz		Hz	real	(0, ∞)
Sensitivity	voltage output sensitivity, Vout/Vin	1			real	(-∞, ∞)
Phase	reference phase in degrees	0.0		deg	real	(-∞, ∞)
Mode	transmission mode: DVB 2k mode, DVB 8k mode	DVB 2k mode			enum	
OversamplingOption	oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1	S		enum	
GuardInterval	guard interval (frac FFT size)	0.125			real	[0, 1]
CodeRate	code rate: DTV 1/2, DTV 2/3, DTV 3/4, DTV 5/6, DTV 7/8	DTV 1/2			enum	
MappingMode	signal consetllaions and mapping: QPSK, QAM-16, QAM-64	QAM-16			enum	
SoftDecision	soft decision viterbi decoding type: Soft, Hard, Cochannel	Soft			enum	
TrunLen	path memory truncation length of Viterbi decoding algorithm, in bytes	10			int	[5, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	Rx_signal	received OFDM signal to be demodulated	timed

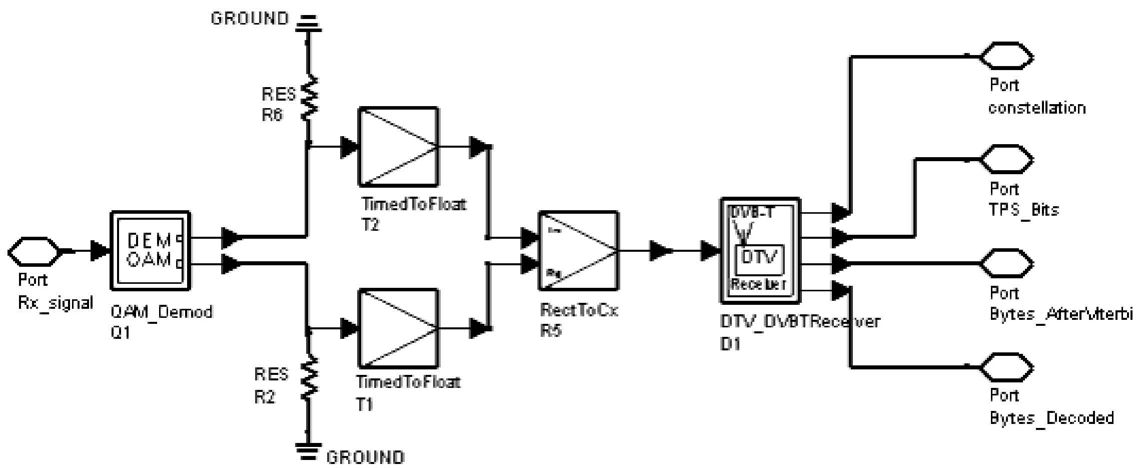
Pin Outputs

Pin	Name	Description	Signal Type
2	Bytes_Decoded	decoded bytes after Reed Solomon decoder	int
3	Bytes_AfterViterbi	decoded bytes after Viterbi decoder	int
4	TPS_Bits	decoded TPS information bits	int
5	constellation	constellation signal after OFDM demodulation	complex

Notes/Equations

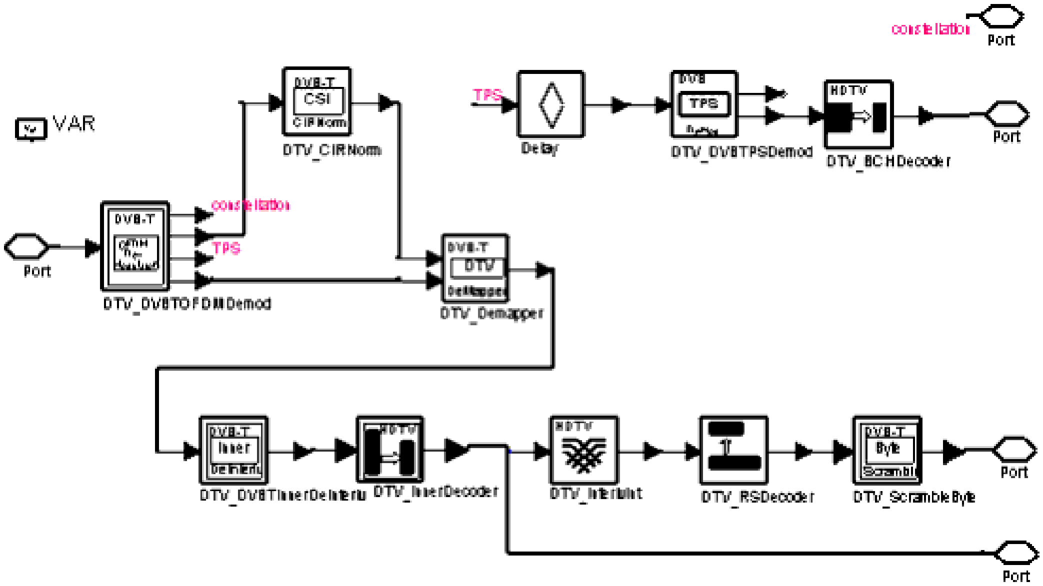
1. This subnetwork model implements the DVB-T RF receiver function. The received RF signal is demodulated and fed to the baseband receiver.
2. The schematic for this RF receiver is shown below.

DTV_DVBTReceiver_RF Schematic



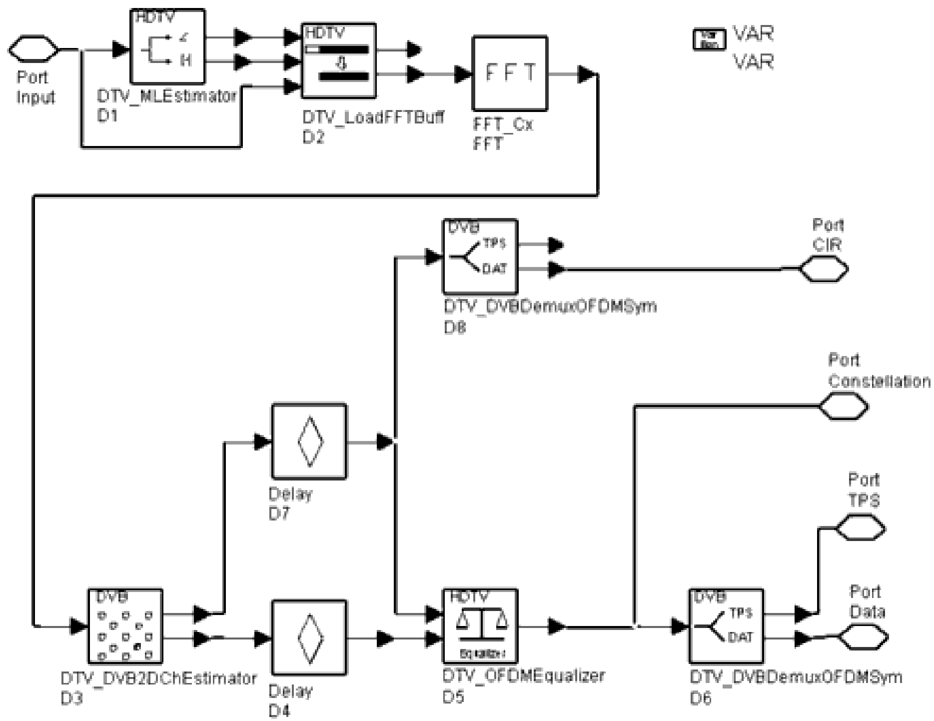
3. The baseband demodulator schematic is shown below.

DTV_DVBTReceiver Schematic



4. Output Delays
    - The constellation pin has one OFDM symbol delay. The first 8 × 1705 (2K mode) or 8 × 6817 (8K mode) constellation output signals not used for EVM calculation.
    - DTV_BCHDecoder works a 68-bit block; so, a Delay component with N=60 is inserted before DTV_DVBTPSDemod. TPS_Bits has a one DVB-T frame (68 OFDM symbols) delay; the first 53 bits are not used.
    - The information bytes for one OFDM symbol in Bytes_AfterViterbi can be calculated as follows:
        - DataPerOFDMSymbol=1512 (2K mode) or 6048 (8K mode)
        - CodedBlockSize=204
        - CodeRate = 1/2, 2/3, 3/4, 5/6 or 7/8,
        - InfoBytes=DelayOFDMSymbols×DataPerOFDMSymbol×CodeRate/8
        - DelayOFDMSymbols = 8
    - The block delay of Bytes_AfterViterbi is BlockDelay_AfterViterbi and can be calculated, as follows:
        - DelayBytes=DelayOFDMSymbols×InfoBytes −(int(DelayOFDMSymbols×InfoBytes/CodedBlockSize))×CodedBlockSize,
        - N=int((TrunLen+DelayBytes)/CodedBlockSize),
        - BlockDelay_AfterViterbi=1+
        - int((DelayOFDMSymbols×InfoBytes)/CodedBlockSize)+N.
          The block size is 204 bytes, N is used when the sum of TrunLen and DelayBytes is more than one block length.
          The block size is 204 bytes, N is used when the sum of TrunLen and DelayBytes is more than one block length.
    - The Bytes_Decoded pin has 11 extra transport MUX packet delays.
    - The block delay of Bytes_Decoded is
        - BlockDelay_Decoded=1+
        - int((DelayOFDMSymbols×InfoBytes)/CodedBlockSize)+N.
        - The block size is 188 bytes.
5. Receiver functions are implemented according to the DVB-T Standard.
   Start of OFDM symbol is detected by the DTV_DVBTOFDMDemod subnetwork (shown below).

DTV_DVBTOFDMDemod Schematic



DTV_MLEstimator calculates the correlation based on guard interval; DTV_LoadFFTBuff selects the index with the maximum correlation value as the start of FFT.

DTV_DVBCh2DEstimator estimates the complex channel impulse responses for continual and scattered pilot subcarriers. The channel impulse responses of the data subcarriers are 2D interpolated based on the estimated CIR.
Each subcarrier value is divided with a complex estimated channel response coefficient (phase tracking, phase synchronization, and equalization). This simple one-tap frequency domain channel response compensation is implemented by DTV_OFDMEqualizer.
After equalization, DTV_DVBDemuxOFDMSym demultiplexes 1705 or 6817 subcarriers into 1512 (2K mode) or 6048 (8K mode) data subcarriers and 1 demodulated TPS.
The demodulated 1512 or 6048 data subcarriers (16-QAM and 64-QAM modulation) are demapped by DTV_Demapper.
Demodulated soft bits are de-interleaved by DTV_DVBTInnerDeinterlv.
De-interleaved bits are then inner decoded (DTV_InnerDecoder), outer de-interleaved (DTV_InterlvInt), outer decoded (DTV_RSDecoder) and descrambled (DTV_ScrambleByte).
The fully decoded stream bytes are then output as Bytes_Decoded.
The partially decoded stream bytes after inner decoding are output as Bytes_AfterViterbi.
The TPS signal is demodulated by DTV_DVBTPSDemod; the demodulated bits are decoded by DTV_BCHDecoder.
The output pins of this DTV_DVBTReceiver subnetwork correspond to those of DTV_DVBTSignalSrc.
This receiver is triggered at each OFDM symbol. The number of samples of each OFDM symbol (Rx_signal input pin) is:

(1+GuardInterval)×2048×OversamplingRatio (2K mode)

(1+GuardInterval)×8192×OversamplingRatio (8K mode)

The number of signals at the constellation output pin is 1705 (2K mode) or 6817 (8K mode) for one OFDM symbol.

6. Parameter Details
GainImbalance and PhaseImbalance add certain impairments to the ideal output RF signal. Impairments are added in the order described here.
The unimpaired RF I and Q envelope voltages have gain and phase imbalance applied. The RF is given by:

$$V_3(t) = A\left(V_1(t)\cos(\omega_c t) - gV_2(t)\sin\left(\omega_c t + \frac{\phi\pi}{180}\right)\right)$$

where $V_1(t)$ is the in-phase RF envelope, $V_2(t)$ is the quadrature phase RF envelope, g is the gain imbalance

$$g = 10^{\frac{GainImbalance}{20}}$$

and, Φ (in degrees) is the phase imbalance.
Mode specifies the 2K or 8K transmission mode as defined in DVB-T.
OversamplingOption specifies the transmission signal oversampling ratio 1, 2, 4, 8, 16, 32. If OversamplingOption=Ratio 2, the IFFT size is 4096 for 2K mode or 16384 for 8K mode.
GuardInterval specifies the guard interval (also called cyclic extension) length for each symbol time, as a fraction of the FFT time period. Guard interval types 1/4, 1/8, 1/16 and 1/32 are defined in the DVB-T specification. GuardInterval can be set to any value between 0.0 and 1.0 (not just 1/4, 1/8, 1/16 and 1/32). For proper demodulation, the value must match the guard interval length actually used in the input signal.
CodeRate specifies the stream code rate: 1/2, 2/3, 3/4, 5/6, or 7/8.
MappingMode specifies signal constellations and mapping for the DVB-T signal source. Mapping modes QPSK, 16-QAM and 64-QAM are available.
SoftDecision specifies the Viterbi decoding algorithm mode.

If SoftDecision=Soft, the Viterbi decoding algorithm is a soft decision decoder and uses channel status information.

If SoftDecision=Hard, the Viterbi decoding algorithm is a hard decision decoder and does not use channel status information.

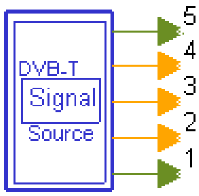
If SoftDecision=Cochannel, the Viterbi decoding algorithm is for co-channel measurement with PAL analog TV and digital DVB-T.

TrunLen is set to the truncation length in the Viterbi decoding algorithm. This parameter is set as bytes. The path memory is 8×TrunLen bits in Viterbi decoding algorithm.
TrunLen sets the truncation length (in bytes) in the Viterbi decoding algorithm. The path memory is 8×TrunLen bits in Viterbi decoding algorithm.

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999
2. W.C.Lee, H.M.Park, K.J.Kang, K.B.Kim, "*Performance Analysis of Viterbi Decoder Using Channel State Information in COFDM System*" IEEE TRANSACTIONS ON BROADCASTING, Vol.,44,NO.4, DECEMBER 1998.

DTV_DVBTSignalSrc



Description: DVB-T signal source
Library: DTV, DVB-T
Class: SDFDTV_DVBTSignalSrc

Parameters

Name	Description	Default	Symbol	Unit	Type	Range
Mode	transmission mode: DVB 2k mode, DVB 8k mode	DVB 2k mode			enum	
OversamplingOption	oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1	S		enum	
GuardInterval	guard interval (fractional FFT size)	0.125			real	[0, 1]
CodeRate	code rate: DTV 1/2, DTV 2/3, DTV 3/4, DTV 5/6, DTV 7/8	DTV 1/2			enum	
MappingMode	signal constellation and mapping: QPSK, QAM-16, QAM-64	QAM-16			enum	
DataType	payload data type: PN9, PN15, FIX4, _4_1_4_0, _8_1_8_0, _16_1_16_0, _32_1_32_0, _64_1_64_0	PN9			enum	

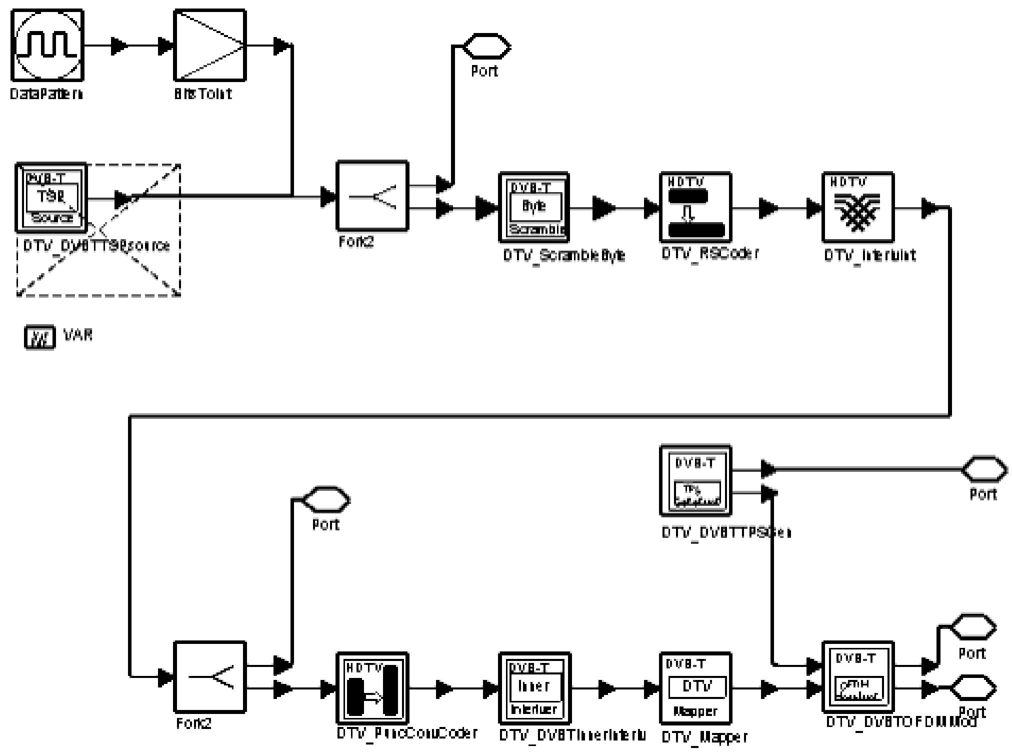
Pin Outputs

Pin	Name	Description	Signal Type
1	DVBT_signal	DVB-T signal	complex
2	Bytes_Uncoded	information bytes of transport packet	int
3	Bytes_BeforeCC	information bytes before convolutional coder	int
4	TPS_Bits	TPS information bits	int
5	constellation	constellation signal before IFFT	complex

Notes/Equations

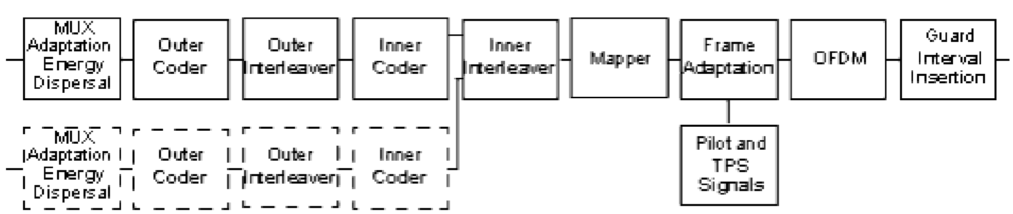
1. This subnetwork model generates a DVB-T signal source. One OFDM symbol is generated each firing.
   The schematic for this subnetwork is shown below.

DTV_DVBTSignalSrc Schematic



2. The DVB-T signal source format follows the DVB-T specification. DVB-T Baseband System Block Diagram is functional block diagram of the DVB-T baseband system. The DTV_DVBTSignalSrc includes: scrambler (DTV_ScrambleByte); outer coder (DTV_RSCoder); outer interleaver (DTV_InterlvInt); inner coder (DTV_PuncConvCoder); inner interleaver (DTV_DVBTInnerInterlv); mapper (DTV_Mapper); and, frame adaptation, OFDM, and guard interval insertion (in DTV_DVBTOFDMMod subnetwork).

DVB-T Baseband System Block Diagram



For a MPEG-2 transport stream, the DTV_DVBTTSPsource model can be activated (shown de-activated in DTV_DVBTSignalSrc Schematic) and the current active source deactivated. DTV_DVBTSignalSrc requires more buffer than the current active source; for example, a code rate of 7/8 is too large.
This signal source works per one OFDM symbol. The number of constellation output pin is 1705 (2K mode) or 6817 (8K mode) per one OFDM symbol. The number of samples of each OFDM symbol (DVBT_signal output pin) is:

- (1+GuardInterval)×2048×OversamplingRatio (2K mode)
- (1+GuardInterval)×8192×OversamplingRatio (8K mode)

3. Parameter Details
Mode is used to select a 2K or 8K transmission mode as defined in DVB-T.
OversamplingOption indicates the oversampling ratio of the transmission signal.

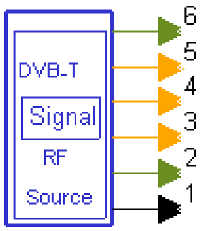
Oversampling ratios 1, 2, 4, 8, 16, 32 are supported in this source. If OversamplingOption = Ratio 2, the IFFT size is 4096 (2K mode) or 16384 (8K mode).
GuardInterval specifies the guard interval (also called cyclic extension) length for each symbol time, as a fraction of the FFT time period. Guard interval types 1/4, 1/8, 1/16 and 1/32 are defined in the DVB-T specification. GuardInterval can be set to any value between 0.0 and 1.0 (not just 1/4, 1/8, 1/16 and 1/32). For proper demodulation, the value must match the guard interval length actually used in the input signal.
CodeRate is defined as code rate of stream. Code rates1/2, 2/3, 3/4, 5/6 and 7/8 are available in this source.
MappingMode specifies signal constellations and mapping: QPSK, 16-QAM or 64-QAM.
For the DataType parameter:

- if PN9 is selected, a 511-bit pseudo-random test pattern is generated according to CCITT Recommendation O.153
- if PN15 is selected, a 32767-bit pseudo-random test pattern is generated according to CCITT Recommendation O.151
- if FIX4 is selected, a zero-stream is generated
- if x_1_x_0 is selected (x equals 4, 8, 16, 32, or 64) a periodic bit stream is generated, with the period being 2x. In one period, the first x bits are 1s and the second x bits are 0s.

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.

DTV_DVBTSignalSrc_RF



Description: DVB-T RF signal source
Library: DTV, DVB-T
Class: TSDFDTV_DVBTSignalSrc_RF

Parameters

Name	Description	Default	Symbol	Unit	Type	Range
ROut	output resistance	DefaultROut		Ohm	real	(0, ∞)
RTemp	physical temperature, in degrees C	DefaultRTemp		Celsius	real	[-273.15, ∞)
Noise	Enable thermal noise?: NO, YES	NO			enum	
FCarrier	carrier frequency	474.0MHz		Hz	real	(0, ∞)
Power	modulator output power	40mW		W	real	(0, ∞)
Bandwidth	bandwidth	(2048/224.0)MHz		Hz	real	(0, ∞)
MirrorSpectrum	Mirror spectrum about carrier?: NO, YES	NO			enum	
GainImbalance	Gain imbalance, Q vs I	0.0		dB	real	(-∞, ∞)
PhaseImbalance	Phase imbalance, Q vs I	0.0		deg	real	(-∞, ∞)
I_OriginOffset	I origin offset (percent)	0.0			real	(-∞, ∞)
Q_OriginOffset	Q origin offset (percent)	0.0			real	(-∞, ∞)
IQ_Rotation	IQ rotation	0.0		deg	real	(-∞, ∞)
Mode	transmission mode: DVB 2k mode, DVB 8k mode	DVB 2k mode			enum	
OversamplingOption	oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1	S		enum	
GuardInterval	guard interval (fractional FFT size)	0.125			real	[0, 1]
CodeRate	code rate: DTV 1/2, DTV 2/3, DTV 3/4, DTV 5/6, DTV 7/8	DTV 1/2			enum	
MappingMode	signal constellation and mapping: QPSK, QAM-16, QAM-64	QAM-16			enum	
DataType	payload data type: PN9, PN15, FIX4, _4_1_4_0, _8_1_8_0, _16_1_16_0, _32_1_32_0, _64_1_64_0	PN9			enum	

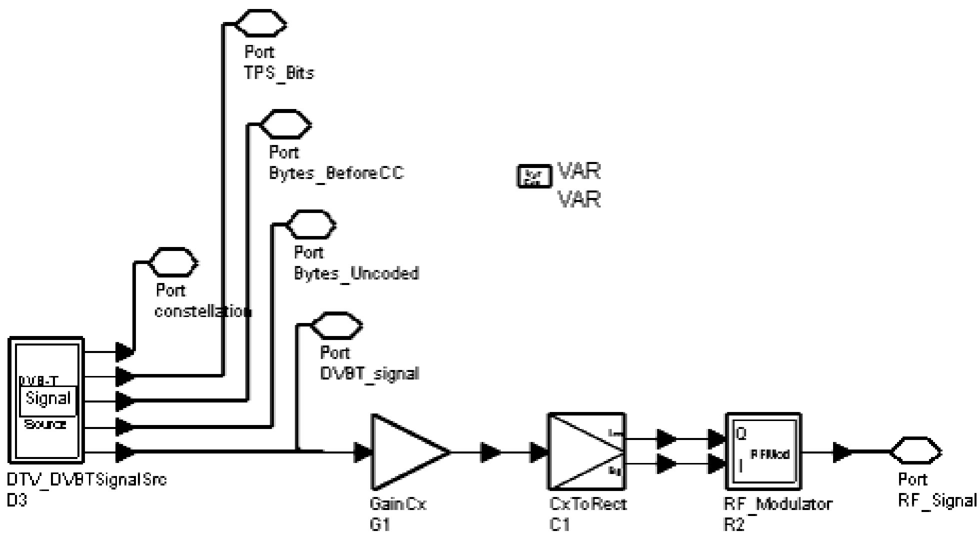
Pin Outputs

Pin	Name	Description	Signal Type
1	RF_signal	RF signal	timed
2	DVBT_signal	DVB-T signal	complex
3	Bytes_Uncoded	information bytes of transport packet	int
4	Bytes_BeforeCC	information bytes before convolutional coder	int
5	TPS_Bits	TPS information bits	int
6	constellation	constellation signal before IFFT	complex

Notes/Equations

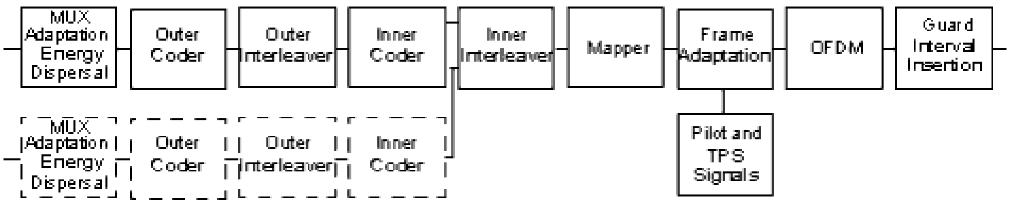
1. This subnetwork model integrates an RF modulator and a baseband signal source. The baseband signal is fed to the RF modulator; after RF modulation the timed signal is output.
   The schematic for this subnetwork is shown below.

DTV_DVBTSignalSrc_RF Schematic



2. The format of DVB-T signal source follows the DVB-T specification. The figure below shows a functional block diagram of a DVB-T baseband system.

DVB-T Baseband System Block Diagram

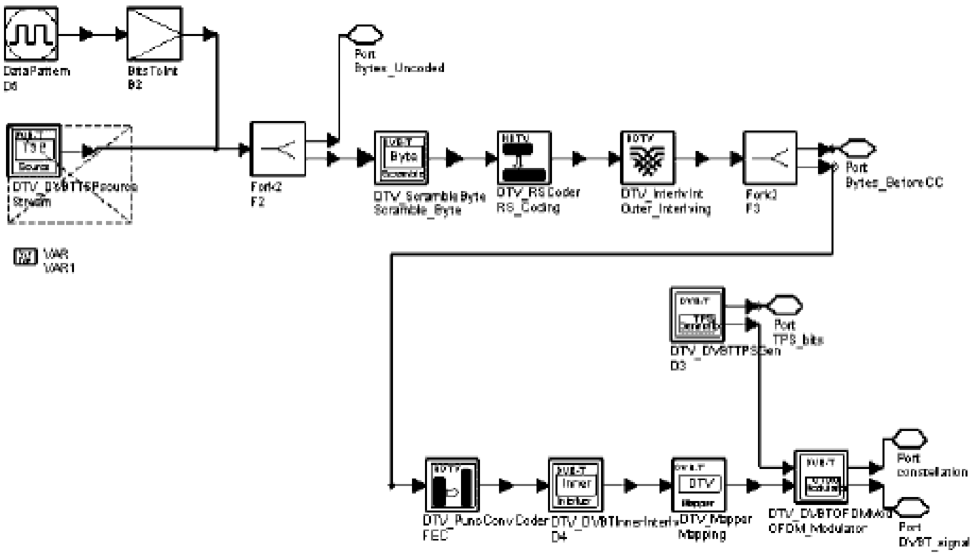


3. The schematic for the signal source is shown in DTV_DVBTSignalSrc Schematic. The DTV_DVBTSignalSrc includes: scrambler (DTV_ScrambleByte); outer coder (DTV_RSCoder); outer interleaver (DTV_InterlvInt); inner coder (DTV_PuncConvCoder); inner interleaver (DTV_DVBTInnerInterlv); mapper

(DTV_Mapper); and, frame adaptation, OFDM, and guard interval insertion (in DTV_DVBTOFDMMod subnetwork).

> **Note**
> To use an MPEG-2 transport stream, DTV_DVBTTSPsource must be active and the current active source deactivated. DTV_DVBTTSPsource needs more buffer than the current active source. In some cases, code rate 7/8 is too large.

DTV_DVBTSignalSrc Schematic



This signal source uses one OFDM symbol; 1705 (2K mode) or 6817 (8K mode) constellations are output. DVBT_signal pin outputs samples for each OFDM symbol:

- (1+GuardInterval)×2048×OversamplingRatio (2K mode)
- (1+GuardInterval)×8192×OversamplingRatio (8K mode)

4. Parameter Details
FCarrier defines the RF frequency for the DVB signal.
Power defines the power level for FCarrier.
Bandwidth indicates signal bandwidth.
The MirrorSpectrum (when set to YES) conjugates the input signal before any other processing is done.
The GainImbalance, PhaseImbalance, I_OriginOffset, Q_OriginOffset, and IQ_Rotation parameters add certain impairments to the ideal output RF signal. Impairments are added in the order described here.
The unimpaired RF I and Q envelope voltages have gain and phase imbalance applied. The RF is given by:

$$V_3(t) = A\left(V_1(t)\cos(\omega_c t) - gV_2(t)\sin\left(\omega_c t + \frac{\phi\pi}{180}\right)\right)$$

where *A* is a scaling factor that depends on the Power and ROut parameters specified by the user, $V_1(t)$ is the in-phase RF envelope, $V_2(t)$ is the quadrature phase RF envelope, *g* is the gain imbalance

$$g = 10^{\frac{GainImbalance}{20}}$$

and, Φ (in degrees) is the phase imbalance.
The signal $V_3(t)$ is rotated by IQ_Rotation degrees; I_OriginOffset and Q_OriginOffset

are then applied to the rotated signal. Note that the amounts specified are percentages with respect to the output rms voltage. The output rms voltage is given by sqrt(2×ROut×Power).

Mode specifies the 2K or 8K transmission mode as defined in the DVB-T specification.

OversamplingOption specifies the transmission signal oversampling ratio 1, 2, 4, 8, 16, 32. If OversamplingOption=2, the IFFT size is 4096 (2K mode) or 16384 (8K mode).

GuardInterval specifies the guard interval (also called cyclic extension) length for each symbol time, as a fraction of the FFT time period. Guard interval types 1/4, 1/8, 1/16 and 1/32 are defined in the DVB-T specification. GuardInterval can be set to any value between 0.0 and 1.0 (not just 1/4, 1/8, 1/16 and 1/32). For proper demodulation, the value must match the guard interval length actually used in the input signal.

CodeRate specifies the stream code rate: 1/2, 2/3, 3/4, 5/6, or 7/8.

MappingMode specifies signal constellation and mapping modes: QPSK, 16-QAM, or 64-QAM.

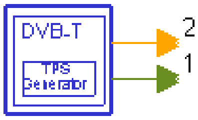
For the DataType parameter:

- if PN9 is selected, a 511-bit pseudo-random test pattern is generated according to CCITT Recommendation O.153
- if PN15 is selected, a 32767-bit pseudo-random test pattern is generated according to CCITT Recommendation O.151
- if FIX4 is selected, a zero-stream is generated
- if x_1_x_0 is selected, where x equals 4, 8, 16, 32, or 64, a periodic bit stream is generated, with the period being 2x. In one period, the first x bits are 1s and the second x bits are 0s.

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.

DTV_DVBTTPSGen



Description: Modulated transmission parameter signal information
Library: DTV, DVB-T
Class: SDFDTV_DVBTTPSGen

Parameters

Name	Description	Default	Unit	Type	Range
Length	length of TPS information bits	54		int	{54}
InitiBit	initialization bit for DBPSK modulation (1 bit)	1		int	{0,1}
Sync	synchronization word (16 bits): W0, W1	W0		enum	
LengthIndicator	TPS length indicator (6 bits)	0 1 0 1 1 1		int array	"0 1 0 1 1 1"
FrameNumber	frame number in one super frame (2 bits): F1, F2, F3, F4	F1		enum	
Constellation	modulation scheme in DVB-T (2bits): QPSK, QAM 16, QAM 64, reserved M	QPSK		enum	
HierarchyInform	signaling format for alpha values (3 bits): Non hierarchical, alpha 1, alpha 2, alpha 4, reserved H1, reserved H2, reserved H3, reserved H4	Non hierarchical		enum	
CodeRateHP	high priority stream current code rate (3 bits): HP 1/2, HP 2/3, HP 3/4, HP 5/6, HP 7/8, Reserved C1 HP, Reserved C2 HP, Reserved C3 HP	HP 1/2		enum	
CodeRateLP	low priority stream current code rate (3 bits): LP 1/2, LP 2/3, LP 3/4, LP 5/6, LP 7/8, Reserved C1 LP, Reserved C2 LP, Reserved C3 LP	LP 1/2		enum	
GuardInterval	guard interval values (2 bits): G 1/32, G 1/16, G 1/8, G 1/4	G 1/32		enum	
TransmissionMode	transmission mode (2 bits): mode 2k, mode 8k, reserved T1, reserved T2	mode 2k		enum	
FutureUse	reserved for future use (currently, all 14 bits are set to 0)	0 0 0 0 0 0 0 0 0 0 0 0 0 0		int array	

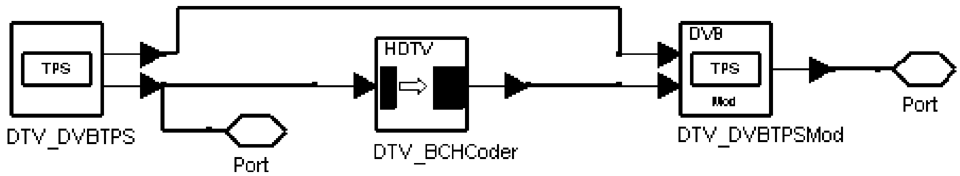
Pin Outputs

Pin	Name	Description	Signal Type
1	TPS	modulated TPS information signal	complex
2	TPS_Bits	TPS information bits	int

Notes/Equations

1. This subnetwork model generates modulated transmission parameter signal information used in TPS carriers in OFDM symbols.
   The schematic for this subnetwork is shown below.

DTV_DVBTTPSGen Schematic



2. DTV_DVBTPS generates 54 bits (1 initialization, 16 synchronization, and 37 information); the 53 TPS synchronization and information transmission mode are extended with 14 parity bits of the BCH (67,53, t = 2) shortened code, derived from the original systematic BCH (127,113, t = 2) code, which is implemented by DTV_BCHCoder; the 68-bit TPS block is modulated by DBPSK, which is implemented by DTV_DVBTPSMod.
   Each firing, the TPS_Bits pin outputs 53 bits (16 synchronization and 37 information) and TPS outputs 68 modulated TPS signals.
3. The TPS is defined over 68 consecutive OFDM symbols (one OFDM frame). Four consecutive frames correspond to one OFDM super-frame.
   The reference sequence corresponding to the TPS carriers of the first symbol of each OFDM frame is used to initialize the TPS modulation on each TPS carrier.
   Each OFDM symbol conveys one TPS bit. Each TPS block (corresponding to one OFDM frame) contains 68 bits:
   - 1 initialization bit
   - 16 synchronization bits
   - 37 information bits
     Of the 37 information bits, 31 are used (6 bits are reserved for future use and are set to zero).
   - 14 redundancy bits for error protection
4. Bit assignments are listed in the table below.

TPS Signal Information

Bit Number	Format	Purpose/Content
S_0		Initialization bit for differential 2_PSK modulation
$S_1 - S_{16}$	0011010111101110 or 1100101000010001	Synchronization word
$S_{17} - S_{22}$	010 111	Length indicator
$S_{23} - S_{24}$	See Signal Format for Frame Number	Frame number
$S_{25} - S_{26}$	See Signal Format for Constellation Patterns	Constellation
$S_{27} - S_{29}$	See Signal Format for α Values	Hierarchy information
$S_{30} - S_{32}$	See Signal Format for Each Code Rate	Code rate, HP stream
$S_{33} - S_{35}$	See Signal Format for Each Code Rate	Code rate, LP stream
$S_{36} - S_{37}$	See Signal Format for Each Guard Interval	Guard interval
$S_{38} - S_{39}$	See Signal Format for Transmission Mode	Transmission mode
$S_{40} - S_{52}$	all set to 0	Reserved for future use
$S_{54} - S_{66}$	BCH code	Error protection

Signal Format for Frame Number

Bits $S_{23} - S_{24}$	Frame Number
00	1 in the super-frame
01	2 in the super-frame
10	3 in the super-frame
11	4 in the super-frame

Signal Format for Constellation Patterns

Bits $S_{25} - S_{26}$	Constellation Characteristics
00	QPSK
01	16-QAM
10	64-QAM
11	reserved

Signal Format for α Values

Bits S_{27} − S_{29}	α Value
000	Non-hierarchical
001	α = 1
010	α = 3
011	α = 3
100	reserved
101	reserved
110	reserved
111	reserved

Signal Format for Each Code Rate

Bits, S_{30} − S_{32} HP Stream, S_{33} − S_{35} LP Stream	Code Rate
000	1/2
001	2/3
010	3/4
011	5/6
100	7/8
101	reserved
110	reserved
111	reserved

Signal Format for Each Guard Interval

Bits S_{36} − S_{37}	Guard Interval Values
00	1/32
01	1/16
10	1/8
11	1/4

Signal Format for Transmission Mode

Bits S_{38} − S_{39}	Transmission Mode
00	2K mode
01	8K mode
10	reserved
11	reserved

5. Error Protection of TPS
The 53 bits containing the TPS synchronization and information (bits s_1 − s_{53}) are extended with 14 parity bits of the BCH (67,53, t = 2) shortened code, derived from the original systematic BCH (127,113, t = 2) code.
The code generator polynomial is:

$$h(x) = x^{14} + x^9 + x^8 + x^6 + x^5 + x^4 + x^2 + x + 1$$

The shortened BCH code is implemented by adding 60 bits, all set to zero, before the information bits input of an BCH(127,113, t = 2) encoder. After BCH encoding these null bits are discarded, leading to a BCH code word of 67 bits.

6. TPS Modulation
   TPS cells are transmitted at the *normal* power level, that is, they are transmitted with energy equal to that of the mean of all data cells, $E[c \times c^*] = 1$.
   Each TPS carrier is DBPSK modulated and conveys the same message. The DBPSK is initialized at the beginning of each TPS block.
   The following rule applies for the differential modulation of carrier k of symbol l (l > 0) in frame m:

   if $s_1 = 0$, then

$$Re\{c_{m,l,k}\} = Re\{c_{m,l-1,k}\} \; ; \; Im\{c_{m,l,k}\} = 0$$

   if $s_1 = 1$, then

$$Re\{c_{m,l,k}\} = -Re\{c_{m,l-1,k}\} \; ; \; Im\{c_{m,l,k}\} = 0$$

   The absolute modulation of the TPS carriers in the first symbol in a frame is derived from the reference sequence w_k as follows:

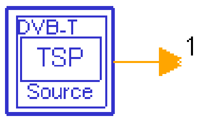
$$Re\{c_{m,l,k}\} = 2\left(\frac{1}{2} - w_k\right)$$

$$Im\{c_{m,l,k}\} = 0$$

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.

DTV_DVBTTSPsource



Description: Transport packets signal source
Library: DTV, DVB-T
Class: SDFDTV_DVBTTSPsource

Parameters

Name	Description	Default	Unit	Type	Range
DataType	payload data type: PN9, PN15, FIX4, _4_1_4_0, _8_1_8_0, _16_1_16_0, _32_1_32_0, _64_1_64_0	PN9		enum	

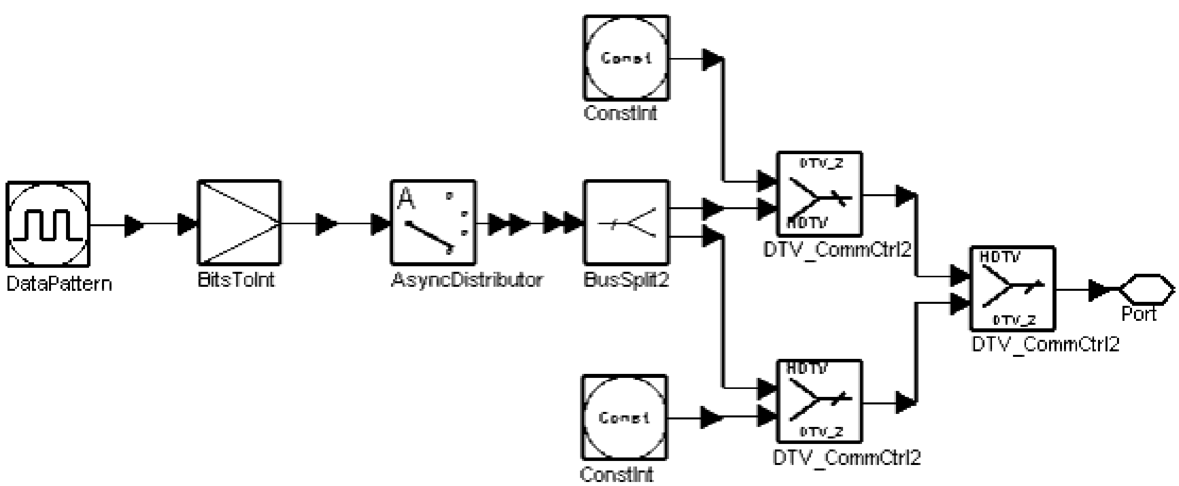
Pin Outputs

Pin	Name	Description	Signal Type
1	TSP	Transport system packet signal source	int

Notes/Equations

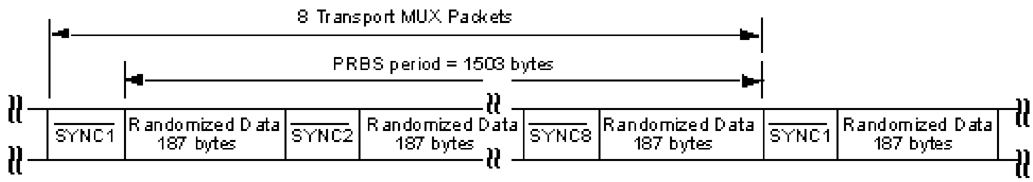
1. This subnetwork model generates MEPG-2 transport MUX packets. The schematic for this subnetwork is shown below.

DTV_DVBTTSPsource Schematic



2. Each firing, 8 transport packets with 8×188 bytes are generated as shown below.

Transport Packet Format



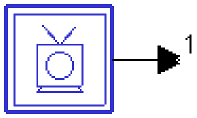
To provide an initialization signal for the descrambler, the MPEG-2 sync byte of the first transport packet in a group of 8 packets is bit-wise inverted from 47_{HEX} (71) to $B8_{HEX}$ (184). So, the first sync of the first packet is $B8_{HEX}$ (184) and the left 7 sync of the left 7 packets are all 47_{HEX} (71).

3. DataPattern specifies the type of data pattern:
   - PN9 specifies a 511-bit pseudo-random test pattern is generated according to CCITT Recommendation O.153
   - PN15 specifies a 32767-bit pseudo-random test pattern is generated according to CCITT Recommendation O.151
   - FIX4 specifies a zero-stream is generated
   - x_1_x_0 (where x equals 4, 8, 16, 32, or 64) specifies a periodic bit stream is generated, with the period being 2 x. In one period, the first x bits are 1 and the second x bits are 0.

References

1. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.

DTV_PALSource



Description: PAL signal source
Library: DTV, DVB-T
Class: TSDFDTV_PALSource

Parameters

Name	Description	Default	Unit	Type	Range
RIn	output resistance	DefaultRIn	Ohm	real	(0, ∞)
ROut	output resistance	DefaultROut	Ohm	real	(0, ∞)
RTemp	physical temperature, in degrees C	DefaultRTemp	Celsius	real	[-273.15, ∞)
FCarrier	carrier frequency	474.0MHz	Hz	real	(0, ∞)
Power	modulator output power	40mW	W	real	(0, ∞)
SamplingRate	sampling rate	(2048/224.0)MHz	Hz	real	(0, ∞)

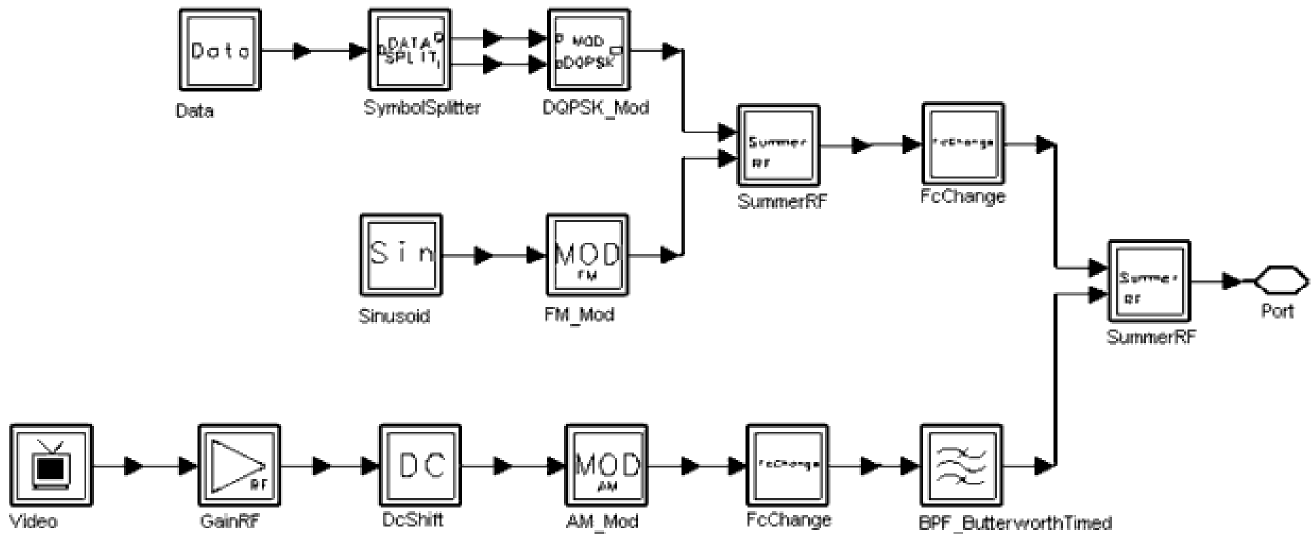
Pin Outputs

Pin	Name	Description	Signal Type
1	PAL_signal	PAL signal	timed

Notes/Equations

1. The subnetwork model generates a PAL signal source. The PAL signal consists of color bars, FM sound (+/- 50kHz dev, 1kHz tone), and NICAM.
   The schematic for this subnetwork is shown below.

DTV_PALSource Schematic



2. This PAL signal source is implemented according to European Air UHF band IV channel E21. E21 band limits are 470 to 478 MHz; center frequency is 474 MHz; video carrier frequency is 471.25 MHz; audio carrier frequency is 477.25 MHz; and, the NICAM carrier frequency is 477.802 MHz.
   RF modulation occurs on the designated band.
   FCarrier is the center frequency of the designated PAL channel. Power sets the RF modulator output power. SamplingRate is the PAL signal bandwidth; its reciprocal is the RF modulation simulation time step.

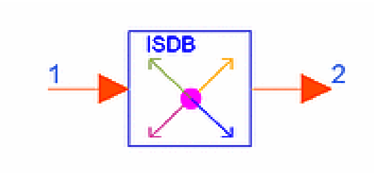
References

1. Recommendations of the CCIR, 1990, Volume XI - Part 1, Broadcasting Service (Television), CCIR (International Radio Consultative Committee), Geneva, 1990.
2. Recommendations of the CCIR, 1990, Annex to Volume XI - Part 1, Broadcasting Service (Television), CCIR (International Radio Consultative Committee), Geneva, 1990.
3. Recommendations of the CCIR, 1990, Volume XII, Television and Sound Transmission (CMTT), CCIR (International Radio Consultative Committee), Geneva, 1990.
4. Reports of the CCIR, 1990, Annex to Volume XII, Television and Sound Transmission (CMTT), CCIR (International Radio Consultative Committee), Geneva, 1990.

ISDB-T Components

- *DTV CarrierRotator* (dtv)
- *DTV CarrierScrambler* (dtv)
- *DTV CDSCDecoder* (dtv)
- *DTV ChEstimator* (dtv)
- *DTV DemuxCohSegs* (dtv)
- *DTV DemuxDiffSegs* (dtv)
- *DTV DemuxTMCC* (dtv)
- *DTV InterSegInterlv* (dtv)
- *DTV ISDBDemodulation* (dtv)
- *DTV ISDBFreqDeinterlv* (dtv)
- *DTV ISDBFreqInterlv* (dtv)
- *DTV ISDBModulation* (dtv)
- *DTV ISDBMuxSegs* (dtv)
- *DTV ISDBOFDMDemod OneLay* (dtv)
- *DTV ISDBOFDMDemod ThreeLay* (dtv)
- *DTV ISDBOFDMDemod TwoLay* (dtv)
- *DTV ISDBOFDMMod OneLay* (dtv)
- *DTV ISDBOFDMMod ThreeLay* (dtv)
- *DTV ISDBOFDMMod TwoLay* (dtv)
- *DTV ISDBOneLayReceiver* (dtv)
- *DTV ISDBOneLayReceiver RF* (dtv)
- *DTV ISDBOneLaySource* (dtv)
- *DTV ISDBOneLaySource RF* (dtv)
- *DTV ISDBPartialReceiver RF* (dtv)
- *DTV ISDBThreeLayReceiver* (dtv)
- *DTV ISDBThreeLayReceiver RF* (dtv)
- *DTV ISDBThreeLaySource* (dtv)
- *DTV ISDBThreeLaySource RF* (dtv)
- *DTV ISDBTimeInterlv* (dtv)
- *DTV ISDBTMCC* (dtv)
- *DTV ISDBTSPSource* (dtv)
- *DTV ISDBTwoLayFreqDeinterlv* (dtv)
- *DTV ISDBTwoLayFreqInterlv* (dtv)
- *DTV ISDBTwoLayReceiver* (dtv)
- *DTV ISDBTwoLayReceiver RF* (dtv)
- *DTV ISDBTwoLaySource* (dtv)
- *DTV ISDBTwoLaySource RF* (dtv)
- *DTV LFSRCoder* (dtv)
- *DTV LoadIFFTBuff* (dtv)
- *DTV MuxCohSegs* (dtv)
- *DTV MuxDiffSegs* (dtv)
- *DTV PackTMCC* (dtv)
- *DTV TimeInterlv* (dtv)
- *DTV TMCCDemod* (dtv)
- *DTV TMCCInfo* (dtv)
- *DTV TMCCMod* (dtv)

DTV_CarrierRotator



Description: Particle rotation within segment
Library: DTV, ISDB-T
Class: SDFDTV_CarrierRotator

Parameters

Name	Description	Default	Unit	Type	Range
Carriers	block length of particles for one segment	384		int	{96, 192, 384}†
StartPoint	start particle number in segment	0 1 2 3		int array	(-∞, ∞)
Phase	initial phase of segment sequence	0		int	(-∞, ∞)

† Carriers = 96, 192, 384 for mode 1, 2, 3, respectively

Pin Inputs

Pin	Name	Description	Signal Type
1	input	symbols to be rotated	anytype

Pin Outputs

Pin	Name	Description	Signal Type
2	output	rotated symbols	anytype

Notes/Equations

1. This model performs intra-segment carrier rotation for each segment in frequency interleaving.
2. This model implements the intra-segment rotation and permutation of the OFDM segment symbols shown in the figure below.

$S'_{(k\ +\ i\ mod\ Carriers)} = S_{i,\ 0,\ k}$
$0 \le i \le Carriers - 1$
k is the segment number
$S_{i,\ j,\ k}$ denotes the complex data of the k th segment before inter-segment interleaving
$S'_{i,\ j,\ k}$ denotes the complex data of the k th segment after inter-segment interleaving

Intra-Segment Carrier Rotation Interleaving

Intra-Segment Carrier Rotation Interleaving

$S'_{0,0,k}$	$S'_{1,0,k}$	$S'_{2,0,k}$	---	$S'_{95,0,k}$
$S'_{(k \bmod 96),0,k}$	$S'_{(k+1 \bmod 96),0,k}$	$S'_{(k+2 \bmod 96),0,k}$	---	$S'_{(k+95 \bmod 96),0,k}$

(a) Intra-segment carrier rotation for Mode 1

$S'_{0,0,k}$	$S'_{1,0,k}$	$S'_{2,0,k}$	---	$S'_{95,0,k}$
$S'_{(k \bmod 192),0,k}$	$S'_{(k+1 \bmod 192),0,k}$	$S'_{(k+2 \bmod 192),0,k}$	---	$S'_{(k+191 \bmod 192),0,k}$

(b) Intra-segment carrier rotation for Mode 2

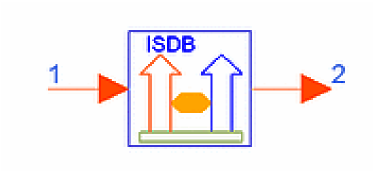
$S'_{0,0,k}$	$S'_{1,0,k}$	$S'_{2,0,k}$	---	$S'_{383,0,k}$
$S'_{(k \bmod 384),0,k}$	$S'_{(k+1 \bmod 384),0,k}$	$S'_{(k+2 \bmod 384),0,k}$	---	$S'_{(k+383 \bmod 384),0,k}$

(c) Intra-segment carrier rotation for Mode 3

References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.

DTV_CarrierScrambler



Description: Carrier scrambler and descrambler
Library: DTV, ISDB-T
Class: SDFDTV_CarrierScrambler

Parameters

Name	Description	Default	Unit	Type	Range
Carriers	number of carriers for each segment in OFDM modulation mode	96		int	{96,192, 384}†
Option	carrier option:Scramble, Descramble: Scramble, Descramble	Scramble		enum	
Sequence	customized carrier mapping index, or empty to use the ISDB defaults			int array	[0, ∞)

† Carriers = 96, 192, 384 for mode 1, 2, 3, respectively

Pin Inputs

Pin	Name	Description	Signal Type
1	input	symbols to be randomized	anytype

Pin Outputs

Pin	Name	Description	Signal Type
2	output	randomized symbols	anytype

Notes/Equations

1. This model performs inter-segment carrier randomization in frequency interleaving for each segment.
2. This model assigns the OFDM symbols to each carrier within each segment in a pre-defined permutation order. Carrier permutation mapping from input to output according to modulation mode is described in Intra-Segment Carrier Randomization for Mode 1 through Intra-Segment Carrier Randomization for Mode 3. These mapping tables are used when Sequence is empty and Option indicates scrambling or de-scrambling. A customized mapping table can be used to implement a user-specified design, in which case Option is ignored.

Intra-Segment Carrier Randomization for Mode 1

From	0	1	2	3	4	5	6	7	8	9	10	11
To	80	93	63	92	94	55	17	81	6	51	9	85
From	12	13	14	15	16	17	18	19	20	21	22	23
To	89	65	52	15	73	66	46	71	12	70	18	13
From	24	25	26	27	28	29	30	31	32	33	34	35
To	95	34	1	38	78	59	91	64	0	28	11	4
From	36	37	38	39	40	41	42	43	44	45	46	47
To	45	35	16	7	48	22	23	77	56	19	8	36
From	48	49	50	51	52	53	54	55	56	57	58	59
To	39	61	21	3	26	69	67	20	74	86	72	25
From	60	61	62	63	64	65	66	67	68	69	70	71
To	31	5	49	42	54	87	43	60	29	2	76	84
From	72	73	74	75	76	77	78	79	80	81	82	83
To	83	40	14	79	27	57	44	37	30	68	47	88
From	84	85	86	87	88	89	90	91	92	93	94	95
To	75	41	90	10	33	32	62	50	58	82	53	24
values indicate carrier indexing; complex data indicated by the From carrier index is carried by the To carrier index												

Intra-Segment Carrier Randomization for Mode 2

From	0	1	2	3	4	5	6	7	8	9	10	11
To	98	35	67	116	135	17	5	93	73	168	54	143
From	12	13	14	15	16	17	18	19	20	21	22	23
To	43	74	165	48	37	69	154	150	107	76	176	79
From	24	25	26	27	28	29	30	31	32	33	34	35
To	175	36	28	78	47	128	94	163	184	72	142	2
From	36	37	38	39	40	41	42	43	44	45	46	47
To	86	14	130	151	114	68	46	183	122	112	180	42
From	48	49	50	51	52	53	54	55	56	57	58	59
To	105	97	33	134	177	84	170	45	187	38	167	10
From	60	61	62	63	64	65	66	67	68	69	70	71
To	189	51	117	156	161	25	89	125	139	24	19	57
From	72	73	74	75	76	77	78	79	80	81	82	83
To	71	39	77	191	88	85	0	162	181	113	140	61
From	84	85	86	87	88	89	90	91	92	93	94	95
To	75	82	101	174	118	20	136	3	121	190	120	92
From	96	97	98	99	100	101	102	103	104	105	106	107
To	160	52	153	127	65	60	133	147	131	87	22	58
From	108	109	110	111	112	113	114	115	116	117	118	119
To	100	111	141	83	49	132	12	155	146	102	164	66
From	120	121	122	123	124	125	126	127	128	129	130	131
To	1	62	178	15	182	96	80	119	23	6	166	56
From	132	133	134	135	136	137	138	139	140	141	142	143
To	99	123	138	137	21	145	185	18	70	129	95	90
From	144	145	146	147	148	149	150	151	152	153	154	155
To	149	109	124	50	11	152	4	31	172	40	13	32
From	156	157	158	159	160	161	162	163	164	165	166	167
To	55	159	41	8	7	144	16	26	173	81	44	103
From	168	169	170	171	172	173	174	175	176	177	178	179
To	64	9	30	157	126	179	148	63	188	171	106	104
From	180	181	182	183	184	185	186	187	188	189	190	191
To	158	115	34	186	29	108	53	91	169	110	27	59
values indicate carrier indexing; complex data indicated by the From carrier index is carried by the To carrier index												

Intra-Segment Carrier Randomization for Mode 3

From	0	1	2	3	4	5	6	7	8	9	10	11
To	62	13	371	11	285	336	365	220	226	92	56	46
From	12	13	14	15	16	17	18	19	20	21	22	23

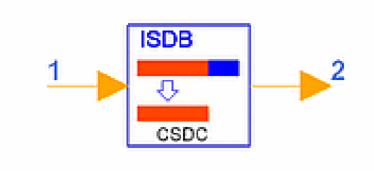
To	120	175	298	352	172	235	53	164	368	187	125	82
From	24	25	26	27	28	29	30	31	32	33	34	35
To	5	45	173	258	135	182	141	273	126	264	286	88
From	36	37	38	39	40	41	42	43	44	45	46	47
To	233	61	249	367	310	179	155	57	123	208	14	227
From	48	49	50	51	52	53	54	55	56	57	58	59
To	100	311	205	79	184	185	328	77	115	277	112	20
From	60	61	62	63	64	65	66	67	68	69	70	71
To	199	178	143	152	215	204	139	234	358	192	309	183
From	72	73	74	75	76	77	78	79	80	81	82	83
To	81	129	256	314	101	43	97	324	142	157	90	214
From	84	85	86	87	88	89	90	91	92	93	94	95
To	102	29	303	363	261	31	22	52	305	301	293	177
From	96	97	98	99	100	101	102	103	104	105	106	107
To	116	296	85	196	191	114	58	198	16	167	145	119
From	108	109	110	111	112	113	114	115	116	117	118	119
To	245	113	295	193	232	17	108	283	246	64	237	189
From	120	121	122	123	124	125	126	127	128	129	130	131
To	128	373	302	320	239	335	356	39	347	351	73	158
From	132	133	134	135	136	137	138	139	140	141	142	143
To	276	243	99	38	287	3	330	153	315	117	289	213
From	144	145	146	147	148	149	150	151	152	153	154	155
To	210	149	383	337	339	151	241	321	217	30	334	161
From	156	157	158	159	160	161	162	163	164	165	166	167
To	322	49	176	359	12	346	60	28	229	265	288	225
From	168	169	170	171	172	173	174	175	176	177	178	179
To	382	59	181	170	319	341	86	251	133	344	361	109
From	180	181	182	183	184	185	186	187	188	189	190	191
To	44	369	268	257	323	55	317	381	121	360	260	275
From	192	193	194	195	196	197	198	199	200	201	202	203
To	190	19	63	18	248	9	240	211	150	230	332	231
From	204	205	206	207	208	209	210	211	212	213	214	215
To	71	255	350	355	83	87	154	218	138	269	348	130
From	216	217	218	219	220	221	222	223	224	225	226	227
To	160	278	377	216	236	308	223	254	25	98	300	201
From	228	229	230	231	232	233	234	235	236	237	238	239
To	137	219	36	325	124	66	353	169	21	35	107	50
From	240	241	242	243	244	245	246	247	248	249	250	251
To	106	333	326	262	252	271	263	372	136	0	366	206
From	252	253	254	255	256	257	258	259	260	261	262	263
To	159	122	188	6	284	96	26	200	197	186	345	340
From	264	265	266	267	268	269	270	271	272	273	274	275

To	349	103	84	228	212	2	67	318	1	74	342	166
From	276	277	278	279	280	281	282	283	284	285	286	287
To	194	33	68	267	111	118	140	195	105	202	291	259
From	288	289	290	291	292	293	294	295	296	297	298	299
To	23	171	65	281	24	165	8	94	222	331	34	238
From	300	301	302	303	304	305	306	307	308	309	310	311
To	364	376	266	89	80	253	163	280	247	4	362	379
From	312	313	314	315	316	317	318	319	320	321	322	323
To	290	279	54	78	180	72	316	282	131	207	343	370
From	324	325	326	327	328	329	330	331	332	333	334	335
To	306	221	132	7	148	299	168	224	48	47	357	313
From	336	337	338	339	340	341	342	343	344	345	346	347
To	75	104	70	147	40	110	374	69	146	37	375	354
From	348	349	350	351	352	353	354	355	356	357	358	359
To	174	41	32	304	307	312	15	272	134	242	203	209
From	360	361	362	363	364	365	366	367	368	369	370	371
To	380	162	297	327	10	93	42	250	156	338	292	144
From	372	373	374	375	376	377	378	379	380	381	382	383
To	378	294	329	127	270	76	95	91	244	274	27	51
Values indicate carrier indexed, and complex data indicated by the carrier index From is carried by the carrier index To												

References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.

DTV_CDSCDecoder



Description: Complete differential set code (273,191) decoder
Library: DTV, ISDB-T
Class: SDFDTV_CDSCDecoder

Parameters

Name	Description	Default	Unit	Type	Range
CodeLength	length of code bits	184		int	(0, 273]
Thresholds	thresholds for error detection	16 15 14 13 12 11 10 9		int array	[0, 17)

Pin Inputs

Pin	Name	Description	Signal Type
1	input	signal to be decoded	int

Pin Outputs

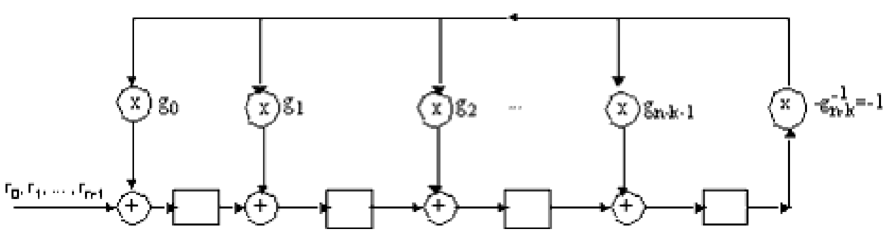
Pin	Name	Description	Signal Type
2	output	decoded signal	int

Notes/Equations

1. This model performs complete differential set code (273,191) error correcting decoding over the input signal. After decoding, 184 or 273 bits are consumed at the input and 102 or 191 bits are produced at the output.
2. For the shortened code, the same number of 0 symbols is inserted into the same position as the CDSC coder; a CDSC decoder is used to decode the block. After decoding, the padded symbols are discarded, leaving the desired information symbols.
   Generating Syndromes
   In the general transmission of a codeword C from a cyclic code by a uniform q-ary input, q-ary output channel we seek the codeword that is nearest in Hamming distance to the received sequence, R. Calculating the syndrome can be done with a simple feedback shift register similar to the encoder circuit. This is an improvement over building (or programming) a general-purpose multiplication of the received sequence R with a parity check matrix H. Once the syndrome is calculated, it is possible to iteratively determine which code positions are to be corrected by cycling the syndrome register.
   We represent the actions of the channel by
   $R = C + E$
   where
   $C = (c_0, c_1, \ldots, c_{n-1})$

represents the transmitted codeword and
$E = (e_0, e_1, \ldots, e_{n-1})$
is the error sequence with both from GF(q). In polynomial form, we express the channel action by
$r(x) = c(x) + e(x)$
Now consider division of *r(x)* by *g(x)*, generator polynomial for the code. This is motivated by recalling the valid codewords are exactly divisible by *g(x)*; that is, they produce zero remainder upon such division. We denote the remainder of this division as another polynomial, *s(x)*, the syndrome polynomial:
$$s(x) = s_0 + s_1 x + \ldots + s_{n-k} x^{n-k}$$
$$= r(x) mod g(x) = [c(x) + e(x)] mod g(x)$$
$$= c(x) mod g(x) + e(x) mod g(x)$$
$$= e(x) mod g(x)$$
Euclid's division theorem implies that the syndrome polynomial is exactly determined by the error sequence, and *s(x)* will have degree *n-k-1* or less.
To calculate the syndrome polynomial, we require a circuit for calculating the remainder on polynomial division. We provide a circuit and repeat the generic structure of the syndrome calculation in Syndrome-Forming Circuit, a device having *n-k q-ary* register cells. The circuit is clocked n times, at which time the syndrome vector (or polynomial) resides in the *(n-k)*– stage register, s_0 is the left-most memory cell.
Once the syndrome vector is determined, the syndrome vector is used to detect or correct errors.
Using Syndromes to Decode Cyclic Codes

Syndrome-Forming Circuit



CDSC (273,191) code is a one-order PG code. It can be decoded using a one-step large numeric logic method. This decoding method is simpler than the method of decoding BCH codes. In this model, it only decodes the CDSC (273,191,d=18) and its shortened codes, such as (184,102).
Using the differential set of the CDSC (273,191), we can determine 17 orthogonal check sums. The differential set of CDSC (273,191,d=18) is
{0,18,24,46,50,67,103,112,115,126,128,159,166,167,186,196,201}
The polynomial of the first orthogonal check sum is
$$W_1(x) = x^{272} + x^{254} + x^{248} + x^{226} + x^{222} + x^{205} + x^{169} + x^{160} + x^{157} + x^{146} + x^{113} + x^{106} + x^{105} + x^{86} + x^{76} + x^{71}$$
The polynomial of the second orthogonal check sum is
$$W_2(x) = x^{18} W_1(x) mod(x^{273} - 1) = x^{272} + x^{266} + x^{244} + x^{240} + x^{223} + x^{187} + x^{178} + x^{164} + x^{131} + x^{124} + x^{123} + x^{104} + x^{94} + x^{89} + x^{17}$$
The polynomial of the third orthogonal check sum is

$$W_3(x) = x^{24}W_1(x) mod(x^{273}+1) = x^{272}+x^{250}+x^{246}+x^{229}+x^{193}+x^{184} + x^{170}+x^{137}+x^{130}+x^{129}+x^{110}+x^{100}+x^{95}+x^{23}+x^{5} \quad ...$$

The polynomial of the third orthogonal check sum is

$$W_{17}(x) = x^{201}W_1(x) mod(x^{273}+1) = ...+...+...+...+...+... + x^{74}+x^{72}+x^{41}+x^{34}+x^{33}+x^{14}+x^{4}$$

where the first part is omitted. According to the differential set, we get the 17 polynomial of the orthogonal check sums; then the 17 orthogonal check sums:

$$A_1 = s_{76} \oplus s_{71}$$

$$A_2 = s_{17}$$

$$A_3 = s_{23} \oplus s_5$$

$$A_4 = s_{45} \oplus s_{27} \oplus s_{21}$$

$$A_5 = s_{49} \oplus s_{31} \oplus s_{25} \oplus s_3$$

$$A_6 = s_{66} \oplus s_{42} \oplus s_{40} \oplus s_{16}$$

$$A_7 = s_{78} \oplus s_{56} \oplus s_{52} \oplus s_{35}$$

$$A_8 = s_{65} \oplus s_{61} \oplus s_{44} \oplus s_8$$

$$A_9 = s_{68} \oplus s_{64} \oplus s_{47} \oplus s_{11} \oplus s_2$$

$$A_{10} = s_{79} \oplus s_{75} \oplus s_{58} \oplus s_{22} \oplus s_{13} \oplus s_{10}$$

$$A_{11} = s_{81} \oplus s_{77} \oplus s_{60} \oplus s_{24} \oplus s_{15} \oplus s_{12} \oplus s_1$$

$$A_{12} = s_{55} \oplus s_{46} \oplus s_{43} \oplus s_{32} \oplus s_{30}$$

$$A_{13} = s_{62} \oplus s_{53} \oplus s_{50} \oplus s_{39} \oplus s_{37} \oplus s_6$$

$$A_{14} = s_{63} \oplus s_{54} \oplus s_{51} \oplus s_{40} \oplus s_{38} \oplus s_7 \oplus s_0$$

$$A_{15} = s_{73} \oplus s_{70} \oplus s_{59} \oplus s_{57} \oplus s_{26} \oplus s_{19} \oplus s_{18}$$

$$A_{16} = s_{80} \oplus s_{69} \oplus s_{67} \oplus s_{36} \oplus s_{29} \oplus s_{28} \oplus s_9$$

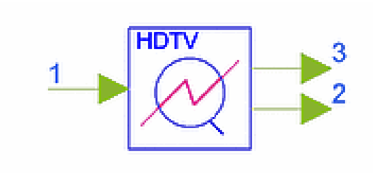
$$A_{17} = s_{74} \oplus s_{72} \oplus s_{41} \oplus s_{34} \oplus s_{33} \oplus s_{14} \oplus s_4$$

After the 17 orthogonal check sums are determined, the one-step numeric logic decoder decodes the received sequence based on the Thresholds value.

References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Frame Structure and Modulation*, Sept.1998.
2. W. Xinmei and X. Guozhen, *Error Correcting Codes: Theory and Application*, Xidian University Press, P.R.China, 1991.

DTV_ChEstimator



Description: OFDM symbol channel estimator and channel interpolator for ISDB-T
Library: DTV, ISDB-T
Class: SDFDTV_ChEstimator

Parameters

Name	Description	Default	Unit	Type	Range
Layers	number of layers	1		int	1 for 1-layer; 2 for 2-layer; 3 for 3-layer systems
Carriers	number of carriers in one OFDM symbol	432		int	108 for mode 1 216 for mode 2; 432 for mode 3
Segments	number of segments in each layer	13		int array	[1, 13]
InSequence	segment sequence at input	11 9 7 5 3 1 0 2 4 6 8 10 12		int array	"0, 1, ..., Nseg-1]"
OutSequence	segment sequence at output	0 1 2 3 4 5 6 7 8 9 10 11 12		int array	"... ,1 ,0 ,2 ,..."
Order	FFT points=2^Order	13		int	[1, ∞)
CPnumber	number of continual pilots in each segment for each layer	0		int array	{1, 0}
SPnumber	number of scattered pilots in each segment	36		int array	[1, ∞)
SPperiod	distance in carriers between nearby scattered pilots in each segments for each layer	12		int array	[0, ∞)
SPstart	start position of scattered pilots in carriers	0		int array	[1, ∞)
SPoffset	offset value of SPstart in each symbol	3		int array	[0, ∞)
SPphase	initial phase of scattered pilots for each layer	0		int array	[0, SPperiod/ SPoffset[i]-1)]

Pin Inputs

Pin	Name	Description	Signal Type
1	input	output signal from FFT	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	output	segments data whose order is OutSequence	complex
3	Coef	channel estimation	complex

Notes/Equations

1. This model adjusts the transmission spectrum, linear channel estimation, channel interpolation based on the pilot channel. It outputs the segments data and corresponding subchannel estimation according to the OutSequence.
2. Segments is the array of number of segments in each layer. Segments ≥ 1, but the sum of each component in Segments ≤ 13. For example: Segments= "1,5,6" is correct; Segments= "0,7" or Segments= "1,7,8" are not correct.
3. InSequence is [0, NSeg-1], where *Nseg=Segments[0]+....+Segments[Layer-1]* is the sum of each component in Segments. According to ISDB-T, the InSequence is "0,1,2, ... , Nseg-1" after Segments is determined.
4. OutSequence is [0,Nseg-1]. According to ISDB-T, the OutSequence is "... , 1, 0, 2, ..." after Segments is determined. For example: if Segments= "1,4", OutSequence is "3,1,0,2,4"; if Segments= "1,4,5", OutSequence is "9,7,5,3,1,0,2,4,6,8".
5. Order is the order of FFT. It must satisfy $2^{Order} \geq Carriers \times Nseg$.
6. CPnumber is 0 or 1 according to ISDB-T. If the modulation mode is DQPSK in one layer, its corresponding component in CPnumber is 1 per one segment, otherwise, its corresponding component in CPnumber is 0. For example: in a 2-layer system, the first layer is DQPSK modulation, the second layer is 16-QAM modulation, the CPnumber= "1, 0".
7. SPnumber = 0, 9, 18 or 36 according to ISDB-T. If the modulation mode is:
    - differential modulation in one layer, its corresponding component in SPnumber is 0
    - coherent modulation in one layer, its corresponding component in SPnumber is 9, 18 or 36 of mode 1, mode 2, or mode 3 per one segment, respectively.
      For example, in a 3-layer mode 3 system, the first and third layers are coherent modulation and the second layer is differential modulation; SPnumber= "36, 0, 36".
8. SPperiod = 0 or 12 according to ISDB-T. If the modulation mode is:
    - differential modulation in one layer, its corresponding component in SPperiod is 0
    - coherent modulation in one layer, its corresponding component in SPperiod is 12.
      For example, in a 3-layer mode 3 system, the first and third layers are coherent modulation and the second layer is differential modulation; SPperiod= "12, 0, 12".
9. SPstart = 0 according to ISDB-T.
10. SPoffset = 0 or 3 according to ISDB-T. If the modulation mode is:
    - differential modulation in one layer, its corresponding component in SPoffset is 0
    - coherent modulation in one layer, its corresponding component in SPoffset is 3
      For a example, in a 3-layer mode 3 system, the first and third layers are coherent modulation and the second layer is differential modulation; SPoffset= "3, 0, 3".
11. SPphase = 3 in the OFDM receiver if the modulation mode of the corresponding layer is coherent modulation (because DTV_MLEstimator makes one OFDM symbol delay); otherwise, SPphase = 0.
    For a example, in a 3-layer mode 3 system, the first and third layers are coherent

modulation and the second layer is differential modulation; SPphase= "3, 0, 3".

12. Using IntState of Carriers, CPnumber and SPnumber, this model determines the number of CP (continual pilot) and SP (scattered pilots) in each segment in every layer. According to ISDB-T, if the modulation mode in one layer is:

 - for differential modulation there is one CP in every segment; there are no SPs in any segment.

 - for coherent modulation there are 9, 18, 36 SPs in each segment in one layer, for mode 1, 2, and 3, respectively; there are no CPs in any segment.

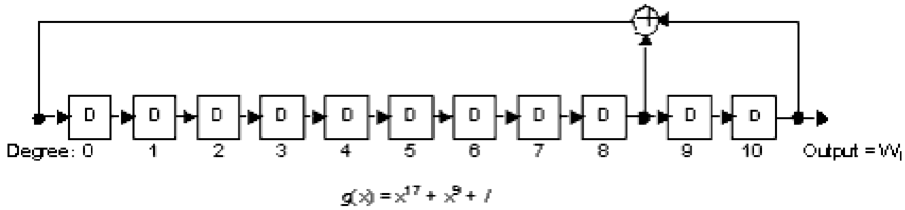
 PRBS sequences in each segment are generated according to Generation of PRBS Sequence and the initial sets of PRBS register in Initial Sets of PRBS Register. The PRBS in initialized so that the first output bit from the PRBS coincides with the first active carrier. A new value is generated by the PRBS on every carrier used in each segment (whether or not it is a pilot).
 The position of one CP in the differential modulation segment is always zero.
 Positions of scattered pilots in the coherent modulation segments are generated as follows. For the symbol of index l (ranging from 0 to 203), carriers for which index k belongs to subset
 $$\{k = 3 \times l \;mod\;\; 4 + 12p \mid p \;\; integer, p \geq 0, k \in [0, Length \times Segments[i]]\}$$
 are SP positions, where i is 0, 1, 2, corresponding to the coherent modulation segments layers. Five parameters control the SP positions.

 - SPnumber determines the number of scattered pilots in each segment: 9 in mode 1 (Length=108), 18 in mode 2 (Length=216), and 36 in mode 3 (Length=432).

 - SPperiod = 12, SPstart = 0, SPoffset = 3 and SPphase = 0 in all modes according to ISDB-T.

 After determining all CP and SP positions in each corresponding segment in every layer, we get the pilots value from the PRBS sequence. So, we can get the channel estimation in this CP and SP pilots.
 $$h(i) = \frac{x(i)}{PilotValue(i)}$$
 where *h(i)* is the channel estimation *x(i)* is the received signal from channel after FFT and *PilotValue(i)* is the PRBS value corresponding to CP and SP position in each segment.
 After getting the subchannel estimation in the CP and SP pilots position, we use the linear interpolation algorithm to get all active subchannel estimation:
 $$h(k) = \alpha h(i) + (1 - \alpha) h(j)$$
 $$\alpha = \frac{j - k}{j - i}$$
 where $i \leq h \leq j$, *h(i)*, and *h(j)* are the subchannel estimation of the CP or SP pilots.
 The transmission spectrum adjustment is made in DTV_LoadIFFTBuff. In the receiver, the transmission spectrum must be inversed. InSequence and OutSequence must be identical to DTV_LoadIFFTBuff. The layer segment data is output by the order of OutSequence. Inserted zeros in DTV_LoadIFFTBuff are discarded. The active carriers and its corresponding subchannel carriers are output for use in the equalizer model.

Generation of PRBS Sequence



Initial Sets of PRBS Register

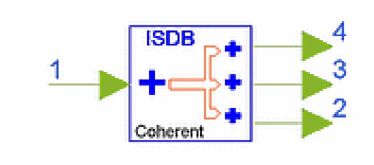
Segment Number	Initial Sets for Mode 1 †	Initial Sets for Mode 2 †	Initial Sets for Mode 3 †
11	1 1 1 1 1 1 1 1 1 1 1	1 1 1 1 1 1 1 1 1 1 1	1 1 1 1 1 1 1 1 1 1 1
9	1 1 0 1 1 0 0 1 1 1 1	0 1 1 0 1 0 1 1 1 1 0	1 1 0 1 1 1 0 0 1 0 1
7	0 1 1 0 1 0 1 1 1 1 0	1 1 0 1 1 1 0 0 1 0 1	1 0 0 1 0 1 0 0 0 0 0
5	0 1 0 0 0 1 0 1 1 1 0	1 1 0 0 1 0 0 0 0 1 0	0 1 1 1 0 0 0 1 0 0 1
3	1 1 0 1 1 1 0 0 1 0 1	1 0 0 1 0 1 0 0 0 0 0	0 0 1 0 0 0 1 1 0 0 1
1	0 0 1 0 1 1 1 1 0 1 0	0 0 0 0 1 0 1 1 0 0 0	1 1 1 0 0 1 1 0 1 1 0
0	1 1 0 0 1 0 0 0 0 1 0	0 1 1 1 0 0 0 1 0 0 1	0 0 1 0 0 0 0 1 0 1 1
2	0 0 0 1 0 0 0 0 1 0 0	0 0 0 0 0 1 0 0 1 0 0	1 1 1 0 0 1 1 1 1 0 1
4	1 0 0 1 0 1 0 0 0 0 0	0 0 1 0 0 0 1 1 0 0 1	0 1 1 0 1 0 1 0 0 1 1
6	1 1 1 1 0 1 1 0 0 0 0	0 1 1 0 0 1 1 1 0 0 1	1 0 1 1 1 0 1 0 0 1 0
8	0 0 0 0 1 0 1 1 0 0 0	1 1 1 0 0 1 1 0 1 1 0	0 1 1 0 0 0 1 0 0 1 0
10	1 0 1 0 0 1 0 0 1 1 1	0 0 1 0 1 0 1 0 0 0 1	1 1 1 1 0 1 0 0 1 0 1
12	0 1 1 1 0 0 0 1 0 0 1	0 0 1 0 0 0 0 1 0 1 1	0 0 0 1 0 0 1 1 1 0 0

† Degree from 0 to 10 in Generation of PRBS Sequence.

References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.

DTV_DemuxCohSegs



Description: OFDM de-segment for coherent modulation
Library: DTV, ISDB-T
Class: SDFDTV_DemuxCohSegs

Parameters

Name	Description	Default	Unit	Type	Range
Carriers	number of carriers in one segment	432		int	108 for mode 1; 216 for mode 2; 432 for mode 3
Segments	number of segments	1		int	[1, 13]
Start_Seg	initial number of segment (0 to Segments-1)	0		int	[0, 12]
SPnumber	number of scattered pilots in each segment	36		int	[0, ∞)†
SPperiod	distance in carriers between nearby scattered pilots	12		int	(0, ∞)††
SPstart	start position of scattered pilots in carriers	0		int	[0, ∞)††
SPoffset	offset value of SPstart in each symbol	3		int	[0, ∞)††
SPphase	initial phase of scattered pilots	3		int	[0, SPperiod/SPoffset-1]†††

† SPnumber = 9 for mode 1, 18 for mode 2, 36 for mode 3, per segment in ISDB-T systems.
†† SPperiod = 12, SPstart = 0, SPoffset = 3 in ISDB-T systems.
††† SPphase=3 in the OFDM receiver (because DTV_MLEstimator makes one OFDM symbol delay)

Pin Inputs

Pin	Name	Description	Signal Type
1	input	received equalized signal	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	output	TSP data output	complex
3	TMCC	TMCC data output	complex
4	AC	AC data output	complex

Notes/Equations

1. This model demultiplexes coherent modulation OFDM segments (such as QPSK, 16-QAM, and 64-QAM modulation) into TSP (transport stream packet) data, TMCC

(transmission and multiplexing configuration control) data, AC (auxiliary channel) data according to Structure of OFDM Segment for Coherent Modulation and Carrier Allocation of AC and TMCC for Coherent Modulation.

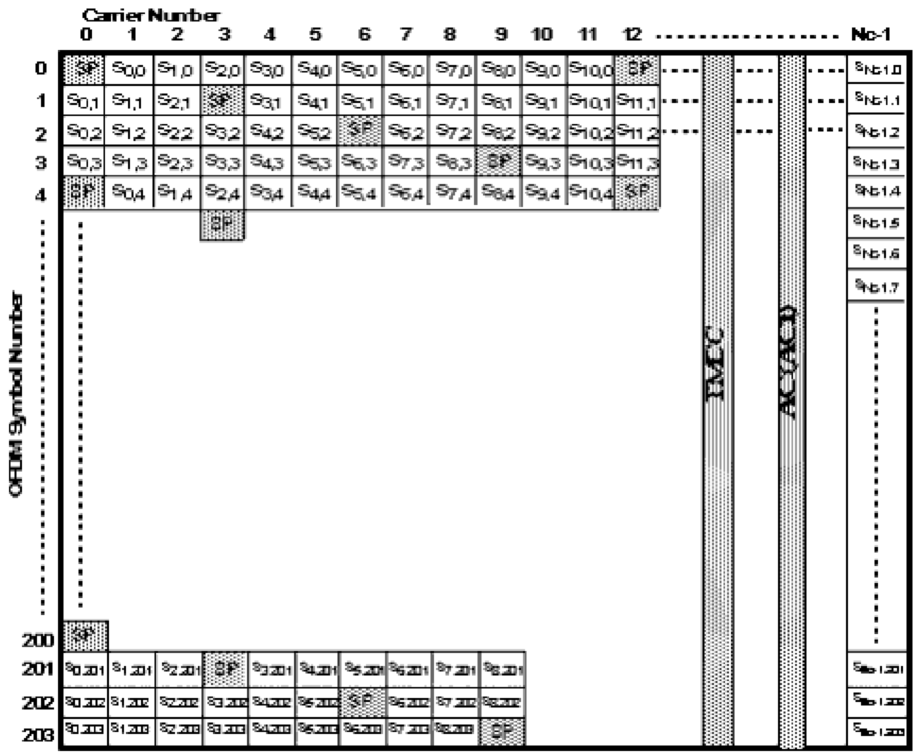
2. IntState of Carriers determines the number of TMCC and AC in each segment. Then, IntState of Start_Seg and Segments determines the TMCC and AC positions in each corresponding segment according to Carrier Allocation of AC and TMCC for Coherent Modulation.
   The PRBS sequences in each segment are generated according to Generation of PRBS Sequence and the initial sets of PRBS register in Initial Sets of PRBS Register. The PRBS in initialized so that the first output bit from the PRBS coincides with the first active carrier. A new value is generated by the PRBS on every used carrier in each segment (whether or not it is a pilot).
   Positions of the corresponding scattered pilots are generated as follows.
   For the symbol of index *l* (ranging from 0 to 203), carriers for which index *k* belongs to subset
   $$\{k = 3 \times l \ mod \ \ 4 + 12p | p \ \ integer, p \geq 0, k \in [0, Length \times Segments]\}$$
   are scattered pilot positions.
   Five parameters control the scattered pilots positions.

   SPnumber determines the number of scattered pilots in each segment: it is 9 in mode 1 (Length=108); 18 in mode 2 (Length=216); and, 36 in mode 3 (Length=432).

   SPperiod= 12, SPstart=0, SPoffset=3 and SPphase = 0 in the three modes according to ISDB-T.

   After determining TMCC, AC, and SP positions in each corresponding segment and the value of the PRBS sequence in all the active carriers in each segment, the model demultiplexes the input data into TMCC, AC, and TSP data. According to the TMCC position and the PRBS sequence, we can get the only one TMCC bit in each TMCC position, then the one transmitted TMCC bit is determined by the mean value of the TMCC positions.
   $$TMCC = \frac{1}{NTMCC} \sum_{l=1}^{NTMCC} \frac{x[TMCCposition[l]]}{PilotValue[TMCCposition[l]]}$$
   where *NTMCC* is the number of TMCCs in one segment; *PilotValue* is the PRBS sequence in corresponding segment; *x[i]* is the input data.
   AC data is:
   $$AC[i] = \frac{x[ACposition[i]]}{PilotValue[ACposition[i]]}$$
   Except for AC, TMCC, and SP positions, the remaining positions in one segment are the TSP data positions.
   $$Data[i] = x[i]$$

Structure of OFDM Segment for Coherent Modulation

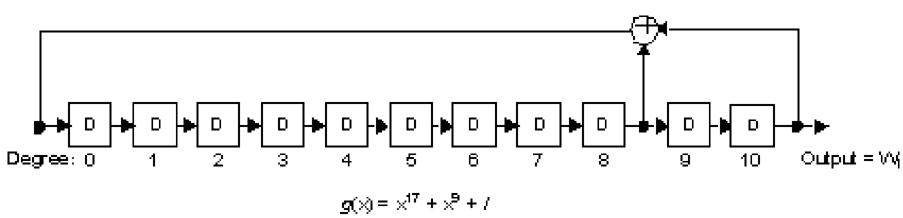


$S_{i,j,k}$ denotes complex data in the data segment after time and frequency interleaving.
Nc=108 for Mode1; 216 for Mode2; 432 for Mode 3

Carrier Allocation of AC and TMCC for Coherent Modulation

Segment	**11**	**9**	**7**	**5**	**3**	**1**	**0**	**2**	**4**	**6**	**8**	**10**	**12**
Mode 1													
AC1_1	10	53	61	11	20	74	35	76	4	40	8	7	98
AC1_2	28	83	100	101	40	100	79	97	89	89	64	89	101
TMCC_1	70	25	17	86	44	47	49	31	83	61	85	101	23
Mode 2													
AC1_1	10	61	20	35	4	8	98	53	11	74	76	40	7
AC1_2	28	100	40	79	89	64	101	83	101	100	97	89	89
AC1_3	161	119	182	184	148	115	118	169	128	143	112	116	206
AC1_4	191	209	208	205	197	197	136	208	148	187	197	172	209
TMCC_1	70	17	44	49	83	85	23	25	86	47	31	61	101
TMCC_2	133	194	155	139	169	209	178	125	152	157	191	193	131
Mode 3													
AC1_1	10	20	4	98	11	76	7	61	35	8	53	74	40
AC1_2	28	40	89	101	101	97	89	100	79	64	83	100	89
AC1_3	161	182	148	118	128	112	206	119	184	115	169	143	116
AC1_4	191	208	197	136	148	197	209	209	205	197	208	187	172
AC1_5	277	251	224	269	290	256	226	236	220	314	227	292	223
AC1_6	316	295	280	299	316	305	244	256	305	317	317	313	305
AC1_7	335	400	331	385	359	332	377	398	364	334	344	328	422
AC1_8	425	421	413	424	403	388	407	424	413	352	364	413	425
TMCC_1	70	44	83	23	86	31	101	17	49	85	25	47	61
TMCC_2	131	155	169	178	152	191	131	194	139	209	125	157	193
TMCC_3	233	265	301	241	263	277	286	260	299	239	302	247	317
TMCC_4	410	355	425	341	373	409	349	371	385	394	368	407	347

Generation of PRBS Sequence



Initial Sets of PRBS Register

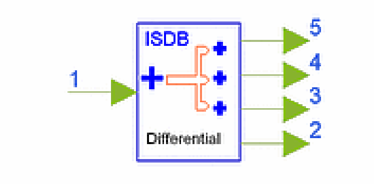
Segment	Initial Sets for Mode 1 †	Initial Sets for Mode 2 †	Initial Sets for Mode 3 †
11	1 1 1 1 1 1 1 1 1 1 1	1 1 1 1 1 1 1 1 1 1 1	1 1 1 1 1 1 1 1 1 1 1
9	1 1 0 1 1 0 0 1 1 1 1	0 1 1 0 1 0 1 1 1 1 0	1 1 0 1 1 1 0 0 1 0 1
7	0 1 1 0 1 0 1 1 1 1 0	1 1 0 1 1 1 0 0 1 0 1	1 0 0 1 0 1 0 0 0 0 0
5	0 1 0 0 0 1 0 1 1 1 0	1 1 0 0 1 0 0 0 0 1 0	0 1 1 1 0 0 0 1 0 0 1
3	1 1 0 1 1 1 0 0 1 0 1	1 0 0 1 0 1 0 0 0 0 0	0 0 1 0 0 0 1 1 0 0 1
1	0 0 1 0 1 1 1 1 0 1 0	0 0 0 0 1 0 1 1 0 0 0	1 1 1 0 0 1 1 0 1 1 0
0	1 1 0 0 1 0 0 0 0 1 0	0 1 1 1 0 0 0 1 0 0 1	0 0 1 0 0 0 0 1 0 1 1
2	0 0 0 1 0 0 0 0 1 0 0	0 0 0 0 0 1 0 0 1 0 0	1 1 1 0 0 1 1 1 1 0 1
4	1 0 0 1 0 1 0 0 0 0 0	0 0 1 0 0 0 1 1 0 0 1	0 1 1 0 1 0 1 0 0 1 1
6	1 1 1 1 0 1 1 0 0 0 0	0 1 1 0 0 1 1 1 0 0 1	1 0 1 1 1 0 1 0 0 1 0
8	0 0 0 0 1 0 1 1 0 0 0	1 1 1 0 0 1 1 0 1 1 0	0 1 1 0 0 0 1 0 0 1 0
10	1 0 1 0 0 1 0 0 1 1 1	0 0 1 0 1 0 1 0 0 0 1	1 1 1 1 0 1 0 0 1 0 1
12	0 1 1 1 0 0 0 1 0 0 1	0 0 1 0 0 0 0 1 0 1 1	0 0 0 1 0 0 1 1 1 0 0

† Degree from 0 to 10 in Generation of PRBS Sequence.

References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.

DTV_DemuxDiffSegs



Description: OFDM de-segment for differential modulation
Library: DTV, ISDB-T
Class: SDFDTV_DemuxDiffSegs

Parameters

Name	Description	Default	Unit	Type	Range
Carriers	number of carriers in one segment	432		int	108 for mode 1; 216 for mode 2; 432 for mode 3
Segments	number of segments	1		int	[1, 13]
Start_Seg	initial number of segment (0 to Segments-1)	0		int	[0, 12]

Pin Inputs

Pin	Name	Description	Signal Type
1	input	received equalized signal	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	output	TSP data output	complex
3	TMCC	TMCC data output	complex
4	AC1	AC1 data output	complex
5	AC2	AC2 data output	complex

Notes/Equations

1. This model demultiplexes the differential modulation OFDM segments (such as DQPSK modulation) into TSP (transport stream packet) data, TMCC (transmission and multiplexing configuration control) data, AC (auxiliary channel) data according to Structure of OFDM Segment for Differential Modulation and Carrier Allocation of CP, AC, and TMCC for Differential Modulation.
2. IntState of Carriers determines the number of TMCC, AC1, and AC2 in each segment. IntState of Start_Seg and Segments determine the TMCC, AC1, and AC2 positions in each corresponding segment according to Carrier Allocation of CP, AC, and TMCC for Differential Modulation.
   The PRBS sequences in each segment are generated according to Generation of PRBS Sequence and the initial sets of PRBS register in Initial Sets of PRBS Register. The PRBS in initialized so that the first output bit from the PRBS coincides with the first active carrier. A new value is generated by the PRBS on every used carriers in each segments (whether or not it is a pilot).

After determining all TMCC, AC1, and AC2 positions in each corresponding segment and the value of the PRBS sequence in all active carriers in each segment, the model demultiplexes the input data into TMCC, AC1, AC2, and TSP data. According to the TMCC position and the PRBS sequence, we can get the only one TMCC bit in each TMCC position, then the one transmitted TMCC bit is determined by the mean value of those TMCC positions.

$$TMCC = \frac{1}{NTMCC} \sum_{l=1}^{NTMCC} \frac{x[TMCCposition[l]]}{PilotValue[TMCCposition[l]]}$$

where *NTMCC* is the number of TMCCs in one segment; *PilotValue* is the PRBS sequence in corresponding segment; *x[i]* is the input data.

AC1 data is:

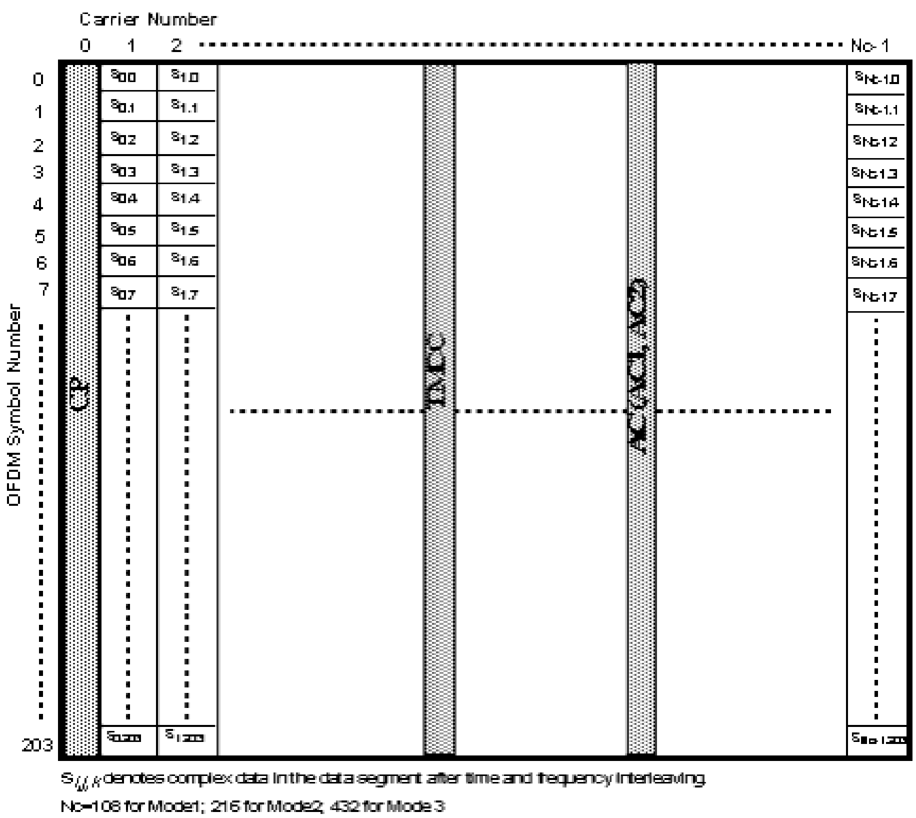
$$AC1[i] = \frac{x[AC1position[i]]}{PilotValue[AC1position[i]]}$$

AC2 data is:

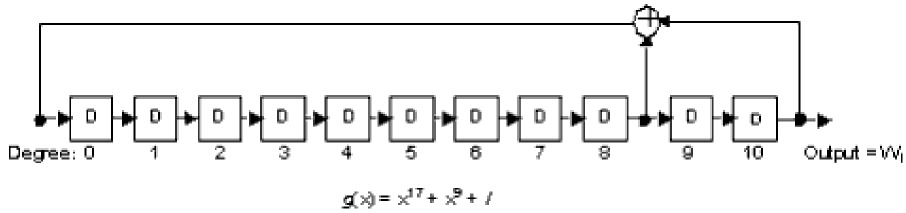
$$AC2[i] = \frac{x[AC2position[i]]}{PilotValue[AC2position[i]]}$$

Except for the AC1, AC2 and TMCC data positions, the remaining positions in one segment are the TSP data positions. *Data[i] = x[i]*.

Structure of OFDM Segment for Differential Modulation



Generation of PRBS Sequence



Carrier Allocation of CP, AC, and TMCC for Differential Modulation

Segment	**11**	**9**	**7**	**5**	**3**	**1**	**0**	**2**	**4**	**6**	**8**	**10**	**12**
Mode 1													
CP	0	0	0	0	0	0	0	0	0	0	0	0	0
AC1_1	10	53	61	11	20	74	35	76	4	40	8	7	98
AC1_2	28	83	100	101	40	100	79	97	89	89	64	89	101
AC2_1	3	3	29	28	23	30	3	5	13	72	36	25	10
AC2_2	45	15	41	45	63	81	72	18	93	95	48	30	30
AC2_3	59	40	84	81	85	92	85	57	98	100	52	42	55
AC2_4	77	58	93	91	105	103	89	92	102	105	74	104	81
TMCC_1	13	25	4	36	10	7	49	31	16	5	78	34	23
TMCC_2	50	63	7	48	28	25	61	39	30	10	82	48	37
TMCC_3	70	73	17	55	44	47	96	47	37	21	85	54	51
TMCC_4	83	80	51	59	47	60	99	65	74	44	98	70	68
TMCC_5	87	93	71	86	54	87	104	72	83	61	102	101	105
Mode 2													
CP	0	0	0	0	0	0	0	0	0	0	0	0	0
AC1_1	10	61	20	35	4	8	98	53	11	74	76	40	7
AC1_2	28	100	40	79	89	64	101	83	101	100	97	89	89
AC1_3	161	119	182	184	148	115	118	169	128	143	112	116	206
AC1_4	191	209	208	205	197	197	136	208	148	187	197	172	209
AC2_1	3	29	23	3	13	36	10	3	28	30	5	72	25
AC2_2	45	41	63	72	93	48	30	15	45	81	18	95	30
AC2_3	59	84	85	85	98	52	55	40	81	92	57	100	42
AC2_4	77	93	105	89	102	74	81	58	91	103	92	105	104
AC2_5	108	108	108	108	108	108	108	108	108	108	108	108	108
AC2_6	111	136	138	113	180	133	111	137	131	111	121	144	118
AC2_7	123	153	189	126	203	138	153	149	171	180	201	156	138
AC2_8	148	189	200	165	208	150	167	192	193	193	206	160	163
AC2_9	166	199	211	200	213	212	185	201	213	197	210	182	189
TMCC_1	13	4	10	49	16	78	23	25	36	7	31	5	34
TMCC_2	50	7	28	61	30	82	37	63	48	25	39	10	48
TMCC_3	70	17	44	96	37	85	51	73	55	47	47	21	54

TMCC_4	83	51	47	99	74	98	68	80	59	60	65	44	70
TMCC_5	87	71	54	104	83	102	105	93	86	87	72	61	101
TMCC_6	133	144	115	139	113	142	121	112	118	157	124	186	131
TMCC_7	171	156	133	147	118	156	158	115	136	169	138	190	145
TMCC_8	181	163	155	155	129	162	178	125	152	204	145	193	159
TMCC_9	188	167	168	173	152	178	191	159	155	207	182	206	176
TMCC_10	201	194	195	180	169	209	195	179	162	212	191	210	213
Mode 3													
CP	0	0	0	0	0	0	0	0	0	0	0	0	0
AC1_1	10	20	4	98	11	76	7	61	35	8	53	74	40
AC1_2	28	40	89	101	101	97	89	100	79	64	83	100	89
AC1_3	161	182	148	118	128	112	206	119	184	115	169	143	116
AC1_4	191	208	197	136	148	197	209	209	205	197	208	187	172
AC1_5	277	251	224	269	290	256	226	236	220	314	227	292	223
AC1_6	316	295	280	299	316	305	244	256	305	317	317	313	305
AC1_7	335	400	331	385	359	332	377	398	364	334	344	328	422
AC1_8	425	421	413	424	403	388	407	424	413	352	364	413	425
AC2_1	3	23	13	10	28	5	25	29	3	36	3	30	72
AC2_2	45	63	93	30	45	18	30	41	72	48	15	81	95
AC2_3	59	85	98	55	81	57	42	84	85	52	40	92	100
AC2_4	77	105	102	81	91	92	104	93	89	74	58	103	105
AC2_5	108	108	108	108	108	108	108	108	108	108	108	108	108
AC2_6	111	138	180	111	131	121	118	136	113	133	137	111	144
AC2_7	123	189	203	153	171	201	138	153	126	138	149	180	156
AC2_8	148	200	208	167	193	206	163	189	165	150	192	193	160
AC2_9	166	211	213	185	213	210	189	199	200	212	201	197	182
AC2_10	216	216	216	216	216	216	216	216	216	216	216	216	216
AC2_11	245	219	252	219	246	288	219	239	229	226	244	221	241
AC2_12	257	288	264	231	297	311	261	279	309	246	261	234	246
AC2_13	300	301	268	256	308	316	275	301	314	271	297	273	258
AC2_14	309	305	290	274	319	321	293	321	318	297	307	308	320
AC2_15	324	324	324	324	324	324	324	324	324	324	324	324	324
AC2_16	352	329	349	353	327	360	327	354	396	327	347	337	334
AC2_17	369	342	354	365	396	372	339	405	419	369	387	417	354
AC2_18	405	381	366	408	409	376	364	416	424	383	409	422	379
AC2_19	415	416	428	417	413	398	382	427	429	401	429	426	405
TMCC_1	13	10	16	23	36	31	34	4	49	78	25	7	5
TMCC_2	50	28	30	37	48	39	48	7	61	82	63	25	10
TMCC_3	70	44	37	51	55	47	54	17	96	85	73	47	21
TMCC_4	83	47	74	68	59	65	70	51	99	98	80	60	44
TMCC_5	87	54	83	105	86	72	101	71	104	102	93	87	61
TMCC_6	133	115	113	121	118	124	131	144	139	142	112	157	186

TMCC_7	171	133	118	158	136	138	145	156	147	156	115	169	190
TMCC_8	181	155	129	178	152	145	159	163	155	162	125	204	193
TMCC_9	188	168	152	191	155	182	176	167	173	178	159	207	206
TMCC_10	201	195	169	195	162	191	213	194	180	209	179	212	210
TMCC_11	220	265	294	241	223	221	229	226	232	239	252	247	250
TMCC_12	223	277	298	279	241	226	266	244	246	253	264	255	264
TMCC_13	233	312	301	289	263	237	286	260	253	267	271	263	270
TMCC_14	267	315	314	296	276	260	299	263	290	284	275	281	286
TMCC_15	287	320	318	309	303	277	303	270	299	321	302	288	317
TMCC_16	360	355	358	328	373	402	349	331	329	337	334	340	347
TMCC_17	372	363	372	331	385	406	387	349	334	374	352	354	361
TMCC_18	379	371	378	341	420	409	397	371	345	394	368	361	375
TMCC_19	383	389	394	375	423	422	404	384	368	407	371	398	392
TMCC_20	410	396	425	395	428	426	417	411	385	411	378	407	429

Initial Sets of PRBS Register

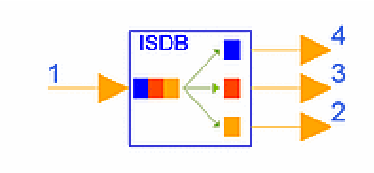
Segment	Initial Sets for Mode 1 †	Initial Sets for Mode 2 †	Initial Sets for Mode 3 †
11	1 1 1 1 1 1 1 1 1 1 1	1 1 1 1 1 1 1 1 1 1 1	1 1 1 1 1 1 1 1 1 1 1
9	1 1 0 1 1 0 0 1 1 1 1	0 1 1 0 1 0 1 1 1 1 0	1 1 0 1 1 1 0 0 1 0 1
7	0 1 1 0 1 0 1 1 1 1 0	1 1 0 1 1 1 0 0 1 0 1	1 0 0 1 0 1 0 0 0 0 0
5	0 1 0 0 0 1 0 1 1 1 0	1 1 0 0 1 0 0 0 0 1 0	0 1 1 1 0 0 0 1 0 0 1
3	1 1 0 1 1 1 0 0 1 0 1	1 0 0 1 0 1 0 0 0 0 0	0 0 1 0 0 0 1 1 0 0 1
1	0 0 1 0 1 1 1 1 0 1 0	0 0 0 0 1 0 1 1 0 0 0	1 1 1 0 0 1 1 0 1 1 0
0	1 1 0 0 1 0 0 0 0 1 0	0 1 1 1 0 0 0 1 0 0 1	0 0 1 0 0 0 0 1 0 1 1
2	0 0 0 1 0 0 0 0 1 0 0	0 0 0 0 0 1 0 0 1 0 0	1 1 1 0 0 1 1 1 1 0 1
4	1 0 0 1 0 1 0 0 0 0 0	0 0 1 0 0 0 1 1 0 0 1	0 1 1 0 1 0 1 0 0 1 1
6	1 1 1 1 0 1 1 0 0 0 0	0 1 1 0 0 1 1 1 0 0 1	1 0 1 1 1 0 1 0 0 1 0
8	0 0 0 0 1 0 1 1 0 0 0	1 1 1 0 0 1 1 0 1 1 0	0 1 1 0 0 0 1 0 0 1 0
10	1 0 1 0 0 1 0 0 1 1 1	0 0 1 0 1 0 1 0 0 0 1	1 1 1 1 0 1 0 0 1 0 1
12	0 1 1 1 0 0 0 1 0 0 1	0 0 1 0 0 0 0 1 0 1 1	0 0 0 1 0 0 1 1 1 0 0

† Degree from 0 to 10 in Generation of PRBS Sequence.

References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.

DTV_DemuxTMCC



Description: TMCC bit decomposer into 20 and 184 bits)
Library: DTV, ISDB-T
Class: SDFDTV_DemuxTMCC

Parameters

Name	Description	Default	Unit	Type	Range
Length	length of TMCC format	204		int	204

Pin Inputs

Pin	Name	Description	Signal Type
1	input	received equalized signal	int

Pin Outputs

Pin	Name	Description	Signal Type
2	Sync	synchronization of TMCC output	int
3	Desc	segment descriptor output	int
4	Info	coded TMCC information	int

Notes/Equations

1. This model demultiplexes the 204 received transmission and multiplexing configuration control bits in ISDB-T systems.
2. According to ISDB-T, the first bit B_0 is the initialization bit, so this bit is discarded.

   $B_1 - B_{16}$, a 16-bit synchronization sequence, takes w0 and w1 (the inverse of w0) in turn in every frame. This model outputs this 16-bit synchronization sequence.

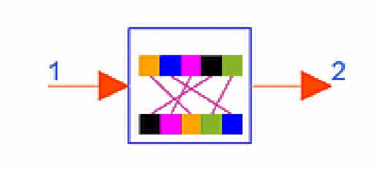
   $B_{17} - B_{19}$ represent the segment descriptor.

   $B_{20} - B_{203}$ include TMCC information (102 bits) and 82-bit parity bits; these 184 bits need CDSC decoding.

References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.

DTV_InterSegInterlv



Description: Inter-segment interleaving of OFDM symbols
Library: DTV, ISDB-T
Class: SDFDTV_InterSegInterlv

Parameters

Name	Description	Default	Unit	Type	Range
Segments	depth of block interleaver	4		int	[1, 13]
Carriers	width of block interleaver	384		int	{96,192,384}
Option	operating option: Interleaving, Deinterleaving: Interleave, Deinterleave	Interleave		enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	input	input symbols to be interleaved	anytype

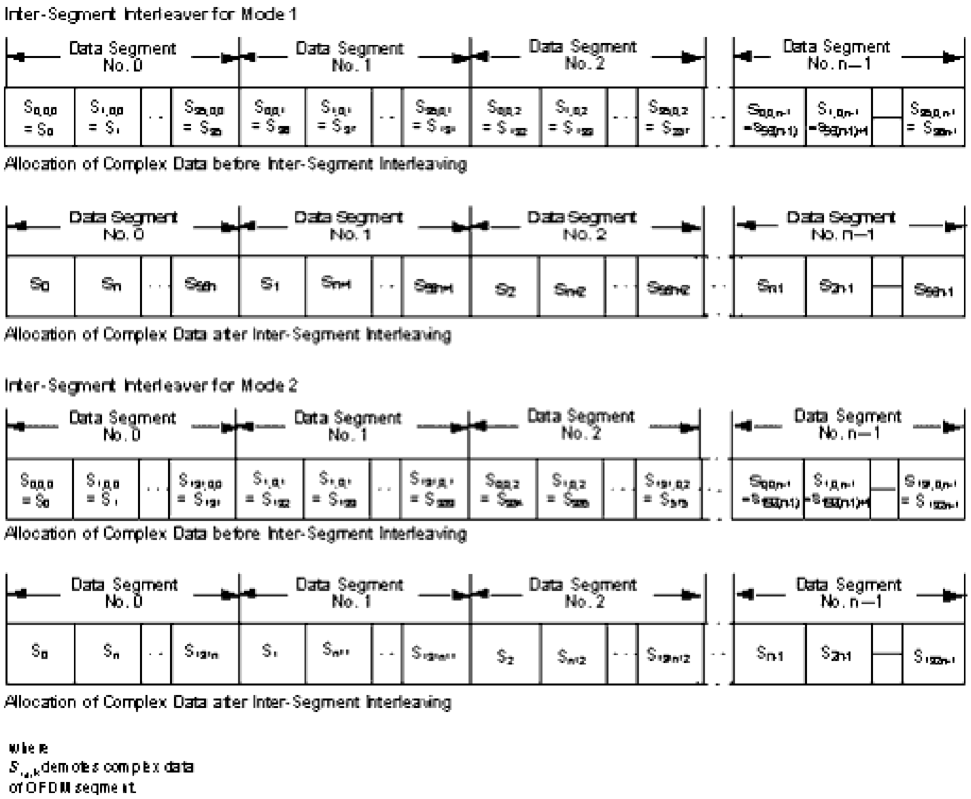
Pin Outputs

Pin	Name	Description	Signal Type
2	output	output symbols after interleaved	anytype

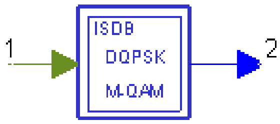
Notes/Equations

1. This model performs inter-segment symbol interleaving among all segments within the differential or coherent modulation layer.
2. The inter-segment interleaving is carried out among differential modulation (DQPSK) segments and coherent modulation (QPSK, 16-QAM, and 64-QAM) as shown below.

Inter-Segment Interleaver


Inter-Segment Interleaver for Mode 1
Data Segment No. 0
Data Segment No. 1
Data Segment No. 2
Data Segment No. n—1
Allocation of Complex Data before Inter-Segment Interleaving
Allocation of Complex Data after Inter-Segment Interleaving
Inter-Segment Interleaver for Mode 2
Allocation of Complex Data before Inter-Segment Interleaving
Allocation of Complex Data after Inter-Segment Interleaving
where
denotes complex data
of OFDM segment

DTV_ISDBDemodulation



Description: ISDB-T demapper and deinterleaver
Library: DTV, ISDB-T
Class: SDFDTV_ISDBDemodulation

Parameters

Name	Description	Default	Unit	Type	Range
Mode	transmission mode: Mode 1, Mode 2, Mode 3	Mode 1		enum	
MappingMode	signal constellations and mapping: DQPSK, QPSK, QAM-16, QAM-64	DQPSK		enum	
Segments	number of segments per layer	13		int	[1, 13]

Pin Inputs

Pin	Name	Description	Signal Type
1	In	input	complex

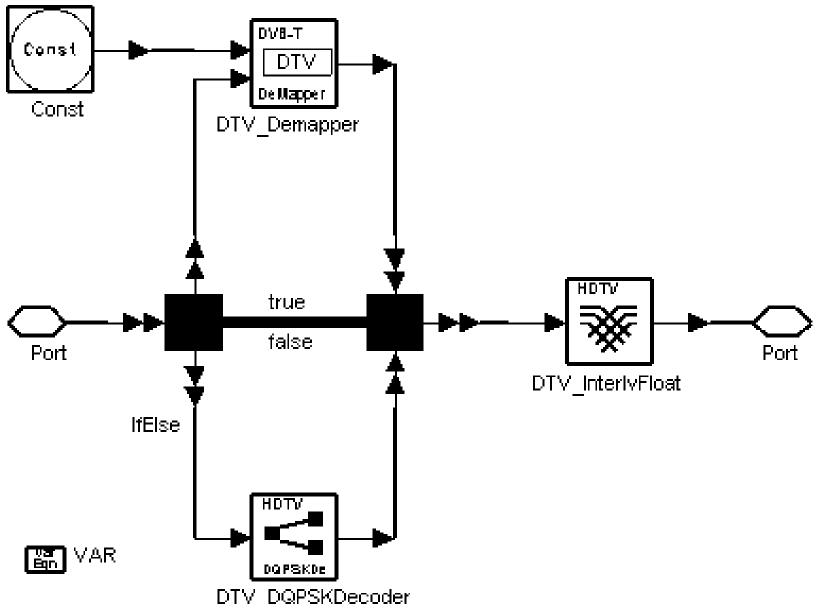
Pin Outputs

Pin	Name	Description	Signal Type
2	Out	output	real

Notes/Equations

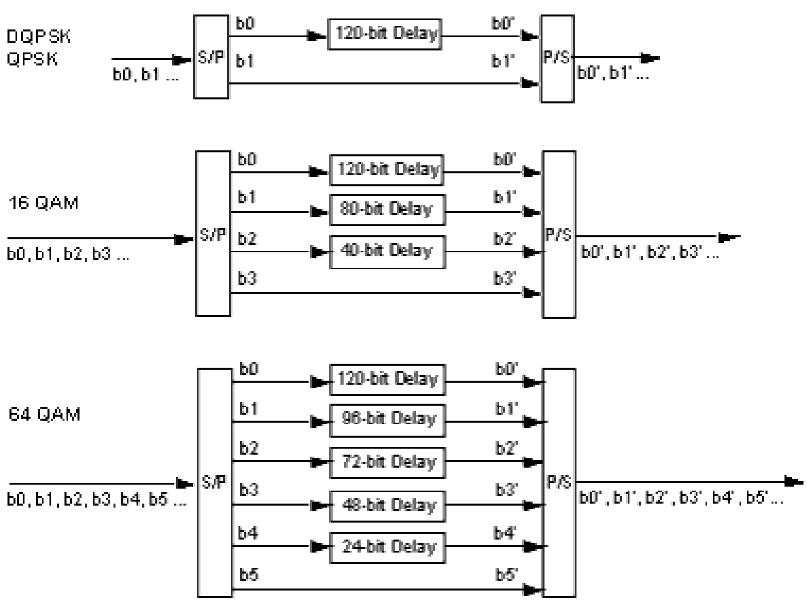
1. This subnetwork model performs hard-decision de-mapping and bit-wise de-interleaving for an ISDB-T receiver.
   The schematic for this subnetwork is shown below.

DTV_ISDBDemodulation Schematic



2. For coherent transmission, the demapper works in a carrier-wise manner; for differential transmission (DQPSK), the demapper works in an hierarchical layer manner; that is, differential is carried out between the *i* th and the *j* th input particles, herein their index satisfies:
   $$j - i = 96 \times 2^{Mode} \times Segments$$
   where *Mode* equals 0, 1, or 2 for Mode 1, Mode 2, or Mode 3, respectively.
3. Output of the demapper will be +1 or -1.
4. DTV_InterlvFloat performs bit-wise de-interleaving; the functional block diagram is shown below.

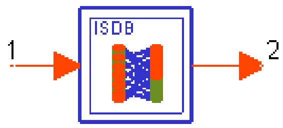
Bit-Wise Deinterleaving



References

1. ARIB STD-B31 Version 1.5, *Transmission System for Digital Terrestrial Television Broadcasting*, July 29, 2003.

DTV_ISDBFreqDeinterlv



Description: Inter-frequency and intra-frequency deinterleaving for ISDB-T
Library: DTV, ISDB-T
Class: SDFDTV_ISDBFreqDeinterlv

Parameters

Name	Description	Default	Unit	Type	Range
Mode	transmission mode: Mode 1, Mode 2, Mode 3	Mode 1		enum	
Segments	number of segments per layer	13		int	[1, 13]

Pin Inputs

Pin	Name	Description	Signal Type
1	In	input	anytype

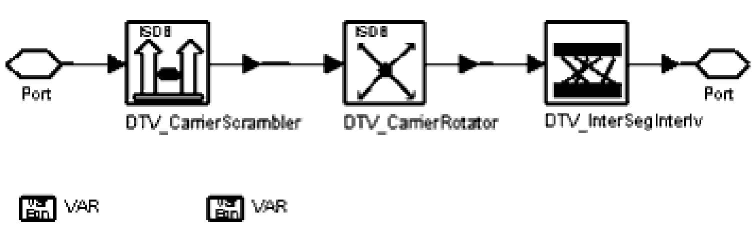
Pin Outputs

Pin	Name	Description	Signal Type
2	Out	output	anytype

Notes/Equations

1. This subnetwork model performs carrier descrambling, carrier rotating, and inter-segment deinterleaving; it is the reverse of the process for DTV_ISDBFreqInterlv. The schematic for this subnetwork is shown below.

DTV_ISDBFreqDeinterlv Schematic



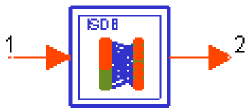
2. Inter-segment deinterleaving is conducted on each differential (DQPSK) and synchronous (QPSK, 16QAM, 64QAM) modulation. Intra-segment deinterleaving is conducted in two steps, carrier randomizing and carrier rotation by segment number, to eliminate periodicity in carrier arrangement. These operations make it possible to prevent burst errors of a specific segment's carrier, which can occur if the carrier arrangement period matches the frequency-selective fading after inter-segment interleaving. If the input consists of only one segment, the carrier rotation and inter-

segment deinterleaving will be bypassed.

References

1. ARIB STD-B31 Version 1.5, *Transmission System for Digital Terrestrial Television Broadcasting*, July 29, 2003.

DTV_ISDBFreqInterlv



Description: Inter-frequency and intra-frequency interleaving for ISDB-T
Library: DTV, ISDB-T
Class: SDFDTV_ISDBFreqInterlv

Parameters

Name	Description	Default	Unit	Type	Range
Mode	transmission mode: Mode 1, Mode 2, Mode 3	Mode 1		enum	
Segments	number of segments per layer	13		int	[1, 13]

Pin Inputs

Pin	Name	Description	Signal Type
1	In	input	anytype

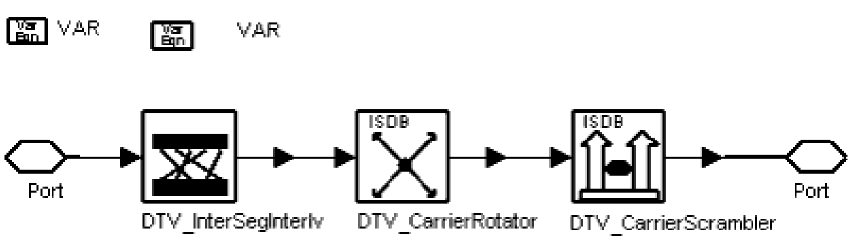
Pin Outputs

Pin	Name	Description	Signal Type
2	Out	output	anytype

Notes/Equations

1. This subnetwork model randomizes data carriers in the frequency domain of an ISDB-T signal generator. It performs inter-segment interleaving, carrier rotating, and carrier scrambling.
   The schematic for this subnetwork is shown below.

   DTV_ISDBFreqInterlv Schematic

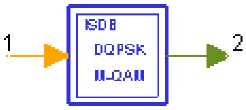
   

2. If the input consists of one segment, the inter-segment interleaver and carrier rotator are bypassed.
3. The subnetwork works on the basis of OFDM symbols, so the input of the subnetwork starts with the first data carrier of the corresponding segment.

References

1. ARIB STD-B31 Version 1.5, *Transmission System for Digital Terrestrial Television Broadcasting*, July 29, 2003.

DTV_ISDBModulation



Description: ISDB-T TSP modulation
Library: DTV, ISDB-T
Class: SDFDTV_ISDBModulation

Parameters

Name	Description	Default	Unit	Type	Range
Mode	transmission mode: Mode 1, Mode 2, Mode 3	Mode 1		enum	
MappingMode	signal constellations and mapping: DQPSK, QPSK, QAM-16, QAM-64	DQPSK		enum	
Segments	number of segments per layer	13		int	[1, 13]

Pin Inputs

Pin	Name	Description	Signal Type
1	In	input	int

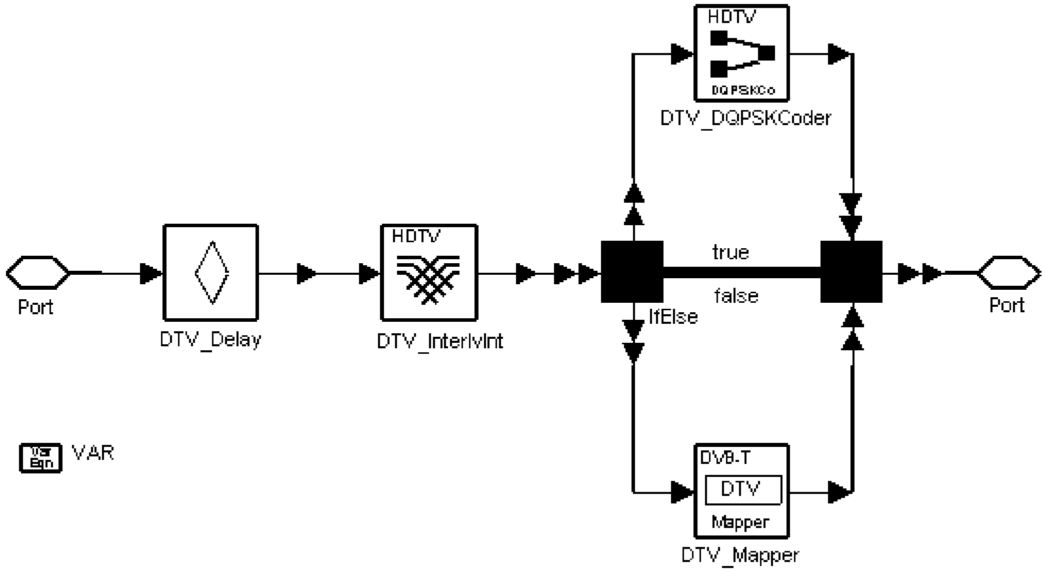
Pin Outputs

Pin	Name	Description	Signal Type
2	Out	output	complex

Notes/Equations

1. This subnetwork model performs bit-wise interleaving and data mapping. The schematic for this subnetwork is shown below.

DTV_ISDBModulation Schematic



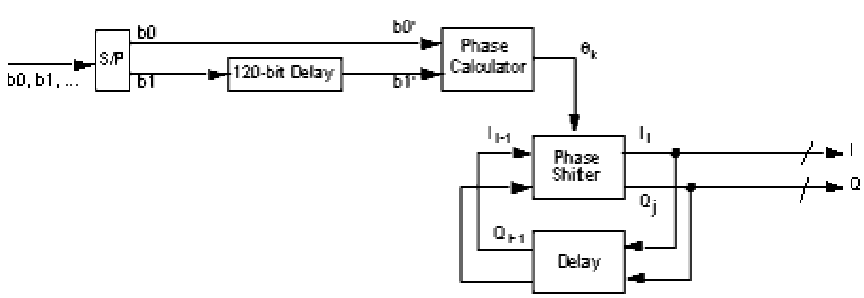
2. DTV_Delay adds delay according to Bit Interleaving Delay Adjustment. Bit interleaving causes a delay of 120 complex data (I+jQ). Total transmitter and receiver delay is adjusted based on two OFDM symbols.

Bit Interleaving Delay Adjustment

Modulation	Number of bits for Delay Adjustment		
	Mode 1	**Mode 2**	**Mode 3**
DQPSKQPSK	384×N-240	768×N-240	1536×N-240
16QAM	768×N-480	1536×N-480	3072×N-480
64QAM	1152×N-720	2304×N-720	4608×N-720
where N = number of segments used in a certain layer			

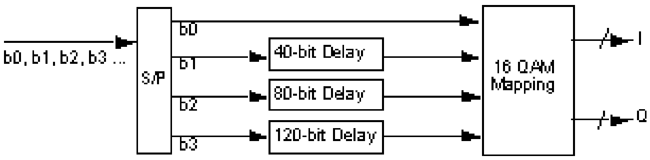
3. Bit interleaving and mapping for the four modulation types are shown in the four figures below.

DQPSK Modulation

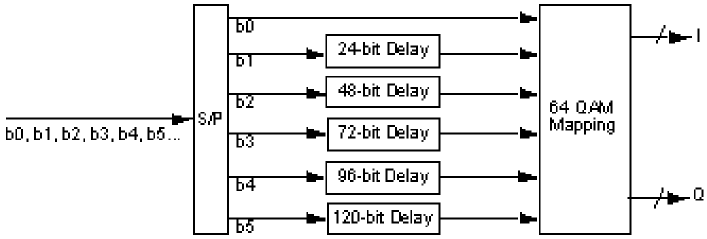


QPSK Modulation

16QAM Modulation



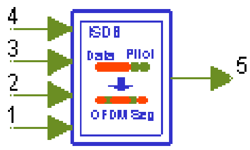
64QAM Modulation



References

1. ARIB STD-B31 Version 1.5, *Transmission System for Digital Terrestrial Television Broadcasting*, July 29, 2003.

DTV_ISDBMuxSegs



Description: Multiplexing of data and pilots into segments for ISDB-T
Library: DTV, ISDB-T
Class: SDFDTV_ISDBMuxSegs

Parameters

Name	Description	Default	Unit	Type	Range
Mode	transmission mode: Mode 1, Mode 2, Mode 3	Mode 1		enum	
MappingMode	signal constellations and mapping: DQPSK, QPSK, QAM-16, QAM-64	DQPSK		enum	
Segments	number of segments per layer	13		int	[1, 13]
StartSeg	initial number of segment	0		int	[0, 12]

Pin Inputs

Pin	Name	Description	Signal Type
1	Data	input data	complex
2	TMCC	tansmission and multiplexing configuration control pilot	complex
3	AC1	ancillary information carried by auxiliary channel 1	complex
4	AC2	ancillary information carried by auxiliary channel 2	complex

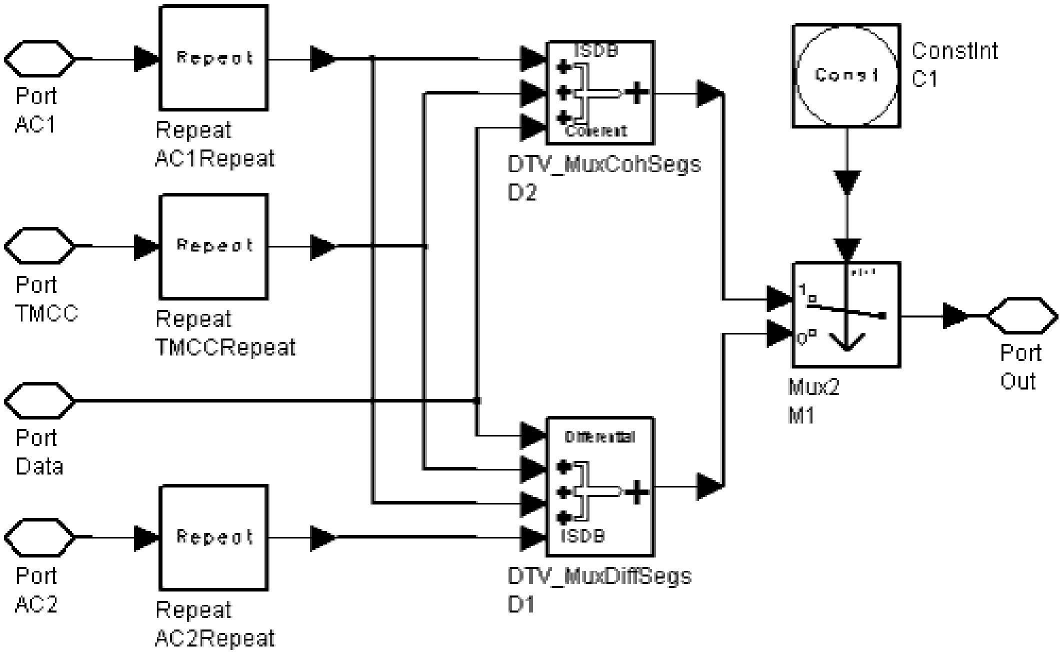
Pin Outputs

Pin	Name	Description	Signal Type
5	Out	output	complex

Notes/Equations

1. This subnetwork model merges auxiliary information (AC1), AC2, TMCC, and data into OFDM segments.
   The schematic for this subnetwork is shown below.

DTV_ISDBMuxSegs Schematic



2. Particles consumed for each hierarchical layer in one OFDM symbol are listed in the table below.

Particles Consumed in One OFDM Symbol

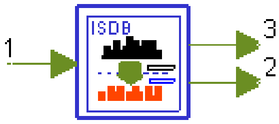
Particle Name	Mode 1		Mode 2		Mode 3	
	Differential Modulation	Coherent Modulation	Differential Modulation	Coherent Modulation	Differential Modulation	Coherent Modulation
Data	96×Segments		192×Segments		384×Segments	
TMCC	1					
AC1	2		4		8	
AC2	5	0	9	0	19	0

3. AC1 is used in coherent and differential modulation; AC2 is used in differential modulation only. When MappingMode=DQPSK, the present layer is differential and AC2 will be ignored.
4. StartSeg specifies the OFDM segment index that the first data segment of the hierarchical layer is mapped to. StartSeg must be set to 0 for layer A. If Data belongs to layer B, and layer A consists of 3 segments, then StartSeg for layer B must be set to 3.

References

1. ARIB STD-B31 Version 1.5, *Transmission System for Digital Terrestrial Television Broadcasting*, July 29, 2003.

DTV_ISDBOFDMDemod_OneLay



Description: One-layer (1~13 segments) OFDM demodulator of ISDB-T
Library: DTV, ISDB-T
Class: SDFDTV_ISDBOFDMDemod_OneLay

Parameters

Name	Description	Default	Unit	Type	Range
Mode	transmission mode: Mode 1, Mode 2, Mode 3	Mode 1		enum	
MappingMode	signal constellations and mapping: DQPSK, QPSK, QAM-16, QAM-64	DQPSK		enum	
Segments	number of segments per layer	13		int	[1, 13]
GuardInterval	guard interval (fractional FFT size)	1/32		real	[0, 1]
OversamplingOption	oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	In	input data	complex

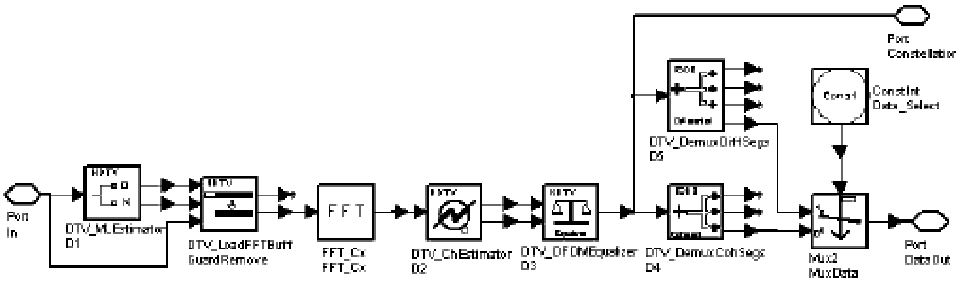
Pin Outputs

Pin	Name	Description	Signal Type
2	DataOut	output	complex
3	Constellation	output	complex

Notes/Equations

1. This subnetwork model demodulates a 1-layer OFDM signal in an ISDB-T 1-layer receiver.
   The schematic for this subnetwork is shown below.

DTV_ISDBOFDMDemod_OneLay Schematic



2. Each firing, pin *In* consumes (1+GuardInterval)×FFTSize×OversamplingOption particles, pin *DataOut* exports 96×pow(2, Mode)×Segments particles, and pin *Constellation* exports 108×pow(2, Mode)×Segments particles.
3. This model introduces a delay of 1 OFDM symbol, so when pin *Constellation* is connected to a signal source reference signal for MER measurement, a delay of 108×pow(2, Mode)×Segments particles must be considered.
4. This model estimates the beginning of input symbols and removes the guard interval, then demodulates the signal by FFT. After channel estimation and equalization, one copy of the signal is exported to pin *Constellation* for MER measurement, one copy of the signal is demultiplexed by DTV_DemuxCohSegs or DTV_DemuxDiffSegs, and pure data carriers are exported to pin *DataOut*.
5. FFT size is given in the table below.

FFT Size

Segment	FFT Size		
	Mode 1	**Mode 2**	**Mode 3**
1	256	512	1024
2	512	1024	2048
3	512	1024	2048
4	1024	2048	4096
5	1024	2048	4096
6	1024	2048	4096
7	2048	4096	8192
8	2048	4096	8192
9	2048	4096	8192
10	2048	4096	8192
11	2048	4096	8192
12	2048	4096	8192
13	2048	4096	8192

6. The input signal starts with the first symbol of an ISDB-T signal frame.
7. Parameter Details

Mode specifies transmission mode 2K (Mode 1), 4K (Mode 2), or 8K (Mode 3) defined in ISDB-T.

MappingMode specifies signal constellation and mapping: DQPSK, QPSK, 16QAM, or 64QAM.

Segments specifies the number of segments per layer.

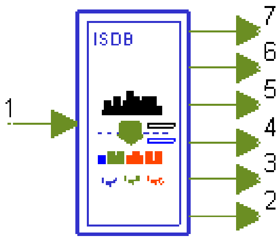
GuardInterval specifies the guard interval (also called cyclic extension) length for each symbol, as a fraction (1/32, 1/16, 1/8, or 1/4) of the FFT time period. The value must match the guard interval length actually used in the input signal in order for the demodulation to work properly.

OversamplingOption specifies the oversampling ratio of the transmission signal. Ratios 1, 2, 4, 8, 16, and 32 are supported in this model. For example, if Ratio 2 is selected, FFT size of the demodulator will double; if Ratio 1 is selected no oversampling will be performed.

References

1. ARIB STD-B31 Version 1.5, *Transmission System for Digital Terrestrial Television Broadcasting*, July 29, 2003.

DTV_ISDBOFDMDemod_ThreeLay



Description: Three-layer OFDM demodulation of ISDB-T
Library: DTV, ISDB-T
Class: SDFDTV_ISDBOFDMDemod_ThreeLay

Parameters

Name	Description	Default	Unit	Type	Range
Mode	transmission mode: Mode 1, Mode 2, Mode 3	Mode 1		enum	
MappingModeA	signal constellations and mapping of layer A: A DQPSK, A QPSK, A QAM-16, A QAM-64	A DQPSK		enum	
SegmentsA	segment number of layer A	1		int	[1, 13]
MappingModeB	signal constellations and mapping of layer B: B DQPSK, B QPSK, B QAM-16, B QAM-64	B DQPSK		enum	
SegmentsB	segment number of layer B	4		int	[1, 13]
MappingModeC	signal constellations and mapping of layer C: C DQPSK, C QPSK, C QAM-16, C QAM-64	C QPSK		enum	
SegmentsC	segment number of layer C	8		int	[1, 13]
GuardInterval	guard interval (fractional FFT size)	1/32		real	[0, 1]
OversamplingOption	oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	In	input data	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	DataA	output data of layer A	complex
3	DataB	output data of layer B	complex
4	DataC	output data of layer C	complex
5	constellationA	constellation signal after OFDM demodulation of layer A	complex
6	constellationB	constellation signal after OFDM demodulation of layer B	complex
7	constellationC	constellation signal after OFDM demodulation of layer C	complex

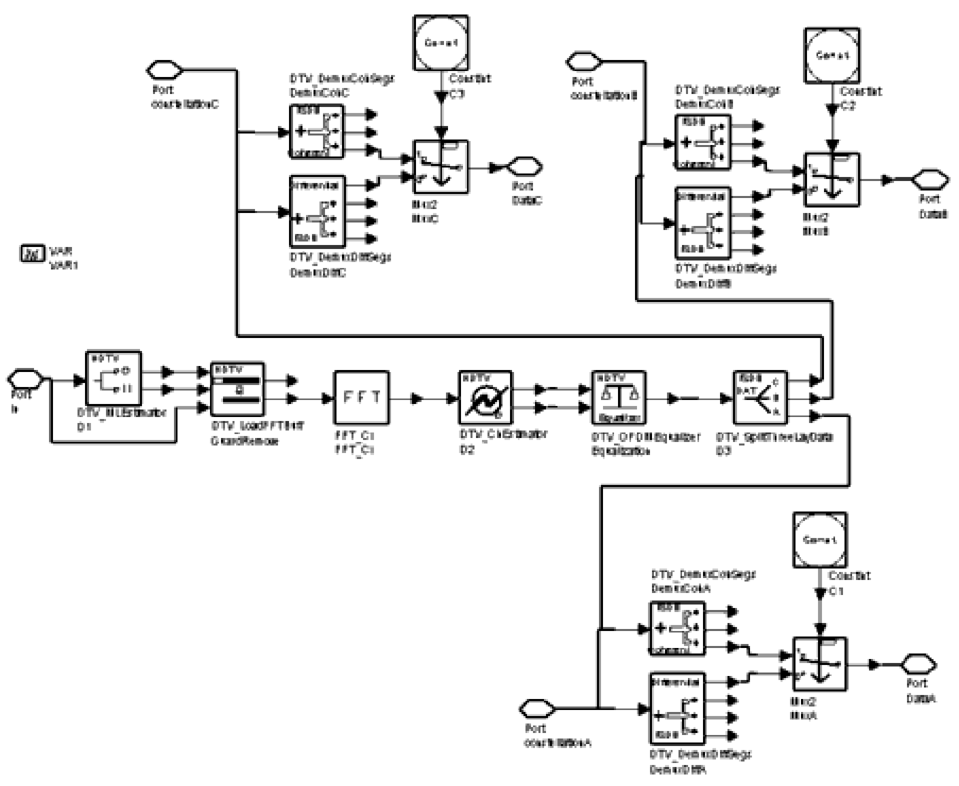
Notes/Equations

1. This subnetwork model demodulates a 3-layer OFDM signal in an ISDB-T 3-layer

receiver.

2. The schematic for this subnetwork is shown in DTV_ISDBOFDMDemod_ThreeLay Schematic.
   The subnetwork estimates the beginning of input symbols and removes the guard interval, then demodulates the signal with an FFT. After channel estimation and equalization, the data stream is split into 3-layer data. For each layer, one copy of the signal is exported to port constellation *X* (*X* represents *A*, *B*, or *C*) for MER measurement, and one copy is de-multiplexed and pure data carriers are exported to port Data *X*.
3. Each firing, port In consumes (1+GuardInterval) × FFTSize × OverSamplingOption particles, port DataX exports 96×pow(2, Mode) × SegmentsX particles, port constellationX exports 108×pow(2, Mode) × SegmentsX particles.
4. This model introduces a delay of one OFDM symbol, so when port constellation *X* is connected to the reference signal from signal source for MER measurement, the delay of size 108×pow(2, Mode)×Segments *X* should be considered.
5. The input signal starts with the first symbol of an ISDB-T signal frame.

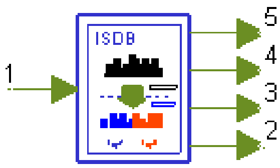
DTV_ISDBOFDMDemod_ThreeLay Schematic



References

1. ARIB STD-B31 Version 1.5, *Transmission System for Digital Terrestrial Television Broadcasting*, July 29, 2003.

DTV_ISDBOFDMDemod_TwoLay



Description: Two-layer OFDM demodulation of ISDB-T
Library: DTV, ISDB-T
Class: SDFDTV_ISDBOFDMDemod_TwoLay

Parameters

Name	Description	Default	Unit	Type	Range
Mode	transmission mode: Mode 1, Mode 2, Mode 3	Mode 1		enum	
MappingModeA	signal constellations and mapping of layer A: A DQPSK, A QPSK, A QAM-16, A QAM-64	A DQPSK		enum	
SegmentsA	segment number of layer A	5		int	[1, 13]
MappingModeB	signal constellations and mapping of layer B: B DQPSK, B QPSK, B QAM-16, B QAM-64	B QAM-64		enum	
SegmentsB	segment number of layer B	8		int	[1, 13]
GuardInterval	guard interval (fractional FFT size)	1/32		real	[0, 1]
OversamplingOption	oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	In	input data	complex

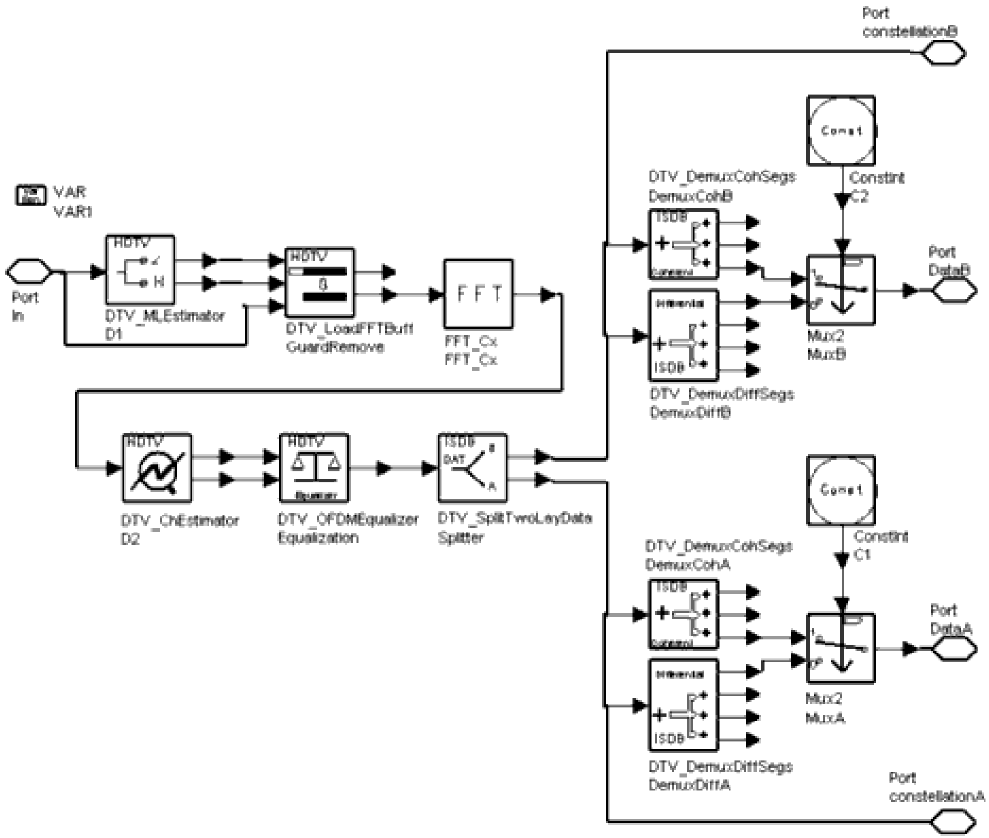
Pin Outputs

Pin	Name	Description	Signal Type
2	DataA	output data of layer A	complex
3	DataB	output data of layer B	complex
4	constellationA	constellation signal after OFDM demodulation of layer A	complex
5	constellationB	constellation signal after OFDM demodulation of layer B	complex

Notes/Equations

1. This subnetwork model demodulates a 2-layer OFDM signal in an ISDB-T 2-layer receiver. The schematic for this subnetwork is shown below.

DTV_ISDBOFDMDemod_TwoLay Schematic



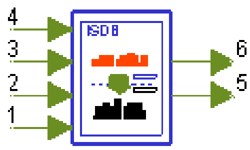
The subnetwork estimates the start of input symbols, removes the guard interval, then demodulates the signal with an FFT. After channel estimation and equalization, the data stream is split into 2-layer data. For each layer, one copy of the signal is exported to port constellation *X* (*X* represents *A* or *B*) for MER measurement, one copy is de-multiplexed, and pure data carriers are exported to port Data *X*.

2. Each firing, port In consumes (1+GuardInterval) × FFTSize × OversamplingOption particles, port Data *X* exports 96 × pow(2, Mode) × Segments *X* particles, port constellation *X* exports 108 × pow(2, Mode) × Segments *X* particles.
3. This model introduces a delay of one OFDM symbol, so when port constellationX is connected to the reference signal from signal source for MER measurement, the delay of size 108×pow(2, Mode)×SegmentsX must be considered.
4. The input signal starts with the first symbol of an ISDB-T signal frame.

References

1. ARIB STD-B31 Version 1.5, *Transmission System for Digital Terrestrial Television Broadcasting*, July 29, 2003.

DTV_ISDBOFDMMod_OneLay



Description: One-layer OFDM modulation of ISDB-T
Library: DTV, ISDB-T
Class: SDFDTV_ISDBOFDMMod_OneLay

Parameters

Name	Description	Default	Symbol	Unit	Type	Range
Mode	transmission mode: Mode 1, Mode 2, Mode 3	Mode 1			enum	
MappingMode	signal constellations and mapping: DQPSK, QPSK, QAM-16, QAM-64	DQPSK			enum	
Segments	number of segments per layer	13			int	[1, 13]
GuardInterval	guard interval (fractional FFT size)	1/32			real	[0, 1]
OversamplingOption	oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1	S		enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	Data	input data	complex
2	TMCC	TMCC information for different layers	complex
3	AC1	ancillary information for auxiliary channel 1	complex
4	AC2	ancillary information for auxiliary channel 2 (DQPSK only)	complex

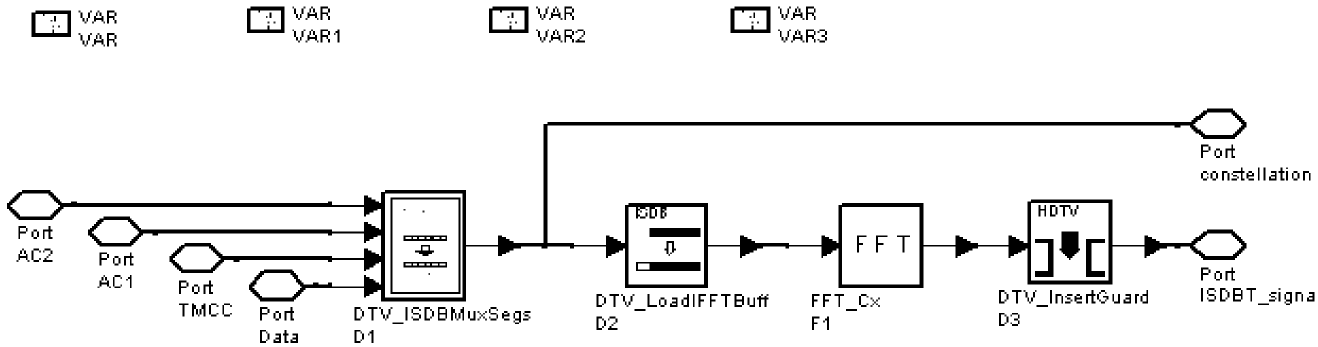
Pin Outputs

Pin	Name	Description	Signal Type
5	ISDBT_signal	ISDB-T signal	complex
6	constellation	constellation signal before IFFT	complex

Notes/Equations

1. This subnetwork model performs OFDM frame adaptation, IFFT, and guard interval insertion for ISDB-T one-layer transmission.
   The schematic for this subnetwork is shown below.

DTV_ISDBOFDMMod_OneLay Schematic

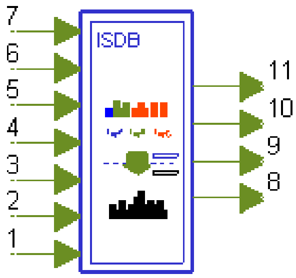


2. For differential modulation (DQPSK), the CP serves as the SP (scattered pilot) of a synchronous modulation segment when the differential modulation segment at the lowermost frequency is adjacent to one of the synchronous modulation segments. The CP is therefore provided at this low-frequency end.
   The TMCC and AC (AC1, AC2) carriers are randomly arranged with regard to frequency in order to reduce degradation caused by periodic dips on channel characteristics under a multi-path environment. AC carriers not only serve as AC pilot signals, but can be used as carriers for additional transmission control information. Note that AC1 carriers for differential modulation segments are arranged at the same positions as those for the synchronous modulation segments.
3. For synchronous modulation (QPSK, 16QAM, 64QAM), the SP is inserted into a segment once every 12 carriers in the carrier direction, and once every 4 symbols in the symbol direction. The AC1 carrier arrangement for synchronous modulation is the same as that for differential modulation. (AC2 is used for differential modulation only).

References

1. ARIB STD-B31 Version 1.5, *Transmission System for Digital Terrestrial Television Broadcasting*, July 29, 2003.

DTV_ISDBOFDMMod_ThreeLay



Description: Three-layer OFDM modulation of ISDB-T
Library: DTV, ISDB-T
Class: SDFDTV_ISDBOFDMMod_ThreeLay

Parameters

Name	Description	Default	Unit	Type	Range
Mode	transmission mode: Mode 1, Mode 2, Mode 3	Mode 1		enum	
MappingModeA	signal constellations and mapping of layer A: A DQPSK, A QPSK, A QAM-16, A QAM-64	A DQPSK		enum	
SegmentsA	segment number of layer A	1		int	[1, 13]
MappingModeB	signal constellations and mapping of layer B: B DQPSK, B QPSK, B QAM-16, B QAM-64	B DQPSK		enum	
SegmentsB	segment number of layer B	4		int	[1, 13]
MappingModeC	signal constellations and mapping of layer C: C DQPSK, C QPSK, C QAM-16, C QAM-64	C QPSK		enum	
SegmentsC	segment number of layer C	8		int	[1, 13]
GuardInterval	guard interval (fractional FFT size)	1/32		real	[0, 1]
OversamplingOption	oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	DataA	input data of layer A	complex
2	DataB	input data of layer B	complex
3	DataC	input data of layer C	complex
4	TMCCDiff	TMCC information for differential layers	complex
5	TMCCCoh	TMCC information for coherent layers	complex
6	AC1	ancillary information for auxiliary channel 1	complex
7	AC2	ancillary information for auxiliary channel 2 (DQPSK only)	complex

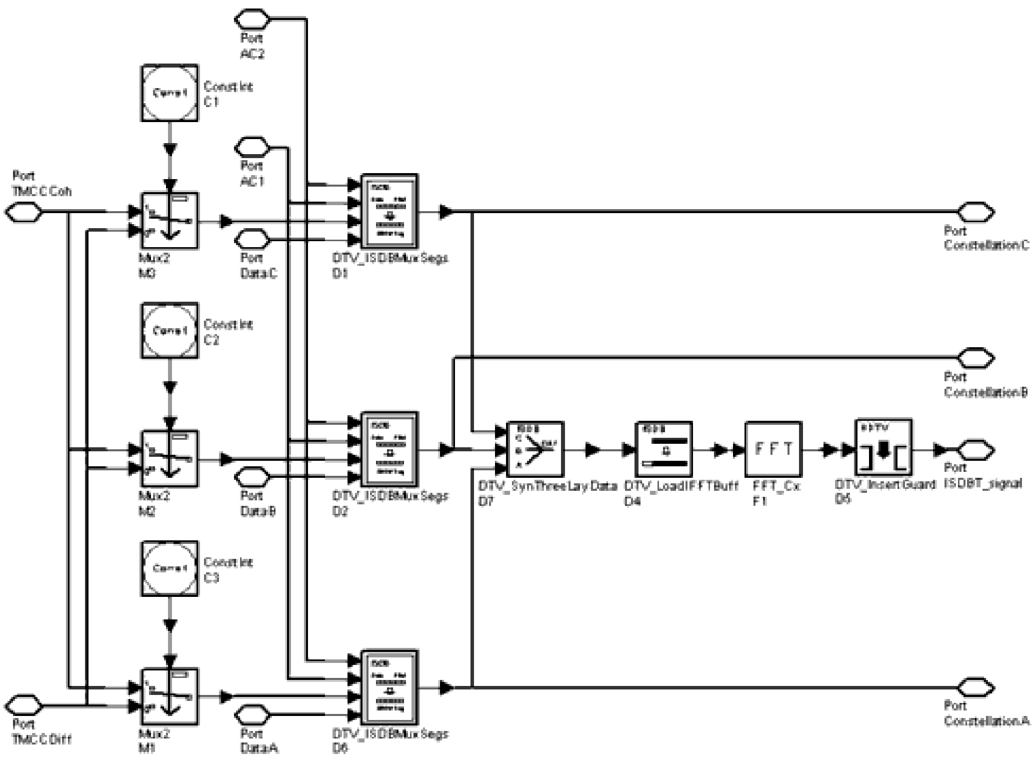
Pin Outputs

Pin	Name	Description	Signal Type
8	ISDBT_signal	OFDM three-layer base-band signal	complex
9	constellationA	constellation signal of layer A before IFFT	complex
10	constellationB	constellation signal of layer B before IFFT	complex
11	constellationC	constellation signal of layer C before IFFT	complex

Notes/Equations

1. This subnetwork model implements OFDM frame adaptation, IFFT, and guard interval insertion for ISDB-T 3-layer transmission.
   The schematic for the subnetwork is shown below.

DTV_ISDBOFDMMod_ThreeLay Schematic



2. Parameter Details

   SegmentsA is set to 1 permanently.

   SegmentsA+SegmentsB+SegmentsC=13 is required.

   SegmentsB and SegmentsC cannot be 0.

   GuardInterval value is 1/32, 1/16, 1/8 or 1/4 (the ratio of guard interval length to useful symbol length).

   OversamplingOption is Ratio 1, Ratio 2, ... , Ratio 32, which indicates the ratio of the output sampling frequency to the basic sampling frequency is 1, 2, ... , 32.

3. Each firing, one OFDM symbol with guard interval is generated. The number of data, TMCC, AC1, and AC2 particles consumed in one OFDM symbol are listed in the table below.

Particles Consumed in One OFDM Symbol

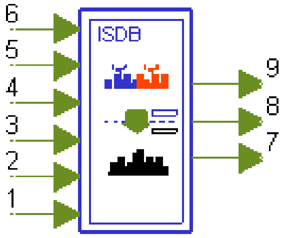
Mode	Data Segment A	Data Segment B	Data Segment C	TMCC Coherent	TMCC Differential	AC1	AC2
1	96×SegmentsA	96×SegmentsB	96×SegmentsC	1	1	2	4
2	192×SegmentsA	192×SegmentsB	192×SegmentsC	1	1	4	9
3	384×SegmentsA	384×SegmentsB	384×SegmentsC	1	1	8	19

4. TMCCCoh always consumes particles whether or not a coherent segment exists.
5. TMCCDiff always consumes particles whether or not a differential segment exists.
6. AC2 always consumes particles whether or not a differential segment exists.
7. Each frame, 204 TMCC consumed particles are generated as follows:
   - The 203-bit original TMCC bits are preceded with initialization bit 0 to form a 204-bit group.
   - The 204-bit group is differential coded with the initialization bit.
   - Each differential coded bit is replaced with +1 for 0 and -1 for 1.
8. Each frame, 203 OFDM symbols are used to transmit AC1 bits.
   - AC1 particles needed in each frame are generated as follows:
     - AC1NumPerSeg bits of 0 are preceded with the original 203×AC1NumPerSeg AC1 bits, where AC1NumPerSeg represents the number of AC1 pilots per segment.
     - 204×AC1NumPerSeg bits obtained from the first step are differential coded with these initial bits, here the differential coding delay is AC1NumPerSeg bits.
     - Each of the 204×AC1NumPerSeg differential coded bits is replaced with +1 for 0 and -1 for 1.
   - For example, in Mode 1, each OFDM symbol consumes 2 AC1 bits, assume the original AC1 bits are 1 1, 1 1, 1 1, ...
     - Preceding the initial bits, we get 0 0, 1 1, 1 1, 1 1, ...
     - After differential coding, 0 0, 1 1, 0 0, 1 1, ... are obtained.
     - +1 +1, -1 -1, +1 +1, -1 -1, ... suitable for the subnetwork are generated.
9. While AC2 is similar to AC1, it is used for differential segments only.

References

1. ARIB STD-B31 Version 1.5, *Transmission System for Digital Terrestrial Television Broadcasting*, July 29, 2003.

DTV_ISDBOFDMMod_TwoLay



Description: Two-layer OFDM modulation of ISDB-T
Library: DTV, ISDB-T
Class: SDFDTV_ISDBOFDMMod_TwoLay

Parameters

Name	Description	Default	Unit	Type	Range
Mode	transmission mode: Mode 1, Mode 2, Mode 3	Mode 1		enum	
MappingModeA	signal constellations and mapping of layer A: A DQPSK, A QPSK, A QAM-16, A QAM-64	A DQPSK		enum	
SegmentsA	segment number of layer A	5		int	[1, 13]
MappingModeB	signal constellations and mapping of layer B: B DQPSK, B QPSK, B QAM-16, B QAM-64	B QAM-64		enum	
SegmentsB	segment number of layer B	8		int	[1, 13]
GuardInterval	guard interval (fractional FFT size)	1/32		real	[0, 1]
OversamplingOption	oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	DataA	input data of layer A	complex
2	DataB	input data of layer B	complex
3	TMCCDiff	TMCC information for differential layers	complex
4	TMCCCoh	TMCC information for coherent layers	complex
5	AC1	ancillary information for auxiliary channel 1	complex
6	AC2	ancillary information for auxiliary channel 2 (DQPSK only)	complex

Pin Outputs

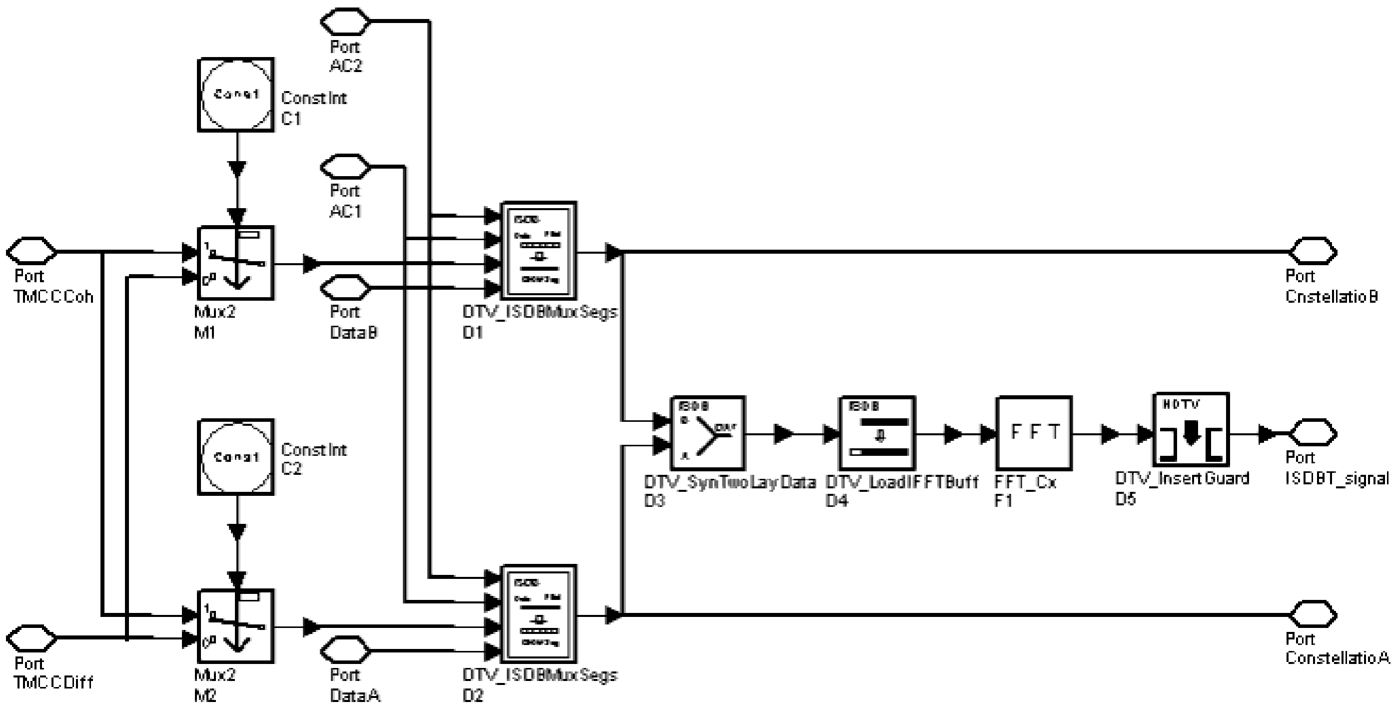
Pin	Name	Description	Signal Type
7	ISDBT_signal	ISDB-T two-layer base-band signal	complex
8	constellationA	constellation signal of layer A before IFFT	complex
9	constellationB	constellation signal of layer B before IFFT	complex

Notes/Equations

1. This subnetwork model implements OFDM segment adaptation, IFFT, and guard interval insertion for ISDB-T 2-layer transmission.

The schematic for this subnetwork is shown below.

DTV_ISDBOFDMMod_TwoLay Schematic



2. Parameter Details
   SegmentsA+SegmentsB=13 is required.
   SegmentsB cannot be 0.
   GuardInterval value is 1/32, 1/16, 1/8 or 1/4 (the ratio of guard interval length to useful symbol length).
   OversamplingOption is Ratio 1, Ratio 2, ... , Ratio 32, which indicates the ratio of the output sampling frequency to the basic sampling frequency is 1, 2, ... , 32.
3. Each firing, the subnetwork generates one OFDM symbol with guard interval. The number of data, TMCC, AC1, and AC2 particles consumed in one OFDM symbol are listed in in the table below.

Particles Consumed in One OFDM Symbol

Mode	Data Segment A	Data Segment B	TMCC Coherent	TMCC Differential	AC1	AC2
1	96×SegmentsA	96×SegmentsB	1	1	2	4
2	192×SegmentsA	192×SegmentsB	1	1	4	9
3	384×SegmentsA	384×SegmentsB	1	1	8	19

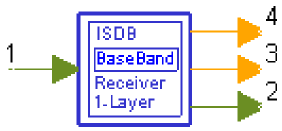
4. TMCCCoh always consumes particles whether or not a coherent segment exists.
5. TMCCDiff always consumes particles whether or not a differential segment exists.
6. AC2 always consumes particles whether or not a differential segment exists.
7. Each frame, 204 TMCC consumed particles are generated as follows:
   - The original 203 TMCC bits are preceded with initialization bit 0 to form a 204-bit group.
   - The 204-bit group is differential coded with the initialization bit.

  - Each of the differential coded bits are replaced with +1 for 0 and -1 for 1.
8. Each frame, 203 OFDM symbols are used to transmit AC1 bits.
   - AC1 particles needed in each frame are generated as follows:
     - AC1NumPerSeg bits of 0 are preceded with the original 203×AC1NumPerSeg AC1 bits, where AC1NumPerSeg represents the number of AC1 pilots per segment.
     - 204×AC1NumPerSeg bits obtained in the first step are differential coded with these initial bits; here the differential coding delay is AC1NumPerSeg bits.
     - Each of the 204×AC1NumPerSeg differential coded bits are replaced with +1 for 0 and -1 for 1.
   - For example, in Mode 1, each OFDM symbol consumes 2 AC1 bits, assume the original AC1 bits are 1 1, 1 1, 1 1, ...
     - Preceding initial bits, we get 0 0, 1 1, 1 1, 1 1, ...
     - After differential coding, 0 0, 1 1, 0 0, 1 1, ... are obtained.
     - +1 +1, -1 -1, +1 +1, -1 -1, ... suitable for the subnetwork are then generated.
9. While AC2 is similar to AC1, it is used for differential segments only.

References

1. ARIB STD-B31 Version 1.5, *Transmission System for Digital Terrestrial Television Broadcasting*, July 29, 2003.

DTV_ISDBOneLayReceiver



Description: ISDB-T one-layer receiver
Library: DTV, ISDB-T
Class: SDFDTV_ISDBOneLayReceiver

Parameters

Name	Description	Default	Unit	Type	Range
Mode	transmission mode: Mode 1, Mode 2, Mode 3	Mode 1		enum	
OversamplingOption	oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	
GuardInterval	guard interval (fractional FFT size)	1/32		real	[0, 1]
CodeRate	convolutional code rate: DTV 1/2, DTV 2/3, DTV 3/4, DTV 5/6, DTV 7/8	DTV 1/2		enum	
MappingMode	signal constellations and mapping: DQPSK, QPSK, QAM-16, QAM-64	DQPSK		enum	
TimeInterlv	length of time interleaver: I_000, I_001, I_010, I_011, I_100	I_000		enum	
Segments	number of segments: Seg 0 is not allowed, Seg 1, Seg 2, Seg 3, Seg 4, Seg 5, Seg 6, Seg 7, Seg 8, Seg 9, Seg 10, Seg 11, Seg 12, Seg 13	Seg 13		enum	
TrunLen	path memory truncation length of Viterbi decoding algorithm, in bytes	10		int	[5, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	In	input OFDM baseband signal	complex

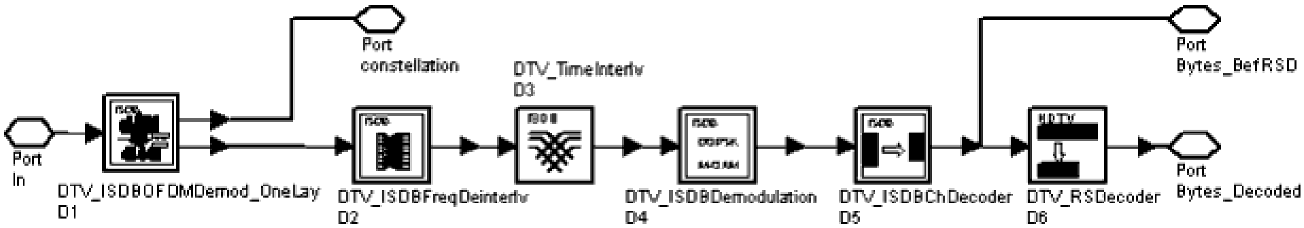
Pin Outputs

Pin	Name	Description	Signal Type
2	constellation	signal constellation after OFDM demodulation	complex
3	Bytes_BefRSD	information bytes before RS decoder	int
4	Bytes_Decoded	information bytes after RS decoder	int

Notes/Equations

1. This 1-layer ISDB-T baseband receiver subnetwork performs 1-layer OFDM demodulation, frequency deinterleaving, time deinterleaving, demapping and bit-wise deinterleaving, inner decoding (Viterbi), byte-wise deinterleaving, derandomizing and Reed-Solomon decoding.
   The schematic for this subnetwork is shown below.

DTV_ISDBOneLayReceiver Schematic



2. FFT size is given in the table below.

FFT Size

Segment	FFT Size		
	Mode 1	**Mode 2**	**Mode 3**
1	256	512	1024
2	512	1024	2048
3	512	1024	2048
4	1024	2048	4096
5	1024	2048	4096
6	1024	2048	4096
7	2048	4096	8192
8	2048	4096	8192
9	2048	4096	8192
10	2048	4096	8192
11	2048	4096	8192
12	2048	4096	8192
13	2048	4096	8192

3. The input signal starts with the first symbol of an ISDB-T signal frame.
4. Parameter Details

   Mode specifies transmission mode 2K (Mode 1), 4K (Mode 2), or 8K (Mode 3) defined in ISDB-T.

   OversamplingOption specifies the oversampling ratio of transmission signal. Ratios 1, 2, 4, 8, 16, and 32 are supported in this model. For example, if Ratio 2 is selected, FFT size of the demodulator will double; if Ratio 1 is selected no oversampling will be performed.

   GuardInterval specifies the guard interval (also called cyclic extension) length for each symbol, as a fraction (1/32, 1/16, 1/8, or 1/4) of the FFT time period. The value must match the guard interval length actually used in the input signal in order for the demodulation to work properly.

   CodeRate specifies the inner code rate 1/2, 2/3, 3/4, 5/6, or 7/8.

MappingMode specifies signal constellation and mapping for DQPSK, QPSK, 16QAM, or 64QAM.

TimeInterlv specifies the time domain interleaver type of the signal: I_000, I_001, I_010, I_011, or I_100.

Segments specifies the number of segments.

TrunLen specifies the truncation length (1×8 bits, 2×8 bits), in bytes, in the Viterbi decoding algorithm.

5. Output Delays
DTV_ISDBChDecoder consists of Viterbi decoder, byte-wise deinterleaver and derandomizer. Viterbi decoder introduces different delay for different path memory truncation length (TrunLen parameter). For BER measurement synchronization, the delay between byte-interleaver and byte deinterleaver must be adjusted to a multiple of 12 bytes, and the delay between randomizer and derandomizer must be adjusted to a multiple of 204 bytes. Here, both delays are adjusted to a multiple of 204 bytes. The basic delay calculation of an ISDB-T receiver is shown in Delay Calculation of ISDB-T Receiver.
Assuming MapRate={2, 2, 4, 6}, CodeRateFrac={1/2, 2/3, 3/4, 5/6, 7/8}, then MapRate[MappingMode+1] represents the bit number mapped onto one data carrier, and CodeRateFrac[CodeRate+1] represents the inner coder rate, we get:

Delay Calculation of ISDB-T Receiver

```
VAR
VAR1
MapRate={2, 2, 4, 6}
CodeRateFrac={1/2, 2/3, 3/4, 5/6, 7/8}
D_OFDMMod=96*Segments*2^Mode
D_TimeInterlvT=if (TimeInterlv==0) then (0) else (96*Segments*204*2^TimeInterlv) endif
D_TimeInterlv=if ((TimeInterlv==1) && (Mode==2)) then (D_TimeInterlvT*2) else (D_TimeInterlvT) endif
D_Modulation= 96*2^Mode*MapRate[MappingMode+1]*2*Segments
D_VB=8*TrunLen
D_ByteInterlv=204*24*CodeRateFrac[CodeRate+1]*MapRate[MappingMode+1]/2*2^Mode*Segments
D_Carrier=D_OFDMMod+D_TimeInterlv
D_AfterVB=(D_Carrier*MapRate[MappingMode+1]+D_Modulation)*CodeRateFrac[CodeRate+1]+D_VB
D_Residual=D_AfterVB/8-204*int(D_AfterVB/8/204)
D_ByteAdjust=if (D_Residual==0) then (0) else (204-D_Residual) endif
D_AfterDerandomize=D_AfterVB/8+D_ByteAdjust+D_ByteInterlv
D_AfterRSDecoder=D_AfterDerandomize*188/204
```

where

D_OFDMMod × 108/96 is the delay between the *Constellation* pins of DTV_ISDBOneLaySource and DTV_ISDBOneLayReceiver.

D_AfterDerandomize is the delay between pins *Bytes_AftRSC* in DTV_ISDBOneLaySource and *Bytes_BefRSD* in DTV_ISDBOneLayReceiver.

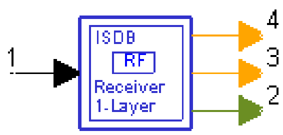
D_AfterRSDecoder is the delay between pins *Bytes_Uncoded* in DTV_ISDBOneLaySource and *Bytes_Decoded* in DTV_ISDBOneLayReceiver.

When connecting the receiver to the signal source in MER and BER measurements, reference signal from the signal generator must be delayed according to the formula shown in Delay Calculation of ISDB-T Receiver.

References

1. ARIB STD-B31 Version 1.5, *Transmission System for Digital Terrestrial Television Broadcasting*, July 29, 2003.

DTV_ISDBOneLayReceiver_RF



Description: ISDB-T one-layer RF receiver
Library: DTV, ISDB-T
Class: TSDFDTV_ISDBOneLayReceiver_RF

Parameters

Name	Description	Default	Unit	Type	Range
RIn	input resistance	DefaultRIn	Ohm	real	(0, ∞)
RTemp	physical temperature, in degrees C	DefaultRTemp	Celsius	real	[-273.15, ∞)
GainImbalance	Gain imbalance, Q vs I	0.0	dB	real	(-∞, ∞)
PhaseImbalance	Phase imbalance, Q vs I	0.0	deg	real	(-∞, ∞)
FCarrier	carrier frequency	611.0MHz	Hz	real	(0, ∞)
Sensitivity	voltage output sensitivity, Vout/Vin	1		real	(-∞, ∞)
Phase	reference phase in degrees	0.0	deg	real	(-∞, ∞)
Mode	transmission mode: Mode 1, Mode 2, Mode 3	Mode 1		enum	
OversamplingOption	oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	
GuardInterval	guard interval (fractional FFT size)	1/32		real	[0, 1]
CodeRate	convolutional code rate: DTV 1/2, DTV 2/3, DTV 3/4, DTV 5/6, DTV 7/8	DTV 1/2		enum	
MappingMode	signal constellations and mapping: DQPSK, QPSK, QAM-16, QAM-64	DQPSK		enum	
TimeInterlv	length of time interleaver: I_000, I_001, I_010, I_011, I_100	I_000		enum	
Segments	number of segments: Seg 0 is not allowed, Seg 1, Seg 2, Seg 3, Seg 4, Seg 5, Seg 6, Seg 7, Seg 8, Seg 9, Seg 10, Seg 11, Seg 12, Seg 13	Seg 13		enum	
TrunLen	path memory truncation length of Viterbi decoding algorithm, in bytes	10		int	[5, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	RF	received OFDM signal to be demodulated	timed

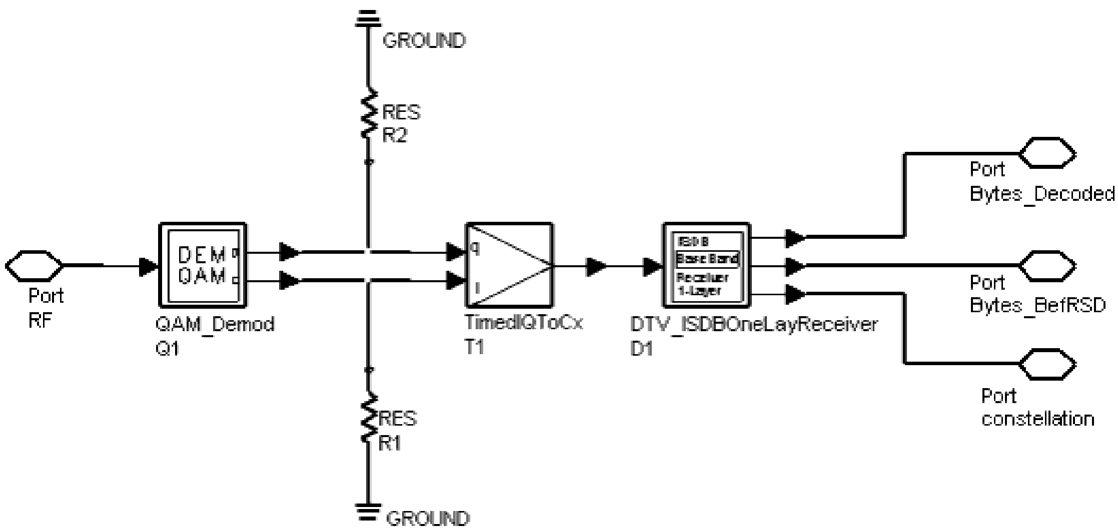
Pin Outputs

Pin	Name	Description	Signal Type
2	constellation	signal constellation after OFDM demodulation	complex
3	Bytes_BefRSD	information bytes before RS decoder	int
4	Bytes_Decoded	information bytes after RS decoder	int

Notes/Equations

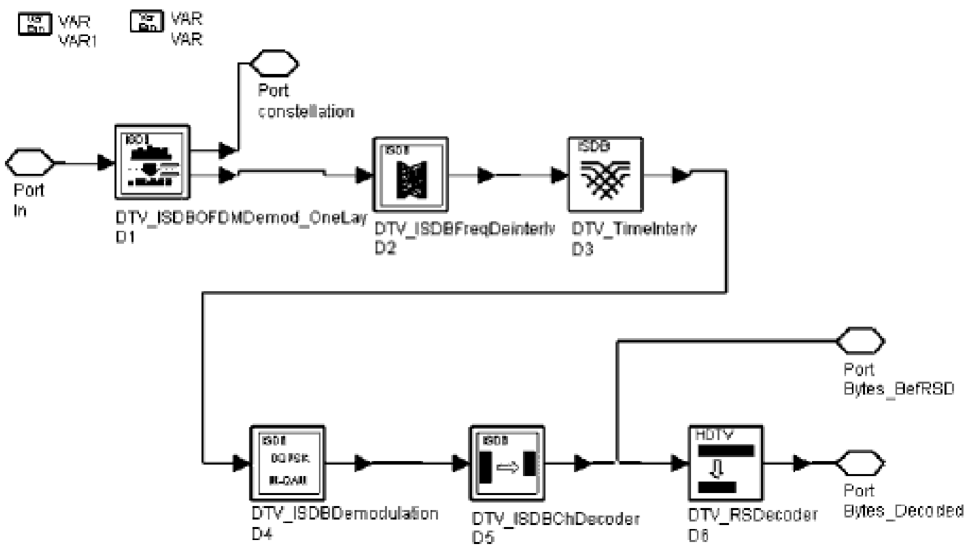
1. This subnetwork model is a 1-layer ISDB-T RF receiver.
   The schematic for this subnetwork is shown below.

DTV_ISDBOneLayReceiver_RF Schematic



2. The input timed signal is demodulated from RF to baseband and fed to the ISDB-T 1-layer receiver.
3. The baseband receiver (DTV_ISDBOneLayReceiver) schematic is shown below.

DTV_ISDBOneLayReceiver Schematic



4. FFT size is given in the table below.

FFT Size

Segment	FFT Size		
	Mode 1	**Mode 2**	**Mode 3**
1	256	512	1024
2	512	1024	2048
3	512	1024	2048
4	1024	2048	4096
5	1024	2048	4096
6	1024	2048	4096
7	2048	4096	8192
8	2048	4096	8192
9	2048	4096	8192
10	2048	4096	8192
11	2048	4096	8192
12	2048	4096	8192
13	2048	4096	8192

5. The input signal starts with the first symbol of an ISDB-T signal frame.
6. Baseband Parameter Details

Mode specifies transmission mode 2K (Mode 1), 4K (Mode 2), or 8K (Mode 3) defined in ISDB-T.

OversamplingOption specifies the oversampling ratio of the transmission signal. Ratios 1, 2, 4, 8, 16, and 32 are supported in this model. For example, if Ratio 2 is selected, FFT size of the demodulator will double; if Ratio 1 is selected no oversampling will be performed.

GuardInterval specifies the guard interval (also called cyclic extension) length for each symbol, as a fraction (1/32, 1/16, 1/8, or 1/4) of the FFT time period. The value must match the guard interval length actually used in the input signal in order for the demodulation to work properly.

CodeRate specifies the inner code rate 1/2, 2/3, 3/4, 5/6, or 7/8.

MappingMode specifies signal constellation and mapping for DQPSK, QPSK, 16QAM, or 64QAM.

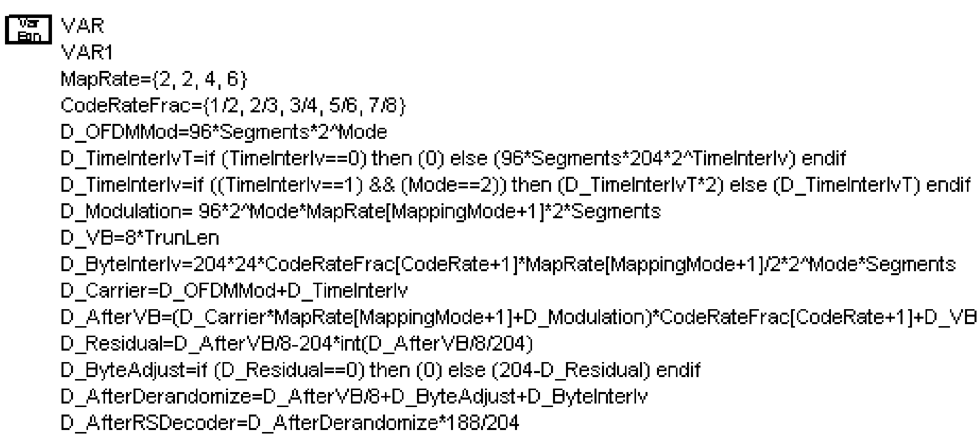
TimeInterlv specifies the time domain interleaver type of the signal: I_000, I_001, I_010, I_011, or I_100.

Segments specifies the number of segments.

TrunLen specifies the truncation length (1×8 bits, 2×8 bits), in bytes, in the Viterbi decoding algorithm.

7. Output Delays
DTV_ISDBChDecoder consists of Viterbi decoder, byte-wise deinterleaver and derandomizer. Viterbi decoder introduces different delay for different path memory truncation length (TrunLen parameter). For BER measurement synchronization, the delay between byte-interleaver and byte deinterleaver must be adjusted to a multiple of 12 bytes and the delay between randomizer and derandomizer must be adjusted to a multiple of 204 bytes. Here, both delays are adjusted to a multiple of 204bytes. The basic delay calculation of an ISDB-T receiver is shown in Delay Calculation of ISDB-T Receiver.
Assuming MapRate={2, 2, 4, 6}, CodeRateFrac={1/2, 2/3, 3/4, 5/6, 7/8}, then MapRate[MappingMode+1] represents the bit number mapped onto one data carrier, and CodeRateFrac[CodeRate+1] represents the inner coder rate, we get:

Delay Calculation of ISDB-T Receiver



where

D_OFDMMod × 108/96 is the delay between the *Constellation* pins in DTV_ISDBOneLaySource and DTV_ISDBOneLayReceiver.

D_AfterDerandomize is the delay between pins *Bytes_AftRSC* in DTV_ISDBOneLaySource and *Bytes_BefRSD* in DTV_ISDBOneLayReceiver.

D_AfterRSDecoder is the delay between pins *Bytes_Uncoded* in DTV_ISDBOneLaySource and *Bytes_Decoded* in DTV_ISDBOneLayReceiver.

When connecting the receiver to the signal source in MER and BER measurements, the reference signal from the signal generator must be delayed according to the formula in Delay Calculation of ISDB-T Receiver.

8. RF Parameter Details
GainImbalance and PhaseImbalance add certain impairments to the ideal output RF signal. Impairments are added as described here.
The unimpaired RF I and Q envelope voltages have gain and phase imbalance applied. The RF is given by:

$$V_3(t) = A\left(V_1(t)\cos(\omega_c t) - gV_2(t)\sin\left(\omega_c t + \frac{\phi\pi}{180}\right)\right)$$

where $V_1(t)$ is the in-phase RF envelope, $V_2(t)$ is the quadrature phase RF envelope, *g* is the gain imbalance

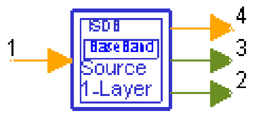
$$g = 10^{\frac{GainImbalance}{20}}$$

and, Φ (in degrees) is the phase imbalance.

References

1. ARIB STD-B31 Version 1.5, *Transmission System for Digital Terrestrial Television Broadcasting*, July 29, 2003.

DTV_ISDBOneLaySource



Description: ISDB-T one-layer signal source
Library: DTV, ISDB-T
Class: SDFDTV_ISDBOneLaySource

Parameters

Name	Description	Default	Unit	Type	Range
Mode	transmission mode: Mode 1, Mode 2, Mode 3	Mode 1		enum	
OversamplingOption	oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	
GuardInterval	guard interval (fractional FFT size)	1/32		real	[0, 1]
CodeRate	convolutional Code Rate: DTV 1/2, DTV 2/3, DTV 3/4, DTV 5/6, DTV 7/8	DTV 1/2		enum	
MappingMode	signal constellations and mapping: DQPSK, QPSK, QAM-16, QAM-64	DQPSK		enum	
TimeInterlv	length of time interleaver: I_000, I_001, I_010, I_011, I_100	I_000		enum	
Segments	number of segments: Seg 0 is not allowed, Seg 1, Seg 2, Seg 3, Seg 4, Seg 5, Seg 6, Seg 7, Seg 8, Seg 9, Seg 10, Seg 11, Seg 12, Seg 13	Seg 13		enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	Data	input data	int

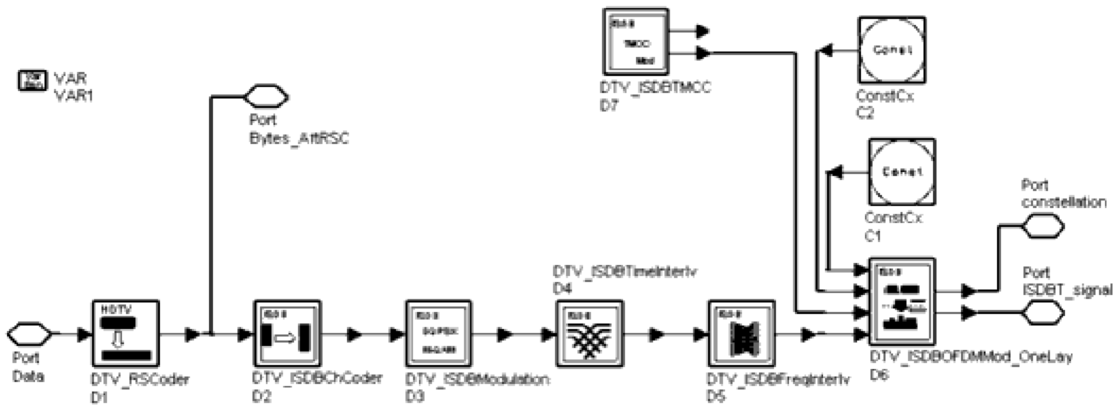
Pin Outputs

Pin	Name	Description	Signal Type
2	ISDBT_signal	ISDB-T signal	complex
3	constellation	constellation signal before IFFT	complex
4	Bytes_AftRSC	information bytes after RS coder	int

Notes/Equations

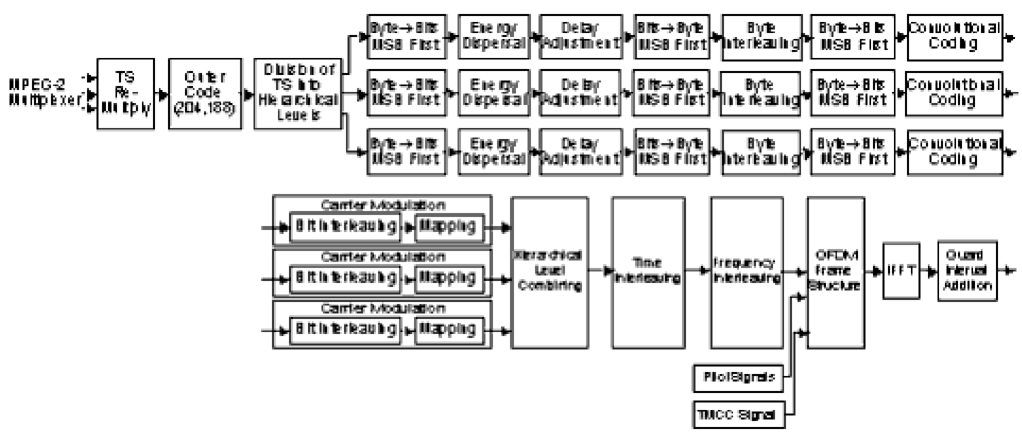
1. This subnetwork model provides an ISDB-T one-layer signal source. It generates one OFDM symbol each firing.
   The schematic for this subnetwork is shown below.

DTV_ISDBOneLaySource Schematic



2. A transport stream (TS) input (defined in *MPEG-2 Systems*) is subjected to multiple channel-coding steps, bit-wise interleaving and data mapping, time interleaving, frequency interleaving, and is sent as a single OFDM signal.
   The ISDB-T signal source format follows the ISDB-T specification. The figure below shows the functional block diagram of the ISDB-T baseband system.

ISDB-T Baseband System Functional Block Diagram



The transmission spectrum of television broadcasting consists of 13 successive OFDM blocks (OFDM segments); each bandwidth equals 1/14 of a television broadcast channel bandwidth. An OFDM-segment carrier configuration that allows connection of multiple segments makes it possible to provide an appropriate transmission bandwidth in terms of units of segment width for the target media; at the same time it allows use of the same receiver for ISDB-T and ISDB-T_{SB} (Transmission System for Digital Terrestrial Sound Broadcasting).
In consideration of the suitability of the distance between SFN stations and the robustness to Doppler shift during mobile-reception, ISDB-T offers three different spacings between OFDM carrier frequencies; these spacings are identified as system modes. Spacings between OFDM carrier frequencies are approximately 4, 2, and 1 kHz in modes 1, 2, and 3, respectively. The number of carriers varies depending on the mode, but the information bit rate that can be transmitted remains the same in all modes.
TMCC signals convey control information that assists in receiver operations.

3. Parameter Details

   Mode specifies transmission mode 1, 2, or 3 (defined in ISDB-T specification).

OversamplingOption specifies the oversampling ratio of the transmission signal. Ratios 1, 2, 4, 8, 16, and 32 are supported in this source.

GuardInterval specifies the guard interval (also called cyclic extension) length for each symbol time, as a fraction of the FFT time period. Guard intervals 1/4, 1/8, 1/16, and 1/32 are defined in the ISDB-T specification; in this source, GuardInterval is defined as a real value between 0.0 and 1.0. Users can set any value between 0.0 and 1.0, not just 1/4, 1/8, 1/16 and 1/32. The value must match the guard interval length actually used in the input signal so demodulation will work properly.

CodeRate is defined as code rate of stream; rates 1/2, 2/3, 3/4, 5/6 and 7/8 are supported in this source.

MappingMode specifies signal constellations and ISDB-T signal source mapping; modes DQPSK, QPSK, 16-QAM, and 64-QAM are supported in this source.

TimeInterlv specifies the time interleaving length. There are five different values for each mode.

Segments specifies the number of segments. Recommended IFFT sizes are given with regard to the total number of segments listed in the following table.

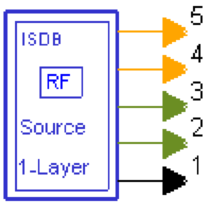
Number of Segments and IFFT Sizes

No. of Segments	**Mode 1**		**Mode 2**		**Mode 3**	
	IFFT Order	**IFFT Size**	**IFFT Order**	**IFFT Size**	**IFFT Order**	**IFFT Size**
1	8	256	9	512	10	1024
2, 3	9	512	10	1024	11	2048
4, 5, 6	10	1024	11	2048	12	4096
7, 8, 9, 10, 11, 12, 13	11	2048	12	4096	13	8192

References

1. ARIB STD-B31 Version 1.5, *Transmission System for Digital Terrestrial Television Broadcasting*, July 29, 2003.

DTV_ISDBOneLaySource_RF



Description: ISDB-T one-layer RF signal source
Library: DTV, ISDB-T
Class: TSDFDTV_ISDBOneLaySource_RF

Parameters

Name	Description	Default	Unit	Type	Range
ROut	output resistance	DefaultROut	Ohm	real	(0, ∞)
RTemp	physical temperature, in degrees C	DefaultRTemp	Celsius	real	[-273.15, ∞)
FCarrier	carrier frequency	611.0MHz	Hz	real	(0, ∞)
Power	modulator output power	40mW	W	real	(0, ∞)
BasicSamplingRate	basic sampling rate	(2048/252.0)MHz	Hz	real	(0, ∞)
MirrorSpectrum	Mirror spectrum about carrier?: NO, YES	NO		enum	
GainImbalance	Gain imbalance, Q vs I	0.0	dB	real	(-∞, ∞)
PhaseImbalance	Phase imbalance, Q vs I	0.0	deg	real	(-∞, ∞)
I_OriginOffset	I origin offset (percent)	0.0		real	(-∞, ∞)
Q_OriginOffset	Q origin offset (percent)	0.0		real	(-∞, ∞)
IQ_Rotation	IQ rotation	0.0	deg	real	(-∞, ∞)
Mode	transmission mode: Mode 1, Mode 2, Mode 3	Mode 1		enum	
OversamplingOption	oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	
GuardInterval	guard interval (fractional FFT size)	1/32		real	[0, 1]
CodeRate	convolutional Code Rate: DTV 1/2, DTV 2/3, DTV 3/4, DTV 5/6, DTV 7/8	DTV 1/2		enum	
MappingMode	signal constellations and mapping: DQPSK, QPSK, QAM 16, QAM 64	DQPSK		enum	
TimeInterlv	length of time interleaver: I_000, I_001, I_010, I_011, I_100	I_000		enum	
Segments	number of segments: Seg 0 is not allowed, Seg 1, Seg 2, Seg 3, Seg 4, Seg 5, Seg 6, Seg 7, Seg 8, Seg 9, Seg 10, Seg 11, Seg 12, Seg 13	Seg 13		enum	
DataType	payload data type: PN9, PN15, FIX4, _4_1_4_0, _8_1_8_0, _16_1_16_0, _32_1_32_0, _64_1_64_0	PN9		enum	

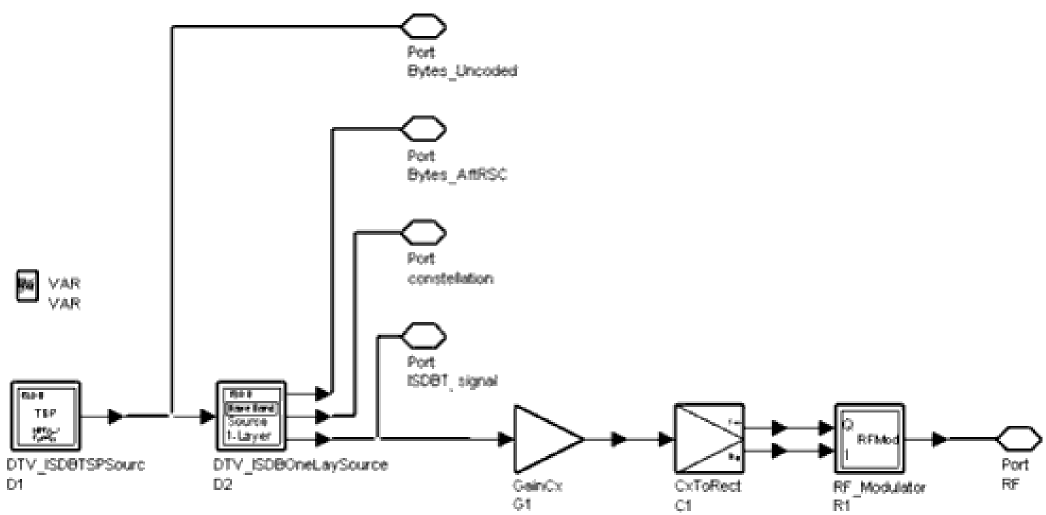
Pin Outputs

Pin	Name	Description	Signal Type
1	RF	RF signal	timed
2	ISDBT_signal	ISDB-T signal	complex
3	constellation	constellation signal before IFFT	complex
4	Bytes_AftRSC	information bytes after RS coder	int
5	Bytes_Uncoded	information bytes of transport packet	int

Notes/Equations

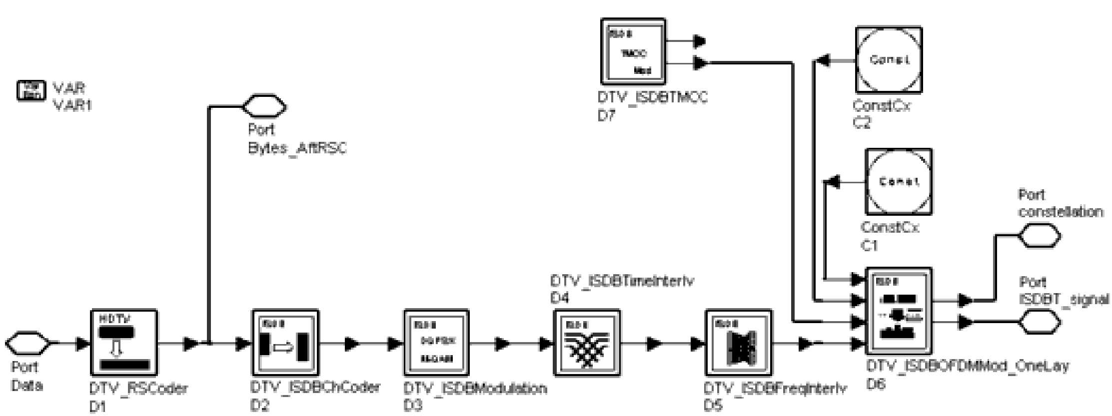
1. This subnetwork model integrates an RF modulator with the baseband signal source. The ISDB-T baseband signal is fed into the RF modulator. The RF signal is timed signal after RF modulation.
   The schematic for this subnetwork is shown below.

DTV_ISDBOneLaySource_RF Schematic



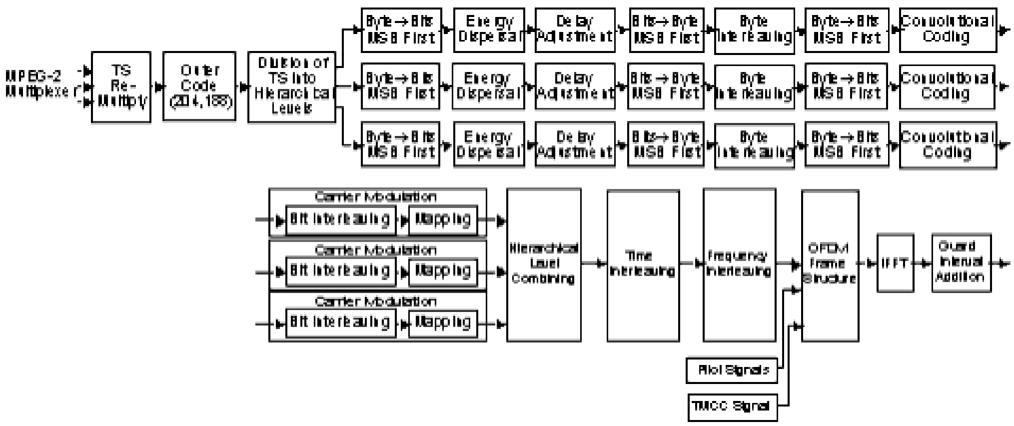
2. The ISDB-T signal source format follows the ISDB-T specification. The schematic for DTV_ISDBOneLaySource is shown below.

DTV_ISDBOneLaySource Schematic



The ISDB-T baseband system functional block diagram is shown below.

Baseband System Functional Block Diagram



3. Parameter Details
   FCarrier defines the RF frequency for the ISDB signal.
   Power defines the power level for FCarrier.
   BasicSamplingRate indicates basic sampling rate.
   The MirrorSpectrum is used to conjugate the input signal (when set to YES) before any other processing is done.
   GainImbalance, PhaseImbalance, I_OriginOffset, Q_OriginOffset, and IQ_Rotation parameters are used to add certain impairments to the ideal output RF signal. Impairments are added in the order described here.
   The unimpaired RF I and Q envelope voltages have gain and phase imbalance applied. RF is given by:

$$V_3(t) = A\left(V_1(t)\cos(\omega_c t) - gV_2(t)\sin\left(\omega_c t + \frac{\phi\pi}{180}\right)\right)$$

where

A is a scaling factor that depends on the Power and ROut parameters specified by the user

V_1 (*t*) is the in-phase RF envelope

V_2 (*t*) is the quadrature phase RF envelope

g is the gain imbalance

$$g = 10^{\frac{GainImbalance}{20}}$$

Φ (in degrees) is the phase imbalance

The V3(t) signal is rotated by IQ_Rotation degrees. I_OriginOffset and Q_OriginOffset are then applied to the rotated signal. Note that the amounts specified are percentages with respect to the output rms voltage. The output rms voltage is given by sqrt(2×ROut×Power). Mode is used to select transmission mode of 1, 2, or 3 defined in ISDB-T.

OversamplingOption indicates the oversampling ratio of transmission signal. Oversampling ratios 1, 2, 4, 8, 16, and 32 are supported in this source. OversamplingOption is Ratio 1, Ratio 2, ... , Ratio 32, which indicates the oversampling ratio of transmission signal is 1, 2, ... , 32.
GuardInterval specifies the guard interval (also called cyclic extension) length for each symbol time, as a fraction of the FFT time period. Guard intervals 1/4, 1/8, 1/16, and 1/32 are defined in the ISDB-T specification; in this source, GuardInterval is specified as a real value between 0.0 and 1.0. Users can set any value between 0.0 and 1.0; the value must match the guard interval length actually used in the input signal in order for the demodulation to work properly.
CodeRate is defined as code rate of stream. Rates 1/2, 2/3, 3/4, 5/6, and 7/8 are supported in this source.
MappingMode specifies signal constellation and ISDB-T signal source mapping. Modes DQPSK, QPSK, 16-QAM, and 64-QAM are supported in this source.
TimeInterlv specifies the time interleaving length. Time interleaving lengths, based on mode, are given in the following table.

Time Interleaving Length

TimeInterlv	Time Interleaving Length I (Mode 1)	Time Interleaving Length I (Mode 2)	Time Interleaving Length I (Mode 3)
I_000	0	0	0
I_001	4	2	1
I_010	8	4	2
I_011	16	8	4
I_100	32	16	8

Segments specifies the number of segments. Recommended IFFT sizes are given in the following table.

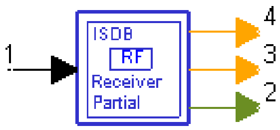
Number of Segments and IFFT Sizes

No. of Segments	Mode 1		Mode 2		Mode 3	
	IFFT Order	IFFT Size	IFFT Order	IFFT Size	IFFT Order	IFFT Size
1	8	256	9	512	10	1024
2, 3	9	512	10	1024	11	2048
4, 5, 6	10	1024	11	2048	12	4096
7, 8, 9, 10, 11, 12, 13	11	2048	12	4096	13	8192

References

1. ARIB STD-B31 Version 1.5, *Transmission System for Digital Terrestrial Television Broadcasting*, July 29, 2003.

DTV_ISDBPartialReceiver_RF



Description: ISDB-T one-segment RF receiver
Library: DTV, ISDB-T
Class: TSDFDTV_ISDBPartialReceiver_RF

Parameters

Name	Description	Default	Unit	Type	Range
RIn	input resistance	DefaultRIn	Ohm	real	(0, ∞)
RTemp	physical temperature, in degrees C	DefaultRTemp	Celsius	real	[-273.15, ∞)
GainImbalance	Gain imbalance, Q vs I	0.0	dB	real	(-∞, ∞)
PhaseImbalance	Phase imbalance, Q vs I	0.0	deg	real	(-∞, ∞)
FCarrier	carrier frequency	611.0MHz	Hz	real	(0, ∞)
Sensitivity	voltage output sensitivity, Vout/Vin	1		real	(-∞, ∞)
Phase	reference phase in degrees	0.0	deg	real	(-∞, ∞)
Mode	transmission mode: Mode 1, Mode 2, Mode 3	Mode 1		enum	
OversamplingOption	oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	
GuardInterval	guard interval (fractional FFT size)	1/32		real	[0, 1]
CodeRate	convolutional code rate: DTV 1/2, DTV 2/3, DTV 3/4, DTV 5/6, DTV 7/8	DTV 1/2		enum	
MappingMode	signal constellations and mapping: DQPSK, QPSK, QAM-16, QAM-64	DQPSK		enum	
TimeInterlv	length of time interleaver: I_000, I_001, I_010, I_011, I_100	I_000		enum	
TrunLen	path memory truncation length of Viterbi decoding algorithm, in bytes	10		int	[5, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	RF	received OFDM signal to be demodulated	timed

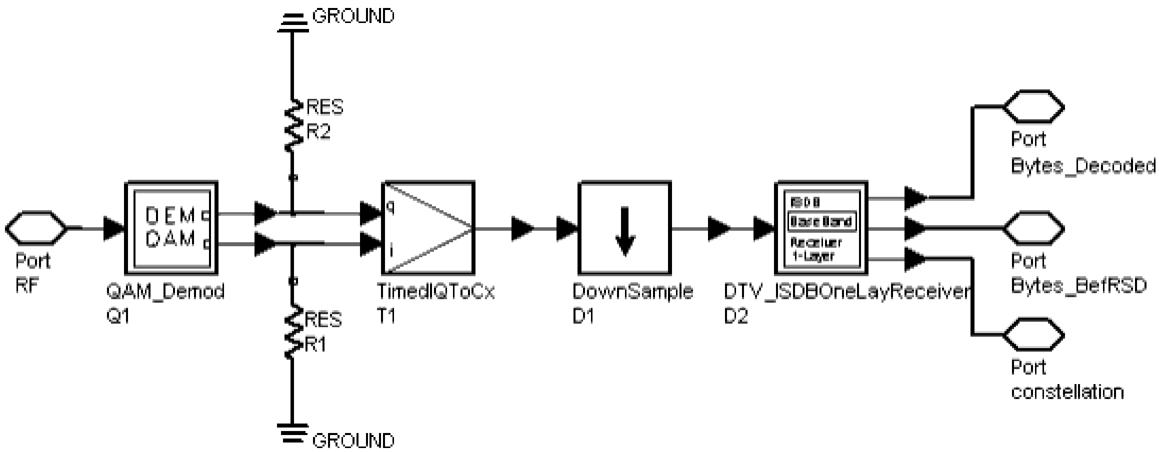
Pin Outputs

Pin	Name	Description	Signal Type
2	constellation	signal constellation after OFDM demodulation	complex
3	Bytes_BefRSD	information bytes before RS decoder	int
4	Bytes_Decoded	information bytes after RS decoder	int

Notes/Equations

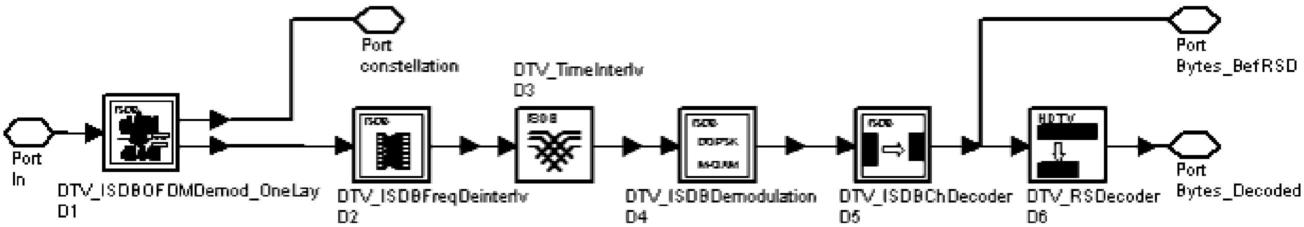
1. This is a 1-segment ISDB-T RF receiver.
   The schematic for this subnetwork is shown below.

DTV_ISDBPartialReceiver_RF Schematic



2. The input timed signal is demodulated from RF to baseband and downsampled by a factor of 8; the downsampled signal is fed to the ISDB-T 1-layer receiver whose segment number is set to 1.
3. FFT size of the OFDM demodulator in DTV_ISDBOneLayReceiver is 256 when OversamplingOption is set to Ratio 1.
4. The input signal starts with the first symbol of an ISDB-T signal frame.
5. The baseband receiver (DTV_ISDBOneLayReceiver) schematic is shown below.

DTV_ISDBOneLayReceiver Schematic



6. Baseband Parameter Details

   Mode specifies transmission mode 2K (Mode 1), 4K (Mode 2), or 8K (Mode 3) defined in ISDB-T.

   OversamplingOption specifies the oversampling ratio of transmission signal. Ratios 1, 2, 4, 8, 16, and 32 are supported in this model. For example, if *Ratio 2* is selected, FFT size of the demodulator will double; if *Ratio 1* is selected no oversampling will be performed.

   GuardInterval specifies the guard interval (also called cyclic extension) length for each symbol, as a fraction (1/32, 1/16, 1/8, or 1/4) of the FFT time period. The value must match the guard interval length actually used in the input signal in order for the demodulation to work properly.

CodeRate specifies the inner code rate 1/2, 2/3, 3/4, 5/6, or 7/8.

MappingMode specifies signal constellation and mapping for DQPSK, QPSK, 16QAM, or 64QAM.

TimeInterlv specifies time domain interleaver type of the signal: I_000, I_001, I_010, I_011, or I_100.

TrunLen specifies the truncation length (1×8 bits, 2×8 bits), in bytes, in the Viterbi decoding algorithm.

7. Output Delays
DTV_ISDBChDecoder consists of Viterbi decoder, byte-wise deinterleaver and derandomizer. Viterbi decoder introduces different delay for different path memory truncation length (parameter TrunLen). For BER measurement synchronization, the delay between byte-interleaver and byte deinterleaver must be adjusted to a multiple of 12 bytes and the delay between randomizer and derandomizer must be adjusted to a multiple of 204 bytes. Here, both delays are adjusted to a multiple of 204bytes. The basic delay calculation of an ISDB-T receiver is shown in Delay Calculation of ISDB-T Partial Receiver.
Assuming MapRate={2, 2, 4, 6}, CodeRateFrac={1/2, 2/3, 3/4, 5/6, 7/8}, then MapRate[MappingMode+1] represents the bit number mapped onto one data carrier, and CodeRateFrac[CodeRate+1] represents the inner coder rate, we get:

Delay Calculation of ISDB-T Partial Receiver

```
VAR
VAR1
MapRate={2, 2, 4, 6}
CodeRateFrac={1/2, 2/3, 3/4, 5/6, 7/8}
D_OFDMMod=96*Segments*2^Mode
D_TimeInterlvT=if (TimeInterlv==0) then (0) else (96*Segments*204*2^TimeInterlv) endif
D_TimeInterlv=if ((TimeInterlv==1) && (Mode==2)) then (D_TimeInterlvT*2) else (D_TimeInterlvT) endif
D_Modulation= 96*2^Mode*MapRate[MappingMode+1]*2*Segments
D_VB=8*TrunLen
D_ByteInterlv=204*24*CodeRateFrac[CodeRate+1]*MapRate[MappingMode+1]/2*2^Mode*Segments
D_Carrier=D_OFDMMod+D_TimeInterlv
D_AfterVB=(D_Carrier*MapRate[MappingMode+1]+D_Modulation)*CodeRateFrac[CodeRate+1]+D_VB
D_Residual=D_AfterVB/8-204*int(D_AfterVB/8/204)
D_ByteAdjust=if (D_Residual==0) then (0) else (204-D_Residual) endif
D_AfterDerandomize=D_AfterVB/8+D_ByteAdjust+D_ByteInterlv
D_AfterRSDecoder=D_AfterDerandomize*188/204
```

where

D_OF *DMMod* × *108/96* is the delay between the *Constellation* pins of the signal source and DTV_ISDBPartialReceiver_RF.

D_AfterDerandomize is the delay between pins *Bytes_AftRSC* of the signal source and *Bytes_BefRSD* in DTV_ISDBPartialReceiver_RF.

D_AfterRSDecoder is the delay between pins *Bytes_Uncoded* of the signal source and *Bytes_Decoded* in DTV_ISDBPartialReceiver_RF.

When connecting the receiver to signal source in MER and BER measurements, reference signal from the signal generator must be delayed according to the formula in Delay Calculation of ISDB-T Partial Receiver.

8. RF Parameter Details
GainImbalance and PhaseImbalance add certain impairments to the ideal output RF signal. Impairments are added as described here.
The unimpaired RF I and Q envelope voltages have gain and phase imbalance applied. The RF is given by:

$$V_3(t) = A\left(V_1(t)\cos(\omega_c t) - gV_2(t)\sin\left(\omega_c t + \frac{\phi\pi}{180}\right)\right)$$

where V_1 (t) is the in-phase RF envelope, V_2 (t) is the quadrature phase RF envelope, g is the gain imbalance

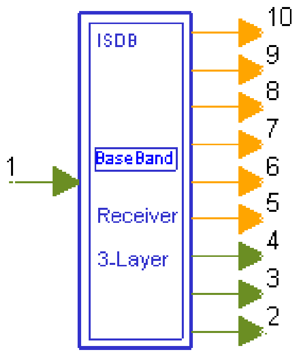
$$g = 10^{\frac{GainImbalance}{20}}$$

and, Φ (in degrees) is the phase imbalance.

References

1. ARIB STD-B31 Version 1.5, *Transmission System for Digital Terrestrial Television Broadcasting*, July 29, 2003.

DTV_ISDBThreeLayReceiver



Description: ISDB-T three-layer receiver
Library: DTV, ISDB-T
Class: SDFDTV_ISDBThreeLayReceiver

Parameters

Name	Description	Default	Unit	Type	Range
Mode	transmission mode: Mode 1, Mode 2, Mode 3	Mode 1		enum	
OversamplingOption	oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	
GuardInterval	guard interval (fractional FFT size)	1/32		real	[0:1]
CodeRateA	convolutional code rate for Layer A: A 1/2, A 2/3, A 3/4, A 5/6, A 7/8	A 1/2		enum	
MappingModeA	signal constellations and mapping for Layer A: A DQPSK, A QPSK, A QAM-16, A QAM-64	A DQPSK		enum	
TimeInterlvA	length of time interleaver for Layer A: A I_000, A I_001, A I_010, A I_011, A I_100	A I_000		enum	
TrunLenA	path memory truncation length of Viterbi decoding algorithm, in bytes	10		int	[5, ∞)
SegmentsA	segments number of Layer A: A Seg 0 is not allowed, A Seg 1, A Seg 2, A Seg 3, A Seg 4, A Seg 5, A Seg 6, A Seg 7, A Seg 8, A Seg 9, A Seg 10, A Seg 11	A Seg 1		enum	
CodeRateB	convolutional code rate for Layer B: B 1/2, B 2/3, B 3/4, B 5/6, B 7/8	B 1/2		enum	
MappingModeB	signal constellations and mapping for Layer B: B DQPSK, B QPSK, B QAM-16, B QAM-64	B DQPSK		enum	
TimeInterlvB	length of time interleaver for Layer B: B I_000, B I_001, B I_010, B I_011, B I_100	B I_000		enum	
TrunLenB	path memory truncation length of Viterbi decoding algorithm, in bytes	10		int	[5, ∞)
SegmentsB	segments number of Layer B: B Seg 0 is not allowed, B Seg 1, B Seg 2, B Seg 3, B Seg 4, B Seg 5, B Seg 6, B Seg 7, B Seg 8, B Seg 9, B Seg 10, B Seg 11	B Seg 4		enum	
CodeRateC	convolutional code rate for Layer C: C 1/2, C 2/3, C 3/4, C 5/6, C 7/8	C 1/2		enum	
MappingModeC	signal constellations and mapping for Layer C: C DQPSK, C QPSK, C QAM-16, C QAM-64	C QPSK		enum	
TimeInterlvC	length of time interleaver for Layer C: C I_000, C I_001, C I_010, C I_011, C I_100	C I_000		enum	
TrunLenC	path memory truncation length of Viterbi decoding algorithm, in bytes	10		int	[5, ∞)
SegmentsC	segments number of Layer C: C Seg 0 is not allowed, C Seg 1, C Seg 2, C Seg 3, C Seg 4, C Seg 5, C Seg 6, C Seg 7, C Seg 8, C Seg 9, C Seg 10, C Seg 11	C Seg 8		enum	

Pin Inputs

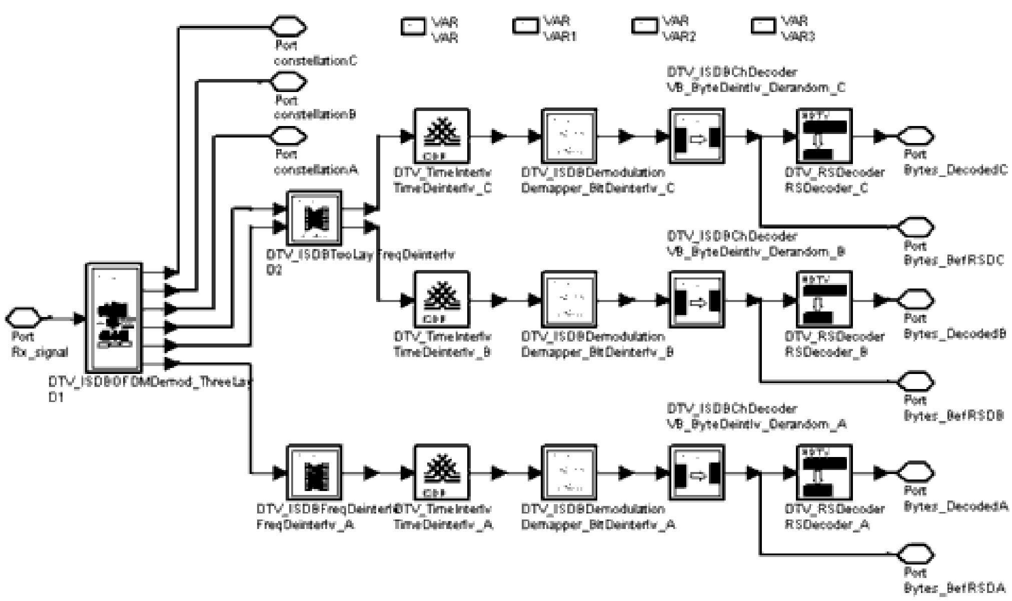
Pin	Name	Description	Signal Type
1	Rx_signal	received signal to be demodulated	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	constellationA	constellation signal after OFDM demodulation of layer A	complex
3	constellationB	constellation signal after OFDM demodulation of layer B	complex
4	constellationC	constellation signal after OFDM demodulation of layer C	complex
5	Bytes_BefRSDA	decoded bytes after Viterbi decoder and de-randomizer of layer A	int
6	Bytes_DecodedA	decoded bytes after Reed Solomon decoder of layer A	int
7	Bytes_BefRSDB	decoded bytes after Viterbi decoder and de-randomizer of layer B	int
8	Bytes_DecodedB	decoded bytes after Reed Solomon decoder of layer B	int
9	Bytes_BefRSDC	decoded bytes after Viterbi decoder and de-randomizer of layer C	int
10	Bytes_DecodedC	decoded bytes after Reed Solomon decoder of layer C	int

Notes/Equations

1. This ISDB-T baseband receiver performs 3-layer OFDM demodulation, frequency deinterleaving, time deinterleaving, demapping and bit-wise deinterleaving, inner decoding (Viterbi), byte-wise deinterleaving, derandomizing, and Reed-Solomon decoding.
   The schematic for this subnetwork is shown in DTV_ISDBThreeLayReceiver Schematic.



DTV_ISDBThreeLayReceiver Schematic

2. The input signal starts with the first symbol of an ISDB-T signal frame.
3. Parameter Details

   Mode specifies transmission mode 2K (Mode 1), 4K (Mode 2), or 8K (Mode 3) defined in ISDB-T.

   OversamplingOption specifies the oversampling ratio of transmission signal. Ratios 1, 2, 4, 8, 16, and 32 are supported in this model. For example, if Ratio 2 is selected, FFT size of the demodulator will double; if Ratio 1 is selected no oversampling will be performed.

   GuardInterval specifies the guard interval (also called cyclic extension) length for each symbol, as a fraction (1/32, 1/16, 1/8, or 1/4) of the FFT time period. The value must match the guard interval length actually used in the input signal in order for the demodulation to work properly.

CodeRateX (X represents A, B, or C) specifies the inner code rate 1/2, 2/3, 3/4, 5/6, or 7/8.

MappingModeX specifies signal constellation and mapping for DQPSK, QPSK, 16QAM, or 64QAM.

TimeInterlvX is time domain interleaver type of the signal: I_000, I_001, I_010, I_011, or I_100.

SegmentsX specifies the number of segments for each layer. SegmentsA+SegmentsB+SegmentsC=13 is required. SegmentsB and SegmentsC cannot be 0. SegmentsA is permanently set to 1.

TrunLenX specifies the truncation length (1×8 bits, 2×8 bits), in bytes, in the Viterbi decoding algorithm.

4. Output Delays
DTV_ISDBChDecoder consists of Viterbi decoder, byte-wise deinterleaver and derandomizer. Viterbi decoder introduces different delay for different path memory truncation length (TrunLen parameter). For BER measurement synchronization, the delay between byte-interleaver and byte deinterleaver must be adjusted to a multiple of 12 bytes, the delay between randomizer and derandomizer must be adjusted to a multiple of 204 bytes. Here, both delays are adjusted to a multiple of 204bytes.
The basic delay calculation of an ISDB-T receiver is shown in Delay Calculation of an ISDB-T Receiver; delays for layers A, B, and C are each calculated with their own hierarchical parameters.
Assuming MapRate={2, 2, 4, 6}, CodeRateFrac={1/2, 2/3, 3/4, 5/6, 7/8}, then MapRate[MappingMode+1] represents the bit number mapped onto one data carrier, and CodeRateFrac[CodeRate+1] represents the inner coder rate, we get:

```
VAR
VAR1
MapRate={2, 2, 4, 6}
CodeRateFrac={1/2, 2/3, 3/4, 5/6, 7/8}
D_OFDMMod=96*Segments*2^Mode
D_TimeInterlvT=if (TimeInterlv==0) then (0) else (96*Segments*204*2^TimeInterlv) endif
D_TimeInterlv=if ((TimeInterlv==1) && (Mode==2)) then (D_TimeInterlvT*2) else (D_TimeInterlvT) endif
D_Modulation= 96*2^Mode*MapRate[MappingMode+1]*2*Segments
D_VB=8*TrunLen
D_ByteInterlv=204*24*CodeRateFrac[CodeRate+1]*MapRate[MappingMode+1]/2*2^Mode*Segments
D_Carrier=D_OFDMMod+D_TimeInterlv
D_AfterVB=(D_Carrier*MapRate[MappingMode+1]+D_Modulation)*CodeRateFrac[CodeRate+1]+D_VB
D_Residual=D_AfterVB/8-204*int(D_AfterVB/8/204)
D_ByteAdjust=if (D_Residual==0) then (0) else (204-D_Residual) endif
D_AfterDerandomize=D_AfterVB/8+D_ByteAdjust+D_ByteInterlv
D_AfterRSDecoder=D_AfterDerandomize*188/204
```

Delay Calculation of an ISDB-T Receiver

where

D_OFDMMod×108/96 is the delay between *Constellation* pins in DTV_ISDBThreeLaySource and DTV_ISDBThreeLayReceiver.

D_AfterDerandomize is the delay between pins *Bytes_AftRSC* in DTV_ISDBThreeLaySource and *Bytes_BefRSD* in DTV_ISDBThreeLayReceiver.

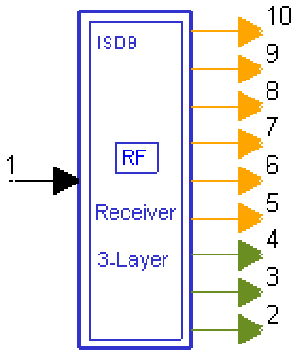
D_AfterRSDecoder is the delay between pins *Bytes_Uncoded* in DTV_ISDBThreeLaySource and *Bytes_Decoded* in DTV_ISDBThreeLayReceiver.

When connecting the receiver to the signal source in MER and BER measurements, the signal generator reference signal must be delayed according to the basic formula in Delay Calculation of an ISDB-T Receiver.

References

1. ARIB STD-B31 Version 1.5, Transmission System for Digital Terrestrial Television Broadcasting, July 29, 2003.

DTV_ISDBThreeLayReceiver_RF



Description: ISDB-T three-layer RF receiver
Library: DTV, ISDB-T
Class: TSDFDTV_ISDBThreeLayReceiver_RF

Parameters

Name	Description	Default	Unit	Type	Range
RIn	input resistance	DefaultRIn	Ohm	real	(0, ∞)
RTemp	physical temperature, in degrees C	DefaultRTemp	Celsius	real	[-273.15, ∞)
GainImbalance	Gain imbalance, Q vs I	0.0	dB	real	(-∞, ∞)
PhaseImbalance	Phase imbalance, Q vs I	0.0	deg	real	(-∞, ∞)
FCarrier	carrier frequency	611.0MHz	Hz	real	(0, ∞)
Sensitivity	voltage output sensitivity, Vout/Vin	1		real	(-∞, ∞)
Phase	reference phase in degrees	0.0	deg	real	(-∞, ∞)
Mode	transmission mode: Mode 1, Mode 2, Mode 3	Mode 1		enum	
OversamplingOption	oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	
GuardInterval	guard interval (fractional FFT size)	1/32		real	[0, 1]
CodeRateA	convolutional code rate for Layer A: A 1/2, A 2/3, A 3/4, A 5/6, A 7/8	A 1/2		enum	
MappingModeA	signal constellations and mapping for Layer A: A DQPSK, A QPSK, A QAM-16, A QAM-64	A DQPSK		enum	
TimeInterlvA	length of time interleaver for Layer A: A I_000, A I_001, A I_010, A I_011, A I_100	A I_000		enum	
TrunLenA	path memory truncation length of Viterbi decoding algorithm, in bytes	10		int	[5, ∞)
SegmentsA	segments number of Layer A: A Seg 0 is not allowed, A Seg 1, A Seg 2, A Seg 3, A Seg 4, A Seg 5, A Seg 6, A Seg 7, A Seg 8, A Seg 9, A Seg 10, A Seg 11	A Seg 1		enum	
CodeRateB	convolutional code rate for Layer B: B 1/2, B 2/3, B 3/4, B 5/6, B 7/8	B 1/2		enum	
MappingModeB	signal constellations and mapping for Layer B: B DQPSK, B QPSK, B QAM-16, B QAM-64	B DQPSK		enum	
TimeInterlvB	length of time interleaver for Layer B: B I_000, B I_001, B I_010, B I_011, B I_100	B I_000		enum	
TrunLenB	path memory truncation length of Viterbi decoding algorithm, in bytes	10		int	[5, ∞)
SegmentsB	segments number of Layer B: B Seg 0 is not allowed, B Seg 1, B Seg 2, B Seg 3, B Seg 4, B Seg 5, B Seg 6, B Seg 7, B Seg 8, B Seg 9, B Seg 10, B Seg 11	B Seg 4		enum	
CodeRateC	convolutional code rate for Layer C: C 1/2, C 2/3, C 3/4, C 5/6, C 7/8	C 1/2		enum	
MappingModeC	signal constellations and mapping for Layer C: C DQPSK, C QPSK, C QAM-16, C QAM-64	C QPSK		enum	
TimeInterlvC	length of time interleaver for Layer C: C I_000, C I_001, C I_010, C I_011, C I_100	C I_000		enum	
TrunLenC	path memory truncation length of Viterbi decoding algorithm, in bytes	10		int	[5, ∞)
SegmentsC	segments number of Layer C: C Seg 0 is not allowed, C Seg 1, C Seg 2, C Seg 3, C Seg 4, C Seg 5, C Seg 6, C Seg 7, C Seg 8, C Seg 9, C Seg 10, C Seg 11	C Seg 8		enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	RF	received OFDM signal to be demodulated	timed

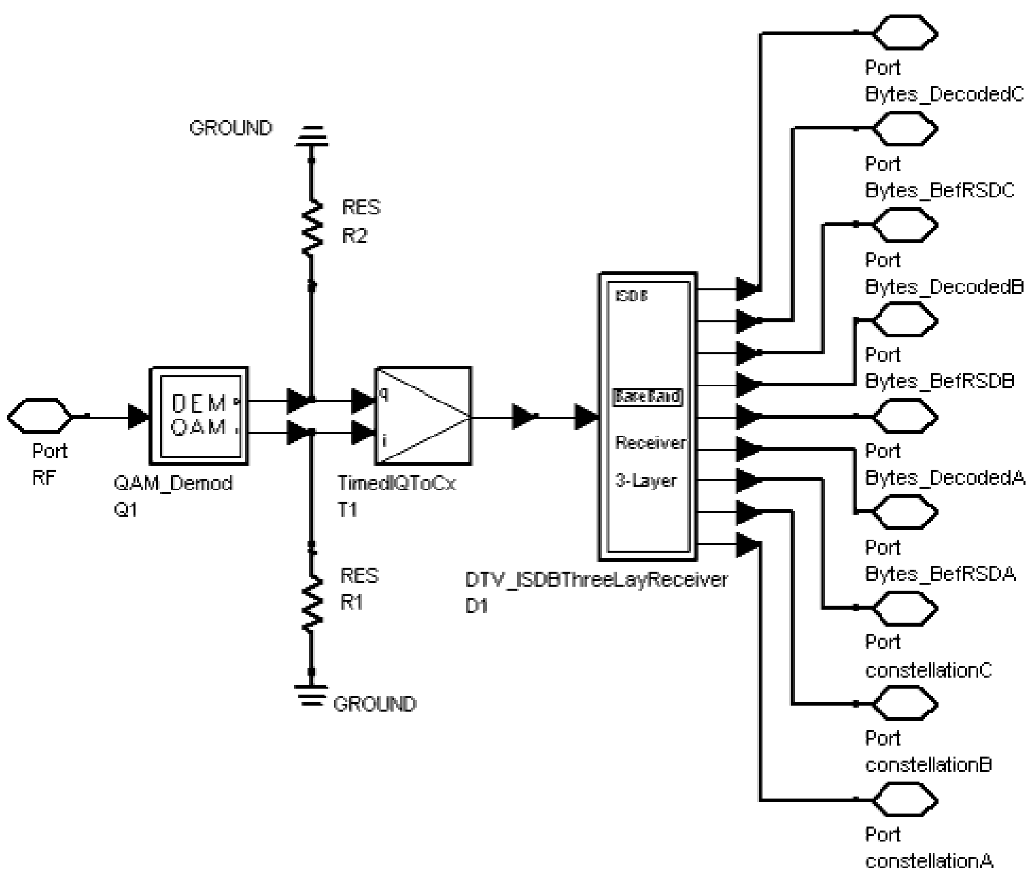
Pin Outputs

Pin	Name	Description	Signal Type
2	constellationA	constellation signal after OFDM demodulation of layer A	complex
3	constellationB	constellation signal after OFDM demodulation of layer B	complex
4	constellationC	constellation signal after OFDM demodulation of layer C	complex
5	Bytes_BefRSDA	decoded bytes after Viterbi decoder and de-randomizer of layer A	int
6	Bytes_DecodedA	decoded bytes after Reed Solomon decoder of layer A	int
7	Bytes_BefRSDB	decoded bytes after Viterbi decoder and de-randomizer of layer B	int
8	Bytes_DecodedB	decoded bytes after Reed Solomon decoder of layer B	int
9	Bytes_BefRSDC	decoded bytes after Viterbi decoder and de-randomizer of layer C	int
10	Bytes_DecodedC	decoded bytes after Reed Solomon decoder of layer C	int

Notes/Equations

1. This is a 3-layer ISDB-T RF receiver.
   The schematic for this subnetwork is shown below.

DTV_ISDBThreeLayReceiver_RF Schematic

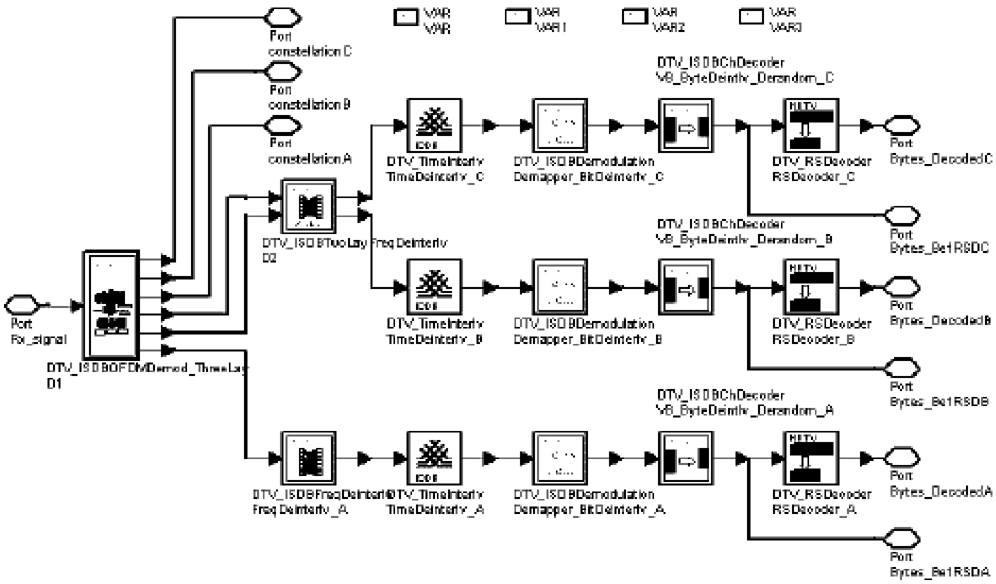


2. The input timed signal is demodulated from RF to baseband and fed to the ISDB-T 3-

layer baseband receiver.

3. The input signal starts with the first symbol of an ISDB-T signal frame.
4. The baseband receiver schematic (DTV_ISDBThreeLayReceiver) is shown below.

DTV_ISDBThreeLayReceiver Schematic



5. Baseband Parameter Details

Mode specifies transmission mode 2K (Mode 1), 4K (Mode 2), or 8K (Mode 3) defined in ISDB-T.

OversamplingOption specifies the oversampling ratio of transmission signal. Ratios 1, 2, 4, 8, 16, and 32 are supported in this model. For example, if Ratio 2 is selected, FFT size of the demodulator will double; if Ratio 1 is selected no oversampling will be performed.

GuardInterval specifies the guard interval (also called cyclic extension) length for each symbol, as a fraction (1/32, 1/16, 1/8, or 1/4) of the FFT time period. The value must match the guard interval length actually used in the input signal in order for the demodulation to work properly.

CodeRateX (X represents A, B, or C) specifies the inner code rate 1/2, 2/3, 3/4, 5/6, or 7/8.

MappingModeX specifies signal constellation and mapping for DQPSK, QPSK, 16QAM, or 64QAM.

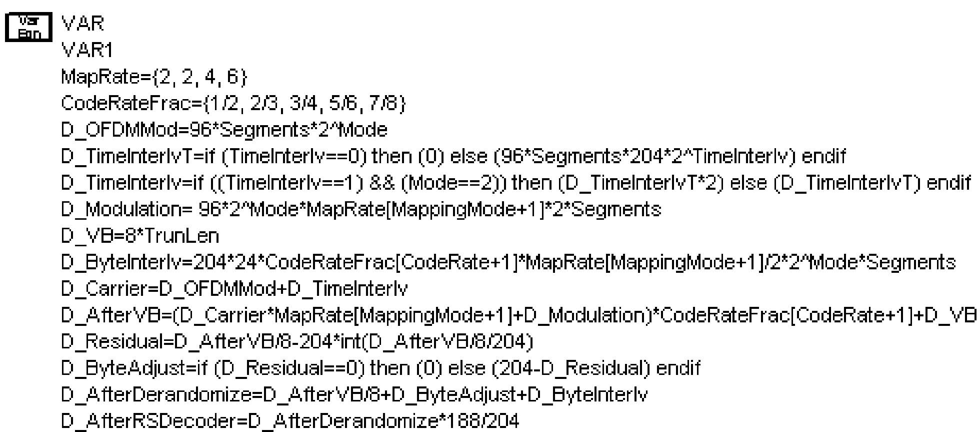
TimeInterlvX specifies the time domain interleaver type of the signal: I_000, I_001, I_010, I_011, or I_100.

SegmentsX specifies the number segments used for each layer. SegmentsA+SegmentsB+SegmentsC=13 is required. SegmentsB and SegmentsC cannot be 0. SegmentsA is permanently set to 1.

TrunLenX specifies the truncation length (1×8 bits, 2×8 bits), in bytes, in the Viterbi decoding algorithm.

6. Output Delays
DTV_ISDBChDecoder consists of Viterbi decoder, byte-wise deinterleaver and derandomizer. Viterbi decoder introduces different delay for different path memory truncation length (parameter TrunLen). For BER measurement synchronization, the delay between byte-interleaver and byte deinterleaver must be adjusted to a multiple of 12 bytes and the delay between randomizer and derandomizer must be adjusted to a multiple of 204 bytes. Here, both delays are adjusted to a multiple of 204bytes. The basic delay calculation of an ISDB-T receiver is shown in Delay Calculation of an ISDB-T Receiver; delays for layers A, B and, C are each calculated with their own hierarchical parameters. Assuming MapRate={2, 2, 4, 6}, CodeRateFrac={1/2, 2/3, 3/4, 5/6, 7/8}, then MapRate[MappingMode+1] represents the bit number mapped onto one data carrier, and CodeRateFrac[CodeRate+1] represents the inner coder rate, we get:

Delay Calculation of an ISDB-T Receiver



where

D_OFDMMod × 108/96 is the delay between *Constellation* pins in DTV_ISDBThreeLaySource and DTV_ISDBThreeLayReceiver.

D_AfterDerandomize is the delay between pin *Bytes_AftRSC* in DTV_ISDBThreeLaySource and *Bytes_BefRSD* in DTV_ISDBThreeLayReceiver.

D_AfterRSDecoder is the delay between pin *Bytes_Uncoded* in DTV_ISDBThreeLaySource and *Bytes_Decoded* in DTV_ISDBThreeLayReceiver.

When connecting the receiver to the signal source in MER and BER measurements, the reference signal from the signal generator must be delayed according to the formula in Delay Calculation of an ISDB-T Receiver.

7. RF Parameter Details
GainImbalance and PhaseImbalance add certain impairments to the ideal output RF signal. Impairments are added as described here.
The unimpaired RF I and Q envelope voltages have gain and phase imbalance applied. The RF is given by:

$$V_3(t) = A\left(V_1(t)\cos(\omega_c t) - gV_2(t)\sin\left(\omega_c t + \frac{\phi\pi}{180}\right)\right)$$

where $V_1(t)$ is the in-phase RF envelope, $V_2(t)$ is the quadrature phase RF envelope, g is the gain imbalance

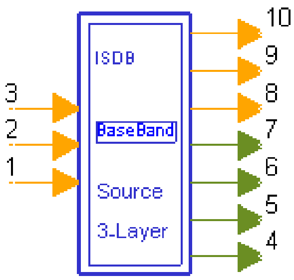
$$g = 10^{\frac{GainImbalance}{20}}$$

and, Φ (in degrees) is the phase imbalance.

References

1. ARIB STD-B31 Version 1.5, *Transmission System for Digital Terrestrial Television Broadcasting*, July 29, 2003.

DTV_ISDBThreeLaySource



Description: ISDB-T three-layer signal source
Library: DTV, ISDB-T
Class: SDFDTV_ISDBThreeLaySource

Parameters

Name	Description	Default	Unit	Type	Range
Mode	transmission mode: Mode 1, Mode 2, Mode 3	Mode 1		enum	
OversamplingOption	oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	
GuardInterval	guard interval (fractional FFT size)	1/32		real	[0, 1]
CodeRateA	convolutional code rate for Layer A: A 1/2, A 2/3, A 3/4, A 5/6, A 7/8	A 1/2		enum	
MappingModeA	signal constellations and mapping for Layer A: A DQPSK, A QPSK, A QAM-16, A QAM-64	A DQPSK		enum	
TimeInterlvA	length of time interleaver for Layer A: A I_000, A I_001, A I_010, A I_011, A I_100	A I_000		enum	
SegmentsA	segments number of Layer A: A Seg 0 is not allowed, A Seg 1, A Seg 2, A Seg 3, A Seg 4, A Seg 5, A Seg 6, A Seg 7, A Seg 8, A Seg 9, A Seg 10, A Seg 11	A Seg 1		enum	
CodeRateB	convolutional code rate for Layer B: B 1/2, B 2/3, B 3/4, B 5/6, B 7/8	B 1/2		enum	
MappingModeB	signal constellations and mapping for Layer B: B DQPSK, B QPSK, B QAM-16, B QAM-64	B DQPSK		enum	
TimeInterlvB	length of time interleaver for Layer B: B I_000, B I_001, B I_010, B I_011, B I_100	B I_000		enum	
SegmentsB	segments number of Layer B: B Seg 0 is not allowed, B Seg 1, B Seg 2, B Seg 3, B Seg 4, B Seg 5, B Seg 6, B Seg 7, B Seg 8, B Seg 9, B Seg 10, B Seg 11	B Seg 4		enum	
CodeRateC	convolutional code rate for Layer C: C 1/2, C 2/3, C 3/4, C 5/6, C 7/8	C 1/2		enum	
MappingModeC	signal constellations and mapping for Layer C: C DQPSK, C QPSK, C QAM-16, C QAM-64	C QPSK		enum	
TimeInterlvC	length of time interleaver for Layer C: C I_000, C I_001, C I_010, C I_011, C I_100	C I_000		enum	
SegmentsC	segments number of Layer C: C Seg 0 is not allowed, C Seg 1, C Seg 2, C Seg 3, C Seg 4, C Seg 5, C Seg 6, C Seg 7, C Seg 8, C Seg 9, C Seg 10, C Seg 11	C Seg 8		enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	DataA	input data of layer A	int
2	DataB	input data of layer B	int
3	DataC	input data of layer C	int

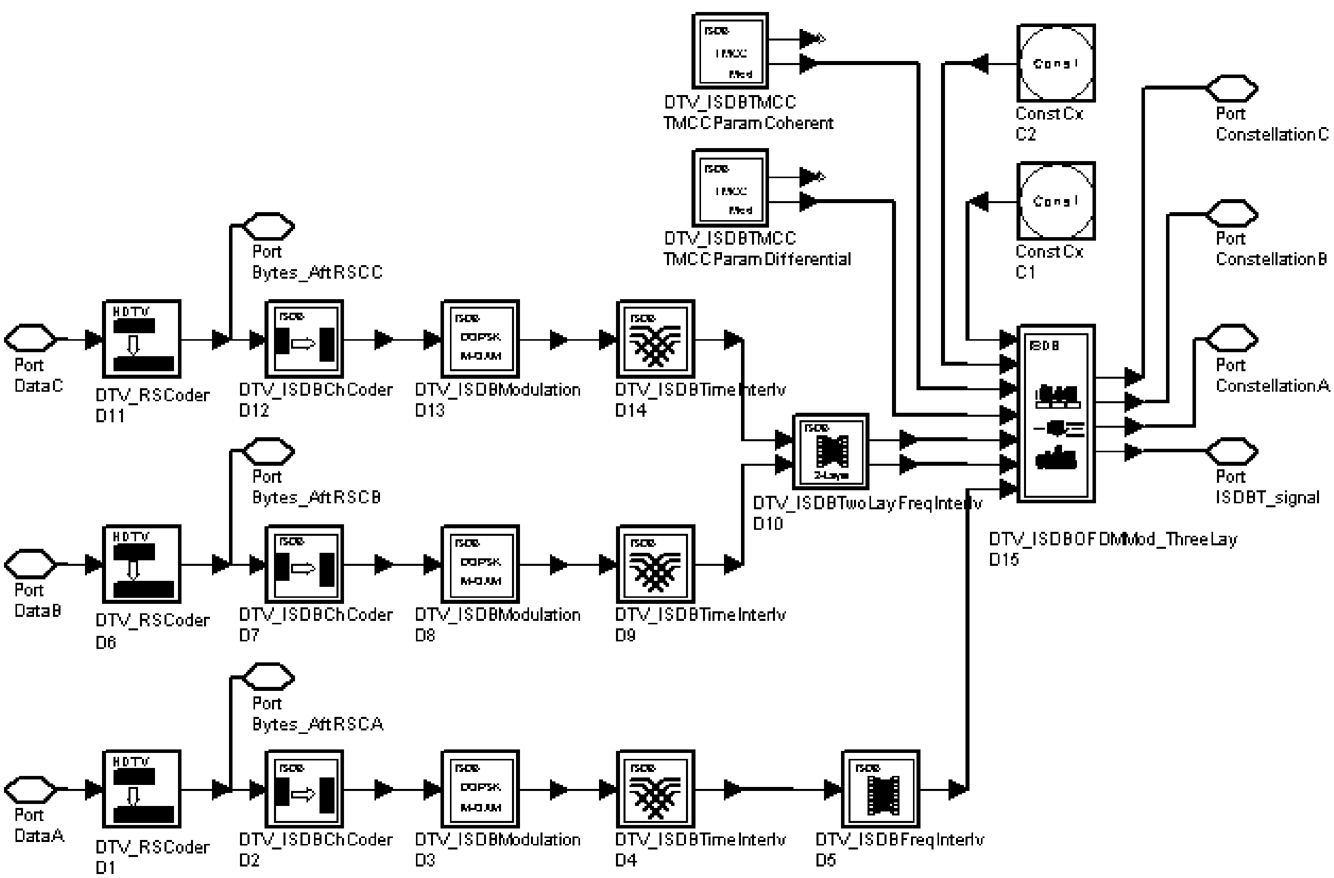
Pin Outputs

Pin	Name	Description	Signal Type
4	ISDBT_signal	ISDB-T three layer base-band signal	complex
5	constellationA	constellation signal of layer A before IFFT	complex
6	constellationB	constellation signal of layer B before IFFT	complex
7	constellationC	constellation signal of layer C before IFFT	complex
8	Bytes_AftRSCA	information bytes after RS encoder of layer A	int
9	Bytes_AftRSCB	information bytes after RS encoder of layer B	int
10	Bytes_AftRSCC	information bytes after RS encoder of layer C	int

Notes/Equations

1. This subnetwork model generates a 3-layer ISDB-T baseband signal.
   The schematic for this subnetwork is shown below.

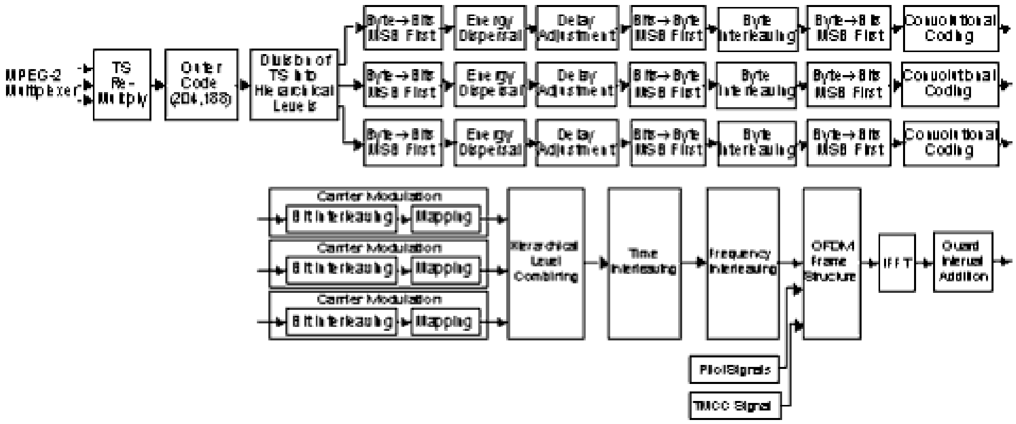
DTV_ISDBThreeLaySource Schematic



2. The subnetwork input is a transport stream as defined in MPEG-2 Systems.

The signal format follows ISDB-T transmission specification. The figure below shows the ISDB-T baseband system functional block diagram.

ISDB-T Baseband System Functional Block Diagram



3. Auxiliary information AC1 and AC2 are set to 0 bit (same as CP).
4. Parameter Details

    GuardInterval value is 1/32, 1/16, 1/8 or 1/4 (the ratio of guard interval length to useful symbol length).

    SegmentsA+SegmentsB+SegmentsC=13 is required.

    SegmentsB and SegmentsC cannot be 0.

    SegmentsA is permanently set to 1.

    Time interleaving lengths, based on mode, are listed in the following table.

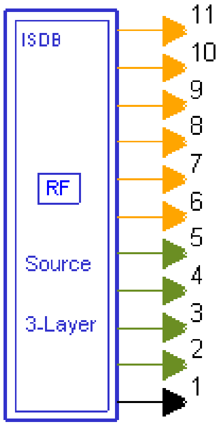
Time Interleaving Length

TimeInterlv	Time Interleaving Length I (Mode 1)	Time Interleaving Length I (Mode 2)	Time Interleaving Length I (Mode 3)
I_000	0	0	0
I_001	4	2	1
I_010	8	4	2
I_011	16	8	4
I_100	32	16	8

References

1. ARIB STD-B31 Version 1.5, *Transmission System for Digital Terrestrial Television Broadcasting*, July 29, 2003.

DTV_ISDBThreeLaySource_RF



Description: ISDB-T three-layer RF signal source
Library: DTV, ISDB-T
Class: TSDFDTV_ISDBThreeLaySource_RF

Parameters

Name	Description	Default	Unit	Type	Range
ROut	output resistance	DefaultROut	Ohm	real	(0, ∞)
RTemp	physical temperature, in degrees C	DefaultRTemp	Celsius	real	[-273.15, ∞)
FCarrier	carrier frequency	611.0MHz	Hz	real	(0, ∞)
Power	modulator output power	40mW	W	real	(0, ∞)
BasicSamplingRate	basic sampling rate	(2048/252.0)MHz	Hz	real	(0, ∞)
MirrorSpectrum	Mirror spectrum about carrier?: NO, YES	NO		enum	
GainImbalance	Gain imbalance, Q vs I	0.0	dB	real	(-∞, ∞)
PhaseImbalance	Phase imbalance, Q vs I	0.0	deg	real	(-∞, ∞)
I_OriginOffset	I origin offset (percent)	0.0		real	(-∞, ∞)
Q_OriginOffset	Q origin offset (percent)	0.0		real	(-∞, ∞)
IQ_Rotation	IQ rotation	0.0	deg	real	(-∞, ∞)
Mode	transmission mode: Mode 1, Mode 2, Mode 3	Mode 1		enum	
OversamplingOption	oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	
GuardInterval	guard interval (fractional FFT size)	1/32		real	[0, 1]
CodeRateA	convolutional code rate for Layer A: A 1/2, A 2/3, A 3/4, A 5/6, A 7/8	A 1/2		enum	
MappingModeA	signal constellations and mapping for Layer A: A DQPSK, A QPSK, A QAM-16, A QAM-64	A DQPSK		enum	
TimeInterlvA	length of time interleaver for Layer A: A I_000, A I_001, A I_010, A I_011, A I_100	A I_000		enum	
SegmentsA	segments number of Layer A: A Seg 0 is not allowed, A Seg 1, A Seg 2, A Seg 3, A Seg 4, A Seg 5, A Seg 6, A Seg 7, A Seg 8, A Seg 9, A Seg 10, A Seg 11	A Seg 1		enum	
CodeRateB	convolutional code rate for Layer B: B 1/2, B 2/3, B 3/4, B 5/6, B 7/8	B 1/2		enum	
MappingModeB	signal constellations and mapping for Layer B: B DQPSK, B QPSK, B QAM-16, B QAM-64	B DQPSK		enum	
TimeInterlvB	length of time interleaver for Layer B: B I_000, B I_001, B I_010, B I_011, B I_100	B I_000		enum	
SegmentsB	segments number of Layer B: B Seg 0 is not allowed, B Seg 1, B Seg 2, B Seg 3, B Seg 4, B Seg 5, B Seg 6, B Seg 7, B Seg 8, B Seg 9, B Seg 10, B Seg 11	B Seg 4		enum	
CodeRateC	convolutional code rate for Layer C: C 1/2, C 2/3, C 3/4, C 5/6, C 7/8	C 1/2		enum	
MappingModeC	signal constellations and mapping for Layer C: C DQPSK, C QPSK, C QAM-16, C QAM-64	C QPSK		enum	
TimeInterlvC	length of time interleaver for Layer C: C I_000, C I_001, C I_010, C I_011, C I_100	C I_000		enum	
SegmentsC	segments number of Layer C: C Seg 0 is not allowed, C Seg 1, C Seg 2, C Seg 3, C Seg 4, C Seg 5, C Seg 6, C Seg 7, C Seg 8, C Seg 9, C Seg 10, C Seg 11	C Seg 8		enum	
DataType	payload data type: PN9, PN15, FIX4, _4_1_4_0, _8_1_8_0, _16_1_16_0, _32_1_32_0, _64_1_64_0	PN9		enum	

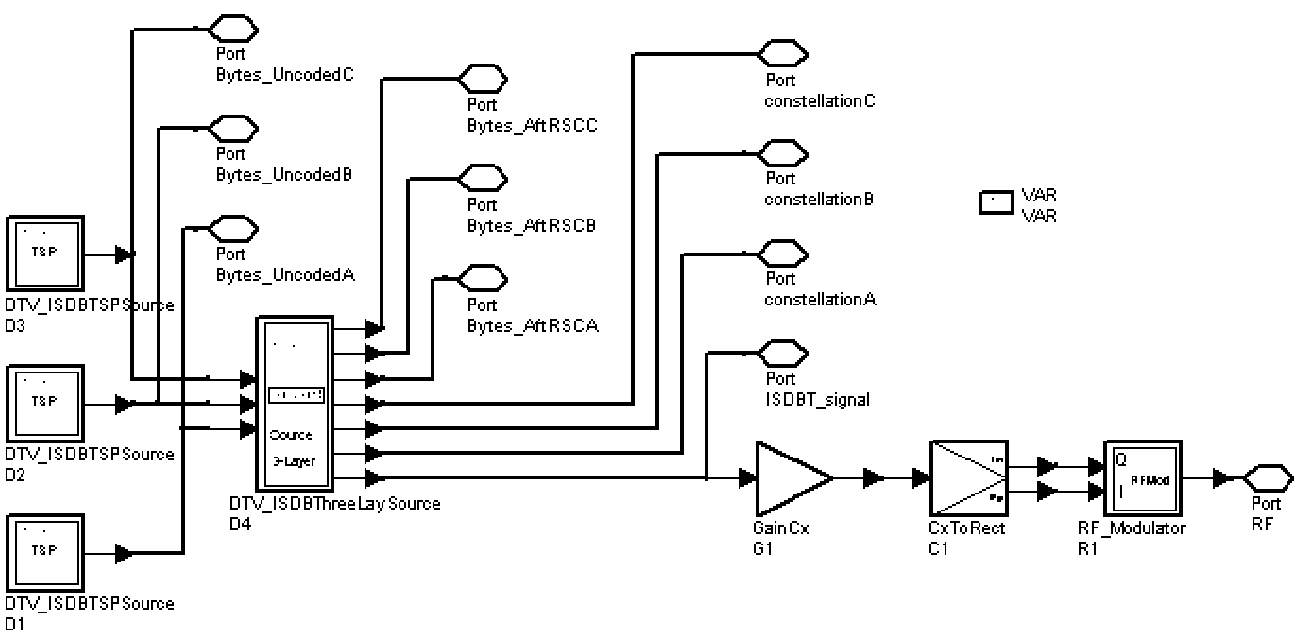
Pin Outputs

Pin	Name	Description	Signal Type
1	RF	RF signal	timed
2	ISDBT_signal	ISDB-T two-layer base-band signal	complex
3	constellationA	constellation signal of layer A before IFFT	complex
4	constellationB	constellation signal of layer B before IFFT	complex
5	constellationC	constellation signal of layer C before IFFT	complex
6	Bytes_AftRSCA	information bytes after RS encoder of layer A	int
7	Bytes_UncodedA	information bytes before RS encoder of layer A	int
8	Bytes_AftRSCB	information bytes after RS encoder of layer B	int
9	Bytes_UncodedB	information bytes before RS encoder of layer B	int
10	Bytes_AftRSCC	information bytes after RS encoder of layer C	int
11	Bytes_UncodedC	information bytes before RS encoder of layer C	int

Notes/Equations

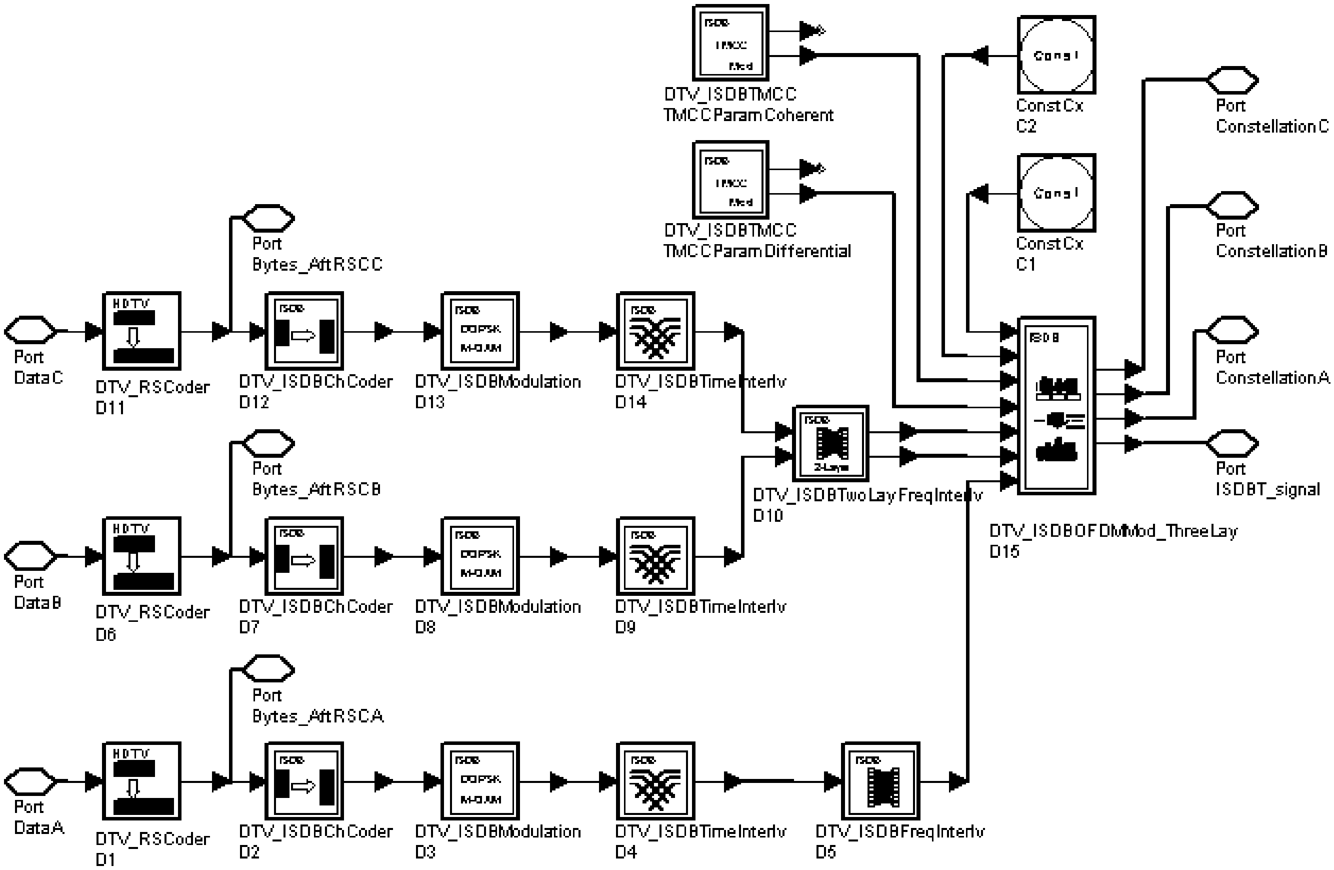
1. This subnetwork model generates a 3-layer ISDB-T RF signal source. The ISDB-T baseband signal is fed into the RF modulator. The RF signal is a timed signal after RF modulation.
   The schematic for this subnetwork is shown below.

DTV_ISDBThreeLaySource_RF Schematic



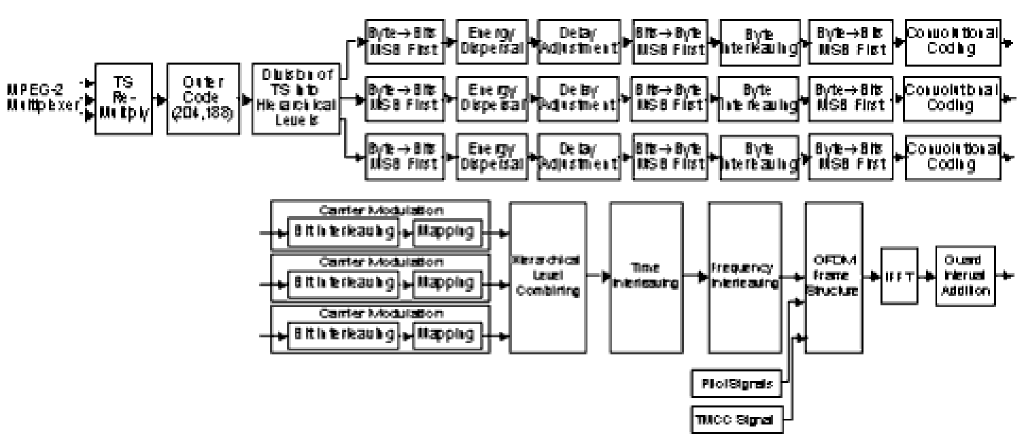
2. The format of 3-layer ISDB-T baseband signal source is based on ISDB-T specifications; the schematic for DTV_ISDBThreeLaySource is shown below.

DTV_ISDBThreeLaySource Schematic



The functional block diagram of the ISDB-T baseband system is shown below.

ISDB-T Baseband System Functional Block Diagram



3. Auxiliary information AC1 and AC2 are set to 0 bits (same as CP).
4. Parameter Details
   - FCarrier defines the RF frequency for the ISDB signal.
   - Power defines the power level for FCarrier.
   - BasicSamplingRate specifies the basic sampling rate.
   - MirrorSpectrum, when set to YES, is used to conjugate the input signal before any other processing is done.
   - GainImbalance, PhaseImbalance, I_OriginOffset, Q_OriginOffset, and IQ_Rotation are used to add certain impairments to the ideal output RF signal. Impairments are added as described here.

The unimpaired RF I and Q envelope voltages have gain and phase imbalance applied. The RF is given by:

$$V_3(t) = A\left(V_1(t)\cos(\omega_c t) - gV_2(t)\sin\left(\omega_c t + \frac{\phi\pi}{180}\right)\right)$$

where *A* is a scaling factor that depends on the Power and ROut parameters specified by the user, $V_1(t)$ is the in-phase RF envelope, $V_2(t)$ is the quadrature phase RF envelope, *g* is the gain imbalance

$$g = 10^{\frac{GainImbalance}{20}}$$

and, Φ (in degrees) is the phase imbalance.
Next, the signal $V_3(t)$ is rotated by IQ_Rotation degrees.

I_OriginOffset and Q_OriginOffset are then applied to the rotated signal. Note that the amounts specified are percentages with respect to the output rms voltage. The output rms voltage is given by sqrt(2×ROut×Power). Mode is used to select transmission mode of 1, 2, or 3 defined in ISDB-T.

- OversamplingOption specifies the oversampling ratio of transmission signal. Ratios 1, 2, 4, 8, 16, 32 are supported.
- *GuardInterval* specifies the guard interval (also called cyclic extension) length for each symbol, as a fraction (1/32, 1/16, 1/8, or 1/4) of the FFT time period. The value must match the guard interval length actually used in the input signal in order for the demodulation to work properly.
- *CodeRateX* (*X* represents *A*, *B*, or *C*) is defined as code rate of stream. Code rates 1/2, 2/3, 3/4, 5/6 and 7/8 are available.
- *MappingModeX* specifies signal constellation and mapping: DQPSK, QPSK, 16QAM, or 64QAM.
- *TimeInterlvX* specifies the time domain interleaver type of the signal: I_000, I_001, I_010, I_011, or I_100. Time interleaving lengths are given in the following table.
- *SegmentsX* specifies the number of segments per layer. SegmentsA+SegmentsB+SegmentsC=13 is required. SegmentsB and SegmentsC cannot be 0. SegmentsA is permanently set to 1.

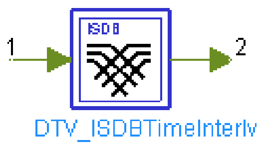
Time Interleaving Lengths

TimeInterlvX	Time Interleaving Length		
	Mode 1	**Mode 2**	**Mode 3**
I_000	0	0	0
I_001	4	2	1
I_010	8	4	2
I_011	16	8	4
I_100	32	16	8

References

1. ARIB STD-B31 Version 1.5, *Transmission System for Digital Terrestrial Television Broadcasting*, July 29, 2003.

DTV_ISDBTimeInterlv



Description: ISDB-T intra-segment time interleaver
Library: DTV, ISDB-T
Class: SDFDTV_ISDBTimeInterlv

Parameters

Name	Description	Default	Unit	Type	Range
Mode	transmission mode: Mode 1, Mode 2, Mode 3	Mode 1		enum	
MappingMode	signal constellations and mapping: DQPSK, QPSK, QAM 16, QAM 64	DQPSK		enum	
Segments	number of segments per layer	13		int	[1, 13]
I	time interleaving length: I_000, I_001, I_010, I_011, I_100	I_000		enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	In	input symbols to be interleaved	complex

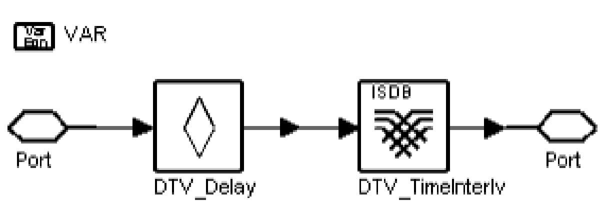
Pin Outputs

Pin	Name	Description	Signal Type
2	Out	output symbols after interleaved	complex

Notes/Equations

1. This subnetwork model interleaves modulated symbols in the time domain of an ISDB-T signal generator.
   The schematic for this subnetwork is shown below.

DTV_ISDBTimeInterlv Schematic



2. DTV_Delay delays the input complex carrier such that the total number of transmission and reception delays for each layer is a multiple of frames.
3. Relationships of the I parameter, the number of delay-adjustment symbols, and the number of delayed frames are given in the tables below.

Time Interleaving Parameter and Delay Adjustment Values

Mode 1

Subnetwork I Parameter Setting	TimeInterlv I Parameter Setting	Delay Adjustment Symbols	Delayed Frames in Tx and Rx
I_000	0	0	0
I_001	4	28	2
I_010	8	56	4
I_011	16	112	8
I_100	32	224	16

Mode 2

Subnetwork I Parameter Setting	TimeInterlv I Parameter Setting	Delay Adjustment Symbols	Delayed Frames in Tx and Rx
I_000	0	0	0
I_001	2	14	1
I_010	4	28	2
I_011	8	56	4
I_100	16	112	8

Mode 3

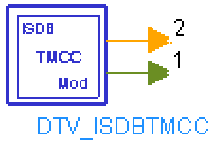
Subnetwork I Parameter Setting	TimeInterlv I Parameter Setting	Delay Adjustment Symbols	Delayed Frames in Tx and Rx
I_000	0	0	0
I_001	1	109	1
I_010	2	14	1
I_011	4	28	2
I_100	8	56	4

4. The subnetwork works on the basis of OFDM symbols, so the input of the subnetwork starts with the first data carrier of the corresponding hierarchical layer.

References

1. ARIB STD-B31 Version 1.5, *Transmission System for Digital Terrestrial Television Broadcasting*, July 29, 2003.

DTV_ISDBTMCC



Description: ISDB-T transmission and multiplexing configuration control signal
Library: DTV, ISDB-T
Class: SDFDTV_ISDBTMCC

Parameters

Name	Description	Default	Unit	Type	Range
InitiBit	initialization bit for the DBPSK modulation (1 bit)	0		int	{0, 1}
SynchWord	synchronization word (16 bits): W0, W1	W0		enum	
SegmentDescriptor	segment descriptor (3 bits): Differential, Coherent	Differential		enum	
SystemDescriptor	system description (2 bits): ISDB-T, ISDB-TSB, Reserved Des 2, Reserved Des 3	ISDB-T		enum	
CountDownIndex	index for transmission parameter change (4 bits): Ordinary, Frames 15, Frames 14, Frames 13, Frames 12, Frames 11, Frames 10, Frames 9, Frames 8, Frames 7, Frames 6, Frames 5, Frames 4, Frames 3, Frames 2, Frames 1	Ordinary		enum	
AlarmBroadcastStartFlag	start flag for emergency-alarm broadcasting (1 bit): No startup control, Startup control	No startup control		enum	
Cur_PartialReceptionFlag	current partial reception layer (1 bit): Cur Un-used, Cur Used	Cur Used		enum	
Cur_A_MappingMode	current signal constellations and mapping for Layer A (3 bits): Cur A DQPSK, Cur A QPSK, Cur A 16QAM, Cur A 64QAM, Cur A Reserved MappingMode 1, Cur A Reserved MappingMode 2, Cur A Reserved MappingMode 3, Cur A Un-used Layer MappingMode	Cur A DQPSK		enum	
Cur_A_CodeRate	current code rate for Layer A (3 bits): Cur A 1/2, Cur A 2/3, Cur A 3/4, Cur A 5/6, Cur A 7/8, Cur A Reserved CodeRate 1, Cur A Reserved CodeRate 2, Cur A Un-used Layer CodeRate	Cur A 1/2		enum	
Cur_A_TimeInterlv_I	current length of time interleaver for Layer A (3 bits): Cur A I 0 0 0, Cur A I 4 2 1, Cur A I 8 4 2, Cur A I	Cur A I 8 4 2		enum	

	16 8 4, Cur A I 32 16 8, Cur A Reserved I 1, Cur A Reserved I 2, Cur A Un-used Layer I				
Cur_A_Segments	current number of segments for Layer A (4 bits): Cur A Reserved Seg 1, Cur A Seg 1, Cur A Seg 2, Cur A Seg 3, Cur A Seg 4, Cur A Seg 5, Cur A Seg 6, Cur A Seg 7, Cur A Seg 8, Cur A Seg 9, Cur A Seg 10, Cur A Seg 11, Cur A Seg 12, Cur A Seg 13, Cur A Reserved Seg 2, Cur A Un-used Layer Seg	Cur A Seg 13		enum	
Cur_B_MappingMode	current signal constellations and mapping for Layer B (3 bits): Cur B DQPSK, Cur B QPSK, Cur B 16QAM, Cur B 64QAM, Cur B Reserved MappingMode 1, Cur B Reserved MappingMode 2, Cur B Reserved MappingMode 3, Cur B Un-used Layer MappingMode	Cur B 16QAM		enum	
Cur_B_CodeRate	current code rate for Layer B (3 bits): Cur B 1/2, Cur B 2/3, Cur B 3/4, Cur B 5/6, Cur B 7/8, Cur B Reserved CodeRate 1, Cur B Reserved CodeRate 2, Cur B Un-used Layer CodeRate	Cur B 1/2		enum	
Cur_B_TimeInterlv_I	current length of time interleaver for Layer B (3 bits): Cur B I 0 0 0, Cur B I 4 2 1, Cur B I 8 4 2, Cur B I 16 8 4, Cur B I 32 16 8, Cur B Reserved I 1, Cur B Reserved I 2, Cur B Un-used Layer I	Cur B I 8 4 2		enum	
Cur_B_Segments	current number of segments for Layer B (4 bits): Cur B Reserved Seg 1, Cur B Seg 1, Cur B Seg 2, Cur B Seg 3, Cur B Seg 4, Cur B Seg 5, Cur B Seg 6, Cur B Seg 7, Cur B Seg 8, Cur B Seg 9, Cur B Seg 10, Cur B Seg 11, Cur B Seg 12, Cur B Seg 13, Cur B Reserved Seg 2, Cur B Un-used Layer Seg	Cur B Reserved Seg 1		enum	
Cur_C_MappingMode	current signal constellations and mapping for Layer C (3 bits): Cur C DQPSK, Cur C QPSK, Cur C 16QAM, Cur C 64QAM, Cur C Reserved MappingMode 1, Cur C Reserved MappingMode 2, Cur C Reserved MappingMode 3, Cur C Un-used Layer MappingMode	Cur C 64QAM		enum	
Cur_C_CodeRate	current code rate for Layer C (3 bits): Cur C 1/2, Cur C 2/3, Cur C 3/4, Cur C 5/6, Cur C 7/8, Cur C Reserved CodeRate 1, Cur C Reserved CodeRate 2, Cur C Un-used Layer CodeRate	Cur C 1/2		enum	
Cur_C_TimeInterlv_I	current length of time interleaver for Layer C (3 bits): Cur C I 0 0 0, Cur C I 4 2 1, Cur C I 8 4 2, Cur C I 16 8 4, Cur C I 32 16 8, Cur C Reserved I 1, Cur C Reserved I 2,	Cur C I 8 4 2		enum	

	Cur C Un-used Layer I				
Cur_C_Segments	current number of segments for Layer C (4 bits): Cur C Reserved Seg 1, Cur C Seg 1, Cur C Seg 2, Cur C Seg 3, Cur C Seg 4, Cur C Seg 5, Cur C Seg 6, Cur C Seg 7, Cur C Seg 8, Cur C Seg 9, Cur C Seg 10, Cur C Seg 11, Cur C Seg 12, Cur C Seg 13, Cur C Reserved Seg 2, Cur C Un-used Layer Seg	Cur C Seg 6		enum	
Next_PartialReceptionFlag	Next partial reception layer (1 bit): Next Un-used, Next Used	Next Un-used		enum	
Next_A_MappingMode	Next signal constellations and mapping for Layer A (3 bits): Next A DQPSK, Next A QPSK, Next A 16QAM, Next A 64QAM, Next A Reserved MappingMode 1, Next A Reserved MappingMode 2, Next A Reserved MappingMode 3, Next A Un-used Layer MappingMode	Next A QPSK		enum	
Next_A_CodeRate	Next code rate for Layer A (3 bits): Next A 1/2, Next A 2/3, Next A 3/4, Next A 5/6, Next A 7/8, Next A Reserved CodeRate 1, Next A Reserved CodeRate 2, Next A Un-used Layer CodeRate	Next A 1/2		enum	
Next_A_TimeInterlv_I	Next length of time interleaver for Layer A (3 bits): Next A I 0 0 0, Next A I 4 2 1, Next A I 8 4 2, Next A I 16 8 4, Next A I 32 16 8, Next A Reserved I 1, Next A Reserved I 2, Next A Un-used Layer I	Next A I 8 4 2		enum	
Next_A_Segments	Next number of segments for Layer A (4 bits): Next A Reserved Seg 1, Next A Seg 1, Next A Seg 2, Next A Seg 3, Next A Seg 4, Next A Seg 5, Next A Seg 6, Next A Seg 7, Next A Seg 8, Next A Seg 9, Next A Seg 10, Next A Seg 11, Next A Seg 12, Next A Seg 13, Next A Reserved Seg 2, Next A Un-used Layer Seg	Next A Reserved Seg 1		enum	
Next_B_MappingMode	Next signal constellations and mapping for Layer B (3 bits): Next B DQPSK, Next B QPSK, Next B 16QAM, Next B 64QAM, Next B Reserved MappingMode 1, Next B Reserved MappingMode 2, Next B Reserved MappingMode 3, Next B Un-used Layer MappingMode	Next B 16QAM		enum	
Next_B_CodeRate	Next code rate for Layer B (3 bits): Next B 1/2, Next B 2/3, Next B 3/4, Next B 5/6, Next B 7/8, Next B Reserved CodeRate 1, Next B Reserved CodeRate 2, Next B Un-used Layer CodeRate	Next B 1/2		enum	
Next_B_TimeInterlv_I	Next length of time interleaver for Layer B (3 bits): Next B I 0 0 0, Next B I 4 2 1, Next B I 8 4 2, Next B I 16 8 4, Next B I 32 16 8, Next B	Next B I 8 4 2		enum	

	Reserved I 1, Next B Reserved I 2, Next B Un-used Layer I				
Next_B_Segments	Next number of segments for Layer B (4 bits): Next B Reserved Seg 1, Next B Seg 1, Next B Seg 2, Next B Seg 3, Next B Seg 4, Next B Seg 5, Next B Seg 6, Next B Seg 7, Next B Seg 8, Next B Seg 9, Next B Seg 10, Next B Seg 11, Next B Seg 12, Next B Seg 13, Next B Reserved Seg 2, Next B Un-used Layer Seg	Next B Seg 6		enum	
Next_C_MappingMode	Next signal constellations and mapping for Layer C (3 bits): Next C DQPSK, Next C QPSK, Next C 16QAM, Next C 64QAM, Next C Reserved MappingMode 1, Next C Reserved MappingMode 2, Next C Reserved MappingMode 3, Next C Un-used Layer MappingMode	Next C QPSK		enum	
Next_C_CodeRate	Next code rate for Layer C (3 bits): Next C 1/2, Next C 2/3, Next C 3/4, Next C 5/6, Next C 7/8, Next C Reserved CodeRate 1, Next C Reserved CodeRate 2, Next C Un-used Layer CodeRate	Next C 1/2		enum	
Next_C_TimeInterlv_I	Next length of time interleaver for Layer C (3 bits): Next C I 0 0 0, Next C I 4 2 1, Next C I 8 4 2, Next C I 16 8 4, Next C I 32 16 8, Next C Reserved I 1, Next C Reserved I 2, Next C Un-used Layer I	Next C I 8 4 2		enum	
Next_C_Segments	Next number of segments for Layer C (4 bits): Next C Reserved Seg 1, Next C Seg 1, Next C Seg 2, Next C Seg 3, Next C Seg 4, Next C Seg 5, Next C Seg 6, Next C Seg 7, Next C Seg 8, Next C Seg 9, Next C Seg 10, Next C Seg 11, Next C Seg 12, Next C Seg 13, Next C Reserved Seg 2, Next C Un-used Layer Seg	Next C Seg 5		enum	
FutureUse	reserved for future use (all set to "1" 15 bits)	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1		int array	"111111111111111"

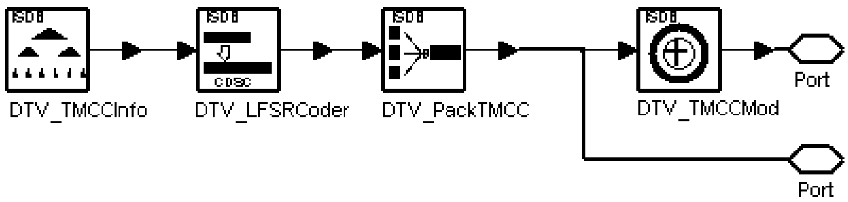
Pin Outputs

Pin	Name	Description	Signal Type
1	TMCC	modulated TMCC signal	complex
2	TMCC_Bits	TMCC bits	int

Notes/Equations

1. This subnetwork model generates a TMCC signal. The TMCC signal provides information on how the receiver is to perform demodulation of information such as the hierarchical configuration and the OFDM-segment transmission parameters. The TMCC signal is transmitted by the TMCC carrier.
2. The schematic for this subnetwork is shown below.

DTV_ISDBTMCC Schematic

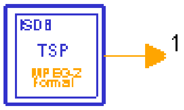


3. TMCC information assists the receiver in demodulating and decoding various information, including system identification, the transmission-parameter switching indicator, the broadcast emergency-alarm start flag, and *current* and *next* information. *Current* information represents the current hierarchical configuration and transmission parameters; *next* information includes the transmission parameters after switching. The *next* information can be specified or changed before the switching countdown.
4. Because TMCC information is used to specify transmission parameters and control receiver operation, it must be transmitted with greater reliability than program signals. Due to the difficulties involved with a receiver using the same concatenated-code decoding circuit for TMCC information and program signals (and because the use of block code is advantageous due to its shorter processing time) the shortened code (184,102) of the difference cyclic code (273,191) is used as the error-correction code for TMCC information.
   Because the same TMCC signals are transmitted by multiple carriers it is possible to reduce the required C/N by simply adding these signals, thereby ensuring improved reception performance. These error-correction techniques and the addition process make it possible to receive TMCC signals at a lower C/N than for program signals.
5. DTV_PackTMCC multiplexes the CDSC-coded TMCC information bits (184 bits) and other no-coded 20 bits, which include initialization bit, synchronization of TMCC and system type.
6. DTV_TMCCMod performs DBPSK modulation.

References

1. ARIB STD-B31 Version 1.5, *Transmission System for Digital Terrestrial Television Broadcasting*, July 29, 2003.

DTV_ISDBTSPSource



Description: MPEG-2 format signal for ISDB-T
Library: DTV, ISDB-T
Class: SDFDTV_ISDBTSPSource

Parameters

Name	Description	Default	Unit	Type	Range
DataPattern	data pattern: PN9, PN15, FIX4, _4_1_4_0, _8_1_8_0, _16_1_16_0, _32_1_32_0, _64_1_64_0	PN9		enum	

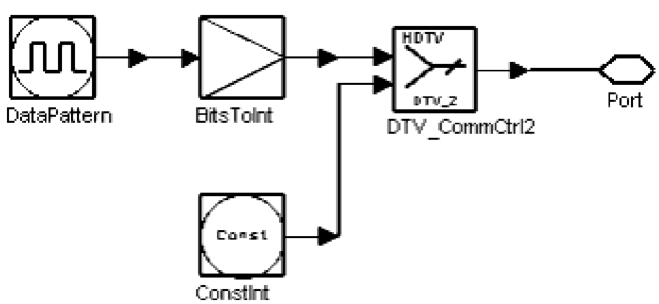
Pin Outputs

Pin	Name	Description	Signal Type
1	Out	MPEG-2 format transmission stream package	int

Notes/Equations

1. This subnetwork model generates a TSP for an ISDB-T signal generator. The schematic for this subnetwork is shown below.

DTV_ISDBTSPSource Schematic



2. The TSP signal format (shown in the figure below) is like MPEG-2, that is, one synchronization byte (47 Hex or 71 Dec) followed by 187 data bytes.

TSP Signal Format

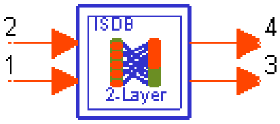
3. DataPattern specifies the type of data filled in the *Data* domain shown in the figure above.

- If PN9 is selected, a 511-bit pseudo-random test pattern is generated according to CCITT Recommendation O.153.
- If PN15 is selected, a 32767-bit pseudo-random test pattern is generated according to CCITT Recommendation O.151.
- If FIX4 is selected, a zero-stream is generated.
- If x_1_x_0 is selected, where x equals 4, 8, 16, 32, or 64, a periodic bit stream is generated, with the period being 2x. In one period, the first x bits are ones and the second x bits are zeros.

References

1. ARIB STD-B31 Version 1.5, *Transmission System for Digital Terrestrial Television Broadcasting*, July 29, 2003.
2. CCITT, Recommendation O.151(10/92).
3. CCITT, Recommendation O.153(10/92).

DTV_ISDBTwoLayFreqDeinterlv



Description: ISDB-T two-layer inter-frequency and intra-frequency deinterleaving
Library: DTV, ISDB-T
Class: SDFDTV_ISDBTwoLayFreqDeinterlv

Parameters

Name	Description	Default	Unit	Type	Range
Mode	transmission mode: Mode 1, Mode 2, Mode 3	Mode 1		enum	
MappingModeA	signal constellations and mapping of layer A: A DQPSK, A QPSK, A QAM-16, A QAM-64	A DQPSK		enum	
SegmentsA	segment number of layer A	5		int	[1, 13]
MappingModeB	signal constellations and mapping of layer B: B DQPSK, B QPSK, B QAM-16, B QAM-64	B QAM-64		enum	
SegmentsB	segment number of layer B	8		int	[1, 13]

Pin Inputs

Pin	Name	Description	Signal Type
1	In1	input	anytype
2	In2	input	anytype

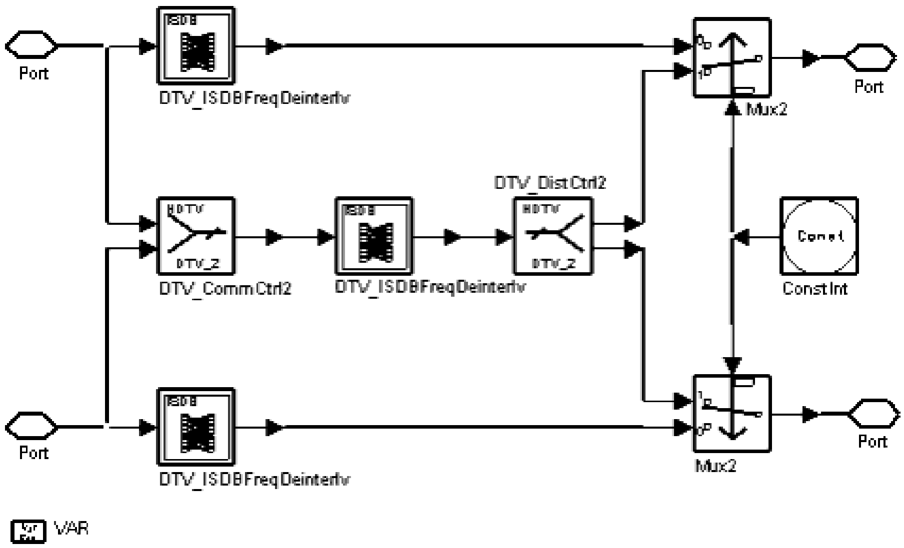
Pin Outputs

Pin	Name	Description	Signal Type
3	Out1	output	anytype
4	Out2	output	anytype

Notes/Equations

1. This subnetwork model performs carrier descrambling, carrier rotating, and inter-segment deinterleaving; it is the reverse of the process for *DTV_ISDBTwoLayFreqInterlv* (dtv).
   The schematic for this subnetwork is shown below.

DTV_ISDBTwoLayFreqDeinterlv Schematic

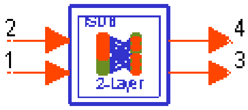


2. Inter-segment deinterleaving must be conducted on two or more data segments when they belong to the same type of modulated portion, even if their hierarchical levels differ.

References

1. ARIB STD-B31 Version 1.5, *Transmission System for Digital Terrestrial Television Broadcasting*, July 29, 2003.

DTV_ISDBTwoLayFreqInterlv



Description: ISDB-T two-layer inter-frequency and intra-frequency interleaving
Library: DTV, ISDB-T
Class: SDFDTV_ISDBTwoLayFreqInterlv

Parameters

Name	Description	Default	Unit	Type	Range
Mode	transmission mode: Mode 1, Mode 2, Mode 3	Mode 1		enum	
MappingModeA	signal constellations and mapping of layer A: A DQPSK, A QPSK, A QAM-16, A QAM-64	A DQPSK		enum	
SegmentsA	segment number of layer A	5		int	[1, 13]
MappingModeB	signal constellations and mapping of layer B: B DQPSK, B QPSK, B QAM-16, B QAM-64	B QAM-64		enum	
SegmentsB	segment number of layer B	8		int	[1, 13]

Pin Inputs

Pin	Name	Description	Signal Type
1	In1	input	anytype
2	In2	input	anytype

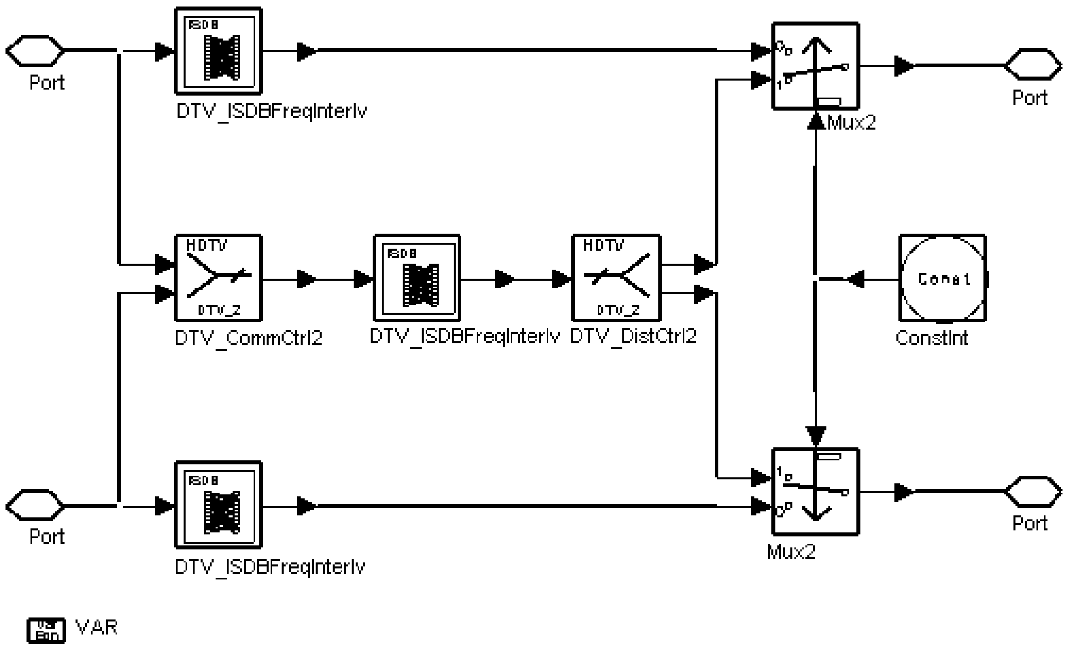
Pin Outputs

Pin	Name	Description	Signal Type
3	Out1	output	anytype
4	Out2	output	anytype

Notes/Equations

1. This subnetwork model performs frequency interleaving for ISDB-T 2-layer hierarchical transmission.
   The schematic for this subnetwork is shown below.

DTV_ISDBTwoLayFreqInterlv Schematic

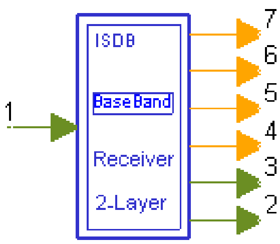


2. Inter-segment interleaving must be conducted on two or more data segments when they belong to the same type of modulated portion, even if their hierarchical levels differ.
3. See also, *DTV_ISDBTwoLayFreqDeinterlv* (dtv)

References

1. ARIB STD-B31 Version 1.5, *Transmission System for Digital Terrestrial Television Broadcasting*, July 29, 2003.

DTV_ISDBTwoLayReceiver



Description: ISDB-T two-layer receiver
Library: DTV, ISDB-T
Class: SDFDTV_ISDBTwoLayReceiver

Parameters

Name	Description	Default	Unit	Type	Range
Mode	transmission mode: Mode 1, Mode 2, Mode 3	Mode 1		enum	
OversamplingOption	oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	
GuardInterval	guard interval (fractional FFT size)	1/32		real	[0:1]
CodeRateA	convolutional code rate for Layer A: A 1/2, A 2/3, A 3/4, A 5/6, A 7/8	A 1/2		enum	
MappingModeA	signal constellations and mapping for Layer A: A DQPSK, A QPSK, A QAM-16, A QAM-64	A DQPSK		enum	
TimeInterlvA	length of time interleaver for Layer A: A I_000, A I_001, A I_010, A I_011, A I_100	A I_000		enum	
TrunLenA	path memory truncation length of Viterbi decoding algorithm, in bytes	10		int	[5, ∞)
SegmentsA	segments number of Layer A: A Seg 0 is not allowed, A Seg 1, A Seg 2, A Seg 3, A Seg 4, A Seg 5, A Seg 6, A Seg 7, A Seg 8, A Seg 9, A Seg 10, A Seg 11, A Seg 12	A Seg 5		enum	
CodeRateB	convolutional code rate for Layer B: B 1/2, B 2/3, B 3/4, B 5/6, B 7/8	B 7/8		enum	
MappingModeB	signal constellations and mapping for Layer B: B DQPSK, B QPSK, B QAM-16, B QAM-64	B QAM-64		enum	
TimeInterlvB	length of time interleaver for Layer B: B I_000, B I_001, B I_010, B I_011, B I_100	B I_000		enum	
TrunLenB	path memory truncation length of Viterbi decoding algorithm, in bytes	10		int	[5, ∞)
SegmentsB	segments number of Layer B: B Seg 0 is not allowed, B Seg 1, B Seg 2, B Seg 3, B Seg 4, B Seg 5, B Seg 6, B Seg 7, B Seg 8, B Seg 9, B Seg 10, B Seg 11, B Seg 12	B Seg 8		enum	

Pin Inputs

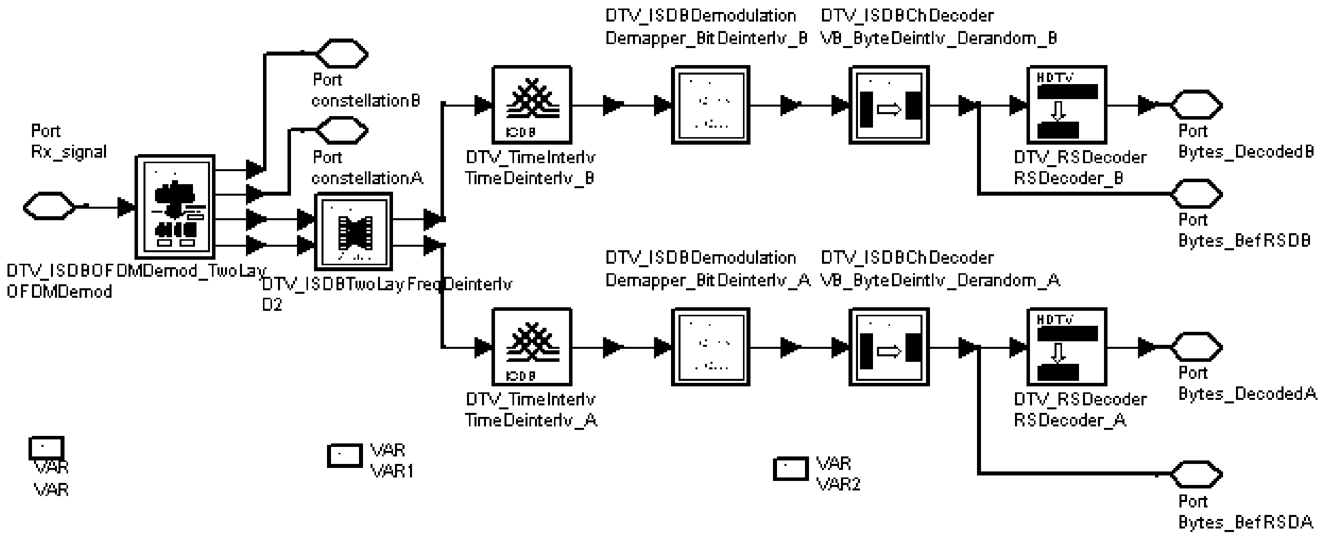
Pin	Name	Description	Signal Type
1	Rx_signal	received signal to be demodulated	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	constellationA	constellation signal after OFDM demodulation of layer A	complex
3	constellationB	constellation signal after OFDM demodulation of layer B	complex
4	Bytes_BefRSDA	decoded bytes after Viterbi decoder and de-randomizer of layer A	int
5	Bytes_DecodedA	decoded bytes after Reed Solomon decoder of layer A	int
6	Bytes_BefRSDB	decoded bytes after Viterbi decoder and de-randomizer of layer B	int
7	Bytes_DecodedB	decoded bytes after Reed Solomon decoder of layer B	int

Notes/Equations

1. This 2-layer ISDB-T baseband receiver subnetwork performs 2-layer OFDM demodulation, frequency deinterleaving, time deinterleaving, demapping and bit-wise deinterleaving, inner decoding (Viterbi), byte-wise deinterleaving, derandomizing and Reed-Solomon decoding.
   The schematic for this subnetwork is shown in DTV_ISDBTwoLayReceiver Schematic.



DTV_ISDBTwoLayReceiver Schematic

2. The input signal starts with the first symbol of an ISDB-T signal frame.
3. Parameter Details

   Mode specifies transmission mode 2K (Mode 1), 4K (Mode 2), or 8K (Mode 3) defined in ISDB-T.

   OversamplingOption specifies the oversampling ratio of transmission signal. Ratios 1, 2, 4, 8, 16, and 32 are supported in this model. For example, if Ratio 2 is selected, FFT size of the demodulator will double; if Ratio 1 is selected no oversampling will be performed.

   GuardInterval specifies the guard interval (also called cyclic extension) length for each symbol, as a fraction (1/32, 1/16, 1/8, or 1/4) of the FFT time period. The value must match the guard interval length actually used in the input signal in order for the demodulation to work properly.

   CodeRateX (X represents A or B) specifies the inner code rate 1/2, 2/3, 3/4, 5/6, or 7/8.

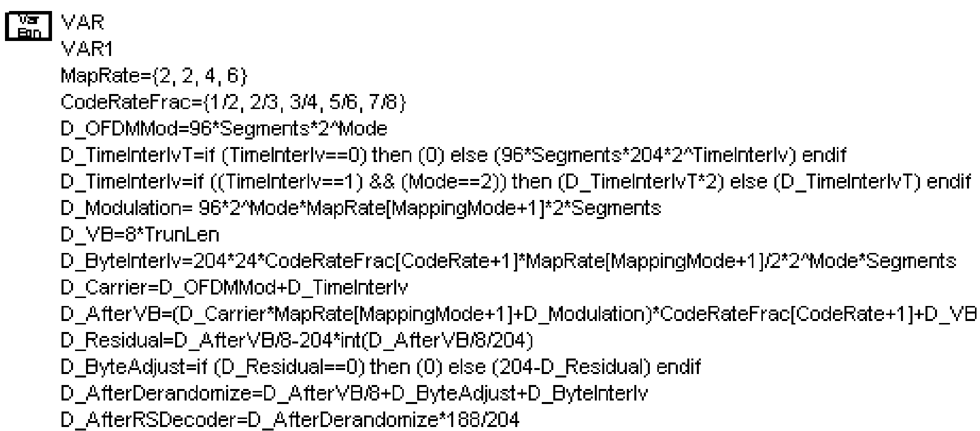
MappingModeX specifies signal constellation and mapping for DQPSK, QPSK, 16QAM or 64QAM.

TimeInterlvX is time domain interleaver type of the signal: I_000, I_001, I_010, I_011, or I_100.

SegmentsX specifies the number of segments used for each layer. SegmentsA+SegmentsB=13 is required. SegmentsB cannot be 0.

TrunLenX is the truncation length (1×8 bits, 2×8 bits), in bytes, in the Viterbi decoding algorithm.

4. Output Delays
DTV_ISDBChDecoder consists of Viterbi decoder, byte-wise deinterleaver and derandomizer. Viterbi decoder introduces different delay for different path memory truncation length (TrunLen parameter). For BER measurement synchronization, the delay between byte interleaver and deinterleaver must be adjusted to a multiple of 12 bytes, and the delay between randomizer and derandomizer must be adjusted to a multiple of 204 bytes. Here, both delays are adjusted to a multiple of 204 bytes. The basic delay calculation of an ISDB-T receiver is shown in ISDB-T Receiver Delay Calculation; delays for layers A and B are each calculated with their own hierarchical parameters. Assuming MapRate={2, 2, 4, 6}, CodeRateFrac={1/2, 2/3, 3/4, 5/6, 7/8}, then MapRate[MappingMode+1] represents the bit number mapped onto one data carrier, and CodeRateFrac[CodeRate+1] represents the inner coder rate; we get:



ISDB-T Receiver Delay Calculation

where

D_OFDMMod × 108/96 is the delay between the *Constellation* pins of DTV_ISDBTwoLaySource and DTV_ISDBTwoLayReceiver.

D_AfterDerandomize is the delay between pins *Bytes_AftRSC* in DTV_ISDBTwoLaySource and *Bytes_BefRSD* in DTV_ISDBTwoLayReceiver.

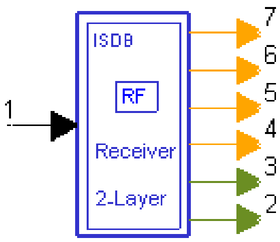
D_AfterRSDecoder is the delay between pins *Bytes_Uncoded* in DTV_ISDBTwoLaySource and *Bytes_Decoded* in DTV_ISDBTwoLayReceiver.

When connecting the receiver to the signal source in MER and BER measurements, the reference signal from the signal generator must be delayed according to the basic formula in ISDB-T Receiver Delay Calculation.

References

1. ARIB STD-B31 Version 1.5, Transmission System for Digital Terrestrial Television Broadcasting, July 29, 2003.

DTV_ISDBTwoLayReceiver_RF



Description: ISDB-T two-layer RF receiver
Library: DTV, ISDB-T
Class: TSDFDTV_ISDBTwoLayReceiver_RF

Parameters

Name	Description	Default	Unit	Type	Range
RIn	input resistance	DefaultRIn	Ohm	real	(0, ∞)
RTemp	physical temperature, in degrees C	DefaultRTemp	Celsius	real	[-273.15, ∞)
GainImbalance	Gain imbalance, Q vs I	0.0	dB	real	(-∞, ∞)
PhaseImbalance	Phase imbalance, Q vs I	0.0	deg	real	(-∞, ∞)
FCarrier	carrier frequency	611.0MHz	Hz	real	(0, ∞)
Sensitivity	voltage output sensitivity, Vout/Vin	1		real	(-∞, ∞)
Phase	reference phase in degrees	0.0	deg	real	(-∞, ∞)
Mode	transmission mode: Mode 1, Mode 2, Mode 3	Mode 1		enum	
OversamplingOption	oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	
GuardInterval	guard interval (fractional FFT size)	1/32		real	[0, 1]
MappingModeA	signal constellations and mapping for Layer A: A DQPSK, A QPSK, A QAM-16, A QAM-64	A DQPSK		enum	
CodeRateA	convolutional code rate for Layer A: A 1/2, A 2/3, A 3/4, A 5/6, A 7/8	A 1/2		enum	
TimeInterlvA	length of time interleaver for Layer A: A I_000, A I_001, A I_010, A I_011, A I_100	A I_000		enum	
TrunLenA	path memory truncation length of Viterbi decoding algorithm, in bytes	10		int	[5, ∞)
SegmentsA	segments number of Layer A: A Seg 0 is not allowed, A Seg 1, A Seg 2, A Seg 3, A Seg 4, A Seg 5, A Seg 6, A Seg 7, A Seg 8, A Seg 9, A Seg 10, A Seg 11, A Seg 12	A Seg 5		enum	
MappingModeB	signal constellations and mapping for Layer B: B DQPSK, B QPSK, B QAM-16, B QAM-64	B QAM-64		enum	
CodeRateB	convolutional code rate for Layer B: B 1/2, B 2/3, B 3/4, B 5/6, B 7/8	B 7/8		enum	
TimeInterlvB	length of time interleaver for Layer B: B I_000, B I_001, B I_010, B I_011, B I_100	B I_000		enum	
TrunLenB	path memory truncation length of Viterbi decoding algorithm, in bytes	10		int	[5, ∞)
SegmentsB	segments number of Layer B: B Seg 0 is not allowed, B Seg 1, B Seg 2, B Seg 3, B Seg 4, B Seg 5, B Seg 6, B Seg 7, B Seg 8, B Seg 9, B Seg 10, B Seg 11, B Seg 12	B Seg 8		enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	RF	received OFDM signal to be demodulated	timed

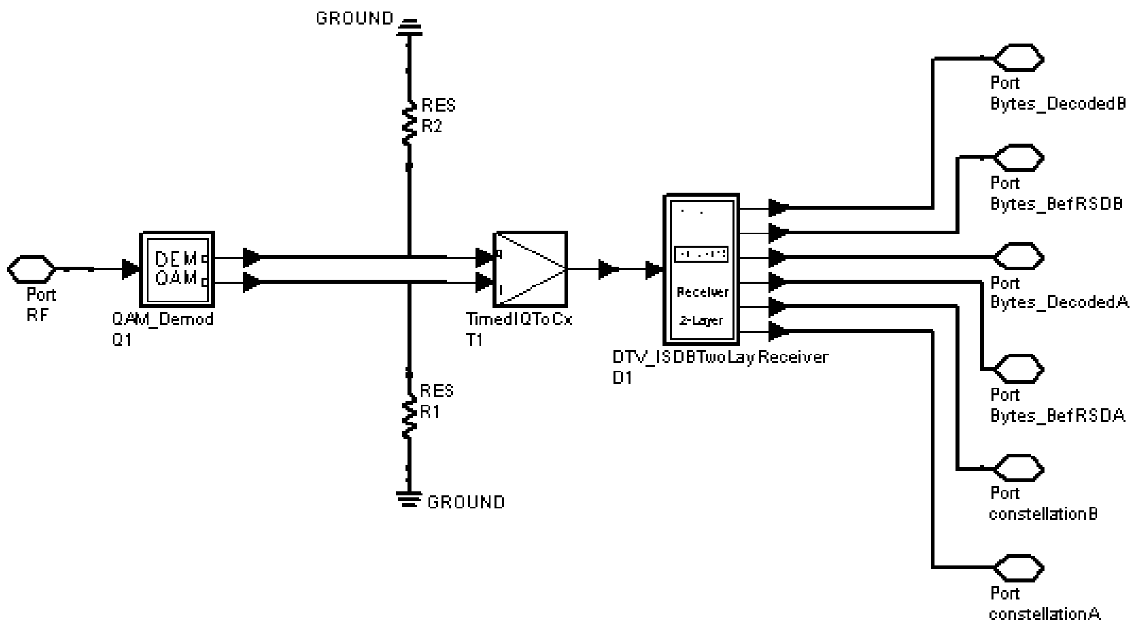
Pin Outputs

Pin	Name	Description	Signal Type
2	constellationA	constellation signal after OFDM demodulation of layer A	complex
3	constellationB	constellation signal after OFDM demodulation of layer B	complex
4	Bytes_BefRSDA	decoded bytes after Viterbi decoder and de-randomizer of layer A	int
5	Bytes_DecodedA	decoded bytes after Reed Solomon decoder of layer A	int
6	Bytes_BefRSDB	decoded bytes after Viterbi decoder and de-randomizer of layer B	int
7	Bytes_DecodedB	decoded bytes after Reed Solomon decoder of layer B	int

Notes/Equations

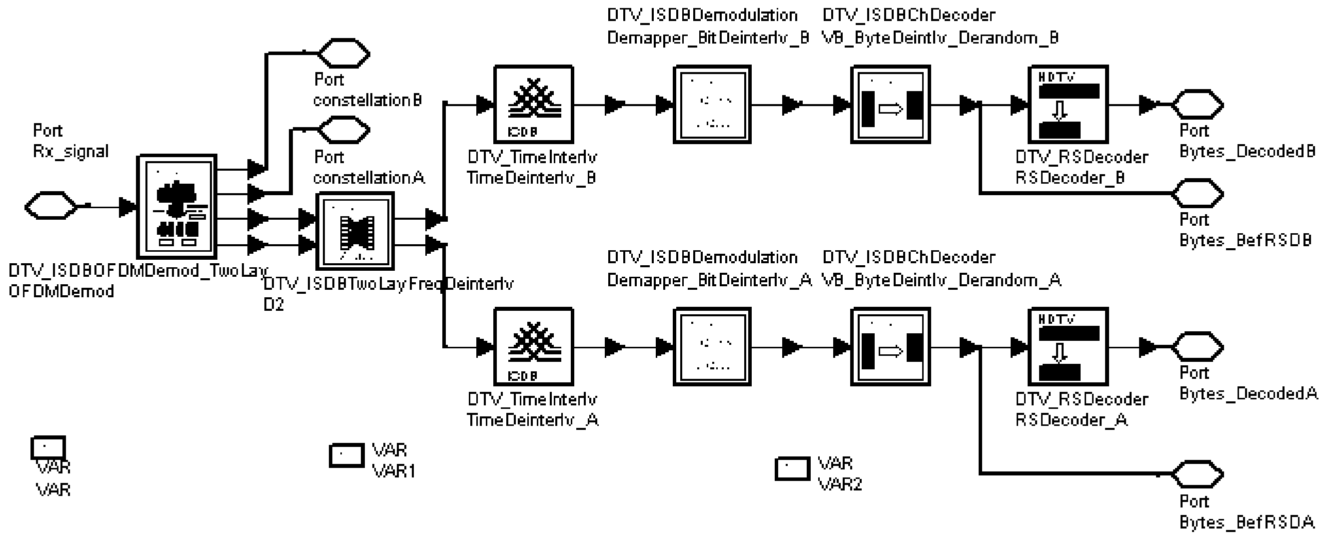
1. This subnetwork model is a 2-layer ISDB-T RF receiver.
   The schematic for this subnetwork is shown below.

DTV_ISDBTwoLayReceiver_RF Schematic



2. The input timed signal is demodulated from RF to baseband and fed to the ISDB-T 2-layer baseband receiver.
3. The input signal starts with the first symbol of an ISDB-T signal frame.
4. The baseband receiver (DTV_ISDBTwoLayReceiver) schematic is shown below.

DTV_ISDBTwoLayReceiver Schematic



5. Baseband Parameter Details

   Mode specifies transmission mode 2K (Mode 1), 4K (Mode 2), or 8K (Mode 3) defined in ISDB-T.

   OversamplingOption specifies the oversampling ratio of transmission signal. Ratios 1, 2, 4, 8, 16, and 32 are supported in this model. For example, if Ratio 2 is selected, FFT size of the demodulator will double; if Ratio 1 is selected no oversampling will be performed.

   GuardInterval specifies the guard interval (also called cyclic extension) length for each symbol, as a fraction (1/32, 1/16, 1/8, or 1/4) of the FFT time period. The value must match the guard interval length actually used in the input signal in order for the demodulation to work properly.

   CodeRateX (X represents A or B) specifies the inner code rate 1/2, 2/3, 3/4, 5/6, or 7/8.

   MappingModeX specifies signal constellation and mapping for DQPSK, QPSK, 16QAM, or 64QAM.

   TimeInterlvX specifies the time domain interleaver type of the signal: I_000, I_001, I_010, I_011, or I_100.

   SegmentsX specifies the number of segments used for each layer. SegmentsA+SegmentsB=13 is required. SegmentsB cannot be 0.

   TrunLenX specifies the truncation length (1×8 bits, 2×8 bits), in bytes, in the Viterbi decoding algorithm.
6. Output Delays
   DTV_ISDBChDecoder consists of Viterbi decoder, byte-wise deinterleaver and derandomizer. Viterbi decoder introduces different delay for different path memory truncation length (parameter TrunLen). For BER measurement, delay synchronization between byte-interleaver and byte deinterleaver is adjusted to a multiple of 12 bytes and the delay between randomizer and derandomizer is adjusted to a multiple of 204 bytes. Here, both delays are adjusted to a multiple of 204 bytes.
   The basic delay calculation of an ISDB-T receiver is shown in Delay Calculation of an

ISDB-T Receiver. Delays for layers A and B are each calculated with their own hierarchical parameters. Assuming MapRate={2, 2, 4, 6}, CodeRateFrac={1/2, 2/3, 3/4, 5/6, 7/8}, then MapRate[MappingMode+1] represents the bit number mapped onto one data carrier, and CodeRateFrac[CodeRate+1] represents the inner coder rate, we get:

Delay Calculation of an ISDB-T Receiver

```
VAR
VAR1
MapRate={2, 2, 4, 6}
CodeRateFrac={1/2, 2/3, 3/4, 5/6, 7/8}
D_OFDMMod=96*Segments*2^Mode
D_TimeInterlvT=if (TimeInterlv==0) then (0) else (96*Segments*204*2^TimeInterlv) endif
D_TimeInterlv=if ((TimeInterlv==1) && (Mode==2)) then (D_TimeInterlvT*2) else (D_TimeInterlvT) endif
D_Modulation= 96*2^Mode*MapRate[MappingMode+1]*2*Segments
D_VB=8*TrunLen
D_ByteInterlv=204*24*CodeRateFrac[CodeRate+1]*MapRate[MappingMode+1]/2*2^Mode*Segments
D_Carrier=D_OFDMMod+D_TimeInterlv
D_AfterVB=(D_Carrier*MapRate[MappingMode+1]+D_Modulation)*CodeRateFrac[CodeRate+1]+D_VB
D_Residual=D_AfterVB/8-204*int(D_AfterVB/8/204)
D_ByteAdjust=if (D_Residual==0) then (0) else (204-D_Residual) endif
D_AfterDerandomize=D_AfterVB/8+D_ByteAdjust+D_ByteInterlv
D_AfterRSDecoder=D_AfterDerandomize*188/204
```

where

D_OFDMMod × 108/96 is the delay between the Constellation pins in DTV_ISDBTwoLaySource DTV_ISDBTwoLayReceiver.

D_AfterDerandomize is the delay between *Bytes_AftRSC* in DTV_ISDBTwoLaySource and *Bytes_BefRSD* in DTV_ISDBTwoLayReceiver.

D_AfterRSDecoder is the delay between pin *Bytes_Uncoded* in DTV_ISDBTwoLaySource and *Bytes_Decoded* in DTV_ISDBTwoLayReceiver.

When connecting the receiver to the signal source in MER and BER measurements, the reference signal from the signal generator must be delayed according to the formula shown in Delay Calculation of an ISDB-T Receiver.

7. RF Parameter Details
GainImbalance and PhaseImbalance add certain impairments to the ideal output RF signal. Impairments are added as described here.
The unimpaired RF I and Q envelope voltages have gain and phase imbalance applied. The RF is given by:

$$V_3(t) = A\left(V_1(t)\cos(\omega_c t) - gV_2(t)\sin\left(\omega_c t + \frac{\phi\pi}{180}\right)\right)$$

where $V_1(t)$ is the in-phase RF envelope, $V_2(t)$ is the quadrature phase RF envelope, g is the gain imbalance

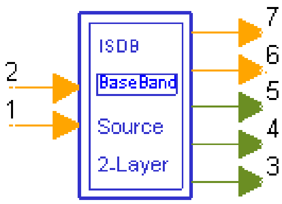
$$g = 10^{\frac{GainImbalance}{20}}$$

and, Φ (in degrees) is the phase imbalance.

References

1. ARIB STD-B31 Version 1.5, *Transmission System for Digital Terrestrial Television Broadcasting*, July 29, 2003.

DTV_ISDBTwoLaySource



Description: ISDB-T two-layer signal source
Library: DTV, ISDB-T
Class: SDFDTV_ISDBTwoLaySource

Parameters

Name	Description	Default	Unit	Type	Range
Mode	transmission mode: Mode 1, Mode 2, Mode 3	Mode 1		enum	
OversamplingOption	oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	
GuardInterval	guard interval (fractional FFT size)	1/32		real	[0, 1]
CodeRateA	convolutional code rate for Layer A: A 1/2, A 2/3, A 3/4, A 5/6, A 7/8	A 1/2		enum	
MappingModeA	signal constellations and mapping for Layer A: A DQPSK, A QPSK, A QAM-16, A QAM-64	A DQPSK		enum	
TimeInterlvA	length of time interleaver for Layer A: A I_000, A I_001, A I_010, A I_011, A I_100	A I_000		enum	
SegmentsA	segments number of Layer A: A Seg 0 is not allowed, A Seg 1, A Seg 2, A Seg 3, A Seg 4, A Seg 5, A Seg 6, A Seg 7, A Seg 8, A Seg 9, A Seg 10, A Seg 11, A Seg 12	A Seg 5		enum	
CodeRateB	convolutional code rate for Layer B: B 1/2, B 2/3, B 3/4, B 5/6, B 7/8	B 7/8		enum	
MappingModeB	signal constellations and mapping for Layer B: B DQPSK, B QPSK, B QAM-16, B QAM-64	B QAM-64		enum	
TimeInterlvB	length of time interleaver for Layer B: B I_000, B I_001, B I_010, B I_011, B I_100	B I_000		enum	
SegmentsB	segments number of Layer B: B Seg 0 is not allowed, B Seg 1, B Seg 2, B Seg 3, B Seg 4, B Seg 5, B Seg 6, B Seg 7, B Seg 8, B Seg 9, B Seg 10, B Seg 11, B Seg 12	B Seg 8		enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	DataA	input data of layer A	int
2	DataB	input data of layer B	int

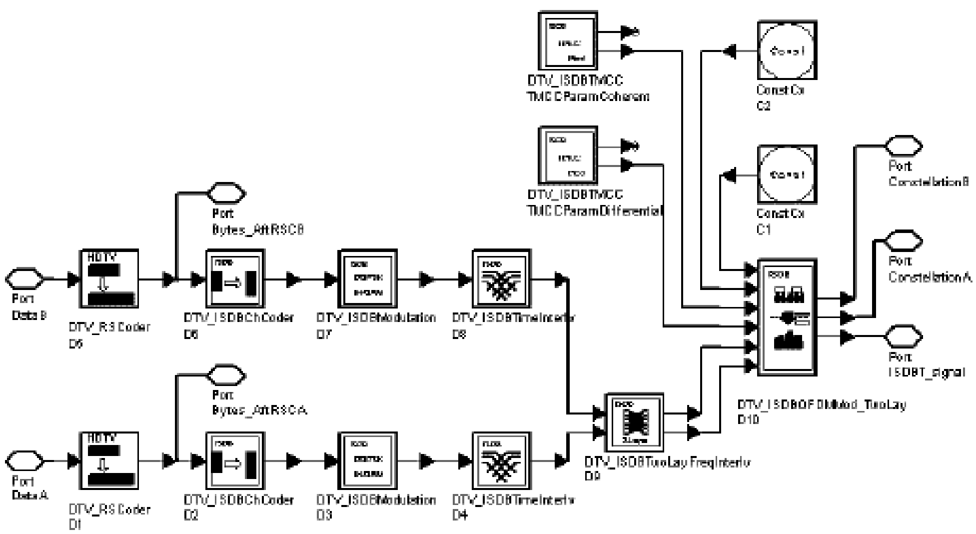
Pin Outputs

Pin	Name	Description	Signal Type
3	ISDBT_signal	ISDB-T two layer base-band signal	complex
4	constellationA	constellation signal of layer A before IFFT	complex
5	constellationB	constellation signal of layer B before IFFT	complex
6	Bytes_AftRSCA	information bytes after RS encoder of layer A	int
7	Bytes_AftRSCB	information bytes after RS encoder of layer B	int

Notes/Equations

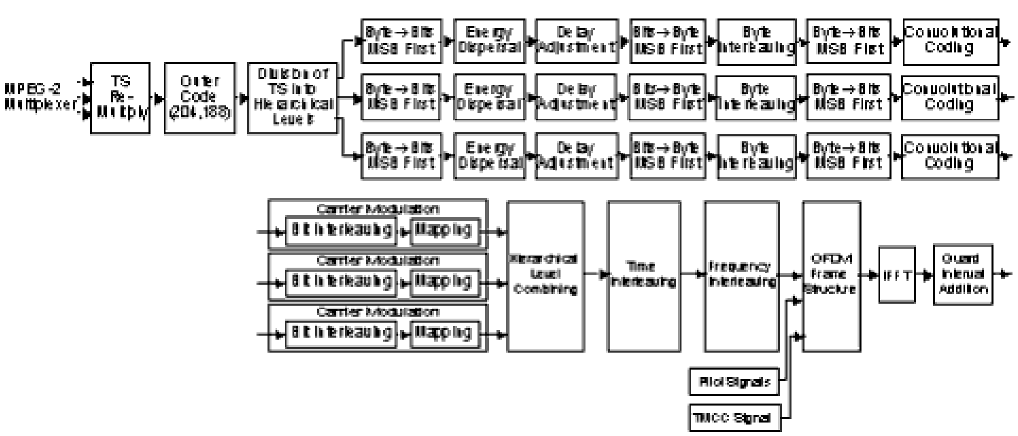
1. This subnetwork model generates a 2-layer ISDB-T baseband signal.
   The schematic for this subnetwork is shown below.

DTV_ISDBTwoLaySource Schematic



2. Input to the subnetwork is a transport stream defined in MPEG-2 Systems.
   The signal format follows the ISDB-T transmission specification. The figure below shows functional block diagram of the ISDB-T baseband system.

ISDB-T Baseband System Functional Block Diagram



3. Auxiliary information AC1 and AC2 are set to bit 0 (same as CP).
4. Parameter Details

   SegmentsA+SegmentsB=13 is required.

   SegmentsB cannot be 0.

   Time interleaving lengths, based on mode, are listed in the table below.

   GuardInterval value is 1/32, 1/16, 1/8 or 1/4 (the ratio of guard interval length to useful symbol length).

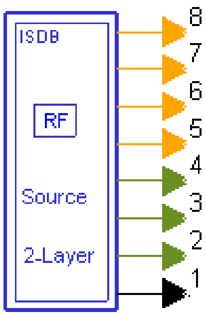
Time Interleaving Length

TimeInterlv	Time Interleaving Length I (Mode 1)	Time Interleaving Length I (Mode 2)	Time Interleaving Length I (Mode 3)
I_000	0	0	0
I_001	4	2	1
I_010	8	4	2
I_011	16	8	4
I_100	32	16	8

References

1. ARIB STD-B31 Version 1.5, *Transmission System for Digital Terrestrial Television Broadcasting*, July 29, 2003.

DTV_ISDBTwoLaySource_RF



Description: ISDB-T two-layer RF signal source
Library: DTV, ISDB-T
Class: TSDFDTV_ISDBTwoLaySource_RF

Parameters

Name	Description	Default	Unit	Type	Range
ROut	output resistance	DefaultROut	Ohm	real	(0, ∞)
RTemp	physical temperature, in degrees C	DefaultRTemp	Celsius	real	[-273.15, ∞)
FCarrier	carrier frequency	611.0MHz	Hz	real	(0, ∞)
Power	modulator output power	40mW	W	real	(0, ∞)
BasicSamplingRate	basic sampling rate	(2048/252.0)MHz	Hz	real	(0, ∞)
MirrorSpectrum	Mirror spectrum about carrier?: NO, YES	NO		enum	
GainImbalance	Gain imbalance, Q vs I	0.0	dB	real	(-∞, ∞)
PhaseImbalance	Phase imbalance, Q vs I	0.0	deg	real	(-∞, ∞)
I_OriginOffset	I origin offset (percent)	0.0		real	(-∞, ∞)
Q_OriginOffset	Q origin offset (percent)	0.0		real	(-∞, ∞)
IQ_Rotation	IQ rotation	0.0	deg	real	(-∞, ∞)
Mode	transmission mode: Mode 1, Mode 2, Mode 3	Mode 1		enum	
OversamplingOption	oversampling ratio option: Ratio 1, Ratio 2, Ratio 4, Ratio 8, Ratio 16, Ratio 32	Ratio 1		enum	
GuardInterval	guard interval (fractional FFT size)	1/32		real	[0, 1]
CodeRateA	convolutional code rate for Layer A: A 1/2, A 2/3, A 3/4, A 5/6, A 7/8	A 1/2		enum	
MappingModeA	signal constellations and mapping for Layer A: A DQPSK, A QPSK, A QAM-16, A QAM-64	A DQPSK		enum	
TimeInterlvA	length of time interleaver for Layer A: A I_000, A I_001, A I_010, A I_011, A I_100	A I_000		enum	
SegmentsA	segments number of Layer A: A Seg 0 is not allowed, A Seg 1, A Seg 2, A Seg 3, A Seg 4, A Seg 5, A Seg 6, A Seg 7, A Seg 8, A Seg 9, A Seg 10, A Seg 11, A Seg 12	A Seg 5		enum	
CodeRateB	convolutional code rate for Layer B: B 1/2, B 2/3, B 3/4, B 5/6, B 7/8	B 7/8		enum	
MappingModeB	signal constellations and mapping for Layer B: B DQPSK, B QPSK, B QAM-16, B QAM-64	B QAM-64		enum	
TimeInterlvB	length of time interleaver for Layer B: B I_000, B I_001, B I_010, B I_011, B I_100	B I_000		enum	
SegmentsB	segments number of Layer B: B Seg 0 is not allowed, B Seg 1, B Seg 2, B Seg 3, B Seg 4, B Seg 5, B Seg 6, B Seg 7, B Seg 8, B Seg 9, B Seg 10, B Seg 11, B Seg 12	B Seg 8		enum	
DataType	payload data type: PN9, PN15, FIX4, _4_1_4_0, _8_1_8_0, _16_1_16_0, _32_1_32_0, _64_1_64_0	PN9		enum	

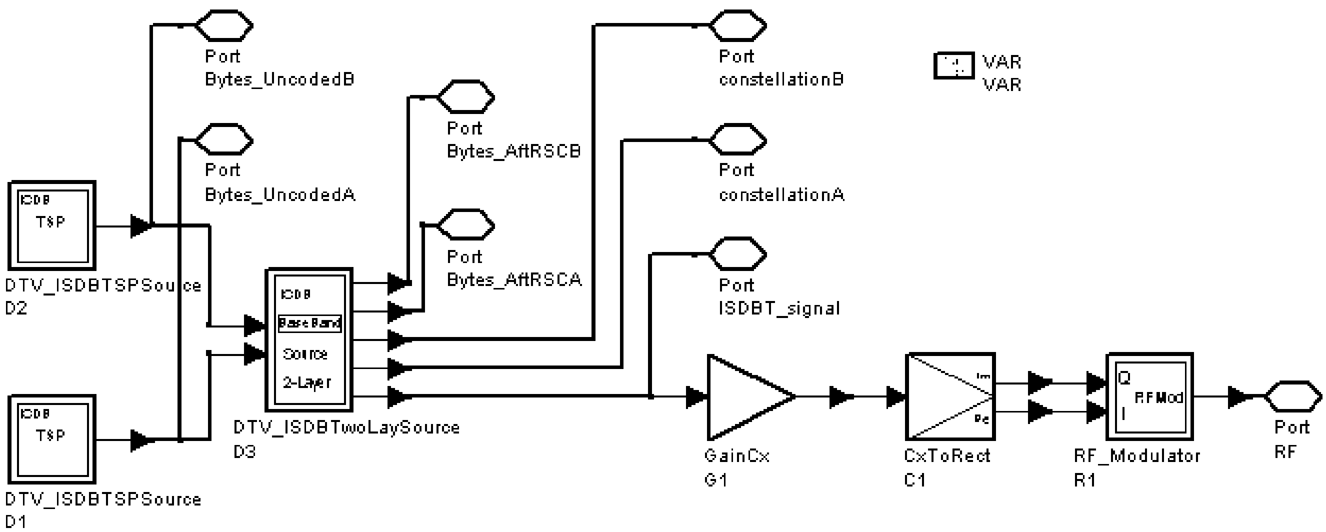
Pin Outputs

Pin	Name	Description	Signal Type
1	RF	RF signal	timed
2	ISDBT_signal	ISDB-T two-layer base-band signal	complex
3	constellationA	constellation signal of layer A before IFFT	complex
4	constellationB	constellation signal of layer B before IFFT	complex
5	Bytes_AftRSCA	information bytes after RS encoder of layer A	int
6	Bytes_UncodedA	information bytes before RS encoder of layer A	int
7	Bytes_AftRSCB	information bytes after RS encoder of layer B	int
8	Bytes_UncodedB	information bytes before RS encoder of layer B	int

Notes/Equations

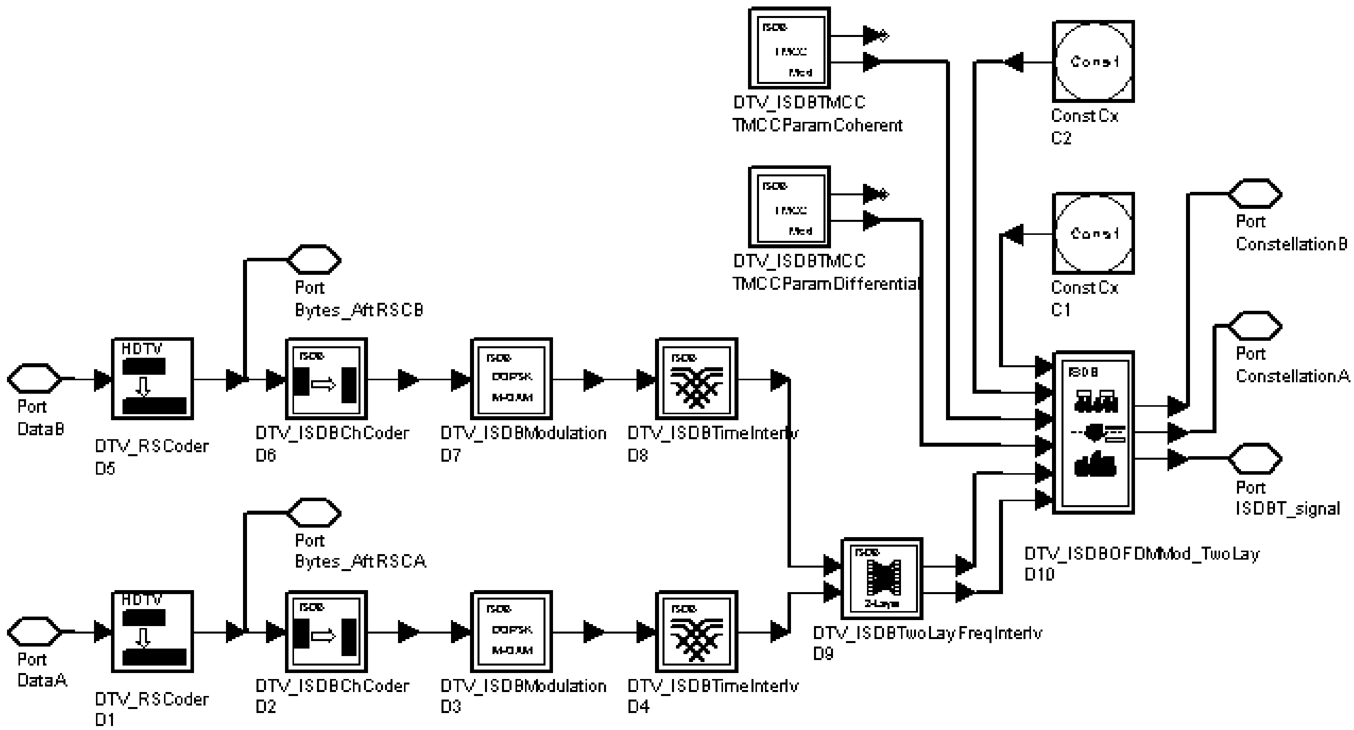
1. This subnetwork model generates a 2-layer ISDB-T RF source signal. The baseband signal of ISDB-T is fed into the RF modulator. RF signal is timed signal after RF modulation.
   The schematic for this subnetwork is shown below.

DTV_ISDBTwoLaySource_RF Schematic



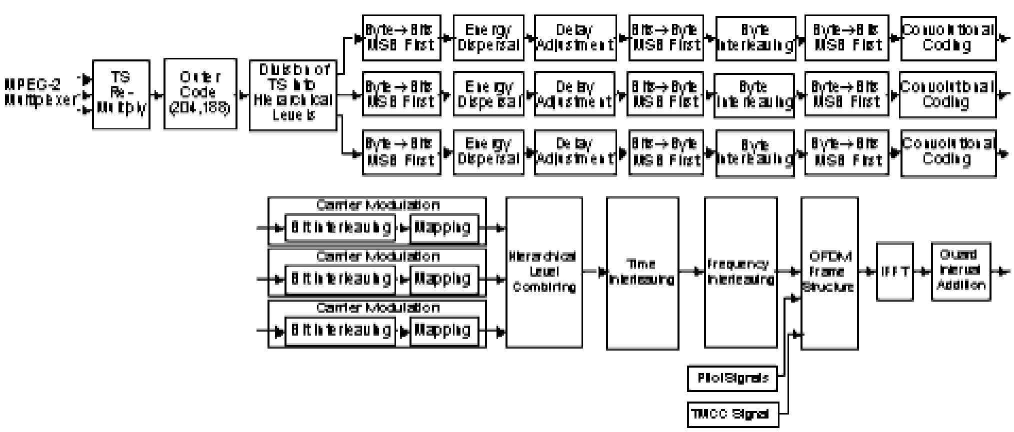
2. The 2-layer ISDB-T baseband signal source format is based on ISDB-T specifications. The schematic for DTV_ISDBTwoLaySource is shown below.

DTV_ISDBTwoLaySource Schematic



3. The ISDB-T baseband system functional block diagram is shown below.

Baseband System Functional Block Diagram



4. Herein auxiliary information AC1 and AC2 are set to 0 bits (same as CP).
5. Parameter Details
   - *FCarrier* defines the RF frequency for the ISDB signal.
   - *Power* defines the power level for FCarrier.
   - *BasicSamplingRate* specifies the basic sampling rate.
   - The *MirrorSpectrum* is used to conjugate the input signal (when set to YES) before any other processing is done.
   - The *GainImbalance*, *PhaseImbalance*, *I_OriginOffset*, *Q_OriginOffset*, and *IQ_Rotation* parameters are used to add certain impairments to the ideal output RF signal. Impairments are added as described here.

     The unimpaired RF I and Q envelope voltages have gain and phase imbalance applied. The RF is given by:

$$V_3(t) = A\left(V_1(t)\cos(\omega_c t) - gV_2(t)\sin\left(\omega_c t + \frac{\phi\pi}{180}\right)\right)$$

where *A* is a scaling factor that depends on the Power and ROut parameters specified by the user, $V_1(t)$ is the in-phase RF envelope, $V_2(t)$ is the quadrature phase RF envelope, *g* is the gain imbalance

$$g = 10^{\frac{GainImbalance}{20}}$$

and, Φ (in degrees) is the phase imbalance.
Next, the signal $V_3(t)$ is rotated by IQ_Rotation degrees.

I_OriginOffset and Q_OriginOffset are then applied to the rotated signal. Note that the amounts specified are percentages with respect to the output rms voltage. The output rms voltage is given by sqrt(2×ROut×Power). Mode is used to select transmission mode of 1, 2, or 3 defined in ISDB-T.

- *OversamplingOption* specifies the oversampling ratio of transmission signal. Oversampling ratios 1, 2, 4, 8, 16, 32 are supported in this source.
- *GuardInterval* specifies the guard interval (also called cyclic extension) length for each symbol, as a fraction (1/32, 1/16, 1/8, or 1/4) of the FFT time period. The value must match the guard interval length actually used in the input signal in order for the demodulation to work properly.
- *CodeRateX* (where *X* represents *A* or *B*) specifies the inner code rate 1/2, 2/3, 3/4, 5/6, or 7/8.
- *MappingModeX* specifies signal constellation and mapping for DQPSK, QPSK, 16QAM, or 64QAM.
- Time interleaving lengths are given in in the table below.

Time Interleaving Lengths

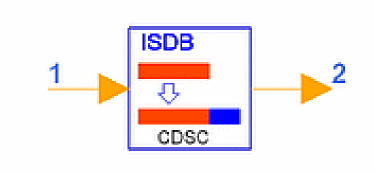
TimeInterlv	Time Interleaving Length		
	Mode 1	**Mode 2**	**Mode 3**
I_000	0	0	0
I_001	4	2	1
I_010	8	4	2
I_011	16	8	4
I_100	32	16	8

- *SegmentsX* specifies the number of segments. SegmentsA+SegmentsB=13 is required. SegmentsB cannot be 0.

References

1. ARIB STD-B31 Version 1.5, *Transmission System for Digital Terrestrial Television Broadcasting*, July 29, 2003.

DTV_LFSRCoder



Description: LFSR cyclic coder
Library: DTV, ISDB-T
Class: SDFDTV_LFSRCoder

Parameters

Name	Description	Default	Unit	Type	Range
Code	length of code bits	184		int	(0, ∞)
Info	length of information bits	102		int	(0, ∞)
Polynomial	generation polynomial's suffix ($X^{P[0]} + X^{P[1]} + \dots X^{P[m]}$)	0 4 10 18 22 24 34 36 40 48 52 56 66 67 71 76 77 82		int array	[0, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	input	signal to be encoded	int

Pin Outputs

Pin	Name	Description	Signal Type
2	output	error protected signal	int

Notes/Equations

1. This model performs cyclic coding over the input signal.
2. Cyclic codes are linear block codes with an important additional property: *a cyclic, or end-around, shift of any codeword is also a codeword*. Algebraically, the codewords constitute a group under the cyclic shift operation.
   If $C = (c_0, c_1, \dots, c_{n-1})$ denotes a codeword with elements in *GF(q)*, we associate with it a polynomial over *GF(q)* of degree at most n−1:
   $$c(x) = c_0 + c_1x + c_2x^2 + \dots + c_{n-1}x^{n-1}$$
   Note the coefficients of the polynomial are in *GF(q)*. Now consider a one-position right cyclic shift of C, producing
   $$C^{(1)} = (c_{n-1}, c_0, \dots, c_{n-2})$$
   The associated polynomial would be
   $$c^{(1)}(x) = c_{n-1} + c_0x + c_1x^2 + \dots + c_{n-2}x^{n-1}$$
   which is another polynomial of degree at most *n-1*.
   Polynomials *c(x)* and $c^{(1)}(x)$ are related by
   $$c^{(1)}(x) = xc(x) mod(x^n - 1)$$

Now suppose that we are given a particular cyclic *(n,k)* code over *GF(q)*. We define the generator polynomial *g(x)* of the cyclic code as the mnemonic polynomial of minimum degree among the set of nonzero codeword polynomials. We assume that the degree of this polynomial is $r \le n-1$ and write

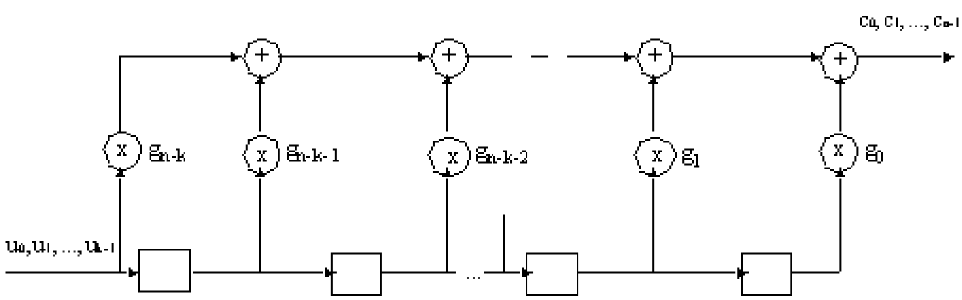
$$g(x) = g_0 + g_1 x + g_2 x^2 + \ldots + g_{n-1} x^{n-1}$$

where again the coefficients are members of *GF(q)*.
Two fundamental properties of cyclic codes are:

> *Property 1*. *c(x)* is a code polynomial if *c(x)=u(x)g(x)*, where *u(x)* is of degree *n-1-r* or less.
>
> *Property 2*. *g(x)* generates an *(n,k)* cyclic code if *g(x)* is of degree *n-k* and is a factor of $x^n - 1$.

Property 1 of cyclic codes suggests one implementation of an encoder: performing the computation of *c(x)=u(x)g(x)*. Such an encoding system is shown in Non-Systematic Encoder for Cyclic Code and is nothing more than a digital transversal filter over *GF(q)* that convolves the information sequence $u_{k-1}, \ldots, u_0$ with the impulse response $g_{n-k}, g_{n-k-1}, \ldots, g_0$.

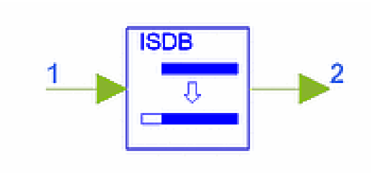
Non-Systematic Encoder for Cyclic Code



References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.
2. W. Xinmei and X. Guozhen, *Error Correcting Codes: Theory and Application*, Xidian University Press, P.R.China, 1991.

DTV_LoadIFFTBuff



Description: Layer data stream loader into IFFT buffer with transmission spectrum adjustment for ISDB-T
Library: DTV, ISDB-T
Class: SDFDTV_LoadIFFTBuff

Parameters

Name	Description	Default	Unit	Type	Range
Carriers	number of carriers in one segment	432		int	108 for mode 1; 216 for mode 2; 432 for mode 3
Segments	number of segments	13		int	[1, 13]
InSequence	segment sequence at input	0 1 2 3 4 5 6 7 8 9 10 11 12		int array	"0,1,... ,Segments-1" †
OutSequence	segment sequence at output	11 9 7 5 3 1 0 2 4 6 8 10 12		int array	"... ,1,0,2,..." ††
Order	IFFT points=2^Order	13		int	[1, ∞) †††

† The InSequence value is [0, Segments-1]. According to ISDB-T, InSequence is "0, 1, 2, ... , Segments-1" after Segments is determined.
†† The OutSequence value is [0, Segments-1]. According to ISDB-T, OutSequence is "...,1,0,2,..." after Segments is determined. For example, if Segments=5, OutSequence is "3,1,0,2,4"; if Segments=10, OutSequence is "9,7,5,3,1,0,2,4,6,8".
††† Order is the order of FFT. It must satisfy $2^{Order} \geq$ Carriers * Segments

Pin Inputs

Pin	Name	Description	Signal Type
1	input	received segments signal	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	output	IFFT input signal with spectrum change and zero padded	complex

Notes/Equations

1. This model loads the adjusted data segments into the IFFT buffer with transmission spectrum adjustment for ISDB-T.
2. The input data segment order is adjusted in order to change its transmission spectrum. The input segment is changed into the output segment; the changed segments are placed in the IFFT buffer by zero padded in the center of the buffer.

Assume *x(0)*, *x(1)*, ... , *x(N-1)* are the signal of the changed segments, where
$N = Length \times Segments + 1$
$M = 2^{FFTStage}$
y(0), *y(1)*, ... , *y(M-1)*
are the outputs of the model. Data loading is performed as follows:

$$y(i) = x\left(\frac{N}{2} + i\right) \qquad i = 0, \ldots, \frac{N+1}{2} - 1$$

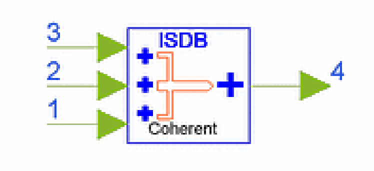
$$y(i) = 0 \qquad i = \frac{N+1}{2}, \ldots, M - \frac{N}{2} - 1$$

$$y(i) = x\left(i - M + \frac{N}{2}\right) \qquad i = M - \frac{N}{2}, \ldots, M$$

References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.

DTV_MuxCohSegs



Description: ISDB-T multiplex coherent segments
Library: DTV, ISDB-T
Class: SDFDTV_MuxCohSegs

Parameters

Name	Description	Default	Unit	Type	Range
Carriers	number of carriers in one segment	432		int	108 for mode 1; 216 for mode 2; 432 for mode 3
Segments	number of segments	1		int	[1, 13]
Start_Seg	initial number of segment (0 to Segments-1)	0		int	[0, 12]
SPnumber	number of scattered pilots in each segment	36		int	[0, ∞) †
SPperiod	distance in carriers between nearby scattered pilots	12		int	(0, ∞) ††
SPstart	start position of scattered pilots in carriers	0		int	[0, ∞) ††
SPoffset	offset value of SPstart in each symbol	3		int	[0, ∞) ††
SPphase	initial phase of scattered pilots	0		int	[0, SPperiod/SPoffset-1]

† SPnumber=9 for mode 1, 18 for mode 2, 36 for mode 3, per segment in ISDB-T systems.
†† SPperiod=12, SPstart=0, SPoffset=3 in ISDB-T systems.

Pin Inputs

Pin	Name	Description	Signal Type
1	data	TSP data iuput	complex
2	TMCC	TMCC data input	complex
3	AC	AC data input	complex

Pin Outputs

Pin	Name	Description	Signal Type
4	output	coherent segments data	complex

Notes/Equations

1. This model multiplexes TSP (transport stream packet) data, TMCC (transmission and multiplexing configuration control) data, and AC (auxiliary channel) data into the coherent modulation OFDM segments (such as QPSK, 16-QAM, and 64-QAM modulation) according to Structure of OFDM Segment for Coherent Modulation and Carrier Allocation of AC and TMCC for Coherent Modulation.

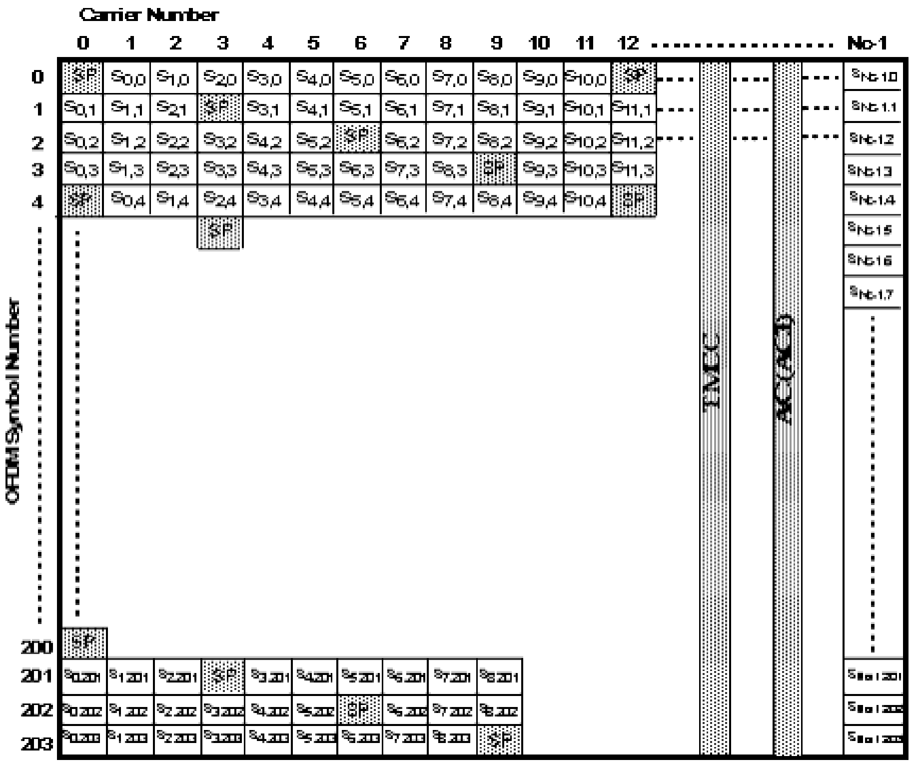
2. IntState of Carriers determines the number of TMCC and AC in each segment. Then, IntState of Start_Seg and Segments determines the TMCC and AC positions in each corresponding segment according to Carrier Allocation of AC and TMCC for Coherent Modulation.
   The PRBS sequences in each segment are generated according to Generation of PRBS Sequence and the initial sets of PRBS register in Initial Sets of PRBS Register. The PRBS in initialized so that the first output bit from the PRBS coincides with the first active carrier. A new value is generated by the PRBS on every used carriers in each segment (whether or not it is a pilot).
   Positions of corresponding scattered pilots are generated as follows. For symbol of index l (ranging from 0 to 203), carriers for which index k belongs to subset
   $\{k = 3 \times l \ mod \ \ 4 + 12p | p \ \ integer, p \geq 0, k \in [0, Length \times Segments]\}$
   are scattered pilots positions. Scattered pilots positions are controlled by

   SPnumber, which determines the number of scattered pilots in each segment, is: 9 in mode 1 (Length=108), 18 in mode 2 (Length=216), or 36 in mode 3 (Length=432).

   SPperiod=12, SPstart=0, SPoffset=3 in all three modes according to ISDB-T.

   After determining TMCC, AC, and SP positions in each corresponding segment and the value of the PRBS sequence in all active carriers in each segment, TMCC, AC, and TSP data are multiplexed into the coherent segments. According to the TMCC position and the PRBS sequence, one TMCC bit is output in every TMCC position.
   $x[TMCCposition[l]] = PilotValue[TMCCposition[l]] \times TMCC$
   where *NTMCC* is the number of TMCCs in one segment; *PilotValue* is the PRBS sequence in the corresponding segment; *x[i]* is segment data.
   AC data is:
   $x[ACposition[i]] = PilotValue[ACposition[i]] \times AC[i]$
   Except for AC, TMCC, and SP positions, the remaining positions in one segment are TSP data positions.
   $x[i] = data[i]$

Structure of OFDM Segment for Coherent Modulation

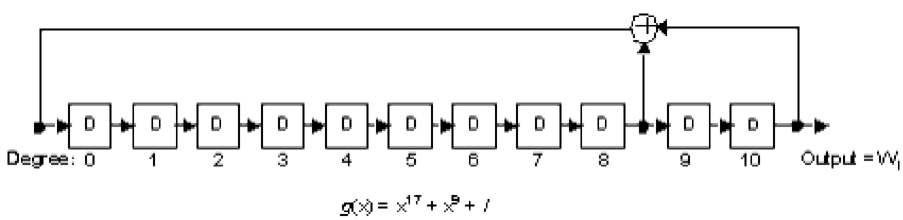


$S_{i,j,k}$ denotes complex data in the data segment after time and frequency interleaving.
Nc=108 for Mode1; 216 for Mode2; 432 for Mode 3

Carrier Allocation of AC and TMCC for Coherent Modulation

Segment	11	9	7	5	3	1	0	2	4	6	8	10	12
Mode 1													
AC1_1	10	53	61	11	20	74	35	76	4	40	8	7	98
AC1_2	28	83	100	101	40	100	79	97	89	89	64	89	101
TMCC_1	70	25	17	86	44	47	49	31	83	61	85	101	23
Mode 2													
AC1_1	10	61	20	35	4	8	98	53	11	74	76	40	7
AC1_2	28	100	40	79	89	64	101	83	101	100	97	89	89
AC1_3	161	119	182	184	148	115	118	169	128	143	112	116	206
AC1_4	191	209	208	205	197	197	136	208	148	187	197	172	209
TMCC_1	70	17	44	49	83	85	23	25	86	47	31	61	101
TMCC_2	133	194	155	139	169	209	178	125	152	157	191	193	131
Mode 3													
AC1_1	10	20	4	98	11	76	7	61	35	8	53	74	40
AC1_2	28	40	89	101	101	97	89	100	79	64	83	100	89
AC1_3	161	182	148	118	128	112	206	119	184	115	169	143	116
AC1_4	191	208	197	136	148	197	209	209	205	197	208	187	172
AC1_5	277	251	224	269	290	256	226	236	220	314	227	292	223
AC1_6	316	295	280	299	316	305	244	256	305	317	317	313	305
AC1_7	335	400	331	385	359	332	377	398	364	334	344	328	422
AC1_8	425	421	413	424	403	388	407	424	413	352	364	413	425
TMCC_1	70	44	83	23	86	31	101	17	49	85	25	47	61
TMCC_2	131	155	169	178	152	191	131	194	139	209	125	157	193
TMCC_3	233	265	301	241	263	277	286	260	299	239	302	247	317
TMCC_4	410	355	425	341	373	409	349	371	385	394	368	407	347

Generation of PRBS Sequence



Initial Sets of PRBS Register

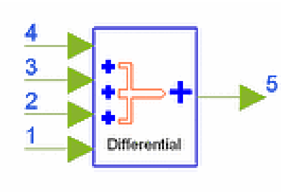
Segment Number	Initial Sets for Mode 1 †	Initial Sets for Mode 2 †	Initial Sets for Mode 3 †
11	1 1 1 1 1 1 1 1 1 1 1	1 1 1 1 1 1 1 1 1 1 1	1 1 1 1 1 1 1 1 1 1 1
9	1 1 0 1 1 0 0 1 1 1 1	0 1 1 0 1 0 1 1 1 1 0	1 1 0 1 1 1 0 0 1 0 1
7	0 1 1 0 1 0 1 1 1 1 0	1 1 0 1 1 1 0 0 1 0 1	1 0 0 1 0 1 0 0 0 0 0
5	0 1 0 0 0 1 0 1 1 1 0	1 1 0 0 1 0 0 0 0 1 0	0 1 1 1 0 0 0 1 0 0 1
3	1 1 0 1 1 1 0 0 1 0 1	1 0 0 1 0 1 0 0 0 0 0	0 0 1 0 0 0 1 1 0 0 1
1	0 0 1 0 1 1 1 1 0 1 0	0 0 0 0 1 0 1 1 0 0 0	1 1 1 0 0 1 1 0 1 1 0
0	1 1 0 0 1 0 0 0 0 1 0	0 1 1 1 0 0 0 1 0 0 1	0 0 1 0 0 0 0 1 0 1 1
2	0 0 0 1 0 0 0 0 1 0 0	0 0 0 0 0 1 0 0 1 0 0	1 1 1 0 0 1 1 1 1 0 1
4	1 0 0 1 0 1 0 0 0 0 0	0 0 1 0 0 0 1 1 0 0 1	0 1 1 0 1 0 1 0 0 1 1
6	1 1 1 1 0 1 1 0 0 0 0	0 1 1 0 0 1 1 1 0 0 1	1 0 1 1 1 0 1 0 0 1 0
8	0 0 0 0 1 0 1 1 0 0 0	1 1 1 0 0 1 1 0 1 1 0	0 1 1 0 0 0 1 0 0 1 0
10	1 0 1 0 0 1 0 0 1 1 1	0 0 1 0 1 0 1 0 0 0 1	1 1 1 1 0 1 0 0 1 0 1
12	0 1 1 1 0 0 0 1 0 0 1	0 0 1 0 0 0 0 1 0 1 1	0 0 0 1 0 0 1 1 1 0 0

† Degree from 0 to 10 in Generation of PRBS Sequence.

References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.

DTV_MuxDiffSegs



Description: ISDB-T multiplex differential segments
Library: DTV, ISDB-T
Class: SDFDTV_MuxDiffSegs

Parameters

Name	Description	Default	Unit	Type	Range
Carriers	number of carriers in one segment	432		int	108 for mode 1; 216 for mode 2; 432 for mode 3
Segments	number of segments	1		int	[1, 13]
Start_Seg	initial number of segment (0 to Segments-1)	0		int	[0, 12]

Pin Inputs

Pin	Name	Description	Signal Type
1	data	TSP data input	complex
2	TMCC	TMCC data input	complex
3	AC1	AC1 data input	complex
4	AC2	AC2 data input	complex

Pin Outputs

Pin	Name	Description	Signal Type
5	output	differential segments data output	complex

Notes/Equations

1. This model multiplexes TSP (transport stream packet), TMCC (transmission and multiplexing configuration control), AC1 (auxiliary channel 1), and AC2 (auxiliary channel 2) data into the differential modulation OFDM segments according to Structure of OFDM Segment for Differential Modulation and Carrier Allocation of CP, AC, and TMCC for Differential Modulation.
2. IntState of Length determines the number of TMCC, AC1, and AC2 in each segment. IntState of Start_Seg and Segments determine the TMCC, AC1, and AC2 positions in each corresponding segment according to Carrier Allocation of CP, AC, and TMCC for Differential Modulation.
   The PRBS sequences in each segment are generated according to Generation of PRBS Sequence and the initial sets of PRBS register in Initial Sets of PRBS Register. The PRBS in initialized so that the first output bit from the PRBS coincides with the first active carrier. A new value is generated by the PRBS on every carrier used in each

segment (whether or not it is a pilot).
After determining all TMCC, AC1, and AC2 positions in each corresponding segment and the value of the PRBS sequence in all the active carriers in each segment, TMCC, AC1, AC2, and TSP data are multiplexed into differential segments.

$$x[TMCCposition[l]] = PilotValue[TMCCposition[l]] \times TMCC$$

where *NTMCC* is the number of TMCC in one segment; *PilotValue* is the PRBS sequence in corresponding segment; *x[i]* is the output segment data.
The output of the input AC1 data is:

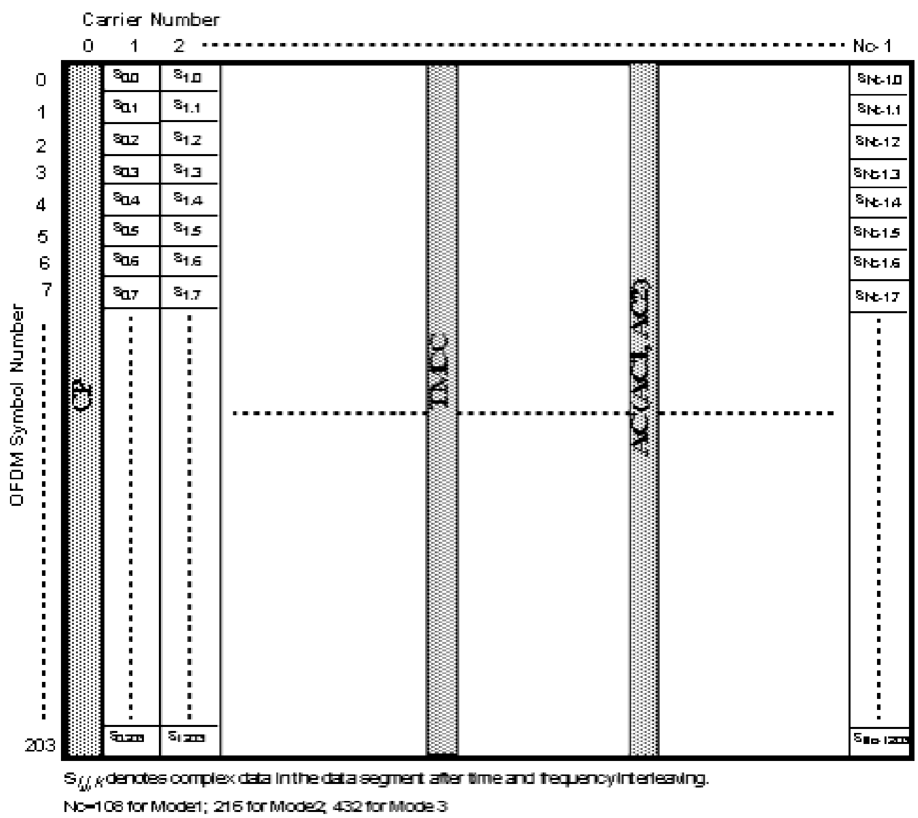
$$x[AC1position[i]] = PilotValue[AC1position[i]] \times AC1[i]$$

AC2 data is:

$$x[AC2position[i]] = PilotValue[AC2position[i]] \times AC2[i]$$

Except for the AC1, AC2, and TMCC data positions, the remaining positions in one segment are the TSP data positions.
x[i] = data[i]

Structure of OFDM Segment for Differential Modulation



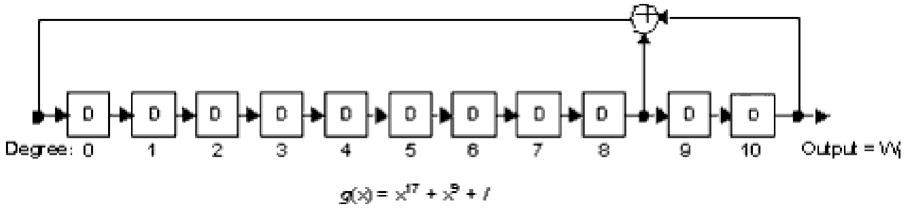
Carrier Allocation of CP, AC, and TMCC for Differential Modulation

Segment	11	9	7	5	3	1	0	2	4	6	8	10	12
Mode 1													
CP	0	0	0	0	0	0	0	0	0	0	0	0	0
AC1_1	10	53	61	11	20	74	35	76	4	40	8	7	98

AC1_2	28	83	100	101	40	100	79	97	89	89	64	89	101
AC2_1	3	3	29	28	23	30	3	5	13	72	36	25	10
AC2_2	45	15	41	45	63	81	72	18	93	95	48	30	30
AC2_3	59	40	84	81	85	92	85	57	98	100	52	42	55
AC2_4	77	58	93	91	105	103	89	92	102	105	74	104	81
TMCC_1	13	25	4	36	10	7	49	31	16	5	78	34	23
TMCC_2	50	63	7	48	28	25	61	39	30	10	82	48	37
TMCC_3	70	73	17	55	44	47	96	47	37	21	85	54	51
TMCC_4	83	80	51	59	47	60	99	65	74	44	98	70	68
TMCC_5	87	93	71	86	54	87	104	72	83	61	102	101	105
Mode 2													
CP	0	0	0	0	0	0	0	0	0	0	0	0	0
AC1_1	10	61	20	35	4	8	98	53	11	74	76	40	7
AC1_2	28	100	40	79	89	64	101	83	101	100	97	89	89
AC1_3	161	119	182	184	148	115	118	169	128	143	112	116	206
AC1_4	191	209	208	205	197	197	136	208	148	187	197	172	209
AC2_1	3	29	23	3	13	36	10	3	28	30	5	72	25
AC2_2	45	41	63	72	93	48	30	15	45	81	18	95	30
AC2_3	59	84	85	85	98	52	55	40	81	92	57	100	42
AC2_4	77	93	105	89	102	74	81	58	91	103	92	105	104
AC2_5	108	108	108	108	108	108	108	108	108	108	108	108	108
AC2_6	111	136	138	113	180	133	111	137	131	111	121	144	118
AC2_7	123	153	189	126	203	138	153	149	171	180	201	156	138
AC2_8	148	189	200	165	208	150	167	192	193	193	206	160	163
AC2_9	166	199	211	200	213	212	185	201	213	197	210	182	189
TMCC_1	13	4	10	49	16	78	23	25	36	7	31	5	34
TMCC_2	50	7	28	61	30	82	37	63	48	25	39	10	48
TMCC_3	70	17	44	96	37	85	51	73	55	47	47	21	54
TMCC_4	83	51	47	99	74	98	68	80	59	60	65	44	70
TMCC_5	87	71	54	104	83	102	105	93	86	87	72	61	101
TMCC_6	133	144	115	139	113	142	121	112	118	157	124	186	131
TMCC_7	171	156	133	147	118	156	158	115	136	169	138	190	145
TMCC_8	181	163	155	155	129	162	178	125	152	204	145	193	159
TMCC_9	188	167	168	173	152	178	191	159	155	207	182	206	176
TMCC_10	201	194	195	180	169	209	195	179	162	212	191	210	213
Mode 3													
CP	0	0	0	0	0	0	0	0	0	0	0	0	0
AC1_1	10	20	4	98	11	76	7	61	35	8	53	74	40
AC1_2	28	40	89	101	101	97	89	100	79	64	83	100	89
AC1_3	161	182	148	118	128	112	206	119	184	115	169	143	116
AC1_4	191	208	197	136	148	197	209	209	205	197	208	187	172
AC1_5	277	251	224	269	290	256	226	236	220	314	227	292	223

AC1_6	316	295	280	299	316	305	244	256	305	317	317	313	305
AC1_7	335	400	331	385	359	332	377	398	364	334	344	328	422
AC1_8	425	421	413	424	403	388	407	424	413	352	364	413	425
AC2_1	3	23	13	10	28	5	25	29	3	36	3	30	72
AC2_2	45	63	93	30	45	18	30	41	72	48	15	81	95
AC2_3	59	85	98	55	81	57	42	84	85	52	40	92	100
AC2_4	77	105	102	81	91	92	104	93	89	74	58	103	105
AC2_5	108	108	108	108	108	108	108	108	108	108	108	108	108
AC2_6	111	138	180	111	131	121	118	136	113	133	137	111	144
AC2_7	123	189	203	153	171	201	138	153	126	138	149	180	156
AC2_8	148	200	208	167	193	206	163	189	165	150	192	193	160
AC2_9	166	211	213	185	213	210	189	199	200	212	201	197	182
AC2_10	216	216	216	216	216	216	216	216	216	216	216	216	216
AC2_11	245	219	252	219	246	288	219	239	229	226	244	221	241
AC2_12	257	288	264	231	297	311	261	279	309	246	261	234	246
AC2_13	300	301	268	256	308	316	275	301	314	271	297	273	258
AC2_14	309	305	290	274	319	321	293	321	318	297	307	308	320
AC2_15	324	324	324	324	324	324	324	324	324	324	324	324	324
AC2_16	352	329	349	353	327	360	327	354	396	327	347	337	334
AC2_17	369	342	354	365	396	372	339	405	419	369	387	417	354
AC2_18	405	381	366	408	409	376	364	416	424	383	409	422	379
AC2_19	415	416	428	417	413	398	382	427	429	401	429	426	405
TMCC_1	13	10	16	23	36	31	34	4	49	78	25	7	5
TMCC_2	50	28	30	37	48	39	48	7	61	82	63	25	10
TMCC_3	70	44	37	51	55	47	54	17	96	85	73	47	21
TMCC_4	83	47	74	68	59	65	70	51	99	98	80	60	44
TMCC_5	87	54	83	105	86	72	101	71	104	102	93	87	61
TMCC_6	133	115	113	121	118	124	131	144	139	142	112	157	186
TMCC_7	171	133	118	158	136	138	145	156	147	156	115	169	190
TMCC_8	181	155	129	178	152	145	159	163	155	162	125	204	193
TMCC_9	188	168	152	191	155	182	176	167	173	178	159	207	206
TMCC_10	201	195	169	195	162	191	213	194	180	209	179	212	210
TMCC_11	220	265	294	241	223	221	229	226	232	239	252	247	250
TMCC_12	223	277	298	279	241	226	266	244	246	253	264	255	264
TMCC_13	233	312	301	289	263	237	286	260	253	267	271	263	270
TMCC_14	267	315	314	296	276	260	299	263	290	284	275	281	286
TMCC_15	287	320	318	309	303	277	303	270	299	321	302	288	317
TMCC_16	360	355	358	328	373	402	349	331	329	337	334	340	347
TMCC_17	372	363	372	331	385	406	387	349	334	374	352	354	361
TMCC_18	379	371	378	341	420	409	397	371	345	394	368	361	375
TMCC_19	383	389	394	375	423	422	404	384	368	407	371	398	392
TMCC_20	410	396	425	395	428	426	417	411	385	411	378	407	429

Generation of PRBS Sequence



Initial Sets of PRBS Register

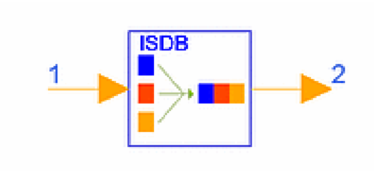
Segment	Initial Sets for Mode 1 †	Initial Sets for Mode 2†	Initial Sets for Mode 3†
11	1 1 1 1 1 1 1 1 1 1 1	1 1 1 1 1 1 1 1 1 1 1	1 1 1 1 1 1 1 1 1 1 1
9	1 1 0 1 1 0 0 1 1 1 1	0 1 1 0 1 0 1 1 1 1 0	1 1 0 1 1 1 0 0 1 0 1
7	0 1 1 0 1 0 1 1 1 1 0	1 1 0 1 1 1 0 0 1 0 1	1 0 0 1 0 1 0 0 0 0 0
5	0 1 0 0 0 1 0 1 1 1 0	1 1 0 0 1 0 0 0 0 1 0	0 1 1 1 0 0 0 1 0 0 1
3	1 1 0 1 1 1 0 0 1 0 1	1 0 0 1 0 1 0 0 0 0 0	0 0 1 0 0 0 1 1 0 0 1
1	0 0 1 0 1 1 1 1 0 1 0	0 0 0 0 1 0 1 1 0 0 0	1 1 1 0 0 1 1 0 1 1 0
0	1 1 0 0 1 0 0 0 0 1 0	0 1 1 1 0 0 0 1 0 0 1	0 0 1 0 0 0 0 1 0 1 1
2	0 0 0 1 0 0 0 0 1 0 0	0 0 0 0 0 1 0 0 1 0 0	1 1 1 0 0 1 1 1 1 0 1
4	1 0 0 1 0 1 0 0 0 0 0	0 0 1 0 0 0 1 1 0 0 1	0 1 1 0 1 0 1 0 0 1 1
6	1 1 1 1 0 1 1 0 0 0 0	0 1 1 0 0 1 1 1 0 0 1	1 0 1 1 1 0 1 0 0 1 0
8	0 0 0 0 1 0 1 1 0 0 0	1 1 1 0 0 1 1 0 1 1 0	0 1 1 0 0 0 1 0 0 1 0
10	1 0 1 0 0 1 0 0 1 1 1	0 0 1 0 1 0 1 0 0 0 1	1 1 1 1 0 1 0 0 1 0 1
12	0 1 1 1 0 0 0 1 0 0 1	0 0 1 0 0 0 0 1 0 1 1	0 0 0 1 0 0 1 1 1 0 0

† Degree from 0 to 10 in Generation of PRBS Sequence.

References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.

DTV_PackTMCC



Description: Complete TMCC bits (204 bits)
Library: DTV, ISDB-T
Class: SDFDTV_PackTMCC

Parameters

Name	Description	Default	Unit	Type	Range
Length	length of TMCC transmission format	204		int	204
InformLength	length of TMCC information after CDSC	184		int	184
InitiBit	initialization bit for the DBPSK modulation (1 bit)	1		int	{0, 1}
SynchWord	synchronization word (16 bits): W0, W1	W0		enum	
SegDesc	segment descriptor (3 bits): Differential, Coherent	Differential		enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	input	TMCC information bits after CDSC coding	int

Pin Outputs

Pin	Name	Description	Signal Type
2	output	complete TMCC transmission format	int

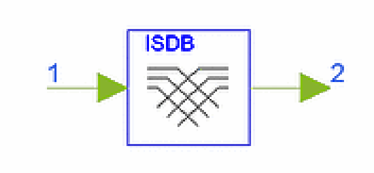
Notes/Equations

1. The model is used to multiplex the CDSC coded TMCC information bits (184 bits) and other no-coded 20 bits, which include initialization bit, synchronization of TMCC and system type.
   According to ISDB-T, the first bit B_0 is the initialization bit for DBPSK modulation; B_0 to B_{16} is a 16-bit synchronization sequence that takes w0 and w1 (the inverse of w0) in turn in every frame; B_{17} to B_{19} represent the segment descriptor (differential modulation 111, coherent modulation 000); B_{20} to B_{203} include TMCC 102 information bits and 82-bit parity (these 184 bits are CDSC coded).

References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.

DTV_TimeInterlv



Description: Interleaver and deinterleaver of complex data
Library: DTV, ISDB-T
Class: SDFDTV_TimeInterlv

Parameters

Name	Description	Default	Unit	Type	Range
Carriers	numbers of carriers in each segment for specific OFDM modulation mode	96		int	{96,192,384} †
Segments	number of segments to be interleaved simultaneously	13		int	[1, 13]
Option	option for interleaving or de-interleaving: Interleave, Deinterleave	Interleave		enum	
Initial_value	initial value in interleaver delay FIFOs	0.0+j*0.0		complex	[0, ∞)
I	factor to multiply when caculating delay period for interleaver branches	0		int	[0, 32]
InitialType	interleaver delay FIFOs initial value type: Const, QPSK, QAM 16, QAM 64	Const		enum	

† Carriers = 96, 192, 384 for mode 1, 2, 3, respectively

Pin Inputs

Pin	Name	Description	Signal Type
1	input	input symbols to be interleaved	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	output	output symbols after interleaved	complex

Notes/Equations

1. This model performs symbol-wise interleaving over the output symbols of constellation mapping and modulation.
2. Time interleaving performed for each segment data is carried out through n_c delay branches, where n_c is the number of carriers per segment. The delay of each branch is:
   $D = I \times m_i$ $m_i = \{i \times 5\}$ mod n_c where I is a parameter for each segment described in Delay Adjustment with Time Interleaving.
3. Signal constellations are output instead of zeros in the delay; this makes power calibration easier.

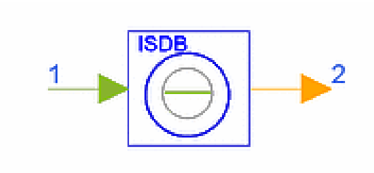
Delay Adjustment with Time Interleaving

Mode	I	No. of Symbols for Delay Adjustment	Number of OFDM Frames to be delayed by Delay Adjustment and Time Interleaving
Mode 1	0	0	0
	4	28	2
	8	56	4
	16	112	8
	32	224	16
Mode 2	0	0	0
	4	14	1
	8	28	2
	16	56	4
	32	112	8
Mode 3	0	0	0
	4	109	1
	8	14	1
	16	28	2
	32	56	4

References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.

DTV_TMCCDemod



Description: TMCC differential demodulation
Library: DTV, ISDB-T
Class: SDFDTV_TMCCDemod

Parameters

Name	Description	Default	Unit	Type	Range
Length	length of TMCC bits per OFDM frame	204		int	204

Pin Inputs

Pin	Name	Description	Signal Type
1	input	TMCC format (204 bits) before demodulation in the receiver	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	output	demodulated TMCC transmission format	int

Notes/Equations

1. The model performs DBPSK demodulation for 204 complex signals about the received TMCC format signal.
   Based on the received signal, this model makes hard decision on the real part of the complex signal.

   $$\begin{cases} B'[i] = 0 \ \ if \ \ Re\{x[i]\} > 0 \\ B'[i] = 1 \ \ if \ \ Re\{x[i]\} < 0 \end{cases}$$

   where $0 \le i < 204$.
   Then set $B_0 = B'\{0\}$, the DBPSK demodulation as follows:

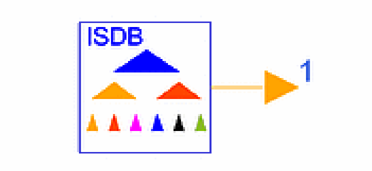
   $B_i = B[i] \oplus B'[i - 1]$

   where $i = 1, 2, \ldots, 203$.

References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.

DTV_TMCCInfo



Description: TMCC information for 102 bits from b20 to b121 in TMCC bit assignment
Library: DTV, ISDB-T
Class: SDFDTV_TMCCInfo

Parameters

Name	Description	Default	Unit	Type	Range
Length	length of TMCC information bits	102		int	{102}
Description	system description (2 bits): ISDB-T, Reserved Des 1, Reserved Des 2, Reserved Des 3	ISDB-T		enum	
Count	index for transmission parameter change (4 bits): Ordinary, Frames 15, Frames 14, Frames 13, Frames 12, Frames 11, Frames 10, Frames 9, Frames 8, Frames 7, Frames 6, Frames 5, Frames 4, Frames 3, Frames 2, Frames 1	Ordinary		enum	
Flag	control flag for alert broadcasting (1 bit): Ordinary Control, Switch-on	Ordinary Control		enum	
CurFlag	current partial reception layer (1 bit): Unused Cur Flag, Used Cur Flag	Used Cur Flag		enum	
CurA_Mod	current modulation for Layer A (3 bits): CurA DQPSK, CurA QPSK, CurA 16QAM, CurA 64QAM, CurA Reserved Mod 1, CurA Reserved Mod 2, CurA Reserved Mod 3, CurA Unused Layer Mod	CurA DQPSK		enum	
CurA_Rate	current code rate for Layer A (3 bits): CurA 1/2, CurA 2/3, CurA 3/4, CurA 5/6, CurA 7/8, CurA Reserved Cod 1, CurA Reserved Cod 2, CurA Unused Layer Cod	CurA 1/2		enum	
CurA_Interlv	current time interleaver for Layer A (3 bits): CurA Int 0 0 0, CurA Int 4 2 1, CurA Int 8 4 2, CurA Int 16 8 4, CurA Int 32 16 8, CurA Reserved Int 1, CurA Reserved Int 2, CurA Unused Layer Int	CurA Int 8 4 2		enum	
CurA_NumSeg	current number of segments for Layer A (4 bits): CurA Reserved Seg 1, CurA Seg 1, CurA Seg 2, CurA Seg 3, CurA Seg 4, CurA Seg 5, CurA Seg 6, CurA Seg 7, CurA Seg 8, CurA Seg 9, CurA Seg 10, CurA Seg 11, CurA Seg 12, CurA Seg 13, CurA Reserved Seg 2, CurA Unused Layer Seg	CurA Seg 13		enum	
CurB_Mod	current modulation for Layer B (3 bits): CurB DQPSK, CurB QPSK, CurB 16QAM, CurB 64QAM, CurB Reserved Mod 1, CurB Reserved Mod 2, CurB Reserved Mod 3, CurB Unused Layer Mod	CurB 16QAM		enum	

CurB_Rate	current code rate for Layer B (3 bits): CurB 1/2, CurB 2/3, CurB 3/4, CurB 5/6, CurB 7/8, CurB Reserved Cod 1, CurB Reserved Cod 2, CurB Unused Layer Cod	CurB 1/2		enum	
CurB_Interlv	current time interleaver for Layer B (3 bits): CurB Int 0 0 0, CurB Int 4 2 1, CurB Int 8 4 2, CurB Int 16 8 4, CurB Int 32 16 8, CurB Reserved Int 1, CurB Reserved Int 2, CurB Unused Layer Int	CurB Int 8 4 2		enum	
CurB_NumSeg	current number of segments for Layer B (4 bits): CurB Reserved Seg 1, CurB Seg 1, CurB Seg 2, CurB Seg 3, CurB Seg 4, CurB Seg 5, CurB Seg 6, CurB Seg 7, CurB Seg 8, CurB Seg 9, CurB Seg 10, CurB Seg 11, CurB Seg 12, CurB Seg 13, CurB Reserved Seg 2, CurB Unused Layer Seg	CurB Unused Layer Seg		enum	
CurC_Mod	current modulation for Layer C (3 bits): CurC DQPSK, CurC QPSK, CurC 16QAM, CurC 64QAM, CurC Reserved Mod 1, CurC Reserved Mod 2, CurC Reserved Mod 3, CurC Unused Layer Mod	CurC 64QAM		enum	
CurC_Rate	current code rate for Layer C (3 bits): CurC 1/2, CurC 2/3, CurC 3/4, CurC 5/6, CurC 7/8, CurC Reserved Cod 1, CurC Reserved Cod 2, CurC Unused Layer Cod	CurC 1/2		enum	
CurC_Interlv	current time interleaver for Layer C (3 bits): CurC Int 0 0 0, CurC Int 4 2 1, CurC Int 8 4 2, CurC Int 16 8 4, CurC Int 32 16 8, CurC Reserved Int 1, CurC Reserved Int 2, CurC Unused Layer Int	CurC Int 8 4 2		enum	
CurC_NumSeg	current number of segments for Layer C (4 bits): CurC Reserved Seg 1, CurC Seg 1, CurC Seg 2, CurC Seg 3, CurC Seg 4, CurC Seg 5, CurC Seg 6, CurC Seg 7, CurC Seg 8, CurC Seg 9, CurC Seg 10, CurC Seg 11, CurC Seg 12, CurC Seg 13, CurC Reserved Seg 2, CurC Unused Layer Seg	CurC Seg 6		enum	
NextFlag	next partial reception layer (1 bit): Unused Next Flag, Used Next	Unused Next Flag		enum	
NextA_Mod	next modulation for Layer A (3 bits): NextA DQPSK, NextA QPSK, NextA 16QAM, NextA 64QAM, NextA Reserved Mod 1, NextA Reserved Mod 2, NextA Reserved Mod 3, NextA Unused Layer Mod	NextA QPSK		enum	
NextA_Rate	next code rate for Layer A (3 bits): NextA 1/2, NextA 2/3, NextA 3/4, NextA 5/6, NextA 7/8, NextA Reserved Cod 1, NextA Reserved Cod 2, NextA Unused Layer Cod	NextA 1/2		enum	
NextA_Interlv	next time interleaving for Layer A (3 bits): NextA Int 0 0 0, NextA Int 4 2 1, NextA Int 8 4 2, NextA Int 16 8 4, NextA Int 32 16 8, NextA Reserved Int 1, NextA Reserved Int 2, NextA Unused Layer Int	NextA Int 8 4 2		enum	
NextA_NumSeg	next number of segments for Layer A (4 bits): NextA Reserved Seg 1, NextA Seg 1, NextA Seg 2, NextA Seg 3, NextA Seg 4, NextA Seg 5, NextA Seg 6, NextA Seg 7, NextA Seg 8, NextA Seg 9, NextA Seg 10, NextA Seg 11,	NextA Reserved Seg 1		enum	

	NextA Seg 12, NextA Seg 13, NextA Reserved Seg 2, NextA Unused Layer Seg				
NextB_Mod	next modulation for Layer B (3 bits): NextB DQPSK, NextB QPSK, NextB 16QAM, NextB 64QAM, NextB Reserved Mod 1, NextB Reserved Mod 2, NextB Reserved Mod 3, NextB Unused Layer Mod	NextB 16QAM		enum	
NextB_Rate	next code rate for Layer B (3 bits): NextB 1/2, NextB 2/3, NextB 3/4, NextB 5/6, NextB 7/8, NextB Reserved Cod 1, NextB Reserved Cod 2, NextB Unused Layer Cod	NextB 1/2		enum	
NextB_Interlv	next time interleaving for Layer B (3 bits): NextB Int 0 0 0, NextB Int 4 2 1, NextB Int 8 4 2, NextB Int 16 8 4, NextB Int 32 16 8, NextB Reserved Int 1, NextB Reserved Int 2, NextB Unused Layer Int	NextB Int 8 4 2		enum	
NextB_NumSeg	next number of segments for Layer B (4 bits): NextB Reserved Seg 1, NextB Seg 1, NextB Seg 2, NextB Seg 3, NextB Seg 4, NextB Seg 5, NextB Seg 6, NextB Seg 7, NextB Seg 8, NextB Seg 9, NextB Seg 10, NextB Seg 11, NextB Seg 12, NextB Seg 13, NextB Reserved Seg 2, NextB Unused Layer Seg	NextB Seg 6		enum	
NextC_Mod	next modulation for Layer C (3 bits): NextC DQPSK, NextC QPSK, NextC 16QAM, NextC 64QAM, NextC Reserved Mod 1, NextC Reserved Mod 2, NextC Reserved Mod 3, NextC Unused Layer Mod	NextC QPSK		enum	
NextC_Rate	next code rate for Layer C (3 bits): NextC 1/2, NextC 2/3, NextC 3/4, NextC 5/6, NextC 7/8, NextC Reserved Cod 1, NextC Reserved Cod 2, NextC Unused Layer Cod	NextC 1/2		enum	
NextC_Interlv	next time interleaving for Layer C (3 bits): NextC Int 0 0 0, NextC Int 4 2 1, NextC Int 8 4 2, NextC Int 16 8 4, NextC Int 32 16 8, NextC Reserved Int 1, NextC Reserved Int 2, NextC Unused Layer Int	NextC Int 8 4 2		enum	
NextC_NumSeg	next number of segments for Layer C (4 bits): NextC Reserved Seg 1, NextC Seg 1, NextC Seg 2, NextC Seg 3, NextC Seg 4, NextC Seg 5, NextC Seg 6, NextC Seg 7, NextC Seg 8, NextC Seg 9, NextC Seg 10, NextC Seg 11, NextC Seg 12, NextC Seg 13, NextC Reserved Seg 2, NextC Unused Layer Seg	NextC Seg 5		enum	
FutureUse	reserved for future use (all set to "1" 15 bits)	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1		int array	"111111111111111"

Pin Outputs

Pin	Name	Description	Signal Type
1	output	TMCC information bits (B20-B121)	int

Notes/Equations

1. This model is used to generate the 102 bits of TMCC information. For the parameters in this model, TMCC information bits are generated according to Bit Assignments for

TMCC Information; specification bit assignments are given in Transmission Parameters through *Number of Segments*.

Bit Assignments for TMCC Information

Bits	No. of Bits	Purpose	Content	Reference
$B_{20} - B_{21}$	2	System descriptor	System descriptor	System Descriptor
$B_{22} - B_{25}$	4	Countdown index	Countdown index	Countdown Index
B_{26}	1	Switch-on control flag used for alert broadcasting	Switch-on control flag used for alert broadcasting	Switch-on Control Flag used for Albert Broadcasting
B_{27}	1	Current configuration information	Partial-reception flag	Partial Reception Flag
$B_{28} - B_{40}$	13	Current configuration information	Transmission parameters for layer a	Transmission Parameters
$B_{41} - B_{53}$	13	Current configuration information	Transmission parameters for layer b	Transmission Parameters
$B_{54} - B_{66}$	13	Current configuration information	Transmission parameters for layer c	Transmission Parameters
B_{67}	1	Next configuration information	Partial-reception flag	Partial Reception Flag
$B_{68} - B_{80}$	13	Next configuration information	Transmission parameters for layer a	Transmission Parameters
$B_{81} - B_{93}$	13	Next configuration information	Transmission parameters for layer b	Transmission Parameters
$B_{94} - B_{106}$	13	Next configuration information	Transmission parameters for layer c	Transmission Parameters
$B_{107} - B_{121}$	15	(reserved for future use)	(reserved for future use)	All set to "1"

Transmission Parameters

	No. of Bits	Reference
Modulation	3	*Modulation Scheme of OFDM Carrier*
Code Rate	3	*Code Rate of Inner Code*
Time Interleaving	3	*Time Interleaving*
Number of Segments	4	*Number of Segments*

System Descriptor

System Descriptor

$B_{20} - B_{21}$	**System**
00	ISDB-T using 13 segments
01,10,11	(reserved for future use)

Countdown Index

$B_{22} - B_{25}$	**Description**
1111	15 Frames before changing transmission parameters
1110	14 Frames before changing transmission parameters
1101	13 Frames before changing transmission parameters
1100	12 Frames before changing transmission parameters
...	...
0010	3 Frames before changing transmission parameters
0001	2 Frames before changing transmission parameters
0000	1 Frames before changing transmission parameters

Switch-on Control Flag used for Albert Broadcasting

B_{26}	**Description**
0	Ordinary
1	Switch-on

Partial Reception Flag

B_{26}, B_{27}	**Partial Reception Layer**
0	Not used
1	Used

Modulation Scheme of OFDM Carrier

	Modulation
000	DQPSK
001	QPSK
010	16-QAM
011	64-QAM
100-110	Reserved
111	Not used

Code Rate of Inner Code

	Code Rate
000	1/2
001	2/3
010	3/4
011	5/6
100	7/8
101-110	Reserved
111	Not used

Time Interleaving

	Time Interleaving Parameter I
001	4(Mode 1), 4(Mode 2), 4(Mode 3)
010	8(Mode 1), 8(Mode 2), 8(Mode 3)
011	16(Mode 1), 16(Mode 2), 16(Mode 3)
100	32(Mode 1), 32(Mode 2), 32(Mode 3)
101-110	Reserved
111	Not used

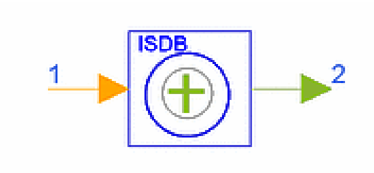
Number of Segments

	No. of Segments used in Layer
0000	0
0001	1
0010	2
0011	3
0100	4
0101	5
0110	6
0111	7
1000	8
1001	9
1010	10
1011	11
1100	12
1101	13
1110	Reserved
1111	Not used

References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.

DTV_TMCCMod



Description: TMCC differential modulation
Library: DTV, ISDB-T
Class: SDFDTV_TMCCMod

Parameters

Name	Description	Default	Unit	Type	Range
Length	length of TMCC bits per OFDM frame	204		int	204

Pin Inputs

Pin	Name	Description	Signal Type
1	input	received TMCC transmission format (204 bits) before modulation in the transmitter	int

Pin Outputs

Pin	Name	Description	Signal Type
2	output	modulated TMCC transmission format	complex

Notes/Equations

1. The model performs DBPSK modulation.
2. $B'[0] = B_0$; DBPSK modulation is:

   $B'[i] = B_i \oplus B'_{i-1}$

   where i = 1, 2, ... , 203.
   Then

   $$\begin{cases} x[i] = 1 + j0 \quad if \quad (B'[i] = 0) \\ x[i] = -1 + j0 \quad if \quad (B'[i] = 1) \end{cases}$$

   coded bits $B'[0] \sim B'[203]$ are converted to {1.0, 0}, {-1.0, 0}.
   where i = 0, 1, ... , 203.

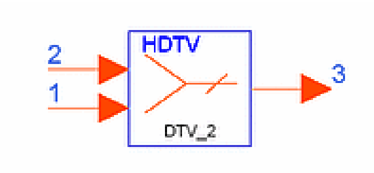
References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.

Multiplex Components for DTV Design Library

- *DTV CommCtrl2* (dtv)
- *DTV CommCtrl3* (dtv)
- *DTV DistCtrl2* (dtv)
- *DTV DistCtrl3* (dtv)
- *DTV SplitThreeLayData* (dtv)
- *DTV SplitThreeLayTSP* (dtv)
- *DTV SplitTwoLayData* (dtv)
- *DTV SplitTwoLayTSP* (dtv)
- *DTV SynLayTMCC1* (dtv)
- *DTV SynLayTMCC2* (dtv)
- *DTV SynLayTMCC3* (dtv)
- *DTV SynThreeLayData* (dtv)
- *DTV SynThreeLayTSP* (dtv)
- *DTV SynTwoLayData* (dtv)
- *DTV SynTwoLayTSP* (dtv)

DTV_CommCtrl2



Description: 2-input commutator with input particle number control
Library: DTV, Multiplex
Class: SDFDTV_CommCtrl2

Parameters

Name	Description	Default	Unit	Type	Range
NumInput1	number of particles from input 1	1		int	[1, ∞)
NumInput2	number of particles from input 2	1		int	[1, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	in1	input 1	anytype
2	in2	input 2	anytype

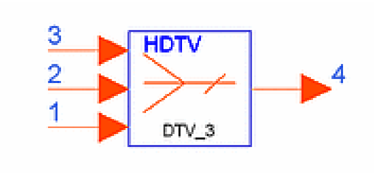
Pin Outputs

Pin	Name	Description	Signal Type
3	output	output comprised of two inputs	anytype

Notes/Equations

1. This model is used to combine two input signals into one.
   NumInput1 of input 1 and NumOutput2 of input 2 data particles are combined and output.

DTV_CommCtrl3



Description: 3-input commutator with input particle number control
Library: DTV, Multiplex
Class: SDFDTV_CommCtrl3

Parameters

Name	Description	Default	Unit	Type	Range
NumInput1	number of particles from input 1	1		int	[1, ∞)
NumInput2	number of particles from input 2	1		int	[1, ∞)
NumInput3	number of particles from input 3	1		int	[1, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	in1	input 1	anytype
2	in2	input 2	anytype
3	in3	input 3	anytype

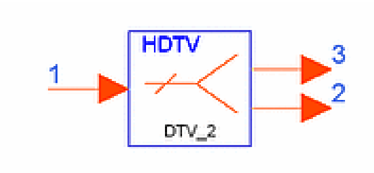
Pin Outputs

Pin	Name	Description	Signal Type
4	output	output comprised of three inputs	anytype

Notes/Equations

1. This model is used to combine three input signals into one.
   NumInput1 of input 1, NumOutput2 of input 2, and NumInput3 of input 3 data particles are combined and output.

DTV_DistCtrl2



Description: 2-output distributor with output particle number control
Library: DTV, Multiplex
Class: SDFDTV_DistCtrl2

Parameters

Name	Description	Default	Unit	Type	Range
NumOutput1	number of particles directed to output 1	1		int	[1, ∞)
NumOutput2	number of particles directed to output 2	1		int	[1, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	input	input to be distributed over the two outputs	anytype

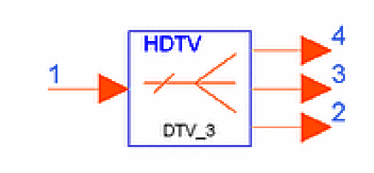
Pin Outputs

Pin	Name	Description	Signal Type
2	out1	output 1	anytype
3	out2	output 2	anytype

Notes/Equations

1. This model is used to distribute one data stream to two outputs. NumOutput1 and NumOutput2 data particles are distributed to output 1, and output 2, respectively.

DTV_DistCtrl3



Description: 3-output distributor with output particle number control
Library: DTV, Multiplex
Class: SDFDTV_DistCtrl3

Parameters

Name	Description	Default	Unit	Type	Range
NumOutput1	number of particles directed to output 1	1		int	[1, ∞)
NumOutput2	number of particles directed to output 2	1		int	[1, ∞)
NumOutput3	number of particles directed to output 3	1		int	[1, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	input	input to be distributed over the three outputs	anytype

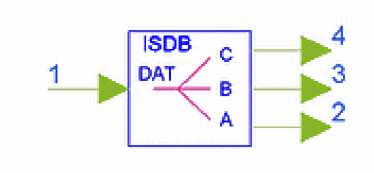
Pin Outputs

Pin	Name	Description	Signal Type
2	out1	output 1	anytype
3	out2	output 2	anytype
4	out3	output 3	anytype

Notes/Equations

1. This model is used to distribute one data stream to three outputs. NumOutput1, NumOutput2 and NumOutput3 data particles are distributed to output 1, output 2, and output 3, respectively.

DTV_SplitThreeLayData



Description: Data stream splitter into 3-layer data
Library: DTV, Multiplex
Class: SDFDTV_SplitThreeLayData

Parameters

Name	Description	Default	Unit	Type	Range
Carriers	number of carriers in one segment	432		int	{96,108,192,216,384,432} †
SegmentsA	number of segments in layer A	1		int	{1} ††
SegmentsB	number of segments in layer B	1		int	[1, 12] ††
SegmentsC	number of segments in layer C	1		int	[1, 12] ††

† According to ISDB-T, the Carriers are 96 and 108, 192 and 216, 384 and 432, corresponding to mode 1, mode 2, and mode 3, respectively.
†† The sum of SegmentsA, SegmentsB, and SegmentsC ≤ 13.

Pin Inputs

Pin	Name	Description	Signal Type
1	Synt	synthesis of 3-layer data streams	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	LayA	layer A output	complex
3	LayB	layer B output	complex
4	LayC	layer C output	complex

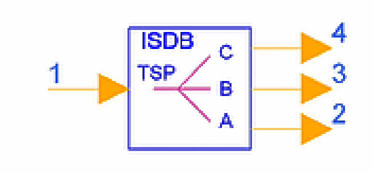
Notes/Equations

1. The model is used to demultiplex one synthetic stream into a 3-layer data stream for use in ISDB-T 3-layer systems only.
   Each firing, Synt consumes (SegmentsA+SegmentsB+SegmentsC)×Carriers tokens; LayA produces SegmentsA×Carriers tokens; LayB produces SegmentsB×Carriers tokens; LayC produces SegmentsC×Carriers tokens.

References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.

DTV_SplitThreeLayTSP



Description: TSP stream splitter into 3-layer TSP stream
Library: DTV, Multiplex
Class: SDFDTV_SplitThreeLayTSP

Parameters

Name	Description	Default	Unit	Type	Range
Length	number of bytes in one TSP	204		int	{204}
SegmentsA	number of segments in layer A	1		int	{1} †
LayerA_Modulation	modulation mode for layer A: A DQPSK, A QPSK, A 16QAM, A 64QAM	A DQPSK		enum	
LayerA_Convolutional_Code	convolutional code rate for layer A: A 1/2, A 2/3, A 3/4, A 5/6, A 7/8	A 1/2		enum	
SegmentsB	number of segments in layer B	5		int	[1, 12] †
LayerB_Modulation	modulation mode for Layer B: B DQPSK, B QPSK, B 16QAM, B 64QAM	B QPSK		enum	
LayerB_Convolutional_Code	convolutional code rate for layer B: B 1/2, B 2/3, B 3/4, B 5/6, B 7/8	B 7/8		enum	
SegmentsC	number of segments in layer C	7		int	[1, 12] †
LayerC_Modulation	modulation mode for layer C: C DQPSK, C QPSK, C 16QAM, C 64QAM	C 64QAM		enum	
LayerC_Convolutional_Code	convolutional code rate for layer C: C 1/2, C 2/3, C 3/4, C 5/6, C 7/8	C 7/8		enum	

† The sum of SegmentsA, SegmentsB and SegmentsC < 13.

Pin Inputs

Pin	Name	Description	Signal Type
1	input	input TSP data stream to be split	int

Pin Outputs

Pin	Name	Description	Signal Type
2	OutA	layer A output	int
3	OutB	layer B output	int
4	OutC	layer C output	int

Notes/Equations

1. This model is used in ISDB-T 3-layer systems to split one TSP data stream into a 3-layer TSP data stream according to the table below.
2. One TSP data stream is split into a 3-layer TSP data stream: layer A, layer B, and layer C.
   The number of TSPs per segment in each layer is determined according to modulation mode and convolutional code rate.
   The model determines the total number of TSPs in each layer by the number of TSPs per segments and the number of segments in each layer in one OFDM frame. To increase simulation speed, the total number of TSPs in each layer is divided by the greatest common divisor, which is the greatest common divisor of the total number of TSPs in each layer. An example follows for mode 1.

   SegmentsA=1
   LayerA_Modulation= A 64QAM
   LayerA_Convolutional_Code= A 2/3

   SegmentsB=5
   LayerB_Modulation= B DQPSK
   LayerB_Convolutional_Code= B 1/2

   SegmentsC=7
   LayerC_Modulation= C 16QAM
   LayerC_Convolutional_Code= C 3/4

   Referring to the following table, the number of TSPs is 48, 12, and 36 per segment, respectively.
   The total number of TSPs in each layer is 48×1, 12×5 and 36×7 in one OFDM frame; the greatest common divisor is 12. After dividing, the total number of TSPs is 4, 5 and 21, respectively. Then, the model splits 204×4×1 integers to OutA pin, 204×1×5 integers to OutB pin, and 204×3×7 integers to OutC pin.

Transmitting TSPs per Segment for ISDB-T

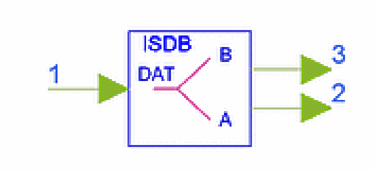
Carrier Modulation	Convolutional Code	Number of Transmitting TSPs † (Mode 1/2/3)
DQPSK, QPSK	1/2	12/24/48
" "	2/3	16/32/64
" "	3/4	18/36/72
" "	5/6	20/40/80
" "	7/8	21/42/84
16-QAM	1/2	24/48/96
" "	2/3	32/64/128
" "	3/4	36/72/144
" "	5/6	40/80/160
" "	7/8	42/84/168
64-QAM	1/2	36/72/144
" "	2/3	48/96/192
" "	3/4	54/108/216
" "	5/6	60/120/240
" "	7/8	63/126/252

† Number of transmitting TSPs per one OFDM frame

References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.

DTV_SplitTwoLayData



Description: Data stream splitter into 2-layer data
Library: DTV, Multiplex
Class: SDFDTV_SplitTwoLayData

Parameters

Name	Description	Default	Unit	Type	Range
Carriers	number of carriers in one segment	432		int	{96,108,192,216,384,432}†
SegmentsA	number of segments in layer A	1		int	[1, 12] ††
SegmentsB	number of segments in layer B	1		int	[1, 12] ††

† According to ISDB-T, the number of Carriers is 96 and 108, 192 and 216, 384 and 432, corresponding to mode 1, mode 2, and mode 3, respectively.
†† The sum of SegmentsA and SegmentsB ≤ 13.

Pin Inputs

Pin	Name	Description	Signal Type
1	Synt	synthesis of 2-layer data stream	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	LayA	layer A output	complex
3	LayB	layer B output	complex

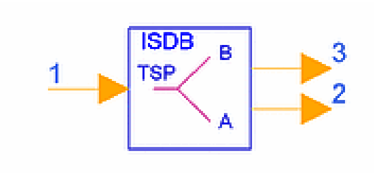
Notes/Equations

1. The model is used in ISDB-T 2-layer systems to demultiplex one synthetic stream into a 2-layer data stream.
2. Each firing, Synt consumes (SegmentsA+SegmentsB)×Carriers tokens; LayA produces SegmentsA×Carriers tokens; LayB produces SegmentsB×Carriers tokens.

References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.

DTV_SplitTwoLayTSP



Description: TSP stream splitter into 2-layer TSP stream
Library: DTV, Multiplex
Class: SDFDTV_SplitTwoLayTSP

Parameters

Name	Description	Default	Unit	Type	Range
Length	number of bytes in one TSP	204		int	{204}
SegmentsA	number of segments in layer A	5		int	[1, 12] †
LayerA_Modulation	modulation mode for layer A: A DQPSK, A QPSK, A 16QAM, A 64QAM	A DQPSK		enum	
LayerA_Convolutional_Code	convolutional code rate for layer A: A 1/2, A 2/3, A 3/4, A 5/6, A 7/8	A 1/2		enum	
SegmentsB	number of segments in layer B	8		int	[1, 12] †
LayerB_Modulation	modulation mode for layer B: B DQPSK, B QPSK, B 16QAM, B 64QAM	B DQPSK		enum	
LayerB_Convolutional_Code	convolutional code rate for layer B: B 1/2, B 2/3, B 3/4, B 5/6, B 7/8	B 7/8		enum	

† The sum of SegmentsA and SegmentsB ≤ 13.

Pin Inputs

Pin	Name	Description	Signal Type
1	input	input TSP data stream to be split	int

Pin Outputs

Pin	Name	Description	Signal Type
2	OutA	layer A output	int
3	OutB	layer B output	int

Notes/Equations

1. This model is used in ISDB-T 2-layer systems to split one TSP data stream into a 2-layer TSP data stream according to the table below.
2. The TSP stream is split into a 2-layer TSP data stream: layer A and layer B. The number of TSPs per segment in each layer is determined according to modulation mode and convolutional code rate.
   The total number of TSPs in each layer is determined by the number of TSPs per

segments and the number of segments in each layer in one OFDM frame. To increase simulation speed, the total number of TSPs in each layer is divided by the greatest common divisor, which is the greatest common divisor between the total number of TSPs in each layer. An example follows for mode 1.

SegmentsA=5
LayerA_Modulation= A DQPSK
LayerA_Convolutional_Code= A 1/2

SegmentsB=7
LayerB_Modulation= B 16QAM
LayerB_Convolutional_Code= B 3/4

Referring to the following table, the number of TSPs is 12 and 36 per segment, respectively. The total number of TSPs in each layer is 12×5 and 36×7 in one OFDM frame; the greatest common divisor is 12. After dividing, the total number of TSPs is 5 and 21, respectively. So, the model distributes 204×1×5 integers to OutA pin, and 204×3×7 integers to OutB pin.

Transmitting TSPs per Segment for ISDB-T

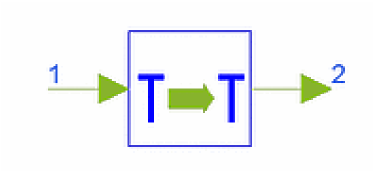
Modulation	Convolutional Code	Number of Transmitting TSPs † (Mode 1/2/3)
DQPSK, QPSK	1/2	12/24/48
" "	2/3	16/32/64
" "	3/4	18/36/72
" "	5/6	20/40/80
" "	7/8	21/42/84
16-QAM	1/2	24/48/96
" "	2/3	32/64/128
" "	3/4	36/72/144
" "	5/6	40/80/160
" "	7/8	42/84/168
64-QAM	1/2	36/72/144
" "	2/3	48/96/192
" "	3/4	54/108/216
" "	5/6	60/120/240
" "	7/8	63/126/252

† Number of transmitting TSPs per one OFDM frame

References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.

DTV_SynLayTMCC1



Description: Synthesizer for 1-layer TMCC received into one TMCC format
Library: DTV, Multiplex
Class: SDFDTV_SynLayTMCC1

Parameters

Name	Description	Default	Symbol	Unit	Type	Range
Segments	number of segments	1	seg		int	[1, 13]

Pin Inputs

Pin	Name	Description	Signal Type
1	input	1-layer input	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	output	synthesis of 1-layer TMCC stream	complex

Notes/Equations

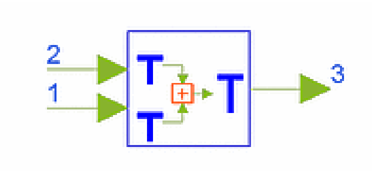
1. The model is used in ISDB-T 1-layer systems to synthesize one layer TMCC streams into one synthetic stream.
2. Because there is one received TMCC signal from each segment in every layer in the DTV_DemuxCohSegs and DTV_DemuxDiffSegs models, all TMCC received must be synthesized to one TMCC signal, as follows.

```
Complex in(0.0,0.0),out(0.0,0.0);
for (int i=0; i<seg ;i++)
 in += (input%(i)).operator Complex();
 out = in/seg;
output%(0) << out;
```

References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.

DTV_SynLayTMCC2



Description: Synthesizer for 2-layer TMCC received into one TMCC format
Library: DTV, Multiplex
Class: SDFDTV_SynLayTMCC2

Parameters

Name	Description	Default	Symbol	Unit	Type	Range
SegmentsA	number of segments in layer A	1	segA		int	[1, 12] †
SegmentsB	number of segments in layer B	1	segB		int	[1, 12] †

† The sum of SegmentsA and SegmentsB ≤ 13.

Pin Inputs

Pin	Name	Description	Signal Type
1	LayA	layer A input	complex
2	LayB	layer B input	complex

Pin Outputs

Pin	Name	Description	Signal Type
3	Synt	synthesis of 2-layer TMCC streams	complex

Notes/Equations

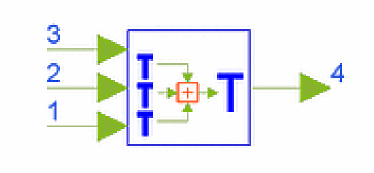
1. The model is used to synthesize 2-layer TMCC streams into one synthetic stream, for use in ISDB-T 2-layer systems.
2. Because there is one received TMCC signal from each segment in every layer in the *DTV_DemuxCohSegs* (dtv) and *DTV_DemuxDiffSegs* (dtv) models, all received TMCC must be synthesized to one TMCC signal, as follows.

```
Complex in1(0.0,0.0),in2(0.0,0.0),out(0.0,0.0);
for (int i=0; i<segA ;i++)
 in1 += (LayA%(i)).operator Complex();
for ( i=0; i<segB; i++)
 in2 += (LayB%(i)).operator Complex();
 out = (in1+in2)/sumAB;
 Synt%(0) << out;
```

References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.

DTV_SynLayTMCC3



Description: Synthesizer for 3-layer TMCC received into one TMCC format
Library: DTV, Multiplex
Class: SDFDTV_SynLayTMCC3

Parameters

Name	Description	Default	Symbol	Unit	Type	Range
SegmentsA	number of segments in layer A	1	segA		int	{1} †, ††
SegmentsB	number of segments in layer B	1	segB		int	[1, 12] ††
SegmentsC	number of segments in layer C	1	segC		int	[1, 12] ††

† According to ISDB-T, the number of segments in the first layer must be 1.
†† The sum of SegmentsA, SegmentsB and SegmentsC ≤ 13.

Pin Inputs

Pin	Name	Description	Signal Type
1	LayA	layer A input	complex
2	LayB	layer B input	complex
3	LayC	layer C input	complex

Pin Outputs

Pin	Name	Description	Signal Type
4	Synt	synthesis of 3-layer TMCC streams	complex

Notes/Equations

1. This model is used in ISDB-T 3-layer systems to synthesize 3-layer TMCC streams into one synthetic stream.
2. Because there is one received TMCC signal from each segment in every layer in the *DTV_DemuxCohSegs* (dtv) and *DTV_DemuxDiffSegs* (dtv) models, all received TMCC must be synthesized into one TMCC signal, as follows.

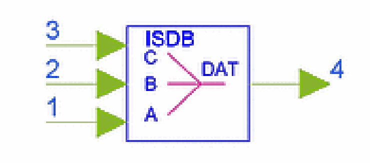
```
Complex in1(0.0,0.0),in2(0.0,0.0),in3(0.0,0.0),out(0.0,0.0);
for (int i=0; i<segA; i++)
 in1 += (LayA%(i)).operator Complex();
for ( i=0; i<segB; i++)
 in2 += (LayB%(i)).operator Complex();
for ( i=0; i<segC; i++)
  in3 += (LayC%(i)).operator Complex();
 out = (in1+in2+in3)/sumABC;
```

```
Synt%(0) << out;
```

References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.

DTV_SynThreeLayData



Description: Synthesizer for 3-layer data into one stream
Library: DTV, Multiplex
Class: SDFDTV_SynThreeLayData

Parameters

Name	Description	Default	Unit	Type	Range
Carriers	number of carriers in one segment	432		int	{96,108,192,216,384,432}†
SegmentsA	number of segments in layer A	1		int	{1} ††, †††
SegmentsB	number of segments in layer B	1		int	[1, 12] †††
SegmentsC	number of segments in layer C	1		int	[1, 12] †††

† According to ISDB-T, the Carriers should be 96 and 108, 192 and 216, 384 and 432, corresponding to mode 1, mode 2, and mode 3, respectively.
†† According to ISDB-T, the number of segments in the first layer must be 1.
††† The sum of SegmentsA, SegmentsB and SegmentsC ≤ 13.

Pin Inputs

Pin	Name	Description	Signal Type
1	LayA	layer A input	complex
2	LayB	layer B input	complex
3	LayC	layer C input	complex

Pin Outputs

Pin	Name	Description	Signal Type
4	Synt	synthesis of 3-layer data streams	complex

Notes/Equations

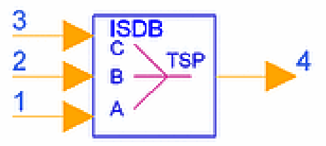
1. This model is used in ISDB-T 3-layer systems to multiplex 3-layer data streams into one synthetic stream.
2. Each firing, LayA consumes SegmentsA×Carriers tokens; LayB consumes SegmentsB×Carriers tokens; LayC consumes SegmentsC×Carriers tokens; Synt produces (SegmentsA+SegmentsB+SegmentsC)×Carriers tokens.

References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T);

Specification of Channel Coding, Framing Structure and Modulation, Sept.1998.

DTV_SynThreeLayTSP



Description: Synthesizer for 3-layer TSP into one TSP stream
Library: DTV, Multiplex
Class: SDFDTV_SynThreeLayTSP

Parameters

Name	Description	Default	Unit	Type	Range
Length	number of bytes in one TSP	204		int	{204}
SegmentsA	number of segments in layer A	1		int	{1} †
LayerA_Modulation	modulation mode for layer A: A DQPSK, A QPSK, A 16QAM, A 64QAM	A DQPSK		enum	
LayerA_Convolutional_Code	convolutional code rate for layer A: A 1/2, A 2/3, A 3/4, A 5/6, A 7/8	A 1/2		enum	
SegmentsB	number of segments in layer B	5		int	[1, 12] †
LayerB_Modulation	modulation mode for layer B: B DQPSK, B QPSK, B 16QAM, B 64QAM	B QPSK		enum	
LayerB_Convolutional_Code	convolutional code rate for layer B: B 1/2, B 2/3, B 3/4, B 5/6, B 7/8	B 7/8		enum	
SegmentsC	number of segments in layer C	7		int	[1, 12] †
LayerC_Modulation	modulation mode for layer C: C DQPSK, C QPSK, C 16QAM, C 64QAM	C 64QAM		enum	
LayerC_Convolutional_Code	convolutional code rate for layer C: C 1/2, C 2/3, C 3/4, C 5/6, C 7/8	C 7/8		enum	

† The sum of SegmentsA, SegmentsB and SegmentsC ≤ 13.

Pin Inputs

Pin	Name	Description	Signal Type
1	InA	layer A input	int
2	InB	layer B input	int
3	InC	layer B input	int

Pin Outputs

Pin	Name	Description	Signal Type
4	output	output TSP stream comprised of 3-layer TSP streams	int

Notes/Equations

1. This model is used in ISDB-T 3-layer systems to synthesize 3-layer TSP streams into one TSP stream, according to the table below.
2. The model synthesizes the 3-layer TSP streams (layer A, layer B, and layer C) into one TSP stream.
   The number of TSPs per segment in each layer is determined according to modulation mode and convolutional code rate.
   The model determines the total number of TSPs in each layer by the number of TSPs per segments and the number of segments in each layer in one OFDM frame. To increase simulation speed, the total number of TSPs in each layer is divided by the greatest common divisor, which is the greatest common divisor of the total number of TSPs in each layer. An example follows for mode 1.

   SegmentsA=1
   LayerA_Modulation= A 64QAM
   LayerA_Convolutional_Code= A 2/3

   SegmentsB=5
   LayerB_Modulation= B DQPSK
   LayerB_Convolutional_Code= B 1/2

   SegmentsC=7
   LayerC_Modulation= C 16QAM
   LayerC_Convolutional_Code= C 3/4

   Referring to the following table, the number of TSPs is 48, 12, and 36 per segment, respectively. The total number of TSPs in each layer is 48×1, 12×5 and 36×7 in one OFDM frame; the greatest common divisor is 12. After dividing, the total number of TSPs is 4, 5 and 21, respectively. Then, the model combines 204×4×1 integers in InA pin, 204×1×5 integers in InB pin, and 204×3×7 integers in InC pin into the output TSP stream.

Transmitting TSPs per Segment for ISDB-T

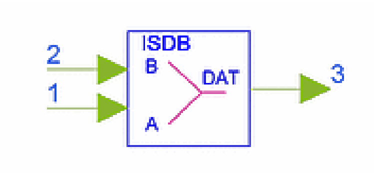
Carrier Modulation	Convolutional Code	Number of Transmitting TSPs † (Mode 1/2/3)
DQPSK, QPSK	1/2	12/24/48
" "	2/3	16/32/64
" "	3/4	18/36/72
" "	5/6	20/40/80
" "	7/8	21/42/84
16-QAM	1/2	24/48/96
" "	2/3	32/64/128
" "	3/4	36/72/144
" "	5/6	40/80/160
" "	7/8	42/84/168
64-QAM	1/2	36/72/144
" "	2/3	48/96/192
" "	3/4	54/108/216
" "	5/6	60/120/240
" "	7/8	63/126/252

† Number of transmitting TSPs per one OFDM frame.

References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.

DTV_SynTwoLayData



Description: Synthesizer for 2-layer data into one stream
Library: DTV, Multiplex
Class: SDFDTV_SynTwoLayData

Parameters

Name	Description	Default	Unit	Type	Range
Carriers	number of carriers in one segment	432		int	{96,108,192,216,384,432} †
SegmentsA	number of segments in layer A	1		int	[1, 12] ††
SegmentsB	number of segments in layer B	1		int	[1, 12] ††

† According to ISDB-T, Carriers should be 96 and 108, 192 and 216, 384 and 432, corresponding to mode 1, mode 2, and mode 3, respectively.
†† The sum of SegmentsA and SegmentsB ≤ 13.

Pin Inputs

Pin	Name	Description	Signal Type
1	LayA	layer A input	complex
2	LayB	layer B input	complex

Pin Outputs

Pin	Name	Description	Signal Type
3	Synt	synthesis of 2-layer data streams	complex

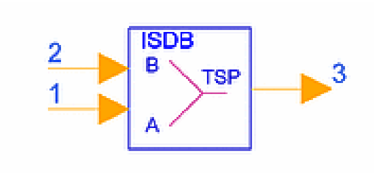
Notes/Equations

1. This model is used in ISDB-T 2-layer systems to multiplex 2-layer data streams into one synthetic stream.
2. Each firing, LayA consumes SegmentsA×Carriers tokens; LayB consumes SegmentsB×Carriers tokens; Synt produces (SegmentsA+SegmentsB)×Carriers tokens.

References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.

DTV_SynTwoLayTSP



Description: Synthesizer for 2-layer TSP into one TSP stream
Library: DTV, Multiplex
Class: SDFDTV_SynTwoLayTSP

Parameters

Name	Description	Default	Unit	Type	Range
Length	number of bytes in one TSP	204		int	{204}
SegmentsA	number of segments in layer A	5		int	[1, 12] †
LayerA_Modulation	modulation mode for layer A: A DQPSK, A QPSK, A 16QAM, A 64QAM	A DQPSK		enum	
LayerA_Convolutional_Code	convolutional code rate for layer A: A 1/2, A 2/3, A 3/4, A 5/6, A 7/8	A 1/2		enum	
SegmentsB	number of segments in layer B	8		int	[1, 12] †
LayerB_Modulation	modulation mode for Layer B: B DQPSK, B QPSK, B 16QAM, B 64QAM	B DQPSK		enum	
LayerB_Convolutional_Code	convolutional code rate for layer B: B 1/2, B 2/3, B 3/4, B 5/6, B 7/8	B 7/8		enum	

† The sum of SegmentsA and SegmentsB ≤ 13.

Pin Inputs

Pin	Name	Description	Signal Type
1	InA	layer A input	int
2	InB	layer B input	int

Pin Outputs

Pin	Name	Description	Signal Type
3	output	output TSP stream comprised of 2-layer TSP streams	int

Notes/Equations

1. This model is used in ISDB-T 2-layer systems to synthesize a 2-layer TSP stream into one TSP stream according to the table below.
2. Layers A and layer B are synthesized into one TSP stream. The number of TSPs per segment in each layer is determined according to modulation mode and convolutional code rate.
   The model determines the total number of TSPs in each layer by the number of TSPs

per segment and the number of segments in each layer in one OFDM frame. To increase simulation speed, the total number of TSPs in each layer is divided by the greatest common divisor, which is the greatest common divisor of the total numbers of TSPs in each layer. An example follows for mode 1.

SegmentsA=5
LayerA_Modulation= A DQPSK
LayerA_Convolutional_Code= A 1/2

SegmentsB=7
LayerB_Modulation= B 16QAM
LayerB_Convolutional_Code= B 3/4

According to the following table, the number of TSPs is 12, and 36 per segment, respectively. The total number of TSPs in each layer is 12×5 and 36×7 in one OFDM frame; the greatest common divisor is 12. After dividing, the total number of TSPs is 5 and 21, respectively. Then, the model combines 204×5×1 integers in InA pin and 204×3×7 integers in InB pin into the output TSP stream.

Transmitting TSPs per Segment for ISDB-T

Carrier Modulation	Convolutional Code	Number of Transmitting TSPs † (Mode 1/2/3)
DQPSK, QPSK	1/2	12/24/48
" "	2/3	16/32/64
" "	3/4	18/36/72
" "	5/6	20/40/80
" "	7/8	21/42/84
16-QAM	1/2	24/48/96
" "	2/3	32/64/128
" "	3/4	36/72/144
" "	5/6	40/80/160
" "	7/8	42/84/168
64-QAM	1/2	36/72/144
" "	2/3	48/96/192
" "	3/4	54/108/216
" "	5/6	60/120/240
" "	7/8	63/126/252

† Number of transmitting TSPs per one OFDM frame.

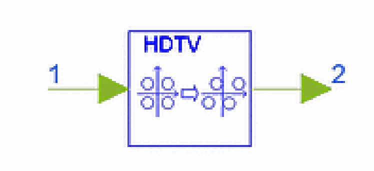
References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.

OFDM Components

- *DTV AddFixPhase* (dtv)
- *DTV InsertGuard* (dtv)
- *DTV LoadFFTBuff* (dtv)
- *DTV MLEstimator* (dtv)
- *DTV OFDMEqualizer* (dtv)
- *DTV RemovePhase* (dtv)

DTV_AddFixPhase



Description: Fixed phase addition to the OFDM symbol
Library: DTV, OFDM
Class: SDFDTV_AddFixPhase

Parameters

Name	Description	Default	Unit	Type	Range
Length	length of input symbol	8192		int	(0, ∞) †
Guard	length of guard interval	512		int	(0, Length] ††
Offset	fixed phase offset	0.25		real	(-0.5, 0.5)

† Length = 2^N in OFDM systems; where *N* is a positive integer. In DVB-T systems, *N*=11 and 13; in ISDB-T systems, *N*=11, 12 and 13.
†† Guard = 1/32, 1/16, 1/8, and 1/4 Length in ISDB-T and DVB-T systems.

Pin Inputs

Pin	Name	Description	Signal Type
1	input	OFDM symbol after insert guard interval process	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	output	symbol added by a fixed phase offset	complex

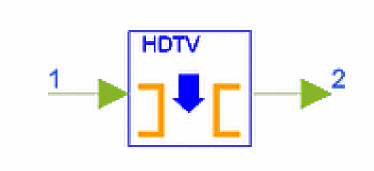
Notes/Equations

1. This model adds a fixed phase offset into the OFDM symbol; it can be used as a tool for frequency synchronization models.
2. Implementation
   Assume *x(0)*, *x(1)*, ... , *x(N−1)* are the transmitted symbols that are combined into an OFDM symbol. Add a fixed phase offset Φ into OFDM symbol, we can get *y(0)*, *y(1)*, ... , *y(N−1)*, as follows:
   $$y(i) = x(i)e^{\frac{j2\pi\Phi i}{N}}$$
   where Φ is the carrier phase offset value (-0.5,0.5). We add the fixed phase offset in the ±0.5 subcarriers OFDM symbol. *N* is the sum of the length of IFFT and the interval guard.

References

1. J.J. van de Beek, M. Sandell, and P.O.Borjesson, *On Synchronization in OFDM Systems Using the Cyclic Prefix*, in Proceedings of Radio Vetenskaplig Konferens (REVK'96), pp.663-667, Lulea Sweden, June 1996.
2. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.
3. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.

DTV_InsertGuard



Description: Guard interval inserter
Library: DTV, OFDM
Class: SDFDTV_InsertGuard

Parameters

Name	Description	Default	Unit	Type	Range
Length	length of input symbol	8192		int	(0, ∞) †
Guard	length of guard interval	512		int	(0, Length] ††

† Length = 2^N in OFDM systems; where *N* is a positive integer. In DVB-T systems, *N*=11 and 13; in ISDB-T systems, *N*=11, 12 and 13.
††Guard = 1/32, 1/16, 1/8, and 1/4 Length in ISDB-T and DVB-T systems.

Pin Inputs

Pin	Name	Description	Signal Type
1	input	signal from the IFFT	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	output	signal output after guard interval insertion	complex

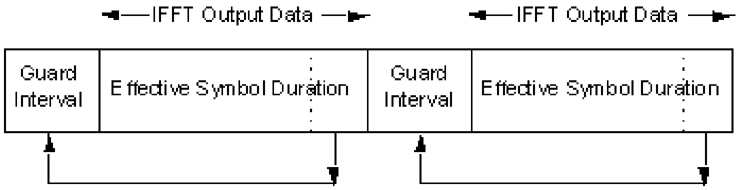
Notes/Equations

1. This model inserts a guard interval after the IFFT procedure.
2. Implementation
   Assume $x(0), x(1), \ldots, x(N-1)$ are the *N* symbols from IFFT. The guard interval (interval length is N_g) is inserted as follows:

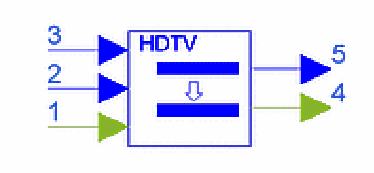
   $x(-i) = x(N-i)\ i = 1, 2, \ldots, N_g$

   After insertion of the guard interval, the length of the output signal is $N + N_g$, the output signal is
   $x(-N_g), \ldots, x(-1), x(0), x(1), \ldots, x(N-1)$
   Guard interval insertion is shown below.

Guard Interval Insertion


IFFT Output Data
IFFT Output Data
Guard Interval
Effective Symbol Duration
Guard Interval
Effective Symbol Duration

DTV_LoadFFTBuff



Description: Received data loader from channel to FFT buffer
Library: DTV, OFDM
Class: SDFDTV_LoadFFTBuff

Parameters

Name	Description	Default	Unit	Type	Range
InLength	length of input sequence	2048		int	[0, ∞)†
Order	FFT points=2^Order	11		int	[1, ∞) ††
MinDelay	min delay from 0 to InLength-1	0		int	(0, InLength]
MaxDelay	max delay from 0 to InLength-1	2047		int	[MinDelay, InLength]
Offset	offset from ML peak to symbol start point	256		int	[−MinDelay, 2 × InLength − 2^{Order} − MaxDelay) †††

† InLength = 2^N in OFDM systems; where *N* is a positive integer. *N*=11 and 13 in DVB-T systems; *N*=11, 12, and 13 in ISDB-T systems.
†† Order=11 and 13 in DVB-T systems, Order=11, 12 and 13 in ISDB-T systems.
††† Offset = 1/32, 1/16, 1/8, and 1/4 InLength in ISDB-T and DVB-T systems.

Pin Inputs

Pin	Name	Description	Signal Type
1	input	input signal from channel	complex
2	corr	ML estimation of theta for OFDM symbol synchronization	real
3	angle	phase offset corresponding to the theta	real

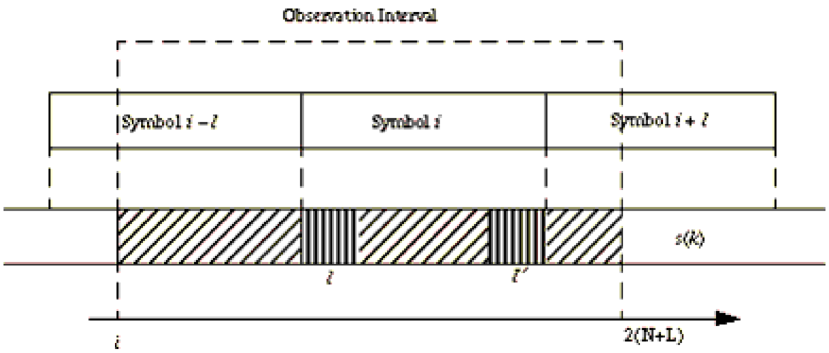
Pin Outputs

Pin	Name	Description	Signal Type
4	output	output signal which be used by FFT	complex
5	phase	phase offset of the current OFDM symbol	real

Notes/Equations

1. This model performs OFDM symbol synchronization, determines phase offset due to frequency offset, then outputs the OFDM symbol (output data is 2^{Order}) to the FFT buffer.
2. Implementation
   Assume *2(N+L)* consecutive samples of *x(k)* (which can be observed in the figure below), and that these samples contain one complete *(N+L)* sample OFDM symbol.

Structure of OFDM Signal with Cyclically Extended Symbols, *s(k)*



The position of this symbol within the observed block of samples, however, is unknown as the channel delay Θ is unknown to the receiver. Define the index sets *I* = [Θ, Θ + *L* − 1] and *I′* = [Θ + *N*, Θ + *N* + *L* − 1] (see Structure of OFDM Signal with Cyclically Extended Symbols, s(k)). The *I′* set therefore contains the indices of data samples that are copied into the cyclic extension; the *I* set contains the indices of this extension. Collect the observed samples in the *2(N+L)−vector X [x(1)* ... *x(2(N + L))]^T*. Note that the samples in the cyclic extension and their replicas, *k* Œ *I* ∪ *I′* are pair-wise correlated, i.e., : ∀ *k* Œ *I*:

$$E\{x(k)x^*(k+m)\} = \begin{cases} \sigma_s^2 + \sigma_n^2 & m = 0 \\ \sigma_s^2 e^{j2\pi\varepsilon} & m = N \\ 0 & otherwise \end{cases}$$

where

$$\sigma_s^2 \equiv E\{|s(k)|^2\}$$

$$\sigma_n^2 \equiv E\{|n(k)|^2\},$$

while the remaining samples *k* Œ *I* ∪ *I′* are mutually not correlated. We now explicitly exploit this correlation property and give the simultaneous maximum likelihood (ML) estimates of Θ and ε.

The log-likelihood function for Θ and ε is the logarithm of the probability density function of the *2(N+L)* observed samples in *X* given the arrival time Θ and carrier offset ε. The ML estimation of Θ and ε is the argument maximizing this function. Under the assumption that *X* is a jointly Gaussian vector, the log-likelihood function can be shown to be

$$\Lambda(\theta, \varepsilon) = 2|\gamma(\theta)|\cos(\{2\pi\varepsilon + \angle\gamma(\theta)\} - \rho\Phi(\theta))$$

where $\angle$ denotes the argument of a complex number,

$$\gamma(m) \equiv \sum_{k=m}^{m+L-1} x(k)x^*(k+N)$$

and

$$\varepsilon(m) \equiv \sum_{k=m}^{m+L-1} |x(k)|^2 + |x(k+N)|^2$$

are correction and energy terms, and

$$\rho \equiv \frac{\sigma_s^2}{\sigma_s^2 + \sigma_n^2}$$

is the magnitude of the correction coefficient between *x(k)* and *x(k+N)*.
The simultaneous ML estimation of Θ and ε becomes

$$\hat{\theta}_{ML} = \arg\max_{\theta}\{2|\gamma(\theta)| - \rho\Phi(\theta)\}$$

$$\hat{\varepsilon}_{ML} = -\frac{1}{2\pi}\angle\gamma(\hat{\theta}_{ML})$$

The processing is done continuously and two signals are generated.

$\hat{\theta}_{ML}$

and

$\hat{\varepsilon}_{ML}$

are the start point and the phase offset in the current OFDM symbol, respectively.
In this model, two signals 2|γ (Θ) − ρ Φ (Θ) and its corresponding phase offset signal

$$\varepsilon = -\frac{1}{2\pi}\angle\gamma(\theta)$$

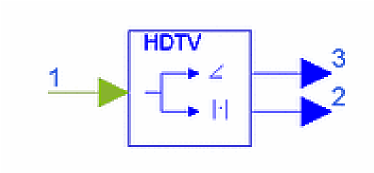
were generated in the *DTV_MLEstimator* (dtv) model; these two signals are input pins (corr and angle) of this model.

This model determines the maximum value $\hat{\theta}_{ML}$
of the corr pin in the range [MinDelay, MaxDelay], then determines the current carrier frequency offset $\hat{\varepsilon}_{ML}$
corresponding to $\hat{\theta}_{ML}$; then, according to time $\hat{\theta}_{ML}$, determines the *N* points signal to the output pin.

References

1. J. J. van de Beek, M. Sandell and P. O. Borjesson, *On Synchronization in OFDM Systems Using the Cyclic Prefix in Proceedings of Radio Vetenskaplig Konferens* (REVK'96), pp.663-667, Lulea, Sweden, June 1996.
2. M. Sandell, J. J. van de Beek and P. O. Borjesson, *Timing and Frequency Synchronization in OFDM Systems Using the Cyclic Prefix in Proceedings of International Symmposium on Synchronization*, pp.16-19, Essen, Germany, December 1995.
3. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.
4. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.

DTV_MLEstimator



Description: ML Estimation and Synchronization of OFDM Symbol
Library: DTV, OFDM
Class: SDFDTV_MLEstimator

Parameters

Name	Description	Default	Unit	Type	Range
Length	length of OFDM symbol	8192		int	(0, ∞) †
Guard	length of guard interval	256		int	[0, Length] ††
Ru	scale of the square term in ML algorithm	0.95		real	(0.0, 1.0)

† Length = 2^N in OFDM systems; where *N* is a positive integer. In DVB-T systems, *N*=11 and 13; in ISDB-T systems, *N*=11, 12 and 13.
†† Guard = 1/32, 1/16, 1/8, and 1/4 Length in ISDB-T and DVB-T systems.

Pin Inputs

Pin	Name	Description	Signal Type
1	input	input signal from channel	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	corr	ML estimation of theta for OFDM symbol synchronization	real
3	angle	phase offset corresponding to the theta	real

Notes/Equations

1. This model calculates parameters for simultaneous ML estimation of θ and ε that are used in timing and frequency synchronization in OFDM systems. Outputs of this model will be used by *DTV_LoadFFTBuff* (dtv).
2. Implementation
θ and ε are defined in *DTV_LoadFFTBuff* (dtv). The log-likelihood function is:
$$\Lambda(\theta, \varepsilon) = 2|\gamma(\theta)|\cos(\{2\pi\varepsilon + \angle\gamma(\theta)\} - \rho\Phi(\theta))$$
where $\angle$ denotes the argument of a complex number;
$$\gamma(m) \equiv \sum_{k=m}^{m+L-1} x(k)x^*(k+N)$$
$$\Phi(m) \equiv \sum_{k=m}^{m+L-1} |x(k)|^2 + |x(k+N)|^2$$
are correction and energy terms, and

$$\rho \equiv \frac{\sigma_s^2}{\sigma_s^2 + \sigma_n^2}$$

is the magnitude of the correction coefficient between *x(k)* and *x(k+N)*. The simultaneous ML-estimation of θ and ε becomes

$$\hat{\theta}_{ML} = \arg\max_{\theta}\{2|\gamma(\theta)| - \rho\Phi(\theta)\}$$

$$\hat{\varepsilon}_{ML} = -\frac{1}{2\pi}\angle\gamma(\hat{\theta}_{ML})$$

In order to determine the above two values for the OFDM symbol, two signals are generated: 2|γ (θ)| − ρ φ (θ) and its corresponding phase offset signal

$$\varepsilon = -\frac{1}{2\pi}\angle\gamma(\theta)$$

The output of the corr pin is the value of 2|γ(θ)| − ρ ε (θ) and the output of the angle pin is the value of

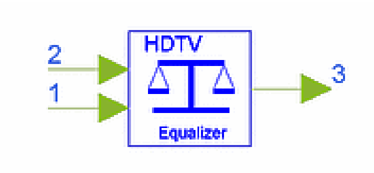
$$\varepsilon = -\frac{1}{2\pi}\angle\gamma(\theta)$$

.

References

1. J. J. van de Beek, M. Sandell and P. O. Borjesson, *On Synchronization in OFDM Systems Using the Cyclic Prefix in Proceedings of Radio Vetenskaplig Konferens* (REVK'96), pp.663-667, Lulea, Sweden, June 1996.
2. M. Sandell, J. J. van de Beek and P. O. Borjesson, *Timing and Frequency Synchronization in OFDM Systems Using the Cyclic Prefix in Proceedings of International Symmposium on Synchronization*, pp.16-19, Essen, Germany, December 1995.
3. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.
4. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.

DTV_OFDMEqualizer



Description: OFDM equalizer by the channel estimation
Library: DTV, OFDM
Class: SDFDTV_OFDMEqualizer

Parameters

Name	Description	Default	Unit	Type	Range
Carriers	number of active carriers in one OFDM symbol	1705		int	(0, ∞) †

† In ISDB-T systems: Carriers = n×108 in mode 1, n×216 in mode 2, or n×384 in mode 3, where n is the number of segments. In DVB-T systems: Carriers = 1705 in 2k mode, 6817 in 8k mode, or 3409 in 4k mode.

Pin Inputs

Pin	Name	Description	Signal Type
1	input	data in the active carriers in OFDM symbol	complex
2	Coef	frequency channel impulse response(CIR) estimation	complex

Pin Outputs

Pin	Name	Description	Signal Type
3	output	output data after channel equalization	complex

Notes/Equations

1. The model performs channel equalization by the channel estimation in each of the active carriers.
2. Implementation
   DTV_ChEstimator (dtv) and *DTV_DVBChEstimator* (dtv) models provide channel estimation and received signal in each active carrier. The OFDM channel equalization algorithm is:
   $$a(i) = \frac{x(i)}{h(i)}$$
   where *h(i)* is the channel estimation, *x(i)* is the received signal in active carriers, and *a(i)* is the equalized output signal.

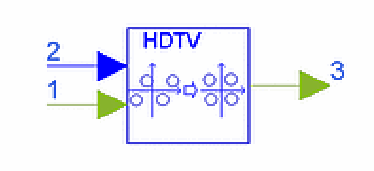
References

1. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T);

Specification of Channel Coding, Framing Structure and Modulation, Sept.1998.

2. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.

DTV_RemovePhase



Description: Compensator for phase offset due to carrier frequency offset
Library: DTV, OFDM
Class: SDFDTV_RemovePhase

Parameters

Name	Description	Default	Unit	Type	Range
Length	length of input symbol	8192		int	(0, ∞) †

† Length = 2^N in OFDM systems; where *N* is a positive integer. In DVB-T systems, *N*=11 and 13; in ISDB-T systems, *N*=11, 12 and 13.

Pin Inputs

Pin	Name	Description	Signal Type
1	input	signal from the OFDM symbol after OFDM symbol synchronization	complex
2	phase	phase offset due to the carrier frequency offset	real

Pin Outputs

Pin	Name	Description	Signal Type
3	output	OFDM signal after removed the phase offset	complex

Notes/Equations

1. This model removes the random phase offset due to carrier frequency offset in the OFDM symbol before OFDM channel estimation.
2. Implementation
   Assume *x(0)*, *x(1)*, ... , *x(N−1)* are the received signal after OFDM synchronization. The phase Φ is the detected phase offset due to the carrier frequency offset in *DTV_LoadFFTBuff* (dtv) model. The phase removed OFDM signal *y(0)*, *y(1)*, ... , *y(N−1)* is:
   $$y(i) = x(i)e^{-\frac{j2\pi\Phi i}{N}}$$

References

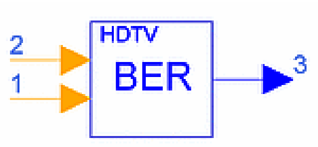
1. J.J. van de Beek, M. Sandell, and P.O.Borjesson, *On Synchronization in OFDM Systems Using the Cyclic Prefix, in Proceedings of Radio Vetenskaplig Konferens* (REVK'96), pp.663-667, Lulea Sweden, June 1996

2. ARIB-JAPAN, Terrestrial Integrated Services Digital Broadcasting (ISDB-T); *Specification of Channel Coding, Framing Structure and Modulation*, Sept.1998.
3. ETSI, Digital Video Broadcasting (DVB); *Framing structure, channel coding and modulation for digital terrestrial television*. EN300 744 v1.2.1, European Telecommunication Standard, July 1999.

Test Components for DTV Design Library

- *DTV BER* (dtv)
- *DTV PowerMeasure* (dtv)

DTV_BER



Description: Bit error rate for ISDB-T and DVB-T
Library: DTV, Test
Class: SDFDTV_BER

Parameters

Name	Description	Default	Unit	Type	Range
Length	length of input byte block	188		int	[1, ∞)
Delay	delay of byte blocks	512		int	[0, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	test	test input bit	int
2	ref	reference input bit	int

Pin Outputs

Pin	Name	Description	Signal Type
3	ber	bit error rate	real

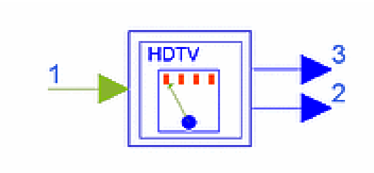
Notes/Equations

1. This model measures the input signal bit error rate.
   Each firing, 1 token at pin ber is produced when Length×8 tokens are consumed (note that Length is bytes, while test and ref are bits).
2. If input test bit is t_i, input reference bit is r_i, the model calculates the error rate after

   Delay according to the following example.
   count=0;
   err =0;
   rate =0;
   if (count>Delay) {
   for (i=0;i<Length × 8;i++) {
   t_i = test%i;
   r_i = ref%i;
   t_i = t_i &1;
   r_i = r_i &1;
   if (t_i != r_i)
   err = err+1;

```
}
}
count++;
if (count>Delay)
rate = err/((count-Delay) × length × 8);
BER%(0) <<rate;
```

DTV_PowerMeasure



Description: Average power measurement
Library: DTV, Test
Class: SDFDTV_PowerMeasure

Parameters

Name	Description	Default	Symbol	Unit	Type	Range
BlockSize	number of particles in a block	16	m		int	[1, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	input	input signal	real

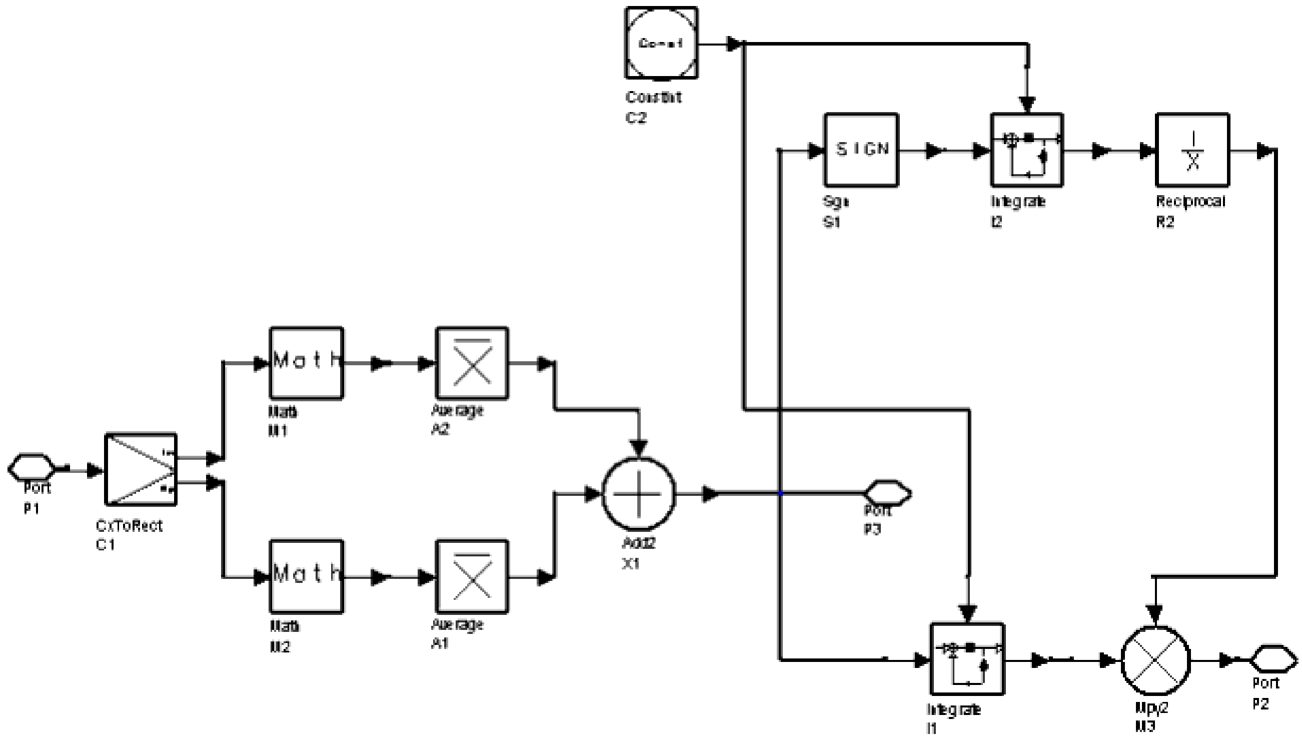
Pin Outputs

Pin	Name	Description	Signal Type
2	Ave_P	average power of all input signals	real
3	B_P	average power of input signals in a block	real

Notes/Equations

1. This subnetwork model measures the average power of the input signals. The schematic for this subnetwork is shown below.

DTV_PowerMeasure Schematic



2. Each firing, 1 token at B_P and Avg_P are produced when m input tokens are consumed.
   If input signal *s(t) = x(t) + jy(t)*,
   average signal power
   $$P = \int_a^b (x^2(t) + y^2(t))dt$$
   for discrete signals
   $$P = \frac{\sum_{n=a} (x^2(n) + y^2(n))}{b - a}$$
   For B_P out, $b - a = m$; for Avg_P, a = 0, b = current input points.