Agilent Technologies

Advanced Design System 2011.01

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CDMA Design Library

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The following third-party libraries are used by the NlogN Momentum solver:

"This program includes Metis 4.0, Copyright © 1998, Regents of the University of Minnesota", http://www.cs.umn.edu/~metis , METIS was written by George Karypis (karypis@cs.umn.edu).

Intel@ Math Kernel Library, http://www.intel.com/software/products/mkl

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CDMA Design Examples

Channel Coding Design Examples

These design examples are provided in the **/examples/cdma/IS95A_ChnCodec_wrk** directory.

IS95A_ChnCodec_wrk Design Names

- DsnCDMA_AccessChannelCodec
- DsnCDMA_ForwardChannelCodec
- DsnCDMA_PagingChannelCodec
- DsnCDMA_ReverseChannelCodec
- DsnCDMA_SyncChannelCodec

Features

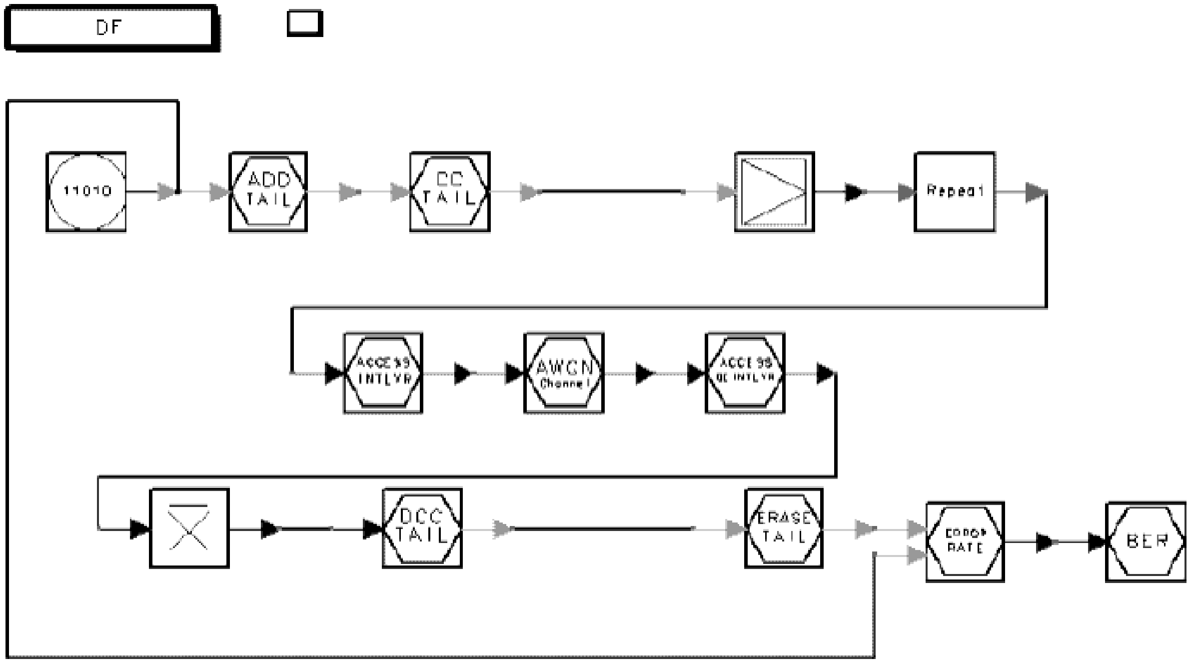
- Random source
- Add tail
- Convolutional code
- Repeat
- Interleaver
- Data rate: 9600 bps, 4800 bps, 2400 bps, or 1200 bps
- Symbol rate: 28.8 kbps
- Eb/No: [0,4](dB), step 1 dB (these parameters can be changed in CDMA_AWGN_Ch)

Description

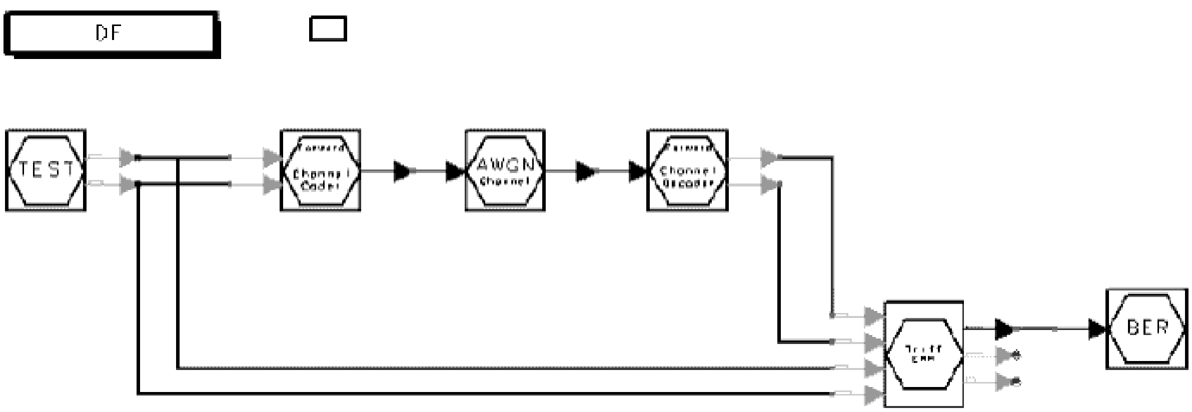
These designs illustrate using the CDMA Design Library to build an IS-95A Channel Coding design.

- CDMA Access Channel Codec design: 4800 bps data rate
- CDMA Forward Channel Codec design: 9600 bps, 4800 bps, 2400 bps, 1200 bps data rate
- CDMA Paging Channel Codec design: 9600 bps, 4800 bps data rate
- CDMA Reverse Channel Codec design: 9600 bps data rate
- CDMA Sync Channel Codec design: 9600 bps, 4800 bps, 2400 bps, 1200 bps data rate

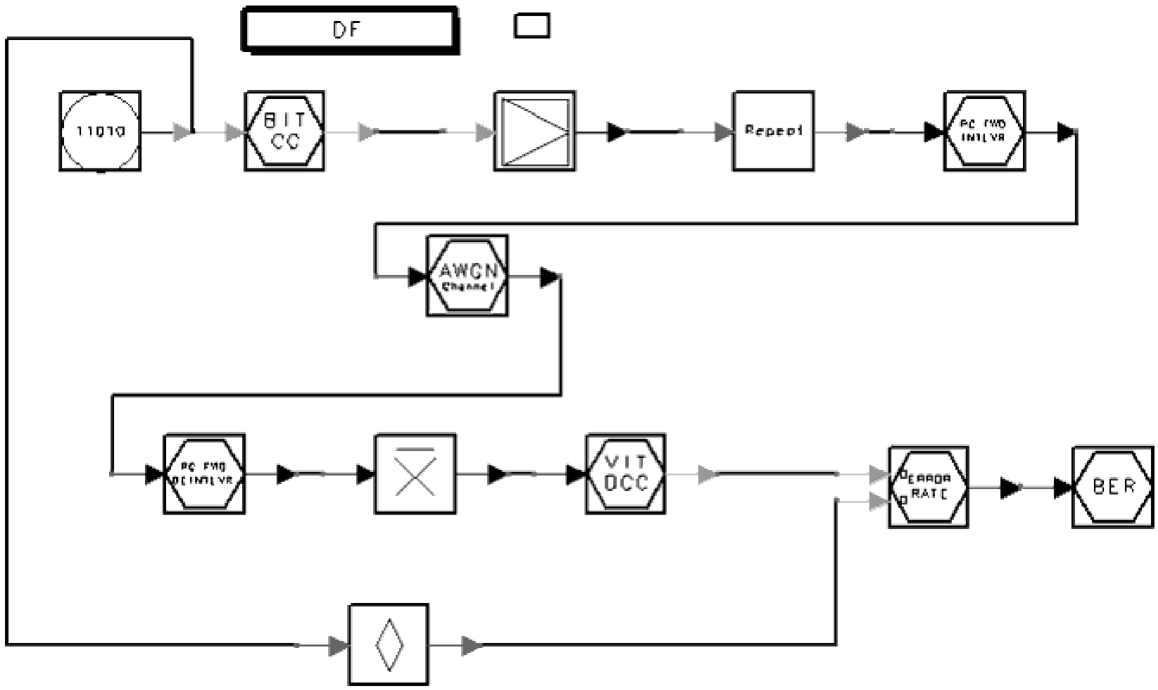
Schematics



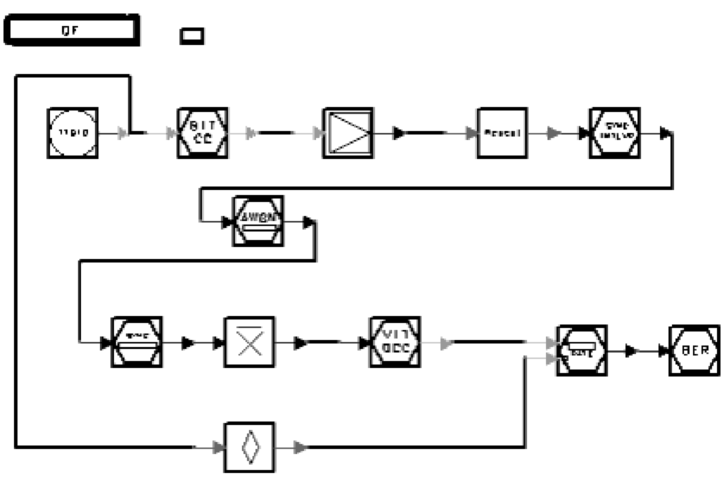
DsnCDMA_AccessChannelCodec



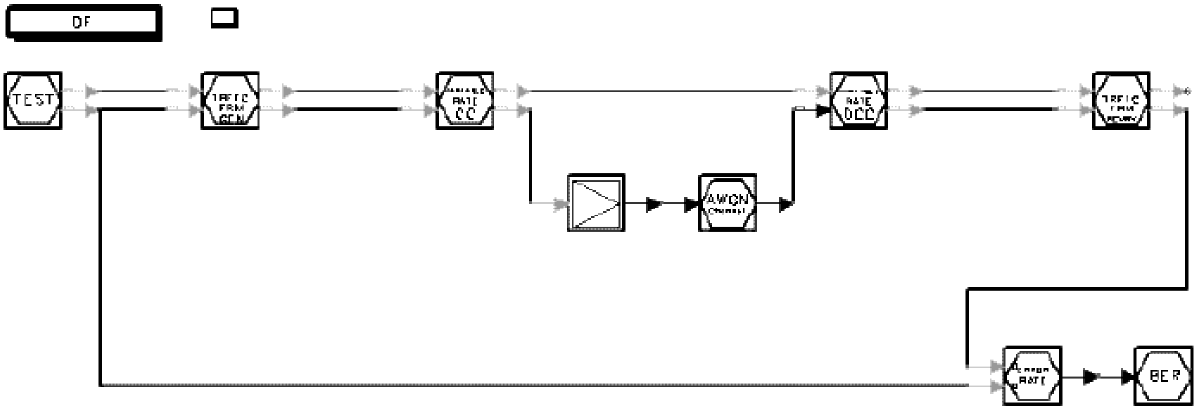
DsnCDMA_ForwardChannnelCodec



DsnCDMA_PagingChannelCodec



DsnCDMA_SyncChannelCodec



DsnCDMA_ReverseChannelCodec

Specifications

The CDMA_TstSrc data rate in the examples is set as a constant rate to accurately calculate the BER; for example, CDMA_ForwardChannelCodec is set as *CONSTANT9600bps* . If the Eb/No ratio is larger, the BER will be zero because the test length is not long enough for this point. It is better to increase the test length to get the BER.

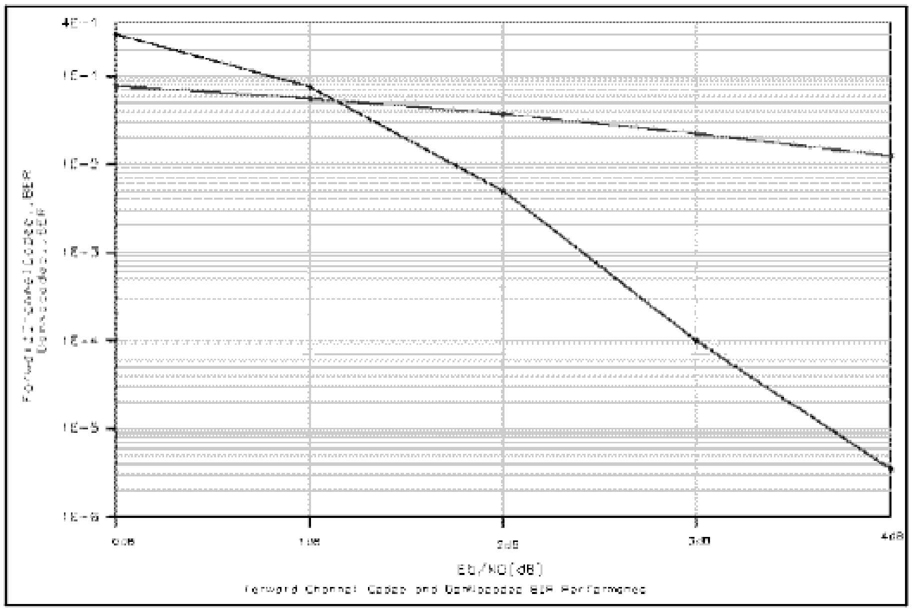
Notes

1. In the CDMA_PagingChannelCodec and CDMA_SyncChannelCodec examples, the delay between the source and sink is due to CDMA_ViterbiBitDCC. The delay is equal to 5* constraint length of the convolutional code.
2. In CDMA Paging Channel, there are two data rates: 9600 bps and 4800 bps. In Vareqn, if times is 1, a 9600 bps frame is used; if times is 2, a 4800 bps frame is used. According to IS-95A, only one of them is selected in a base station.
3. The BER diagram shows IS-95A channel codecs performance. The Eb/No ratio and the points can be changed in the parameters. For example, if EbNoRatio=0 dB, step=0.5 dB, and Dot=5, the Eb/No of the first point is 0 dB, the next point is 0.5 dB, and the fifth point is 2 dB.
   To obtain the BER curve in one simulation, we use some models to increase Eb/No(dB) in a constant step and get a BER for different Eb/No(dB). For example, in CDMA_AWGN_Ch, Eb/No(dB) is a constant value in a period, and the period length is set by FrameNumberA × FrameNumberB.
   CDMA_BER_Sink computes the BER in this period, and the value of the test parameter must be equal to FrameNumberA × FrameNumberB. After the period, if the Dot parameter is larger than 1, the Eb/No will be increased with a step. In the next period with the same length, the new BER of this new period will be computed. After simulation, the dots for BER vs. Eb/No(dB) can be determined. Connecting these dots results in the BER curve.

Test Results

The following figure shows the BER performance of CDMA forward channel codec and no codec. The BER data of no codec is saved in *DsnNocodec.ds*; the graph is saved in

ForwardChannelCodec.dds.



Forward Channel Codec and Nocodec BER Performance

Code Excited Linear Prediction Design Examples

These design examples are provided in the **/examples/cdma/IS95A_CELP_wrk** directory.

IS-96A CELP Speech Codec Demo1

IS95A_CELP_wrk Design Name

- DsnCDMA_CelpCodecDemo1

Features

- Implemented by subnetworks in CDMA CELP Codecs library
- Code excited linear prediction (CELP) speech codec
- Input and output speech waveforms can be compared after simulation

Description

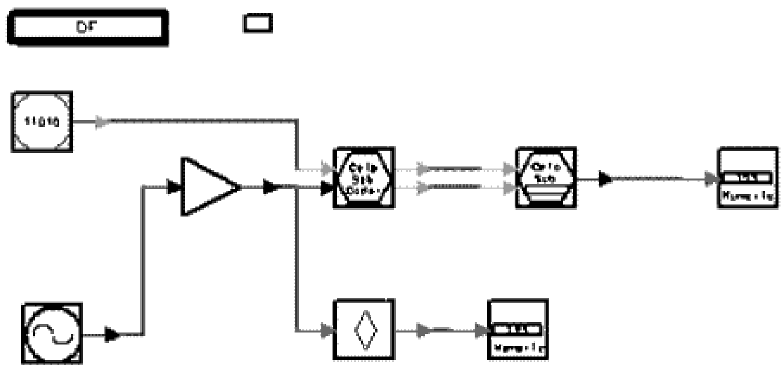
This example demonstrates the use of CELP speech codec components using the algorithm described in IS-96A (which conforms to the general requirements for CDMA systems specified in IS-95).

CDMA_CelpSubCoder and CDMA_CelpSubDecoder subnetworks are used in this example. A sine wave used as a simulated speech source at 128 kbps is input and displayed for reference. With CELP encoding, the signal is converted to a bitstream. After decoding, speech that is recovered and reconstructed at less than 8 kbps is displayed for comparison.

Notes

FSIZE, LPCORDER and FIRSTFLAG parameters in CDMA_CelpSubCoder and CDMA_CelpSubDecoder must be the same to obtain meaningful simulation results.

Schematic

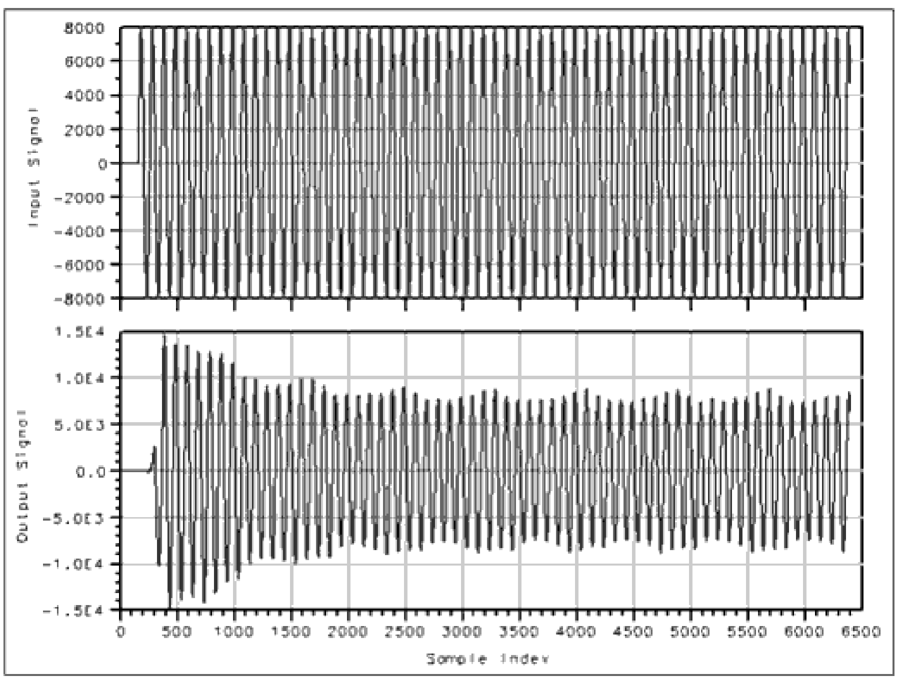


DsnCDMA_CelpCodecDemo1

Specifications

Specification	Simulation Type	Value	Unit
Input sample rate	ADS Ptolemy	8	kHz
Input bit rate	ADS Ptolemy	128	kbps
Output sample rate	ADS Ptolemy	8	kHz
Output bit rate	ADS Ptolemy	8	kbps

Test Results



DsnCDMA_CelpCodecDemo1 Test Results

From the graphs, we can see that the reconstructed signal goes into a status of oscillatory balance slowly from data point ≈1300; this balance remains stable around the waveform envelope of the input signal.

IS-96A CELP Speech Codec Demo2

IS95A_CELP_wrk Design Name

- DsnCDMA_CelpCodecDemo2

Features

- Implemented by CDMA library components
- Code excited linear prediction (CELP) speech codec
- Input and output speech waveforms can be compared after simulation

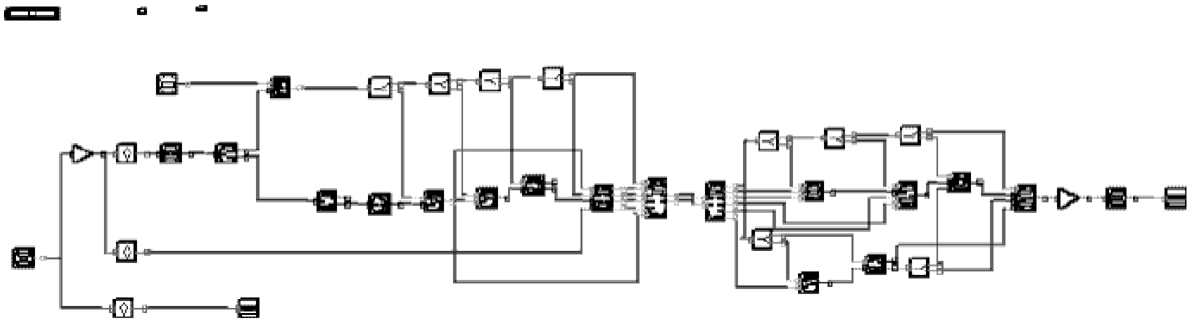
Description

This example demonstrates the use of CELP speech codec components using the algorithm described in IS-96A (which conforms to the general requirements for CDMA system specified in IS-95).

In this example, basic CELP Codecs library components are used. A speech segment at 128 kbps is read from *celp.wav* file that is input and displayed for reference.

With CELP encoding, the signal is converted to a bitstream. After decoding, speech that is recovered and reconstructed at less than 8 kbps is displayed for comparison. Only an 8 kHz sample rate, 16 bits per sample, and mono channel windows. *wav* file is supported; otherwise an error message will be issued.

Schematic



DsnCDMA_CelpCodecDemo2

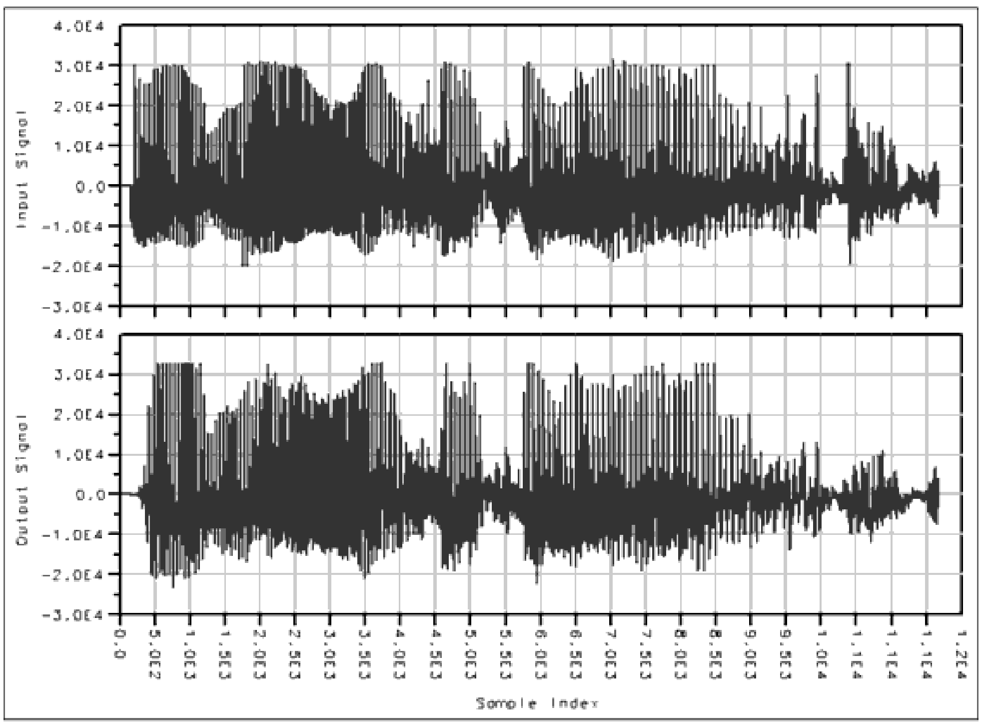
Specifications

Specification	Simulation Type	Value	Unit
Input sample rate	ADS Ptolemy	8	kHz
Input bit rate	ADS Ptolemy	128	kbps
Output sample rate	ADS Ptolemy	8	kHz
Output bit rate	ADS Ptolemy	8	kbps

Notes

The source speech file *celp.wav* must be placed in a directory; the full path name is given in the *FileName* parameter of the CDMA_ReadSigFile component. The output speech file name is defined by the user and is given in the *WriteFileName* parameter of the CDMA_WriteSigFile component.

Test Results



DsnCDMA_CelpCodecDemo2 Test Results

From the graphs, we can see that the waveform of the reconstructed signal is almost the same as the input signal.

Forward Link Rake Receiver Design Examples

These design examples are provided in the **/examples/cdma/IS95A_FwdLink_wrk** directory.

IS-95A Forward Link Rake Receiver with AFC, without Codec

IS95A_FwdLink_wrk Design Name

- DsnCDMA_FwdRake_AFC_NoCodec

Features

- Forward link Rake receiver
- Baseband automatic frequency offset correction (AFC) function
- Without channel codec
- Bipolar NRZ symbols +1 and −1 are used (Sign Decision)
- Tcl/Tk plots for interactive display

Description

This application helps users build a design for testing the forward link Rake receiver (CDMA_FwdRake subnetwork) without channel codec, with AFC function and with sign decision. Since codec is not used, the symbol data is processed.

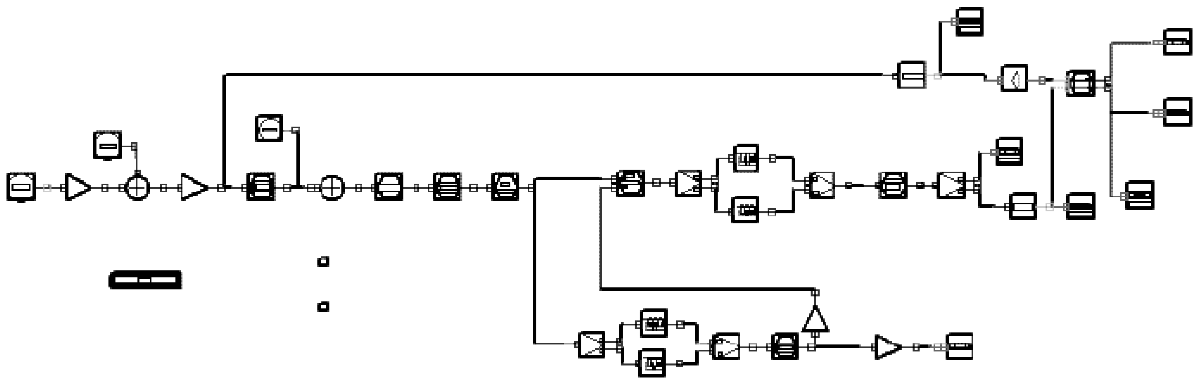
Performance is measured in terms of symbol error rate (SER). Input data is bipolar symbol +1 or −1 with equal probability. Results can be viewed during simulation. Es/No is approximately 20 dB less than the parameter set in the design.

The CDMA_FwdRcvwithAFC subnetwork is not used in the example design because it is for cascaded use with codec.

Parameters

- NChEst (channel estimation length in terms symbols) in VarEqn is used to adjust channel estimation performance. It must be *n* th power of 2 (8, 16, 32, 64), and long enough for frequency estimation accuracy. According to the fading rate of the channel, it cannot be greater than 64. The value set in the example design is 8.
- Variance (Gaussian noise variance) in CDMA_FwdFadingCh subnetwork is used to adjust Es/No.
- TestLen (observation symbols for output symbol error rate) in VarEqn is used to adjust symbol error rate sink length.
- Other parameters are generally unchanged.

Schematic



DsnCDMA_FwdRake_AFC_NoCodec

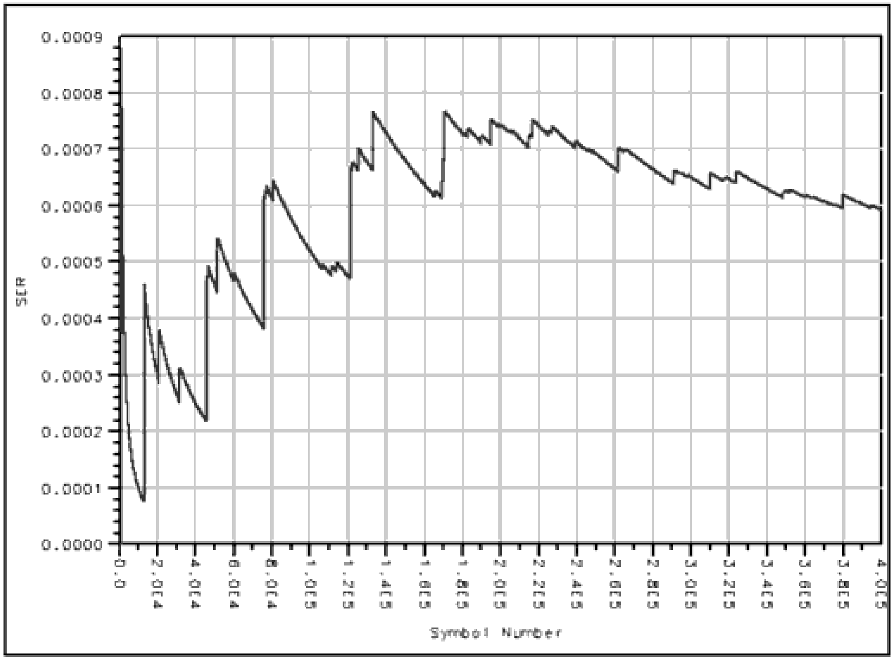
Specifications

Parameter	Description	Simulation Type	Value	Unit
NChEst	channel estimation length in terms of symbol	ADS Ptolemy	8	N/A
Variance	additive white Gaussian noise variance	ADS Ptolemy	1.28	N/A
TestLen	observation symbol length for calculating SER	ADS Ptolemy	400000	N/A
FreqencyOffsetHz	fixed frequency offset added by CDMA_FreqOffset	ADS Ptolemy	500.0	Hz
Vx_Speed	speed of mobile station added to X-axis	ADS Ptolemy	100.0	km/hr
Vy_Speed	speed of mobile station added to Y-axis	ADS Ptolemy	0.0	km/hr

Notes

1. AFC function is realized in baseband. The estimated frequency error output of CDMA_FreqErrEstimate is digital angle frequency. It is read by TkShowValues after Hz conversion by dividing 2×PI× *Ts*, where *Ts* is the duration of one symbol, which is 1/19.2ksps.
2. For convenience, the SER can be viewed during simulation. When simulation time is long and power shutdown or other contingencies occur, numeric sinks cannot store data. The displayed value is effective only when the observed points are large enough.

Test Results



DsnCDMA_FwdRake_AFC_NoCodec Test Results

From the graph, we can see that forward link Rake receiver with AFC function can effectively correct fixed frequency offset and Doppler frequency shift so that SER will remain at a reasonable level.

IS-95A Forward Link Rake Receiver without AFC, without Codec

IS95A_FwdLink_wrk Design Name

- DsnCDMA_FwdRake_NoAFC_NoCodec

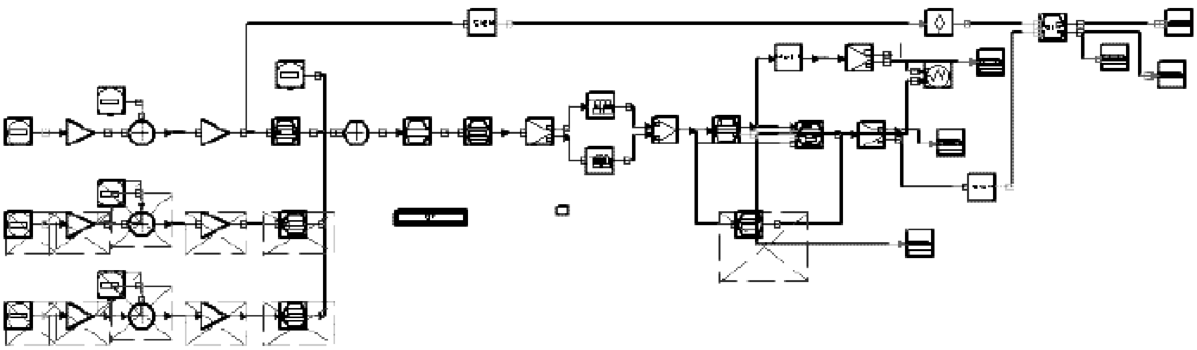
Features

- TkShowValue and TkPlot for interactive display
- Displays: Symbol Number, Symbol Error Rate, and Estimated Channel Profile
- Noise power is user-adjustable
- No channel codec
- Bipolar NRZ symbols +1 and −1 are used (Sign Decision)

Description

This example design help users build a design for testing the forward link Rake receiver without codec, without AFC function, with sign decision. Since codec is not used, symbol data is processed; the performance index is in terms of symbol error rate (SER). The output symbol is bipolar +1 or −1 with equal probability. The Es/No is approximately 10 dB under the parameter set in the design.

Schematic



DsnCDMA_FwdRake_NoAFC_NoCodec

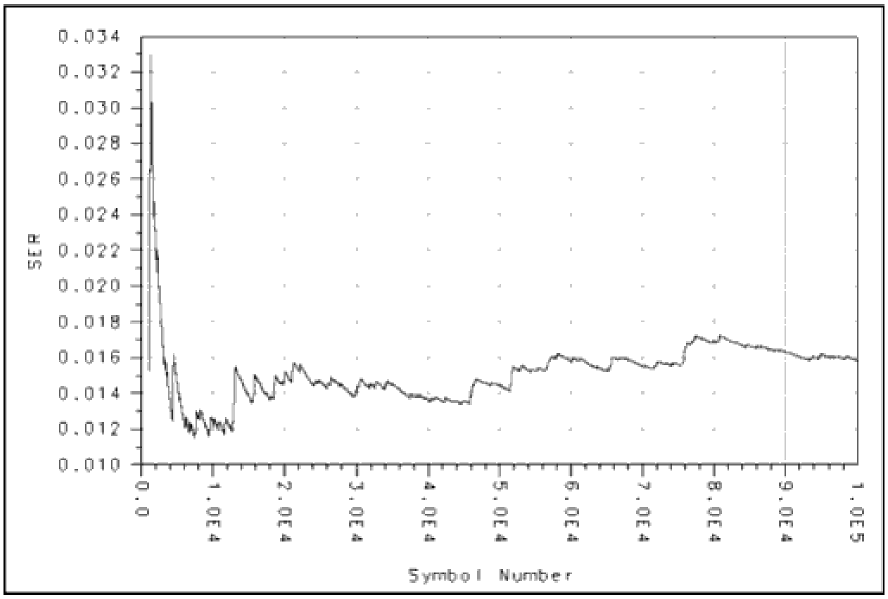
Specifications

Parameter	Description	Simulation Type	Value
NChEst	channel estimation length in terms of symbols in VarEqn to adjust channel estimation performance. It must be *n* th power of 2, such as 8, 16, 32, 64. According to the fading rate of the channel, it cannot be greater than 64.	ADS Ptolemy	32
TestLen	observation symbols for output symbol error rate in VarEqn to adjust symbol error rate sinks start and stop position	ADS Ptolemy	100000
Variance	Gaussian noise variance in CDMA_FwdFadingCh subnetwork to adjust Es/No. Es denotes the energy of the received symbol of one traffic channel, it is approximately 1.0, using the normalized filter default parameter (set in CDMA_OQPSK), channel with no pathloss.	ADS Ptolemy	12.8

Notes

1. To connect the auxiliary models for monitoring channel sounder output (estimated channel profile) by TkXYPlot, the CDMA_CoherentRake and CDMA_FwdChnlSounder components that make up the CDMA_FwdRake subnetwork are used instead of the subnetwork.
   If faster speed is preferred and it is not necessary to monitor channel sounder output, CDMA_FwdRake can be activated to replace CDMA_CoherentRake, CDMA_FwdChnlSounder and auxiliary models.
2. The number of the transmitted user can be added by activating the deactivated source part.
3. For convenience, the SER can be viewed during simulation. When simulation time is long and power shutdown or other contingencies occur, numeric sinks cannot store data. The displayed value is effective only when the observed points are large enough.

Test Results



DsnCDMA_FwdRake_NoAFC_NoCodec Test Results

IS-95A Forward Link

IS95A_FwdLink_wrk Design Name

DsnCDMA_ForwardLink

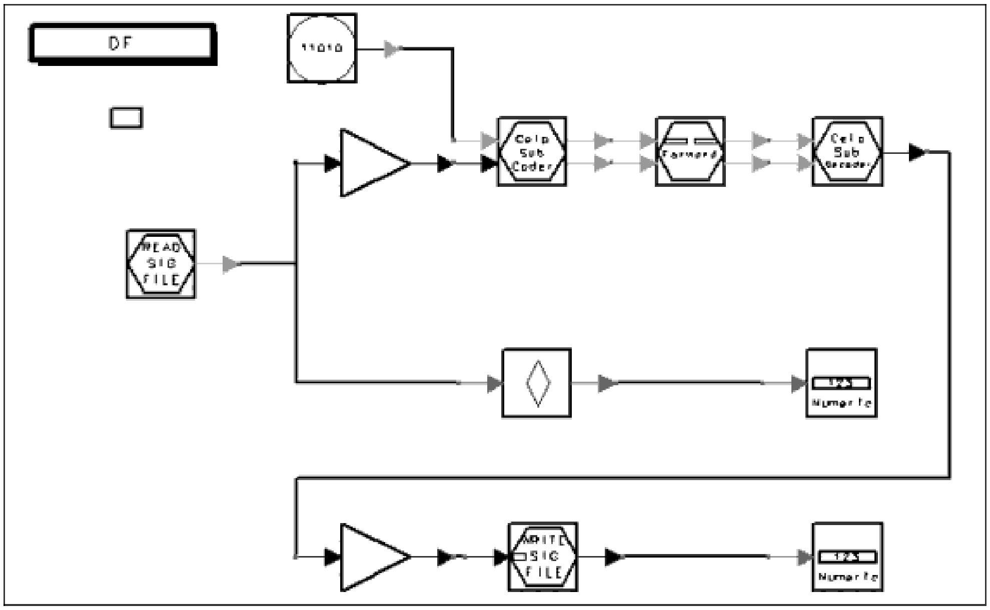
Features

- CELP voice codec
- Channel codec for forward traffic channel
- Spread spectrum transmitter for forward traffic channel
- Rake receiver for forward traffic channel
- Voice file input and voice file output

Description

This example is the system design of CDMA forward link including voice encoder and decoder. It is used to show the application of the CDMA channel codec (forward), CELP codec models and subnetworks.

Schematic



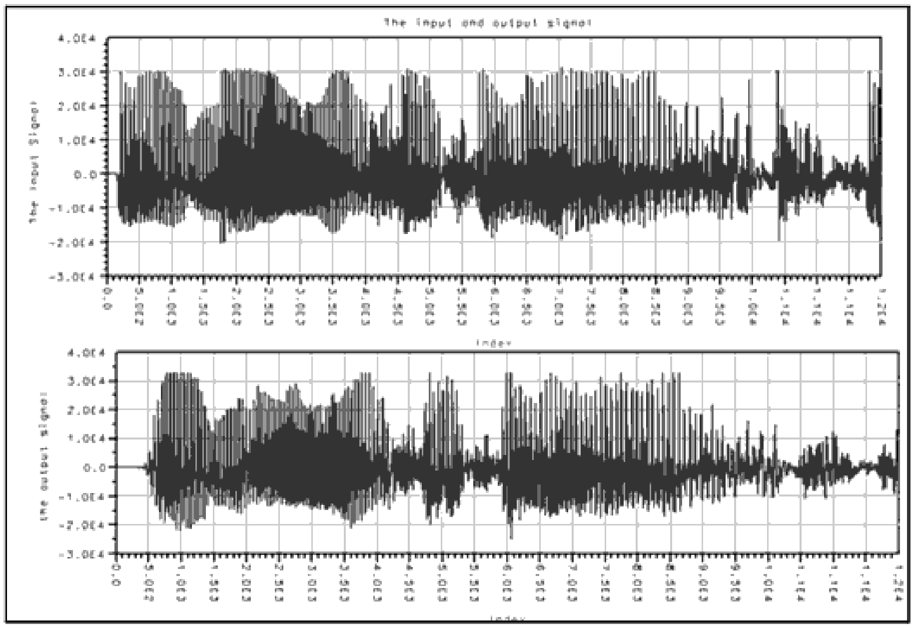
DsnCDMA_ForwardLink

Notes

- CDMA_celpSubCoder: CELP voice encoder.
- CDMA_celpSubDecoder: CELP voice decoder.
- CDMA _Fwd: subsystem including CDMA Forward traffic channel and CDMA pilot channel. The NoiseVariance parameter is the AWGN variance; the default value is 1 and can be changed.
- CDMA_FwdTrfCh: forward channel coding and spectrum spreading part.
- CDMA_FwdFadingCh: CDMA forward traffic channel including base and mobile station antennas, CDMA channel model and AWGN model.
- CDMA_FwdChCoder: CDMA forward traffic channel encoder.
- CDMA_FwdChDecoder: CDMA forward traffic channel decoder.
- CDMA_FwdRcvwithoutAFC: Rake receiver for CDMA forward traffic channel (no AFC).

Test Results

The voice source is provided by the *CelpDemo.wav* file, which must be placed in the your workspace data directory. The output file is *output.wav*. These two files can be played by media player.



DsnCDMA_ForwardLink Test Results

Measurement Design Examples

These design examples are provided in the **/examples/cdma/IS95A_Measure_wrk** directory.

IS-95A Reverse Multiple User Measurement

IS95A_Measure_wrk Design Names

- DsnCDMA_RevMeasure

Features

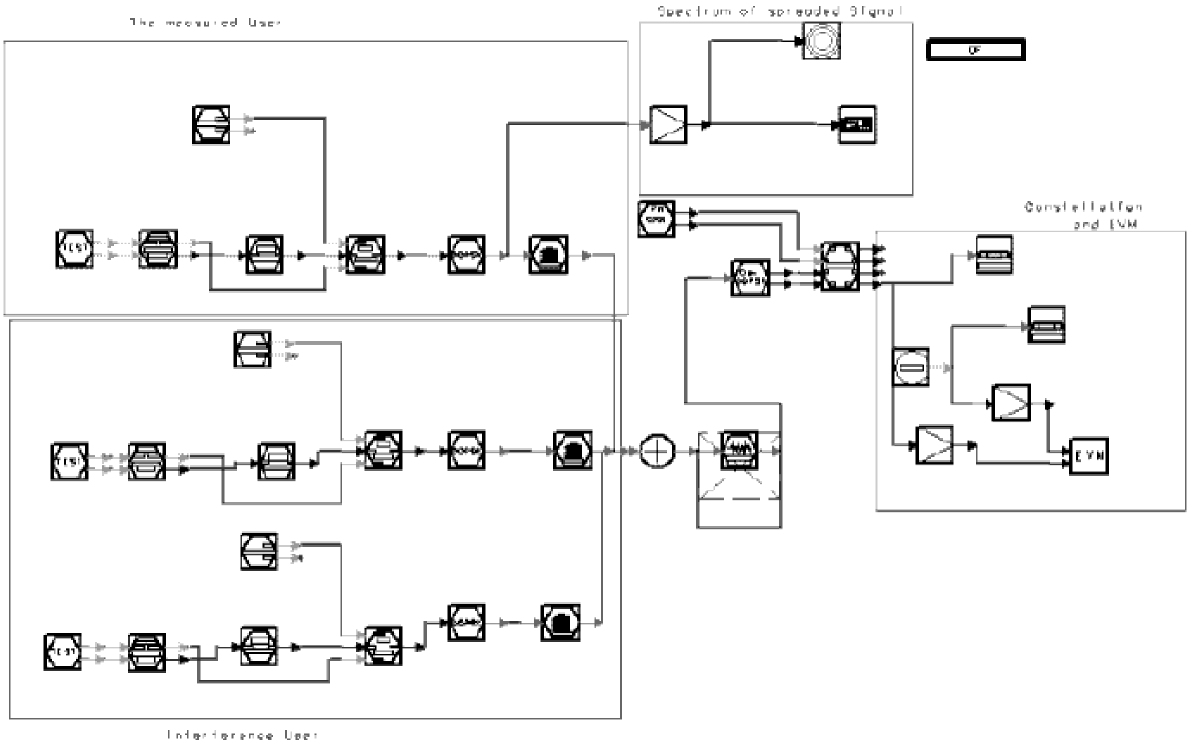
- Spectrum of spread signal
- Constellation of demodulation signal (BPSK)
- Error vector magnitude (EVM) measurement of demodulation signal

Description

This example illustrates several important measurements. Some measurements are implemented in this design; others are performed by post-processing the data in the Data Display window.
Open the following. *dds* files:

- CDMA_ACPR (adjacent channel power ratio)
- CDMA_CCDF (complementary cumulative density function)
  (This file can take several minutes to open, depending on available memory.)
- CDMA_Spec_Constellation: spectrum, constellation and EVM.

Schematic



DsnCDMA_RevMeasure

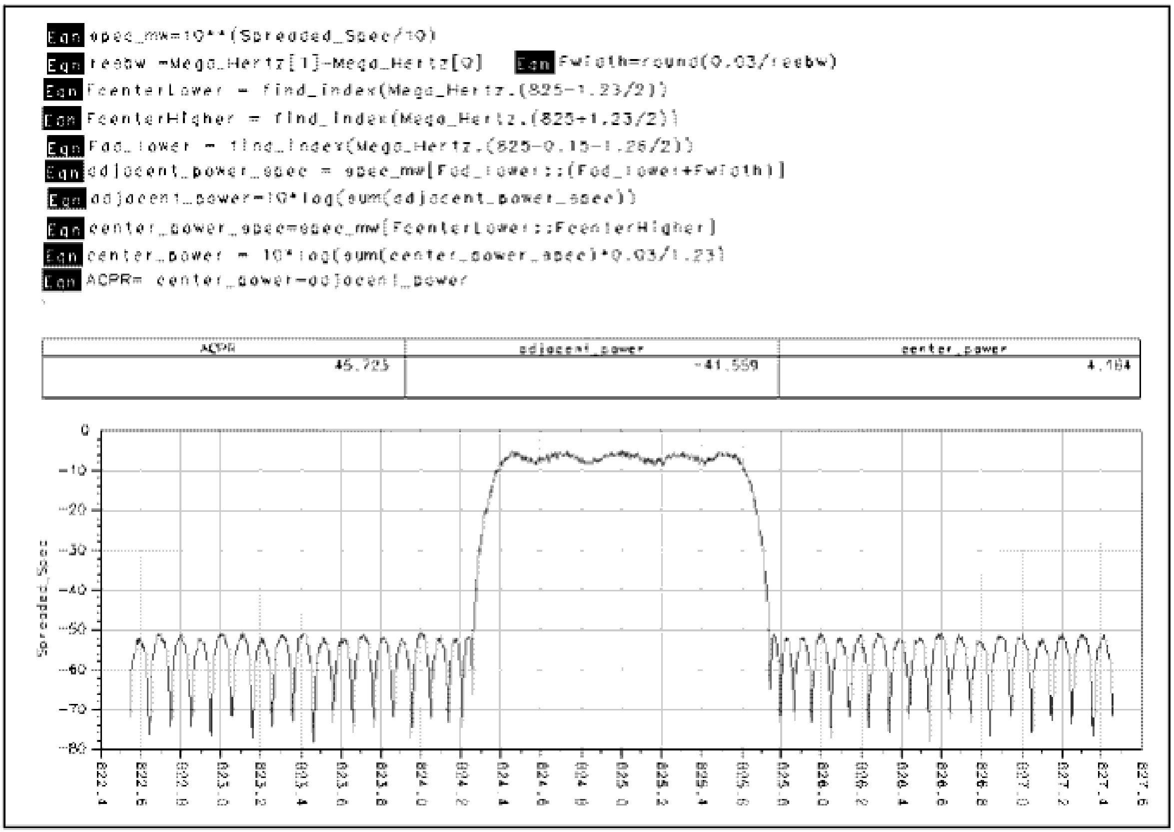
Specifications

In this design, carrier frequency is set to 825 MHz. The TStep of CxToTimed used in spectrum of spread signal test must be (1/(1.2288×4)) μ.

For real BPSK used in CDMA systems, the ErrVecMeas modulation type is BPSK.

It is known that the duration time of a frame in CDMA systems is 20 μ, and a frame before spreading includes 576 symbols. So, in constellation and EVM, the TStep of CxToTimed and SymbolTime of ErrVecMeas must be (20/576) μ. The start and stop of ErrVecMeas must be one or more times 20. And, the Symbol_Burst_Length of this model is 576.

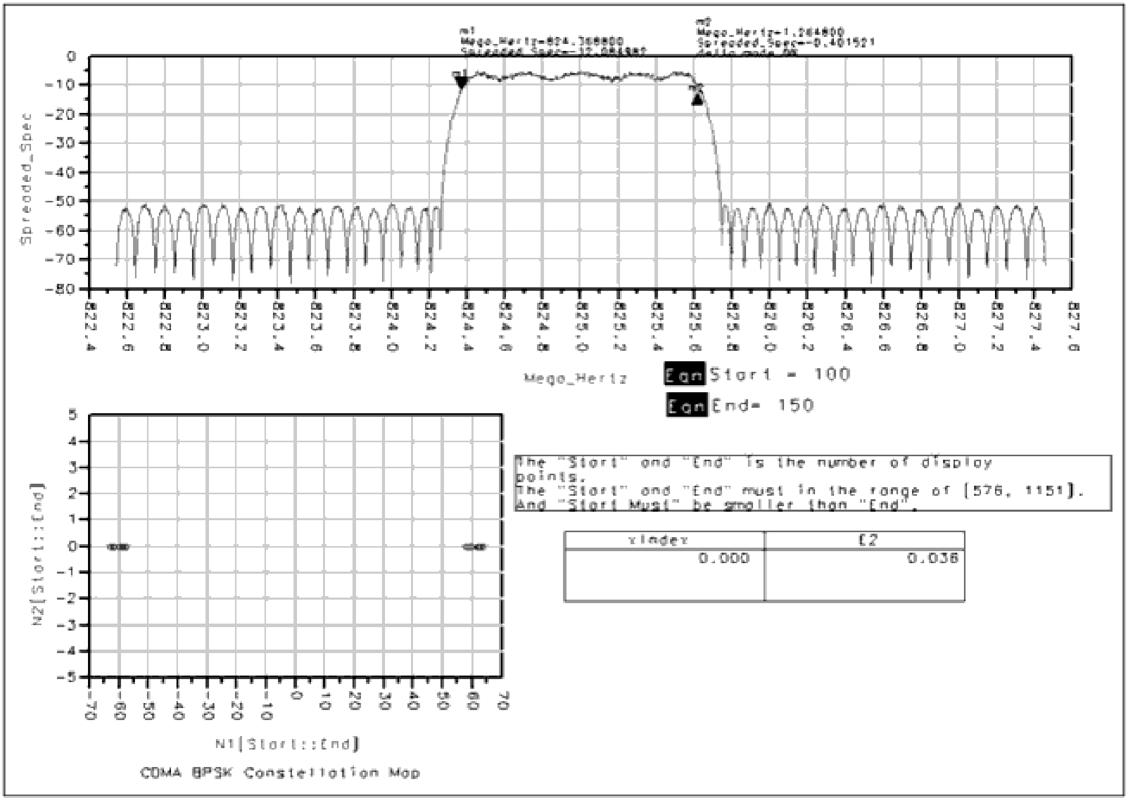
Test Results



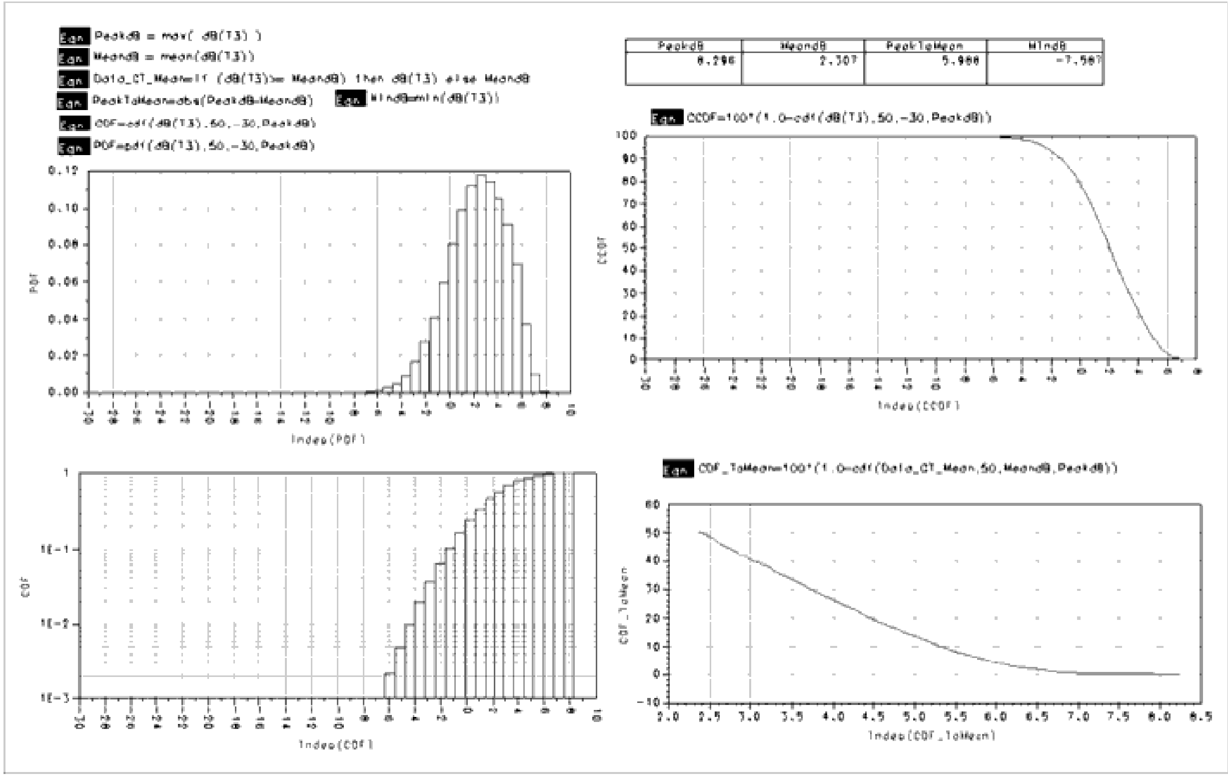
Note:
The adjacent channel power ratio test method compares the power density at the offset frequency in a 30kHz bandwidth to the power within an average bandwidth of the same (30kHz) width in the carrier-channel bandwidth.

In this test result,
offset frequency = 30kHz in [824.355kHz, 824.385kHz] (Fad_lower represents 824.355kHz); carrier-channel bandwidth = 1.23MHz in [824.385KHz, 825.615KHz]
(FcenterLower represents 824.385kHz and FcenterLower represents 824.385KHz);
center_power is a value for normalizing the 1.23MHz Channel Power value to a 30kHz bandwidth.

CDMA_ACPR (Adjacent Channel Power Ratio)



CDMA_Spec_Constellation (Spectrum, Constellation and EVM)



CDMA_CCDF (Complementary Cumulative Density Function)

Reverse Link Rake Receiver Design Examples

These design examples are provided in the **/examples/cdma/IS95A_RevRake_wrk** directory.

IS-95A Reverse Link Rake Receiver (1 User Working)

IS95A_RevRake_wrk Design Names

- DsnCDMA_RevRake_1user_codec
- DsnCDMA_RevRake_1user_PC
- DsnCDMA_RevRake_1user_Nocodec

Features

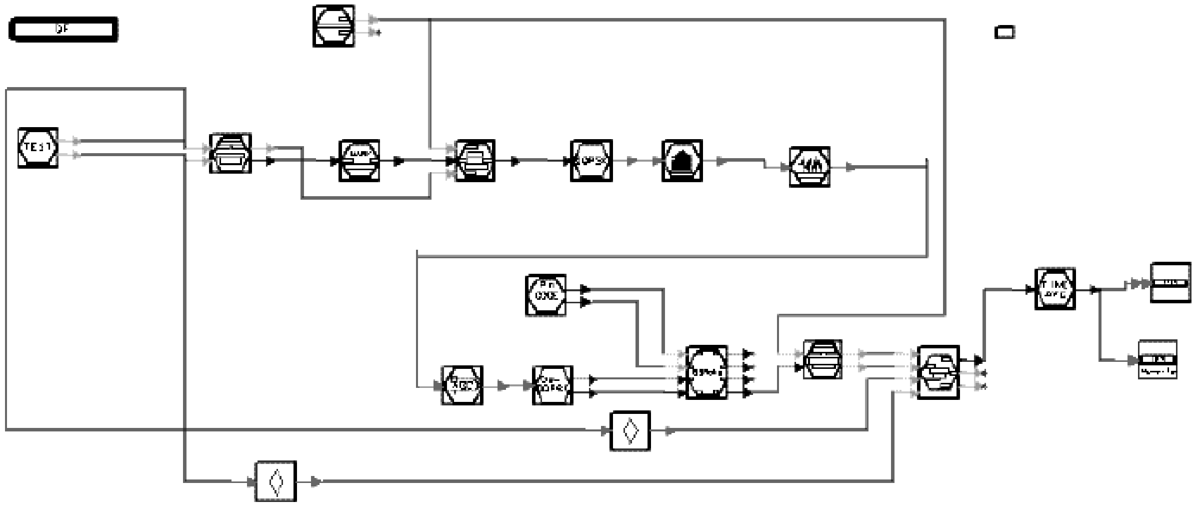
- Tcl/Tk plots for interactive display
- Displays: BER (bit error rate), FER (frame error rate), and SINR (signal-to-interference noise ratio) convergence cure
- Convolutional coder and Viterbi decoder using soft decision algorithm
- Block interleaver and data randomizer
- OQPSK modulation and demodulation
- CDMA multipath fading channel with Doppler shift. Path numbers can be set. Doppler shift can be determined by setting the mobile's speed
- Additive white Gaussian noise (AWGN) channel and signal-to-noise ratio (SNR) can be adjusted by setting the AWGN variance
- Non-coherent reverse link Rake receiver using multipath diversity technology and fast Hadamard transform

Description

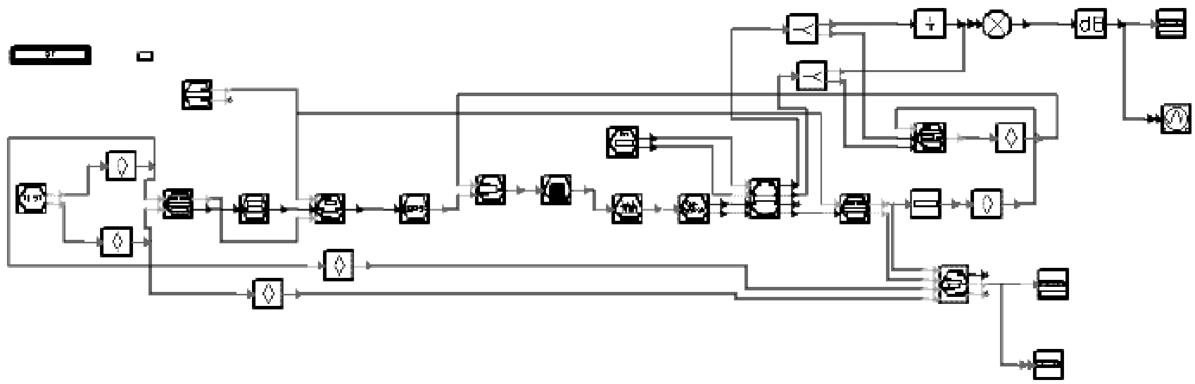
These designs apply an IS-95 reverse link base station Rake receiver to a Rayleigh fading channel with Doppler shift, which includes channel estimation, demodulation and square-law combination, and data rate detection.

Automatic gain control is applied to the signal received from the channel. The signal is demodulated and placed in the Rake receiver, which searches for the strongest paths; signals on these paths are despread and then combined. Deinterleaving, rate detection and decoding are performed and the frame is recovered. The performance of the receiver can be viewed during simulation.

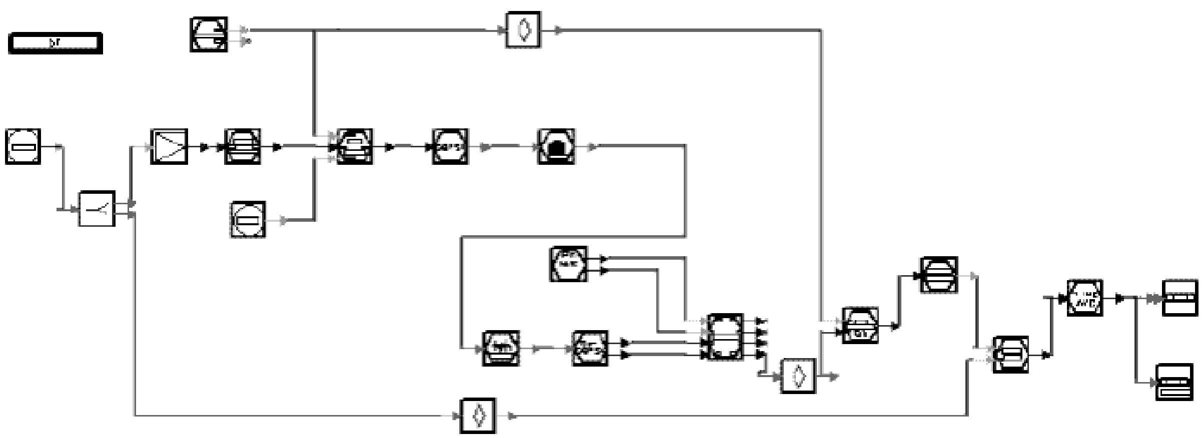
Schematics



DsnCDMA_RevRake_1User_Codec, One User is Working, Codec Used



DsnCDMA_RevRake_1User_PC, One User is Working, Codec Used, Power Control Applied



DsnCDMA_RevRake_1User_NoCodec One User is Working, Codec Not Used

Specifications

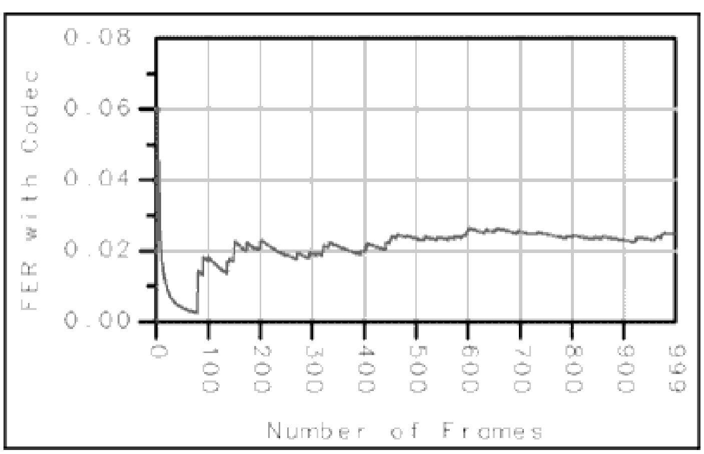
Component	Parameter	Simulation Type	Value	Unit
CDMA_TstSrc	Data Rate	ADS Ptolemy	CONSTANT9600	
CDMA_Channel	X,Y Position	ADS Ptolemy	(1.0, 1.0)	
CDMA_Channel	Vx, Vy Speed	ADS Ptolemy	(100, 0)	km/h
CDMA_Channel	ChannelType	ADS Ptolemy	ThreePath	
CDMA_GNoise	Noise_Variance	ADS Ptolemy	10	
CDMA_BSRake	FingerNum	ADS Ptolemy	2	
CDMA_ReversePowerControl	SIR_Threshold	ADS Ptolemy	9	dB
CDMA_ReversePowerControl	FER_Threshold	ADS Ptolemy	0.05	

Notes

1. Gaussian channel variance is modified according to the signal-to-noise ratio parameter. For example, when noise variance=10, the mobile transmitter signal-to-noise ratio≈14.
2. CDMA channel conditions are modified according to channel parameters X(Y)_Position, Vx(y)_Speed, and ChannelType.
3. For the base station Rake receiver subnetwork CDMA_BSRake, if FingerNum=1, the CDMA system includes channel estimation, demodulation, and square-law combination. MaxSearchChNum is the window length of the channel estimation in path searching (the default value of 30 is set according to the CDMA channel profile). The SINR of the base station receiver output is only the comparison level or standard of the receiver output SINR, which is not the actual SINR of the base station Rake receiver. The power control group sends power control bits according to FER and the current SINR compared to the SINR threshold. If the FER is lower and the current SINR exceeds the threshold, the power control unit sends a 1 bit to the mobile station transmitter to reduce transmission power (otherwise it sends a 0 bit to the mobile station transmitter). With power control, the receiver output will be convergent at an SINR value. The SIR and FER thresholds can then be set.

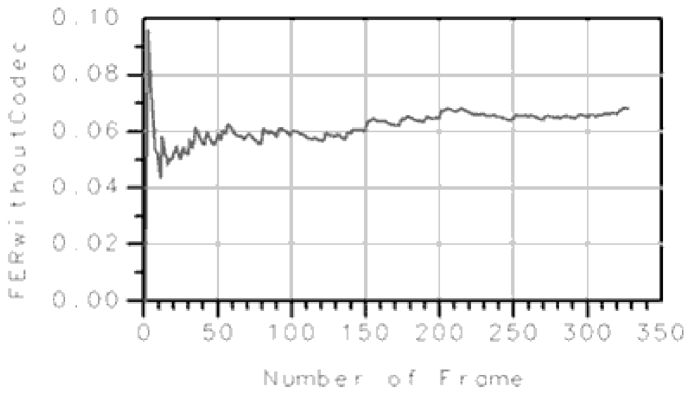
Test Results

The following figures show the performance of IS-95A base station receivers with and without codecs.



Frame Error Rate with Codec

Frame Error Rate with Codec



Frame Error Rate without Codec

IS-95A Reverse Link Rake Receiver (3 Users Working)

IS95A_RevRake_wrk Design Names

- DsnCDMA_RevRake_3user_Codec
- DsnCDMA_RevRake_3user_Nocodec
- DsnCDMA_RevRake_3user_PC

Features

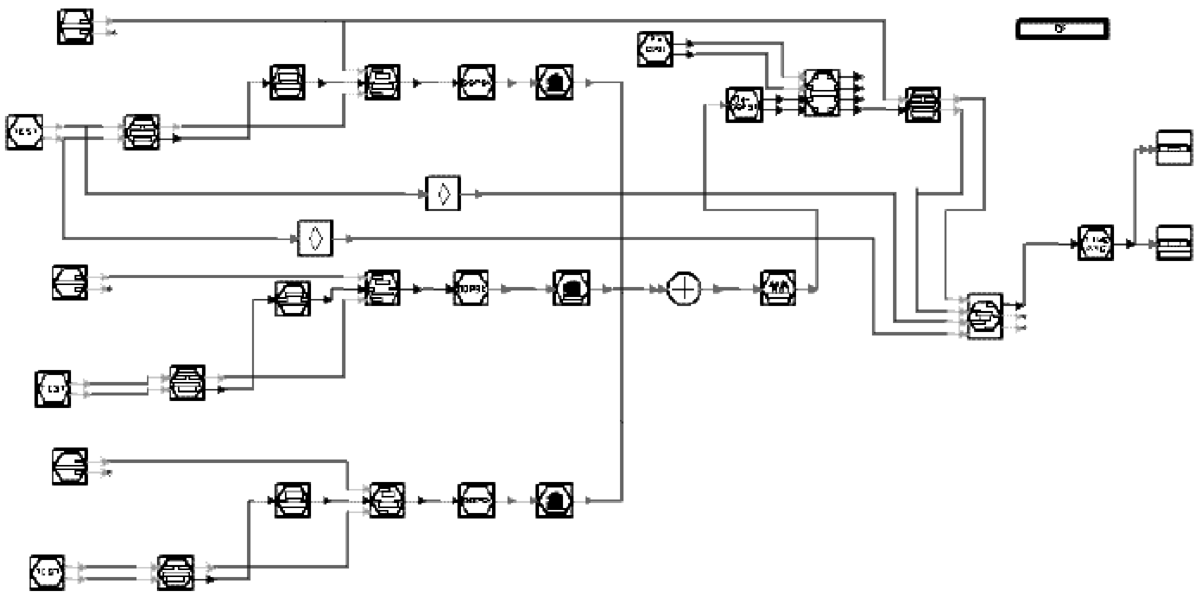
- Tcl/Tk plots for interactive display
- Displays: BER (bit error rate), FER (frame error rate), and SINR (signal-to-interference noise ratio) convergence cure
- Convolutional coder and Viterbi decoder using soft decision algorithm
- Block interleaver and data randomizer
- OQPSK modulation and demodulation
- CDMA multipath fading channel with Doppler shift. Path numbers can be set. Doppler shift can be determined by setting the mobile's speed
- Additive white Gaussian noise (AWGN) channel and signal-to-noise ratio (SNR) can be adjusted by setting the AWGN variance
- Non-coherent reverse link Rake receiver using multipath diversity technology and fast Hadamard transform

Description

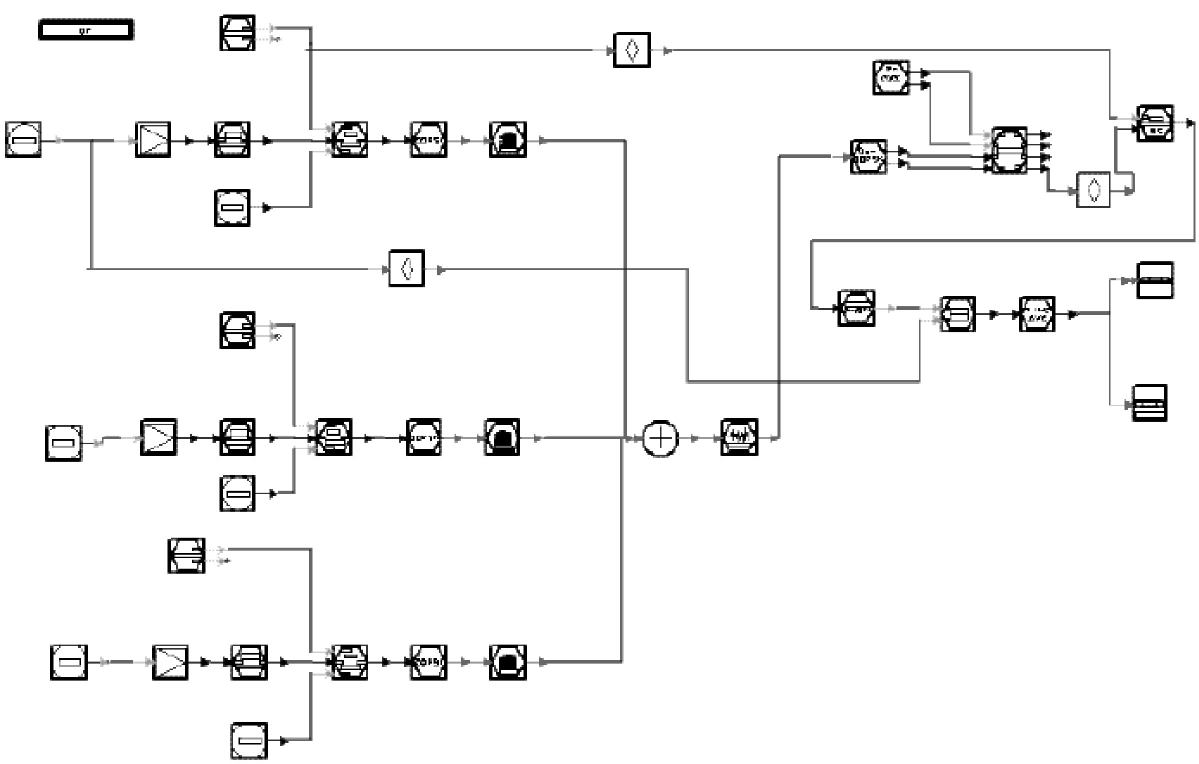
These designs apply an IS-95 reverse link base station Rake receiver to a Rayleigh fading channel with Doppler shift, which includes channel estimation, demodulation and square-law combination, and data rate detection.

Automatic gain control is applied to the signal received from the channel. The signal is demodulated and placed in the Rake receiver, which searches for the strongest paths; signals on these paths are despread and then combined. Deinterleaving, rate detection and decoding are performed and the frame is recovered. The performance of the receiver can be viewed during simulation.

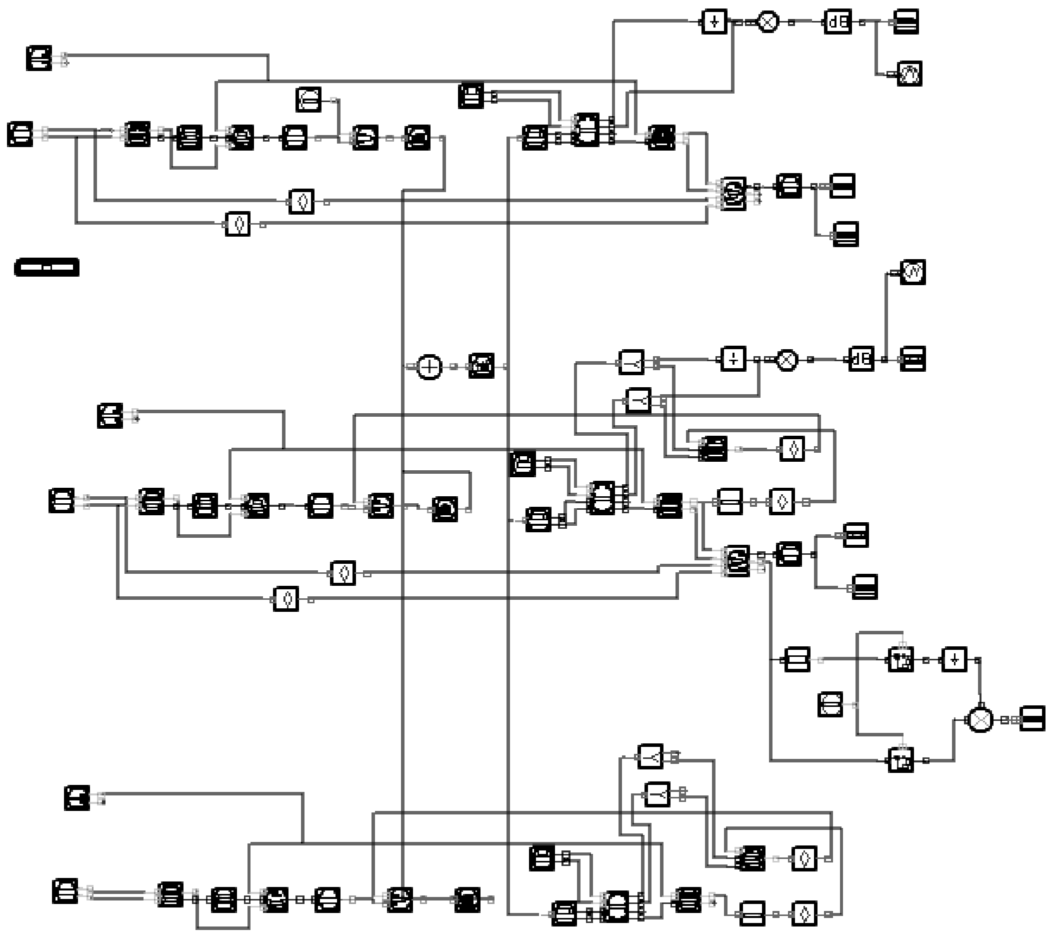
Schematics



DsnCDMA_RevRake_3User_Codec, 3 Users are Working, Codec Used



DsnCDMA_RevRake_3User_NoCodec, 3 Users are Working, Codec Not Used



DsnCDMA_RevRake_3User_PC, 3 Users are Working, Codec Used, Power Control Applied

Specifications

Component	Parameter	Simulation Type	Value	Unit
CDMA_TstSrc	Data Rate	ADS Ptolemy	CONSTANT9600	
CDMA_Channel	X,Y Position	ADS Ptolemy	(1.0, 1.0)	km
CDMA_Channel	Vx, Vy Speed	ADS Ptolemy	(100, 0)	km/h
CDMA_Channel	ChannelType	ADS Ptolemy	ThreePath	
CDMA_GNoise	Noise_Variance	ADS Ptolemy	5	
CDMA_BSRake	FingerNum	ADS Ptolemy	2	
CDMA_ReversePowerControl	SIR_Threshold	ADS Ptolemy	9	dB
CDMA_ReversePowerControl	FER_Threshold	ADS Ptolemy	0.05	

Notes

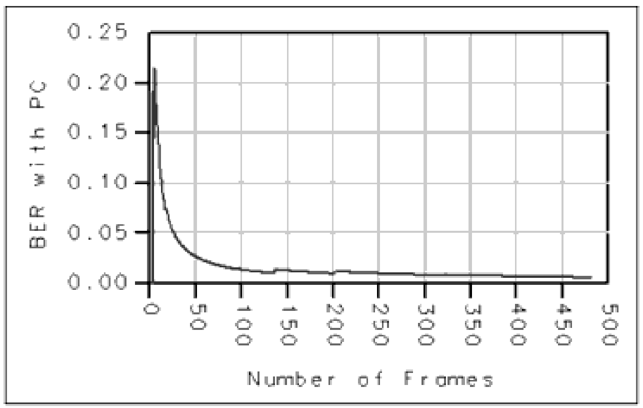
1. Gaussian channel variance is modified according to the signal-to-noise ratio parameter. For example, when noise variance=5, the mobile transmitter signal-to-noise ratio≈17 (here, noise does not include multi-access interference).
2. CDMA channel condition is modified according to channel parameters X(Y)_Position, Vx(y)_Speed, and ChannelType.
3. For the base station Rake receiver subnetwork CDMA_BSRake, if FingerNum=1, the

CDMA system includes channel estimation, demodulation, and square-law combination. MaxSearchChNum is the window length of the channel estimation in path searching (the default value of 30 is set according to the CDMA channel profile).

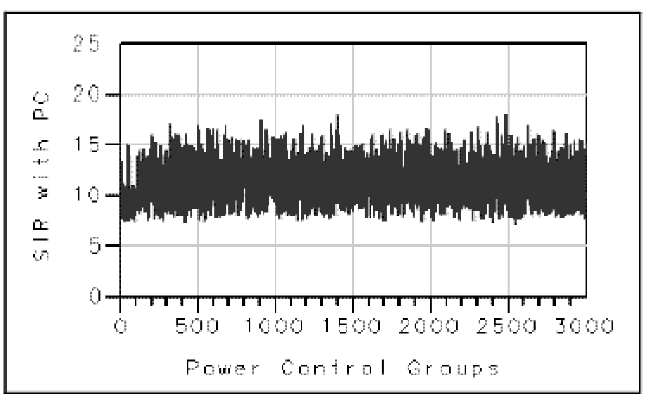
4. The SINR of the base station receiver output is only the comparison level or standard of the receiver output SINR, which is not the actual SINR of the base station Rake receiver. The power control group sends power control bits according to FER and the current SINR compared to the SINR threshold. If the FER is lower and the current SINR exceeds the threshold, the power control unit sends a 1 bit to the mobile station transmitter to reduce transmission power (otherwise it sends a 0 bit to the mobile station transmitter). With power control, the receiver output will be convergent at an SINR value. The SIR and FER thresholds can then be set. In this example, the SIR threshold is 9 dB and the FER threshold is 0.05.

Test Results

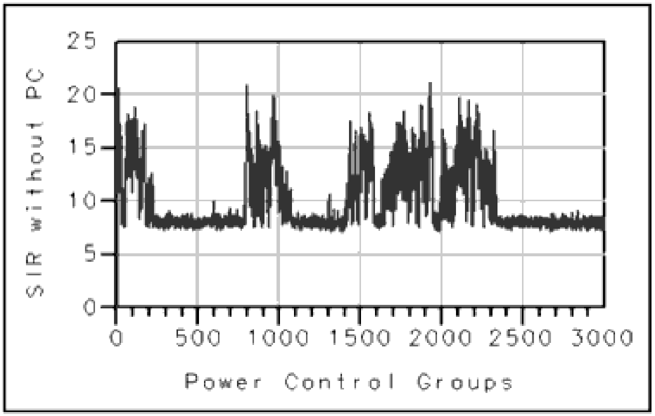
The following figures show the performance of IS-95A base station receivers: BER with power control, and SIR with and without power control. With power control, BER is close to the threshold.



Bit Error Rate with Power Control



Signal to Interference Ratio with Power Control



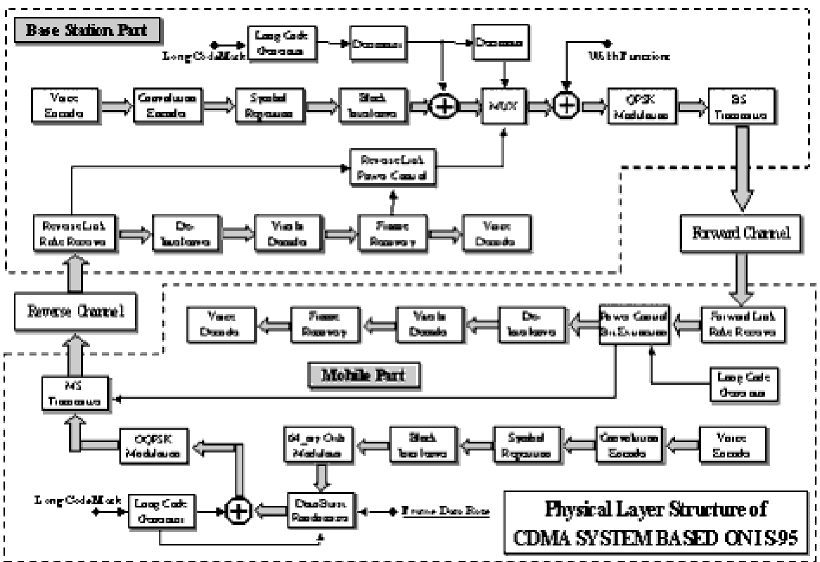
Signal to Interference Ratio without Power Control

CDMA Design Library

Introduction

Code Division Multiple Access (CDMA), a digital wireless spread spectrum communication technology, is one of the most exciting recent developments in the wireless communications field. Modeling and simulation of CDMA wireless communication systems is important for design, development, and production.

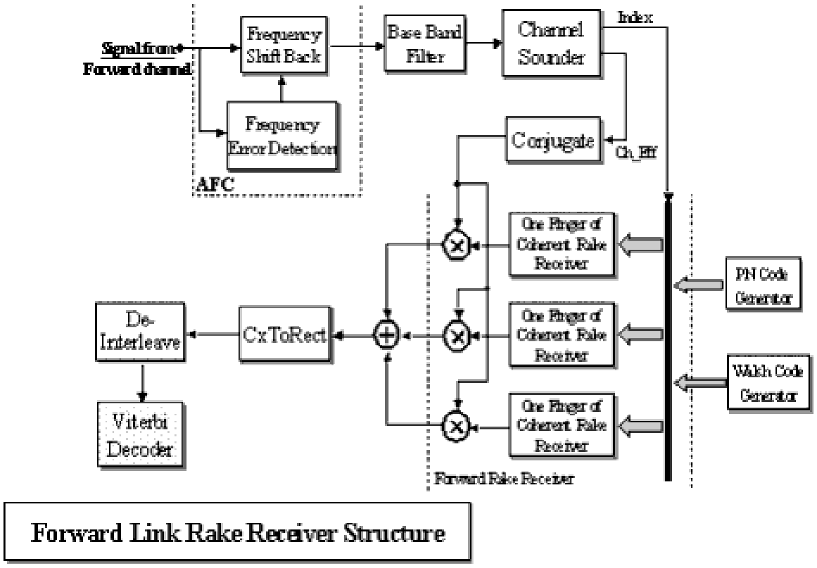
Components in the CDMA Design Library enable end-to-end system modeling and simulation of the physical layer of IS-95 CDMA systems; refer to the following figure. The components are designed to be a baseline system for designers to evaluate their designs and get an idea of nominal ideal system performance.



Physical Layer Structure of CDMA System Based on IS-95

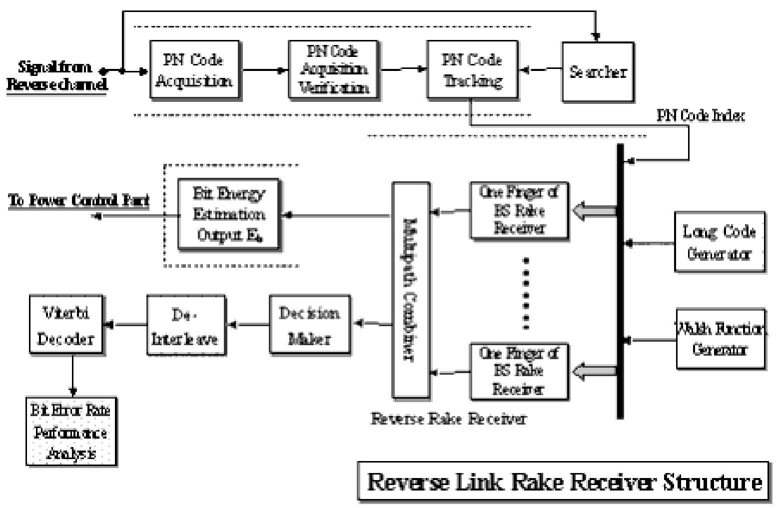
Components in the CDMA design libraries include:

- Channel coding and decoding, framing and recovery: convolutional encoder, symbol repetition, block interleaving and de-interleaving, Viterbi decoder, data rate decision. (See the previous figure.)
- CELP codec: speech codec is a relatively independent part of the system. A set of basic CELP codec components are supplied based on TIA/EIA/IS-96. These components can be used for measuring IS-95 CDMA system performance or for speech processing applications.
- Forward link Rake receiver: 3-finger coherent Rake receiver, matched filter correlator, automatic frequency offset correction, and IS-95 forward link receiver. (See the following figure.)



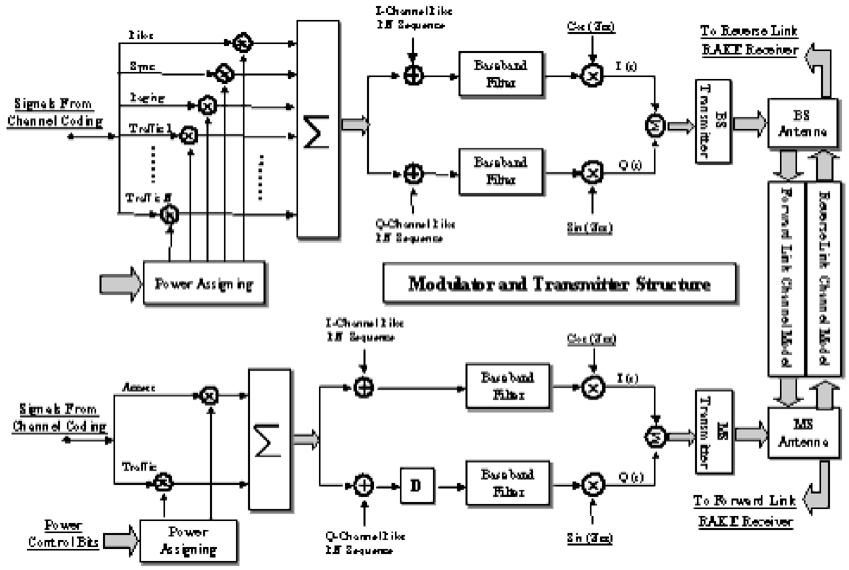
Forward Link Rake Receiver Structure

- Reverse link Rake receiver: channel estimation, demodulator, noncoherent Rake receiver, and data rate detector. (See the following figure.)



Reverse Link Rake Receiver Structure

- Other: reverse power control, QPSK and OQPSK modulation, long code generator, MUX, 64-ary orthogonal modulation, data burst randomizer, Walsh code generator. (See the following figure.)



Modulator and Transmitter Structure

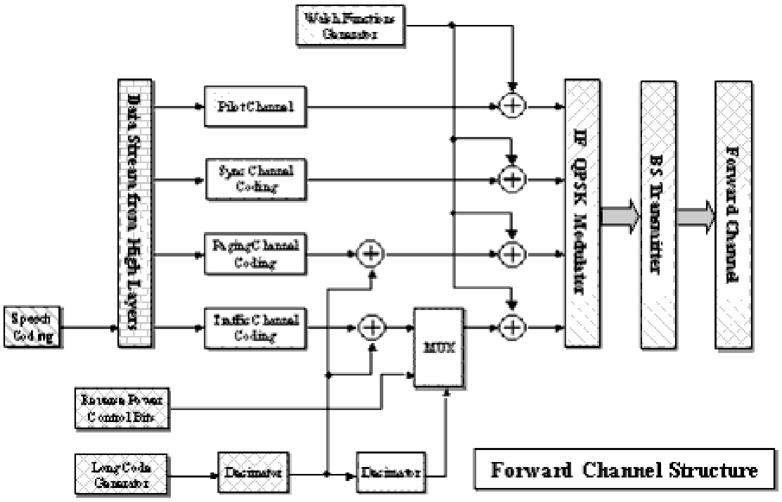
There are six kinds of transmission channels, four in forward link and two in reverse link; refer to the following figures. These are implemented according to the IS-95A standard.

- Pilot channel: an unmodulated, direct-sequence spread spectrum signal is transmitted continuously by each CDMA base station. Pilot channel allows a mobile station to acquire the timing of the forward CDMA channel.
- Sync channel: sync channel is used to obtain initial time synchronization.
- Paging channel: a code channel in a forward CDMA channel is used to transmit control information and pages from a base station to a mobile station.
- Forward traffic channel: forward traffic channel is used for the transmission of user and signaling information to a specific mobile station during a call.
- Access channel: access channel is used by the mobile station to initiate communication with the base station and to respond to paging channel messages.
- Reverse traffic channel: reverse traffic channel is used for user transmission and signaling information to the base station during a call.

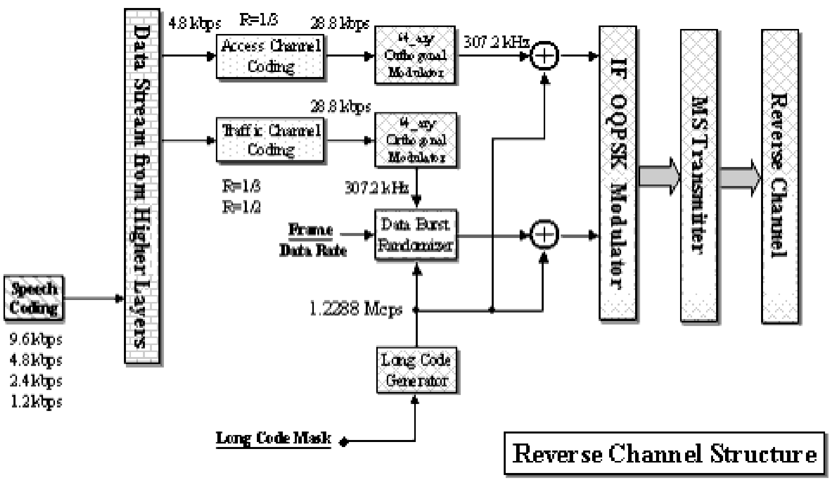
Rake receivers use widely accepted structures and the inner algorithms are optimized and evaluated.

Currently, there is no network interface, so message channels (sync, paging, and access channel) are inserted with random bits. Even though traffic channel bits are co-transmitted with message channel bits (which can influence system performance) the output contains traffic bits only (message channel bits are not useful).

These components provide full simulation of the physical layer of the CDMA system based on IS-95 for single or multiple users. We recommend 3 users (3 forward and 3 reverse links), because 3-user systems can simulate total system performance, while too many users require lengthy simulation. Of course, the number of users can be expanded easily.



Forward Channel Structure of IS-95 CDMA System



Reverse Channel Structure of IS-95 CDMA System

Overview of Component Libraries

Channel Codec Components

Channel Codec components provide frame generation, channel coding in the transmitting end, and channel decoding and frame recovery in the receiving end.

CDMA systems are simulated in the physical layer, so there is no need to form the superframe for sync, paging, and access channel. The contents of these channels are related to the data link layer, so frame generation and frame recovery are provided for the traffic channel.

All channels (except pilot channel) will be convolutionally encoded. Three sets of convolutional encoders and Viterbi decoders are provided: one for fixed data rate signals followed by tail bits; one for variable data rate signals with tail bits; and, one for signals without tail bits. The forward traffic channel Viterbi decoder is designed for decoding and detecting the data rate in forward traffic channel. The reverse traffic channel Viterbi decoder is designed for decoding and detecting the data rate in reverse traffic channel. (The soft decision algorithm is used in the reverse link Rake receiver.)

Using the variable data rate source, all symbols of the frame with the lower rate will be repeated after they are convolutionally encoded in order to determine the fixed symbol rate. For example, the convolutionally encoded symbols of a half rate frame are repeated.

All channels (except pilot channel) will be interleaved. The interleaver and deinterleaver for sync channel, paging and forward traffic channel, access channel, and reverse traffic channel are provided.

CELP Codec Components

Speech codec is important in dual-mode analog/CDMA systems; it provides the basic components required by TIA/EIA/IS-96, in which the specified transcoding procedure is used for the variable rate, 2-way speech service option. This feature conforms to the general requirements specified in IS-95. With these components, users can build the codec described in IS-96, or simulate their speech codec algorithms used in telecommunication systems.

In IS-96, the speech coding scheme uses a code excited linear predictive (CELP) coding algorithm. This technique uses a codebook to vector quantize the residual signal using an analysis-by-synthesis method. The speech codec produces a variable output data rate based on speech activity.

Receiver Components

IS-95 forward link Rake receiver components are:

- CDMA_FwdChnlSounder: used on pilot channel to implement system multipath discrimination (delay estimation), channel estimation (amplitude and phase compensation).
- CDMA_CoherentRake: used on traffic channel to despread the signal.

- CDMA_FreqErrEstimate and CDMA_FreqShifter: used with CDMA_FwdChnlSounder and CDMA_CoherentRake to estimate frequency error and adjust the received signal by correcting frequency error.

IS-95 reverse link base station receiver components provide channel estimation, demodulation and square-law combination, and data rate detection.

- Automatic gain control (AGC) is applied to the signal received from the channel.
- After AGC, the signal is demodulated by the OQPSK demodulator and placed in the Rake receiver.
- In Rake receiver, the strongest paths are searched; the signal on these paths are despread and then combined.
- In data rate detector, deinterleaving, rate detection and Viterbi decoding using soft decision algorithm are performed and the frame is recovered.

Transmission Components

- CDMA_OQPSK differs from the conventional QPSK-in fact, it is a dual BPSK; the I- and Q-channels transmit the same information bits after being spread by PN code.
- CDMA_WalshModulator generates 64-bit Walsh code bits to spread the forward link transmission signal spectrum, thus the process gain is 64.
- CDMA_LongCodeGenerator generates 42-bit M-sequence long codes according to three different kinds of masks.
- CDMA_M_aryModulator converts six information bits into one Walsh symbol (64-bit) according to the index for non-coherent demodulation.
- CDMA_ReversePowerControl provides reverse power control to control base station transmission power and ease the near-far effect, and increase system capacity. (Forward power control needs system statements and cannot be completed in the physical layer, which is not an important factor in forward link.)
- CDMA_MUX long code scrambles data and inserts power control bits (2 successive identical bits) into one power control group. CDMA_PCBitExtraction is the counterpart that extracts the power control bits.
- CDMA_DataRandomizer masks repeated symbols according to different data rates in order to reduce mobile station transmission power.
- CDMA_PowerAllocation allocates power for the forward transmission link (including pilot channel, sync channel, paging channel, and three forward traffic channels).
- CDMA_MSTX and CDMA_BSTX dynamically allocate power for the transmission signal.

Example Designs

Example designs are provided with the CDMA Design Library, in the **/examples/cdma** directory. *CDMA Design Examples* (cdma) describes these designs and provides schematics and simulation results. The workspaces and their corresponding design examples are:

- IS95A_ChnCodec_wrk
  - DsnCDMA_AccessChannelCodec
  - DsnCDMA_ForwardChannelCodec
  - DsnCDMA_PagingChannelCodec
  - DsnCDMA_ReverseChannelCodec
  - DsnCDMA_SyncChannelCodec
- IS95A_CELP_wrk
  - DsnCDMA_CelpCodecDemo1
  - DsnCDMA_CelpCodecDemo2
- IS95A_FwdLink_wrk

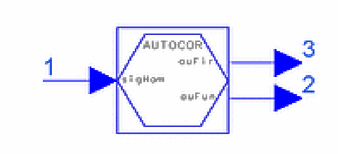
    - DsnCDMA_ForwardLink
    - DsnCDMA_FwdRake_AFC_NoCodec
    - DsnCDMA_FwdRake_NoAFC_NoCodec
- IS95A_Measure_wrk
    - DsnCDMA_RevMeasure
- IS95A_RevRake_wrk
    - DsnCDMA_RevRake_1user_codec
    - DsnCDMA_RevRake_1user_Nocodec
    - DsnCDMA_RevRake_1user_PC
    - DsnCDMA_RevRake_3user_Codec
    - DsnCDMA_RevRake_3user_Nocodec
    - DsnCDMA_RevRake_3user_PC

Glossary of Terms

AFC	automatic frequency offset correction
AGC	automatic gain control
AWGN	additive white Gaussian noise
BER	bit error rate
bps	bits per second
BS	base station
BSC	binary symmetrical channel
CC	convolutional code
CDMA	code division multiple access
CELP	code excited linear predictive
codec	coder and decoder
CRC	cyclic redundancy code
FER	frame error rate
IF	intermediate frequency
K	constraint length
LPC	linear predictive coding
LSB	least significant bit
LSP	line spectral pair
MS	mobile station
MSB	most significant bit
NRZ	non-return-to-zero
OQPSK	offset quadrature phase shift keying
PCM	pulse code modulation
PN code	pseudo noise sequence
QPSK	quadrature phase shift keying
SDF	synchronous data flow
SER	symbol error rate
SINR	signal-to-interference noise ratio
SIR	signal-to-interference ratio
SNR	signal-to-noise ratio
ZIR	zero input response
ZSR	zero state response

CELP Codec Components

CDMA_Autocorrelation



Description Autocorrelation Function Computation.
Library CDMA, CELP Codecs
Class SDFCDMA_Autocorrelation

Parameters

Name	Description	Default	Sym	Type	Range
NoLag	order of autocorrelation function	11		int	(0, ∞)
NoSamplesToAvg	number of input samples to use	160	L_A	int	(0, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	sigHam	The signal after hamming window	real

Pin Outputs

Pin	Name	Description	Signal Type
2	auFun	Autocorrelation value	real
3	auFir	The first autocorrelation function	real

Notes/Equations

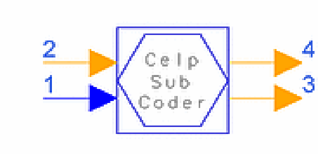
1. This component calculates NoLag values of autocorrelation function R(0) through R(NoLag−1) from the windowed speech signal sw(n) in the analysis window. Each firing, NoLag auFun and 1 auFir tokens are produced when LA sigHam tokens are consumed. NoLag default is 11; LA default is 160.
2. Implementation (refer to *note 1*, paragraph 2.4.3.2.3.)

$$R(k) = \sum_{n=0}^{L_A - 1 - k} s_w(n) s_w(n+k) \qquad k = 0, \ldots, NoLag - 1$$

References

1. TIA/EIA/IS-96-A, Speech Service Option Standard for Wideband Spread Spectrum Digital Cellular System, May 1995.

CDMA_CelpSubCoder



Description CELP Speech Encoder
Library CDMA, CELP Codecs
Class SDFCDMA_CelpSubCoder

Parameters

Name	Description	Default	Type	Range
FSIZE	length of frame	160	int	(0, ∞)
LPCOFFSET	offset introduced by Hamming Window	60	int	(0, ∞)
LPCORDER	order of LPC filter	10	int	(0, ∞)
RATEMODE	data rate: 0=variable rate; 1=rate1; 2=rate1/2	0	int	{0, 1,2}
FIRSTFLAG	flag to indicate use of first frame: 1=discard; 0=process	1	int	{0, 1}

Pin Inputs

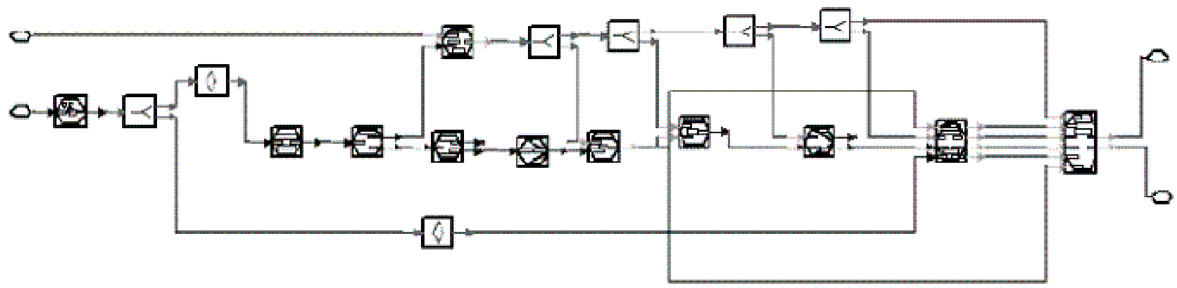
Pin	Name	Description	Signal Type
1	sigIn	phase code modulation speech signal	real
2	blkCtl	blank control bit stream, one bit corresponds to one frame: 1=blank frame, 0=data frame	int

Pin Outputs

Pin	Name	Description	Signal Type
3	pkOut	compressed data of CELP encoder	int
4	rtOut	data rate of current frame	int

Notes/Equations

1. This subnetwork is used to encode the input speech signal of 128 kbps PCM (phase code modulation) data into less than 8 kbps bitstream. The encoding process includes determining input parameters for the decoder that minimize the perceptual difference between the synthesized and the original speech, and quantizing the parameters and packing them into data packets for transmission. In IS-96, the encoder operates on one 20 msec frame at a time; each frame contains 160 PCM samples.
2. Implementation
   Refer to the following figure. The CDMA_CelpSubCoder subnetwork includes CDMA_RemoveDC, CDMA_HammingWindow, CDMA_Autocorrelation, CDMA_VariableDataRate, CDMA_DurbinRecursion, CDMA_LPC_ToLSP, CDMA_QuantizerWi, CDMA_UnquantizerWi, CDMA_LSP_ToLPC, CDMA_PitchCdbkSelector, and CDMA_DataPack.
   Speech signal samples are processed frame by frame; frame size is FSIZE.

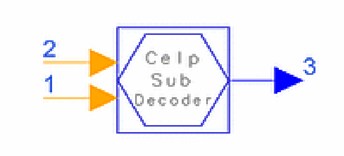


CDMA_CelpSubCoder Network

References

1. TIA/EIA/IS-96-A, Speech Service Option Standard for Wideband Spread Spectrum Digital Cellular System, May 1995.

CDMA_CelpSubDecoder



Description CELP Speech Decoder
Library CDMA, CELP Codecs
Class SDFCDMA_CelpSubDecoder

Parameters

Name	Description	Default	Type	Range
FSIZE	length of frame	160	int	(0, ∞)
LPCORDER	order of LPC filter	10	int	(0, ∞)
POSTFILTERSWITCH	flag to indicate use of post filter: 1=on; 0=off	1	int	{0, 1}
FIRSTFLAG	flag to indicate use of first frame: 1=discard; 0=process	1	int	{0, 1}

Pin Inputs

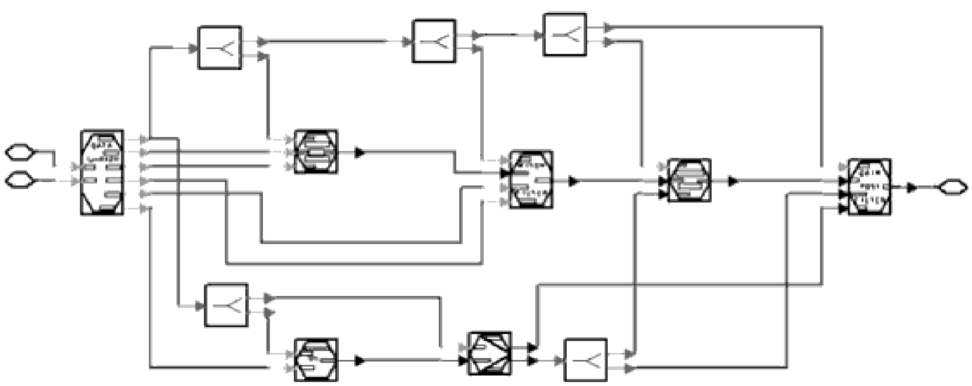
Pin	Name	Description	Signal Type
1	pkIn	compressed data packet	int
2	rtIn	current frame data rate	int

Pin Outputs

Pin	Name	Description	Signal Type
3	sigOut	reconstructed speech signal	real

Notes/Equations

1. This subnetwork is used to reconstruct a speech signal from the bitstream transferred by channel. The decoding process includes unpacking data packets, unquantizing the received parameters, and reconstructing the speech signal from these parameters.
2. Implementation
   Refer to the following figure. The CDMA_CelpSubDecoder subnetwork includes CDMA_DataUnPack, CDMA_ScaledCdbkVector, CDMA_UnquantizerWi, CDMA_LSP_ToLPC, CDMA_PitchFilter, CDMA_FormantFilter, and CDMA_GainPostFilter.

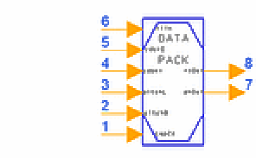


CDMA_CelpSubDecoder Network

References

1. TIA/EIA/IS-96-A, Speech Service Option Standard for Wideband Spread Spectrum Digital Cellular System, May 1995.

CDMA_DataPack



Description Pack Transmission Codes into a Data Packet.
Library CDMA, CELP Codecs
Class SDFCDMA_DataPack

Parameters

Name	Description	Default	Sym	Type	Range
LpcOrder	order of LPC filter	10	P	int	(0, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	lspCd	LSP transmission code.	int
2	pitchB	Pitch gain transmission code.	int
3	pitchL	Pitch lag transmission code.	int
4	cdbkI	Codebook index transmission code.	int
5	cdbkG	Codebook gain transmission code.	int
6	rtIn	Data rate of the current frame.	int

Pin Outputs

Pin	Name	Description	Signal Type
7	pkOut	Data packet.	int
8	rtOut	Data rate of the current frame.	int

Notes/Equations

1. In this component, transmission codes LSP, CBINDEX, CBSEED, CBGAIN, PLAG, and PGAIN are packed into a primary traffic packet with formats that vary according to data rate.
   For rate 1, 11 parity check bits are added for error correction and detection of the 18 most significant bits of rate 1 data. The LpcOrder default is 10.
   Each firing, MAX_NUMBITS pkOut and 1 rtOut tokens are produced when lpcOrder lspCd, MAX_PITCH_SF pitchB, MAX_PITCH_SF pitchL, (2×MAX_PITCH_SF) cdbkI and (2×MAX_PITCH_SF) cdbkG and 1 rtIn tokens are consumed. Here MAX_NUMBITS, MAX_PITCH_SF are constants defined in celpStdValue.h; the MAX_NUMBITS default is 171, the MAX_PITCH_SF default is 4.
2. Implementation
   Compute the parity check bits of rate 1 frame
   The 18 most significant bits are assembled into an information polynomial a(x), where LSPi[3] is the most significant bit of LSP code i, and CBGAINi[1] is the second most significant bit of CBGAIN codes (as shown in reference [1], eq. 2.4.7.1.1-1). 11 parity check bits are encoded from a(x) using systematic cyclic coding. The encoding circuit of the systematic cyclic codes is a dividing circuit [2]. The generator polynomial is:
   $g_{pc}(x) = x^{10} + x^9 + x^8 + x^6 + x^5 + x^3 + 1$
   Data Packing

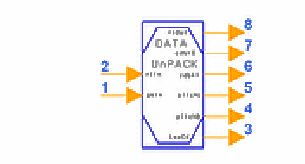
Packet length varies for different data rates. To easily implement in the SDF domain, the longest block of rate 1 frame is selected to be processed; zero bits are appended after the valid data for the lower data rate frame. So, the length of block will be the maximum length of frame.

- if (rtIn = 0) the 171 bits are packed (as given in reference [1] Table 2.4.7.1.2-1).
- if (rtIn = 1) the 80 bits are packed (as given in reference [1] Table 2.4.7.2-1). Other bits are filled with zero.
- if (rtIn = 2) the 40 bits are packed (as given in reference [1] Table 2.4.7.3-1). Other bits are filled with zero.
- if (rtIn = 3) the 16 bits are packed (as given in reference [1] Table 2.4.7.4-1). Other bits are filled with zero.
  Else, blank frame is packed as all zero packet

References

1. TIA/EIA/IS-96-A, Speech Service Option Standard for Wideband Spread Spectrum Digital Cellular System, May 1995.
2. S. Lin and D. J. Costello, Jr., *Error Control Coding Fundamentals and Applications* , Prentice Hall, Englewood Cliffs NJ, 1983.

CDMA_DataUnPack



Description Unpack Data Packet into Parameters.
Library CDMA, CELP Codecs
Class SDFCDMA_DataUnPack

Parameters

Name	Description	Default	Sym	Type	Range
LpcOrder	order of LPC filter	10	P	int	(0, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	pkIn	Data packet transfered from channel.	int
2	rtIn	Data rate of the current frame.	int

Pin Outputs

Pin	Name	Description	Signal Type
3	lspCd	LSP.	int
4	pitchB	pitch gain.	int
5	pitchL	pitch lag.	int
6	cdbkI	codebook index.	int
7	cdbkG	codebook gain.	int
8	rtOut	Data rate of current frame.	int

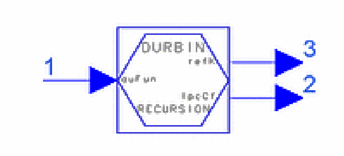
Notes/Equations

1. This component unpacks the data packet into the appropriate LSPi, CBGAINi, CBINDEXi, CBSEEDi, PLAGi, PGAINi codes and rtOut. For rate 1 and Rate1 with bit error packets, check the internal parity check bits to detect insufficient frame quality. Each firing, lpcOrder lspCd, MAX_PITCH_SF pitchB, MAX_PITCH_SF pitchL, (2×MAX_PITCH_SF) cdbkI and (2×MAX_PITCH_SF) cdbkG and 1 rtOut tokens are produced when MAX_NUMBITS pkIn tokens, 1 rtIn tokens are consumed. Here MAX_NUMBITS, MAX_PITCH_SF are constants defined in celpStdValue.h.
   The LpcOrder default is 10; MAX_NUMBITS default is 171; MAX_PITCH_SF default is 4.

References

1. TIA/EIA/IS-96-A, Speech Service Option Standard for Wideband Spread Spectrum Digital Cellular System, May 1995.
2. S. Lin and D. J. Costello, Jr., *Error Control Coding Fundamentals and Applications* , Prentice Hall, Englewood Cliffs NJ, 1983.

CDMA_DurbinRecursion



Description Computing LPC Coefficients using Durbin's Recursion.
Library CDMA, CELP Codecs
Class SDFCDMA_DurbinRecursion

Parameters

Name	Description	Default	Sym	Type	Range
LpcOrder	order of LPC coefficients	10	P	int	(0, ∞)
BETA	scale factor	0.9883	β	real	(0, 1.0]

Pin Inputs

Pin	Name	Description	Signal Type
1	auFun	Autocorrelation value.	real

Pin Outputs

Pin	Name	Description	Signal Type
2	lpcCf	LPC coefficients.	real
3	refK	reflection coefficient.	real

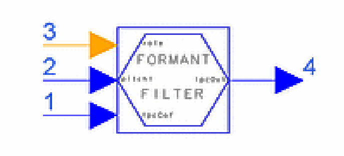
Notes/Equations

1. This component is used to compute LPC coefficients from the autocorrelation function using Durbin's Recursion. (Refer to [1], paragraph 2.4.3.2.4.)
   Each firing, P lpcCf and P refK tokens are produced when (P+1) auFun tokens are consumed. The LpcOrder default is 10.

References

1. TIA/EIA/IS-96-A, Speech Service Option Standard for Wideband Spread Spectrum Digital Cellular System, May 1995.

CDMA_FormantFilter



Description LPC Filter to Reconstruct Speech Signal.
Library CDMA, CELP Codecs
Class SDFCDMA_FormantFilter

Parameters

Name	Description	Default	Sym	Type	Range
FSize	length of frame	160		int	(0, ∞)
LpcOrder	order of LPC filter	10	P	int	(0, ∞)
FirstFrameDiscardFlag	flag to indicate use of first frame: 1=discard, 0=process	1		int	{0, 1}

Pin Inputs

Pin	Name	Description	Signal Type
1	lpcCof	LPC coefficients.	real
2	pitchI	The output signal from pitch filter.	real
3	rate	Data rate of current frame.	int

Pin Outputs

Pin	Name	Description	Signal Type
4	lpcOut	The output signal of this model.	real

Notes/Equations

1. This component filters the input signal through an LPC filter. The default of LPC filter order is 10; the default frame length is 160.
   Each firing, FSize lpcOut tokens are produced when (MAX_PITCH_SF×LpcOrder) lpcCof, FSize pitchI and 1 rate tokens are consumed. The MAX_PITCH_SF constant is defined in celpStdValue.h, the MAX_PITCH_SF default is 4.
2. Implementation.
   The filter is designed using transfer function

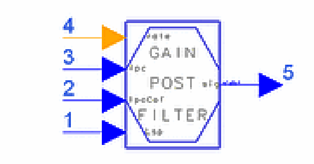
$$\frac{1}{A(z)} = 1 \Big/ \left(1 - \sum_{i=1}^{P} \hat{a}_i z^{-i}\right)$$

   Here $\hat{a}_i$ equals the LPC coefficients generated for the current codebook subframe. All speech codec frames (except frames being encoded into rate 1/8 packets) are subdivided into equal length pitch subframes. Each pitch subframe (except for a rate 1/8 packet) consists of two codebook subframes. For a rate 1/8 packet, one codebook subframe is included in a frame. Refer to [1], Table 2.4.1-1.

References

1. TIA/EIA/IS-96-A, Speech Service Option Standard for Wideband Spread Spectrum Digital Cellular System, May 1995.

CDMA_GainPostFilter



Description Post filter to Enhance Quality of Reconstructed Speech Signal.
Library CDMA, CELP Codecs
Class SDFCDMA_GainPostFilter

Parameters

Name	Description	Default	Sym	Type	Range
PF_Control	post filter control indicator: 1=on, 0=off	1		int	{0, 1}
FSize	length of frame	160		int	(0, ∞)
LpcOrder	order of LPC filter	10	P	int	(0, ∞)
PF_ZeroWghtFactor	weighting factor of post zero filter	0.5	p	real	(0.0, 1.0]
PF_PoleWghtFactor	weighting factor of post pole filter	0.8	s	real	(0.0, 1.0]
AGC_Factor	interpolation factor of post gain	0.9375		real	(0.0, 1.0)
AGC_Num	number of subframes when computing post gain	4		int	(0, ∞)
FirstFrameDiscardFlag	flag to indicate use of first frame: 1=discard, 0=process	1		int	{0, 1}

Pin Inputs

Pin	Name	Description	Signal Type
1	inLsp	Interpolated LSP values.	real
2	lpcCof	LPC coefficients.	real
3	lpcIn	The signal output from LPC filter.	real
4	rate	Data rate of the current frame.	int

Pin Outputs

Pin	Name	Description	Signal Type
5	sigOut	The output signal of this model.	real

Notes/Equations

1. This component generates the output of adaptive postfilter PF(z), pf(n). A gain control is placed on the output of PF(z) to generate the reconstructed speech signal s_d (n); this ensures that the energy of the output signal is close to the energy of the input signal. (Refer to reference [1], paragraph 2.4.8.5.)
   The LPC filter order default is 10; the length of frame default is 160.
   Each firing, FSize sigOut tokens are produced when (MAX_PITCH_SF×LpcOrder) lpcCof, (MAX_PITCH_SF×LpcOrder) inLsp, FSize lpcIn and 1 rate tokens are consumed. The MAX_PITCH_SF constant is defined in celpStdValue.h; the default number of MAX_PITCH_SF is 4.
2. Implementation
   y_d (n) is filtered by postfilter PF(z) to produce pf(n). PF(z) has the form:

$$PF(z) = (B(z)A(z/p))/(A(z/s))$$

where

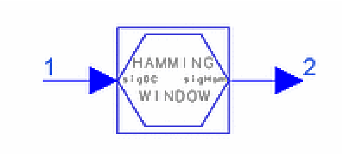
- A(z) is the formant prediction error filter defined in the formant synthesis filter, the coefficients of A(z) are equal to the LPC coefficients appropriate for the current codebook subframe.
- B(z) is an anti-tilt filter designed to offset the spectral tilt as follows (γ is a function of the average of the interpolated LSP frequencies):

  $B(z) = (1 - \gamma z^{-1}) / (1 + \gamma z^{-1})$

References

1. TIA/EIA/IS-96-A, Speech Service Option Standard for Wideband Spread Spectrum Digital Cellular System, May 1995.

CDMA_HammingWindow



Description The Hamming Window for the Input Signal
Library CDMA, CELP Codecs
Class SDFCDMA_HammingWindow

Parameters

Name	Description	Default	Type	Range
MultipleCoeff	coefficient used to amplify the output	1.0	real	(0, ∞)
FSize	length of signal frame	160	int	(0, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	sigDC	The signal with DC removed	real

Pin Outputs

Pin	Name	Description	Signal Type
2	sigHam	The signal after Hamming Window	real

Notes/Equations

1. This component windows the dc-removed input samples with a Hamming window. (See reference [1] paragraph 2.4.3.2.2.)
   Each firing, FSize sigHam tokens are produced when FSize sigDC tokens are consumed. The default length of FSize is 160.
2. Implementation

   $$s_w(n) = \text{MultipleCoeff} \times s(n) \times (0.54 - 0.46 \cos(2\pi\ n / (\text{FSize} - 1)))$$

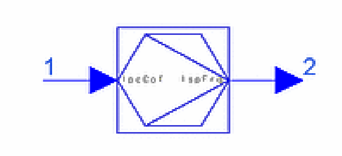
   where

   $$n = 1, 2, \ldots, \text{FSize}$$

References

1. TIA/EIA/IS-96-A, Speech Service Option Standard for Wideband Spread Spectrum Digital Cellular System, May 1995.

CDMA_LPC_ToLSP



Description LPC coefficients to LSP Frequencies Converter.
Library CDMA, CELP Codecs
Class SDFCDMA_LPC_ToLSP

Parameters

Name	Description	Default	Sym	Type	Range
LoopNumber	number of root searches in root scope [0,0.5]	800		int	(0, ∞)
LpcOrder	order of LPC filter	10	LP	int	(0, ∞)
IterateNumber	number of iterations for converging to the root	100		int	(0, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	lpcCof	Input LPC coefficients.	real

Pin Outputs

Pin	Name	Description	Signal Type
2	lspFrq	Output LSP frequencies not interpolated.	real

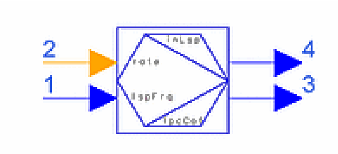
Notes/Equations

1. This component converts LPC coefficients in the time domain to LSP frequencies in the frequency domain for ease of quantization. (See reference [1], paragraph 2.4.3.2.6.)
   Each firing, LP lspFrq tokens are produced when LP lpcCof are consumed. The LpcOrder default is 10.
2. Implementation
   LSP frequencies are roots of the following equations.
   $$\cos\frac{LP}{2}(2\pi w) + p'_1\cos\left(\frac{LP}{2}-1\right)(2\pi w) + \ldots + p'_{\frac{LP}{2}-1}\cos(2\pi w) + \left(\left(p'_{\frac{LP}{2}}\right)/2\right) = 0$$
   $$\cos\frac{LP}{2}(2\pi w) + q'_1\cos\left(\frac{LP}{2}-1\right)(2\pi w) + \ldots + q'_{\frac{LP}{2}-1}\cos(2\pi w) + \left(\left(q'_{\frac{LP}{2}}\right)/2\right) = 0$$
   Search the roots of these equations; LSP frequencies can then be found.

References

1. TIA/EIA/IS-96-A, Speech Service Option Standard for Wideband Spread Spectrum Digital Cellular System, May 1995.

CDMA_LSP_ToLPC



Description LSP Frequencies to LPC Coefficients Converter.
Library CDMA, CELP Codecs
Class SDFCDMA_LSP_ToLPC

Parameters

Name	Description	Default	Sym	Type	Range
LSP_Increase	minimum LSP frequency spacing	0.01	$\Delta \tilde{w}_{min}$	real	(0, ∞)
LpcOrder	order of LPC filter	10	P	int	(0, ∞)
FirstFrameDiscardFlag	flag to indicate use of first frame: 1=discard, 0=process	1		int	{0, 1}

Pin Inputs

Pin	Name	Description	Signal Type
1	lspFrq	LSP converted back from code.	real
2	rate	Data rate of current frame.	int

Pin Outputs

Pin	Name	Description	Signal Type
3	lpcCof	LPC converted back from LSP.	real
4	inLsp	Interpolated LSP according to subframe.	real

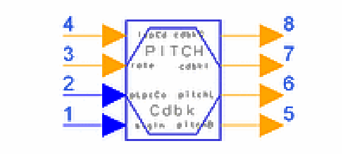
Notes/Equations

1. In this component, LSP frequencies are interpolated; the interpolated LSP frequencies are then converted back to LPC coefficients for use in pitch and codebook parameter searching. The LpcOrder default is 10.
   Each firing, (MAX_PITCH_SF×LpcOrder) lpcCof and (MAX_PITCH_SF×LpcOrder) inLsp tokens are produced when LpcOrder lspFrq and 1 rate tokens are consumed. Here, the MAX_PITCH_SF constant is defined in celpStdValue.h; the MAX_PITCH_SF default is 4.

References

1. TIA/EIA/IS-96-A, Speech Service Option Standard for Wideband Spread Spectrum Digital Cellular System, May 1995.

CDMA_PitchCdbkSelector



Description Optimal Pitch and Codebook Parameters Selector.
Library CDMA, CELP Codecs
Class SDFCDMA_PitchCdbkSelector

Parameters

Name	Description	Default	Sym	Type	Range
MinGain	minimum pitch gain	0.0		real	[0, ∞)
MaxGain	maximum pitch gain	2.0		real	[0, ∞)
StepGain	step of pitch gain when searching	0.25		real	(0, ∞)
MinLag	minimum pitch lag	17		int	[0, ∞)
MaxLag	maximum pitch lag	143		int	[0, ∞)
StepLag	step of pitch lag when searching	1		int	(0, ∞)
MinIndex	minimum codebook index	0		int	[0, ∞)
MaxIndex	maximum codebook index	127		int	[0, ∞)
StepIndex	step of codebook index when searching	1		int	(0, ∞)
MperceptWghtFactor	weighting factor of perceptual weighted filter	0.8	z	real	(0, 1.0]
FSize	length of frame	160		int	[0, ∞)
LpcOrder	order of LPC filter	10	P	int	(0, ∞)
FirstFrameDiscardFlag	flag to indicate use of first frame: 1=discard, 0=process	1		int	{0, 1}

Pin Inputs

Pin	Name	Description	Signal Type
1	sigIn	The speech signal with dc removed.	real
2	pLpcCo	LPC corresponding to pitch subframe.	real
3	rate	Data rate of current frame.	int
4	lspCd	LSP transmission code for Rate 1/8.	int

Pin Outputs

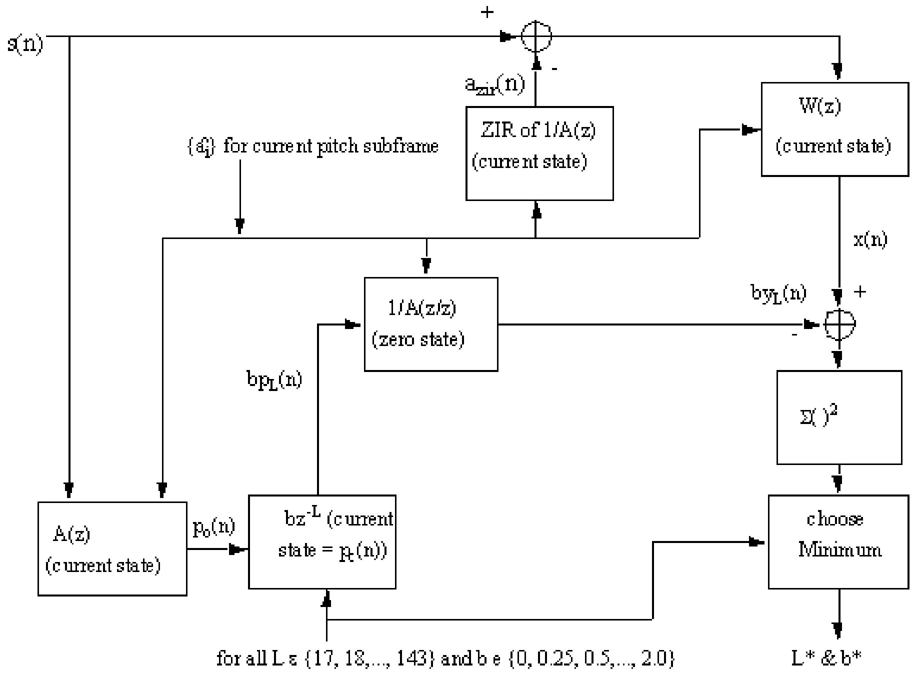
Pin	Name	Description	Signal Type
5	pitchB	transmission code of pitch gain.	int
6	pitchL	transmission code of pitch lag.	int
7	cdbkI	transmission code of codebook index or seed.	int
8	cdbkG	transmission code of codebook gain.	int

Notes/Equations

1. This component selects the optimal pitch lag L* and gain b*, codebook gain G* and index I* and quantifies these parameters to transmission codes. The LpcOrder default is 10; the FSize default is 160.

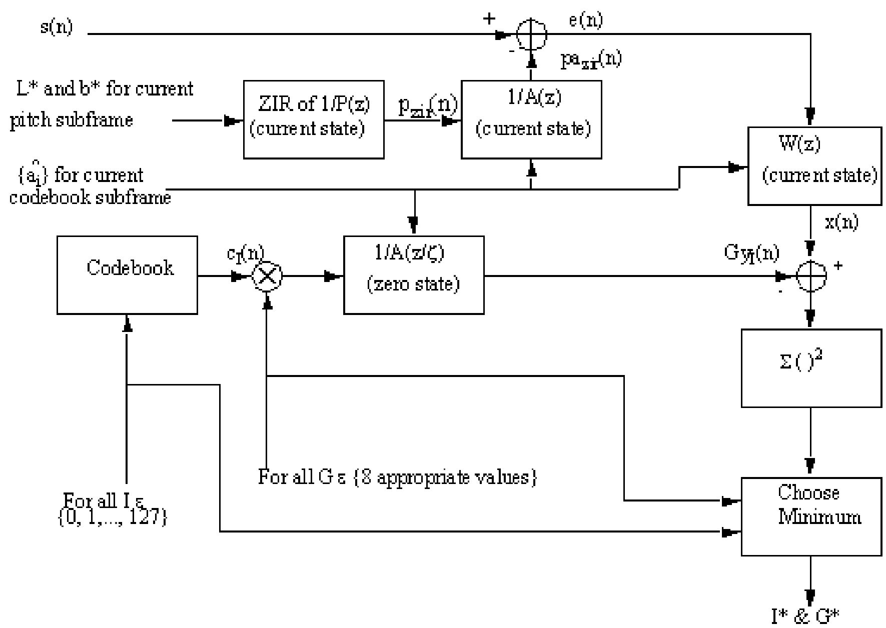
Each firing, MAX_PITCH_SF pitchB, MAX_PITCH_SF pitchL, 2×MAX_PITCH_SF cdbkI, 2×MAX_PITCH_SF cdbkG tokens are produced when FSize sigIn, 1 rate and LpcOrder pLpcCo, LpcOrder lspCd tokens are consumed. Here MAX_PITCH_SF is constant defined in celpStdValue.h; the MAX_PITCH_SF default is 4.

2. Implementation
   Analysis-by-synthesis is used to select pitch parameters, where encoding is done by selecting parameters that minimize the weighted error between the input and the synthesized speech. See the following figure.



Analysis-by-Synthesis for Pitch Parameter Search

A similar method is used to select codebook vector and gain. See the following figure. The selected codebook index and the codebook gain are allowable values that minimize the weighted error between the synthesized speech and the input speech. (See reference [1].)

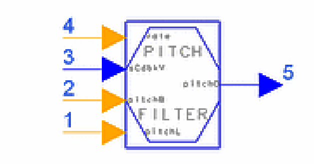


Analysis-by-Synthesis for Codebook Parameter Search

References

1. TIA/EIA/IS-96-A, Speech Service Option Standard for Wideband Spread Spectrum Digital Cellular System, May 1995.

CDMA_PitchFilter



Description The Pitch Filter to Reconstruct Speech Signal.
Library CDMA, CELP Codecs
Class SDFCDMA_PitchFilter

Parameters

Name	Description	Default	Type	Range
FSize	length of frame	160	int	(0, ∞)
MinLag	minimum pitch lag	17	int	(0, ∞)
MaxLag	maximum pitch lag	143	int	(0, ∞)
MinGain	minimum pitch gain	0.0	real	[0, ∞)
FirstFrameDiscardFlag	flag to indicate use of first frame: 1=discard, 0=process	1	int	{0, 1}

Pin Inputs

Pin	Name	Description	Signal Type
1	pitchL	Pitch lag.	int
2	pitchB	Pitch gain.	int
3	sCdbkV	The vector generated by the scaleCdbkGenerator model.	real
4	rate	Data rate of the current frame.	int

Pin Outputs

Pin	Name	Description	Signal Type
5	pitchO	The output of this model.	real

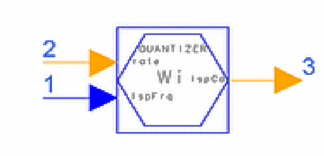
Notes/Equations

1. This component generates the pitch synthesis filter signal. Filter 1/P(z) uses optimal pitch gain b and pitch lag L converted back from the transmission code PLAGi and PGAINi that are appropriate for the current pitch subframe. The FSize default is 160. Each firing, FSize pitchO tokens are produced when MAX_PITCH_SF pitchB, MAX_PITCH_SF pitchL, FSize sCdbkV, 1 rate tokens are consumed. Here MAX_PITCH_SF is constant defined in celpStdValue.h and the default number of MAX_PITCH_SF is 4.

References

1. TIA/EIA/IS-96-A, Speech Service Option Standard for Wideband Spread Spectrum Digital Cellular System, May 1995.

CDMA_QuantizerWi



Description LSP frequencies to Transmission Code Quantizer.
Library CDMA, CELP Codecs
Class SDFCDMA_QuantizerWi

Parameters

Name	Description	Default	Sym	Type	Range
LpcOrder	order of LPC filter	10	P	int	(0, ∞)
FirstFrameDiscardFlag	flag to indicate use of first frame: 1=discard, 0=process	1		int	{0, 1}

Pin Inputs

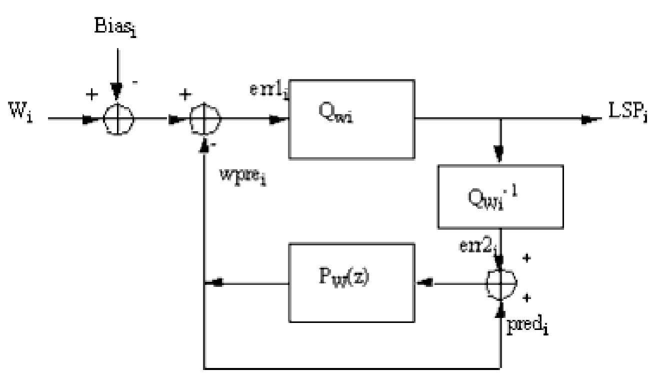
Pin	Name	Description	Signal Type
1	lspFrq	LSP frequecies.	real
2	rate	Data rate of this frame.	int

Pin Outputs

Pin	Name	Description	Signal Type
3	lspCd	The output of the quantizer.	int

Notes/Equations

1. This component converts LSP frequencies to transmission code; a predictor and quantizer are included; see the following figure. The quantizer is a linear quantizer that varies in dynamic range and step size for different rates.
   The LpcOrder default is 10.
   Each firing, P lspCd tokens are produced when P lspFrq and 1 rate tokens are consumed.

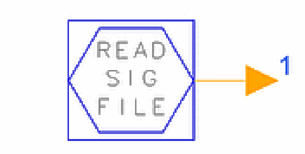


Converting LSP Frequencies to Transmission Codes

References

1. TIA/EIA/IS-96-A, Speech Service Option Standard for Wideband Spread Spectrum Digital Cellular System, May 1995.

CDMA_ReadSigFile



Description Read Waveform File for Signal generation
Library CDMA, CELP Codecs
Class SDFCDMA_ReadSigFile

Parameters

Name	Description	Default	Type
FileName	name of file to be read	file.wav	filename
OutputType	type of simulation: periodic or non_periodic: periodic, non_periodic	periodic	enum

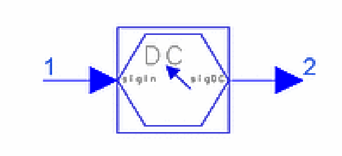
Pin Inputs

Pin	Name	Description	Signal Type
1	sigOut	Output signal.	int

Notes/Equations

1. CDMA_ReadSigFile is a test component to read speech signals from a Microsoft WAV file. The simulation can be stopped at end of file, or the file contents can be periodically repeated. 8 kHz sample rate, 16 bits per sample and mono channel file types are supported.
   Each firing, 1 sigOut token is produced.

CDMA_RemoveDC



Description Remove DC from Input Signal.
Library CDMA, CELP Codecs
Class SDFCDMA_RemoveDC

Parameters

Name	Description	Default	Type	Range
LowPassRatio	lowpass ratio to interpolate filter the average	0.75	real	[0, 1]
FSize	length of signal frame	160	int	(0, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	sigIn	The original speech signal	real

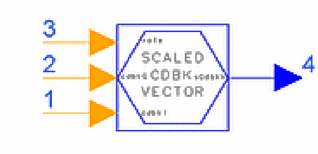
Pin Outputs

Pin	Name	Description	Signal Type
2	sigDC	The signal with dc removed	real

Notes/Equations

1. This component removes the dc offset from the input samples. The FSize default is 160.
   Each firing, FSize sigDC tokens are produced when FSize sigIn tokens are consumed.

CDMA_ScaledCdbkVector



Description Scaled Codebook Vector Generator.
Library CDMA, CELP Codecs
Class SDFCDMA_ScaledCdbkVector

Parameters

Name	Description	Default	Type	Range
FSize	length of frame	160	int	(0, ∞)
FirstFrameDiscardFlag	flag to indicate use of first frame: 1=discard, 0=process	1	int	{0, 1}

Pin Inputs

Pin	Name	Description	Signal Type
1	cdbkI	codebook index.	int
2	cdbkG	codebook gain.	int
3	rate	Data rate the current frame.	int

Pin Outputs

Pin	Name	Description	Signal Type
4	sCdbkV	Vector generated by this model.	real

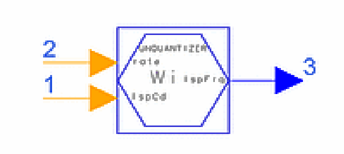
Notes/Equations

1. This component generates the scaled codebook vector according to optimal codebook index and gain for rate (except 1/8), and seed for rate 1/8. The default length of frame is 160. Each firing, FSize sCdbkV tokens are produced when 2×MAX_PITCH_SF cdbkI, 2×MAX_PITCH_SF cdbkG, 1 rate tokens are consumed. Here MAX_PITCH_SF is constant defined in celpStdValue.h and the default number of MAX_PITCH_SF is 4.

References

1. TIA/EIA/IS-96-A, Speech Service Option Standard for Wideband Spread Spectrum Digital Cellular System, May 1995.

CDMA_UnquantizerWi



Description Transmission Code to LSP Frequencies Unquantizer.
Library CDMA, CELP Codecs
Class SDFCDMA_UnquantizerWi

Parameters

Name	Description	Default	Sym	Type	Range
LpcOrder	order of LPC filter	10	P	int	(0, ∞)
FirstFrameDiscardFlag	flag to indicate use of first frame: 1=discard, 0=process	1		int	{0, 1}

Pin Inputs

Pin	Name	Description	Signal Type
1	lspCd	LSP transimission code.	int
2	rate	Data rate of current frame .	int

Pin Outputs

Pin	Name	Description	Signal Type
3	lspFrq	LSP frequencies.	real

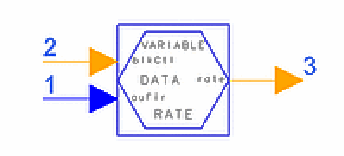
Notes/Equations

1. This component converts LSP transmission codes back to LSP frequencies (this is the reverse function of CDMA_QuantizerWi). LpcOrder default is 10.
   Each firing, P lspFrq tokens are produced when P lspCd and 1 rate tokens are consumed.

References

1. TIA/EIA/IS-96-A, Speech Service Option Standard for Wideband Spread Spectrum Digital Cellular System, May 1995.

CDMA_VariableDataRate



Description Data Rate Selector Based on Speech Activity.
Library CDMA, CELP Codecs
Class SDFCDMA_VariableDataRate

Parameters

Name	Description	Default	Type	Range
RateMode	rate mode indicator: 0=variable rate; 1=fixed rate 1; 2=fixed rate1/2	0	int	{0, 1,2}
BackNoiseThreshold	background noise threshold	160000	int	(0, ∞)
BaseNoiseThreshold	basic noise threshold	5059644	int	(0, ∞)
ThresholdMultiple	multiple coefficient	1.00547	real	(0, ∞)
FirstFrameDiscardFlag	flag to indicate use of first frame: 1=discard, 0=process	1	int	{0, 1}

Pin Inputs

Pin	Name	Description	Signal Type
1	auFir	The first value of autofun.	real
2	blkCtl	Here 0 is not blank frame, 1 is blank frame.	int

Pin Outputs

Pin	Name	Description	Signal Type
3	rate	The rate of the current frame.	int

Notes/Equations

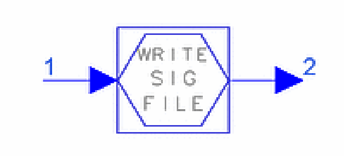
1. This component makes an initial rate selection based on the energy in the frame and a set of three thresholds (see reference [1] 2.4.4). Refer to the following table for packet and data rates. Upon command, the speech codec will generate a blank packet. Each firing, 1 rate token is produced when 1 auFir and 1 blkCtl tokens are consumed.

rate	Packet Type	Bits per Packet
0	Rate 1	171
1	Rate 1/2	80
2	Rate 1/4	40
3	Rate 1/8	16
4	Blank	0
5	Rate 1 with bit errors	171
6	Insufficient frame quality (erasure)	0

References

1. TIA/EIA/IS-96-A, Speech Service Option Standard for Wideband Spread Spectrum Digital Cellular System, May 1995.

CDMA_WriteSigFile



Description Write Reconstructed Signal to a Data File
Library CDMA, CELP Codecs
Class SDFCDMA_WriteSigFile

Parameters

Name	Description	Default	Type
WriteFileName	output file name	output.wav	filename

Pin Inputs

Pin	Name	Description	Signal Type
1	SigOut	The reconstructed speech signal.	real

Pin Outputs

Pin	Name	Description	Signal Type
2	output	output the values written into file1->	real

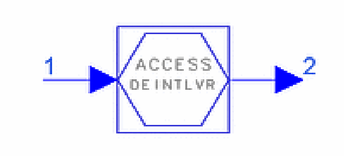
Notes/Equations

1. CDMA_WriteSigFile is a test component to write speech signals into a Microsoft WAV file with an 8 kHz sample rate, 16 bits per sample and a mono channel. The first frame of the input signal is jumped due to initialization, other signals will be written into the file specified by WriteFileName. A default frame length of 160 is used. Each firing, 1 sigOut input token is consumed and 1 output token is produced.

Channel Codec Components

- *CDMA AccessDeintlvr* (cdma)
- *CDMA AccessIntlvr* (cdma)
- *CDMA AddTail* (cdma)
- *CDMA BitCC* (cdma)
- *CDMA CC WithTail* (cdma)
- *CDMA DCC WithTail* (cdma)
- *CDMA EraseTail* (cdma)
- *CDMA ErrorRate* (cdma)
- *CDMA FwdChCoder* (cdma)
- *CDMA FwdChDecoder* (cdma)
- *CDMA FwdViterbiDCC* (cdma)
- *CDMA LogicToNRZ* (cdma)
- *CDMA OneBitQuantizer* (cdma)
- *CDMA OneWayVD* (cdma)
- *CDMA PgFwdTrfDeintlvr* (cdma)
- *CDMA PgFwdTrfIntlvr* (cdma)
- *CDMA Repeat* (cdma)
- *CDMA RevChCoder* (cdma)
- *CDMA RevChDecoder* (cdma)
- *CDMA RevOneway* (cdma)
- *CDMA RevTrfDeintlvr* (cdma)
- *CDMA RevTrfIntlvr* (cdma)
- *CDMA Select1In4* (cdma)
- *CDMA SyncDeintlvr* (cdma)
- *CDMA SyncIntlvr* (cdma)
- *CDMA TrffcFrmGen* (cdma)
- *CDMA TrffcFrmRcvry* (cdma)
- *CDMA VariableRateCC* (cdma)
- *CDMA VariableRateDCC* (cdma)
- *CDMA ViterbiBitDCC* (cdma)

CDMA_AccessDeintlvr



Description Access Channel Deinterleaver. This module de-interleaves the code symbol for CDMA Access Channel.
Library CDMA, Channel Codecs
Class SDFCDMA_AccessDeintlvr
Derived From CDMA_Interleaver

Pin Inputs

Pin	Name	Description	Signal Type
1	input	the input symbol to be interleaved.	real

Pin Outputs

Pin	Name	Description	Signal Type
2	output	the interleaved symbol.	real

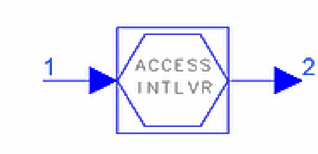
Notes/Equations

1. This component is used to deinterleave the input coded symbol for the CDMA access channel. 576 output tokens are produced when 576 input tokens are consumed.
2. Implementation
Deinterleaving is the reverse function of interleaving. The symbol is written into the deinterleaver by row; the row number is bit-reversed and read by the deinterleaver by column. The bit-reversal function rearranges the input array, of which length N is a power of 2. The index (decimal) is converted into a binary number. For a 32-length array: i
can be denoted as binary number $i_4 i_3 i_2 i_1 i_0$, with a range of 0 to 31; n
is a 5-bit binary number, $n = a_4 a_3 a_2 a_1 a_0$, where $a_4 = i_0$, $a_3 = i_1$, $a_2 = i_2$, $a_1 = i_3$, $a_0 = i_4$. n
is the bit reversal index of i. This function rearranges the input array by exchanging the number of index i for the number of bit reversal index n.

References

1. TIA/EIA/IS-95-A, Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System, May 1995.

CDMA_AccessIntlvr



Description Access Channel Interleaver. This module interleaves the coded symbol for CDMA Access Channel.
Library CDMA, Channel Codecs
Class SDFCDMA_AccessIntlvr
Derived From CDMA_Interleaver

Pin Inputs

Pin	Name	Description	Signal Type
1	input	the input symbol to be interleaved.	real

Pin Outputs

Pin	Name	Description	Signal Type
2	output	the interleaved symbol.	real

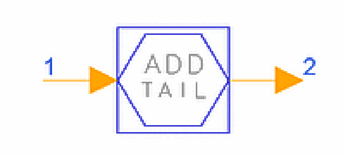
Notes/Equations

1. This component is used to interleave the input coded symbol for the CDMA access channel. 576 output tokens are produced when 576 input tokens are consumed.
2. Implementation
   The interleaver can also be implemented using bit-reversal. This interleaver matrix is written by column, left to right, then read by row in order of the bit-reversal index. Bit-reversal rearranges the input array, of which length N is a power of 2. The index (decimal) is converted into a binary number.
   For a 32-length array: i can be denoted as binary number $i_4i_3i_2i_1i_0$, with a range of 0 to 31; n is a 5-bit binary number, $n = a_4a_3a_2a_1a_0$, where $a_4 = i_0$, $a_3 = i_1$, $a_2 = i_2$, $a_1 = i_3$, $a_0 = i_4$. n is the bit reversal index of i. This function rearranges the input array by exchanging the number of index i for the number of bit reversal index n.

References

1. TIA/EIA/IS-95-A, Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System, May 1995.

CDMA_AddTail



Description Tail bits adder. This model adds tail bits for the frame that needs tail bits for employing convolutional code.
Library CDMA, Channel Codecs
Class SDFCDMA_AddTail

Parameters

Name	Description	Default	Type	Range
FrameLength	input frame length	88	int	(0, ∞)
TailLength	tail bits length	8	int	[0, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	input	The information bits.	int

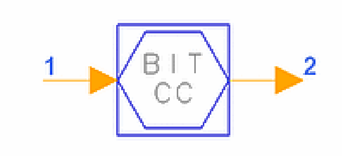
Pin Outputs

Pin	Name	Description	Signal Type
2	output	The data of frame with tail.	int

Notes/Equations

1. This component is used to add tail bits for the frame that needs tail bits for convolutional coding.
   FrameLength+TailLength output tokens are produced when FrameLength input tokens are consumed. For example, in a CDMA access channel, Framelength=88, and TailLength=8; 96 output tokens are produced when 88 input tokens are consumed.

CDMA_BitCC



Description Bit-By-Bit Convolutional Encoder
Library CDMA, Channel Codecs
Class SDFCDMA_BitCC
Derived From CDMA_CnvlCoder

Parameters

Name	Description	Default	Type	Range
CCType	convolutional code type: rate 1/2 K 9 g0 0753 g1 0561, rate 1/3 K 9 g0 0557 g1 0663 g2 0711, rate 1/2 K 7 g0 0554 g1 0744, rate 1/3 K 7 g0 0554 g1 0624 g2 0764, rate 1/2 K 5 g0 046 g1 072, rate 1/3 K 5 g0 066 g1 052 g2 076, rate 1/2 K 5 g0 046 g1 066, rate 1/6 K 5 g0 066 g1 052 g2 076 g3 066 g4 052 g5 076, rate 1/2 K 3 g0 05 g1 07	rate 1/2 K 9 g0 0753 g1 0561	enum	†

† If K < 9 and > 6, only higher K generator bits is useful, the lower (9-K) bits is all 0s.The generator is written in octal format 0xxx. For rate 1/2 K 7 g0 0554 g1 0744, K=7. Generator g1 is $D_6 + D_5 + D_4 + D_3 + 1$, written as 111100100 (that is, 0744). If K <6 and >3, the generator is written as 0xx; it contain 6 bits; the lower (6-K) is 0 and is not useful.

Pin Inputs

Pin	Name	Description	Signal Type
1	input	the bits to be convolutionally encoded.	int

Pin Outputs

Pin	Name	Description	Signal Type
2	output	Convolutionally encoded symbols.	int

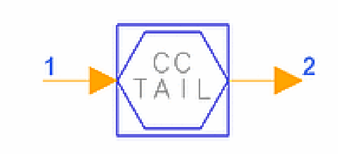
Notes/Equations

1. This component is used to convolutionally encode the input bit.
   1/rate (specified by CCType) output tokens are produced when one input token is consumed.
   For example, in CDMA Sync channel, CC(2,1,9) is used in which the convolutional code rate is 1/2. CCType is set to *rate 1/2 K 9 g0 0753 g1 0561* and two output tokens are produced when one input token is consumed.

References

1. S. Lin and D. J. Costello, Jr., *Error Control Coding Fundamentals and Applications*, Prentice Hall, Englewood Cliffs NJ, 1983.

CDMA_CC_WithTail



Description Convolutional Encoder with tail. This model convolutionally encodes the input tailed frame.
Library CDMA, Channel Codecs
Class SDFCDMA_CC_WithTail
Derived From CDMA_CnvlCoder

Parameters

Name	Description	Default	Type	Range
CCType	convolutional code type: rate 1/2 K 9 g0 0753 g1 0561, rate 1/3 K 9 g0 0557 g1 0663 g2 0711, rate 1/2 K 7 g0 0554 g1 0744, rate 1/3 K 7 g0 0554 g1 0624 g2 0764, rate 1/2 K 5 g0 046 g1 072, rate 1/3 K 5 g0 066 g1 052 g2 076, rate 1/2 K 5 g0 046 g1 066, rate 1/6 K 5 g0 066 g1 052 g2 076 g3 066 g4 052 g5 076, rate 1/2 K 3 g0 05 g1 07	rate 1/2 K 9 g0 0753 g1 0561	enum	†
InputFrameLen	input frame length	96	int	[K, ∞)

† If K < 9 and > 6, only higher K generator bits is useful, the lower (9-K) bits is all zeros.The generator is written as octal format 0xxx. For *rate 1/2 K 7 g0 0554 g1 0744* , K=7. Generator g1 is $D_6 + D_5 + D_4 + D_3 + 1$, written as 111100100 (that is, 0744).If K < 6 and > 3, the generator is written as 0xx; it contain 6 bits, the lower(6-K) is 0 and is not useful.

Pin Inputs

Pin	Name	Description	Signal Type
1	input	The data to be convolutionally encoded	int

Pin Outputs

Pin	Name	Description	Signal Type
2	output	Convolutionally encoded symbols	int

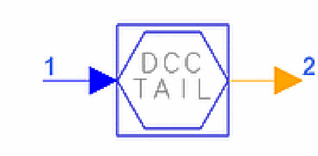
Notes/Equations

1. This component is used to convolutionally encode the input tailed frame. InputFrameLen/rate (specified by CCType) output tokens are produced when InputFrameLen input tokens are consumed.
   For example, in the CDMA access channel, CC(3,1,9) is used where the convolutional code rate is 1/3 and the frame length is 96. CCType is set to *rate 1/3 K 9 g0 0557 g1 0663 g2 0711* and InputFrameLen is 96. 288 output tokens are produced when 96 input tokens are consumed.

References

1. S. Lin and D. J. Costello, Jr., *Error Control Coding Fundamentals and Applications* , Prentice Hall, Englewood Cliffs NJ, 1983.

CDMA_DCC_WithTail



Description Viterbi Decoder for Convolutional Code with Tail. This module does viterbi decoding for truncated convolutional code.
Library CDMA, Channel Codecs
Class SDFCDMA_DCC_WithTail
Derived From CDMA_ViterbiDecoder

Parameters

Name	Description	Default	Type	Range
CCType	convolutional code type: rate 1/2 K 9 g0 0753 g1 0561, rate 1/3 K 9 g0 0557 g1 0663 g2 0711, rate 1/2 K 7 g0 0554 g1 0744, rate 1/3 K 7 g0 0554 g1 0624 g2 0764, rate 1/2 K 5 g0 046 g1 072, rate 1/3 K 5 g0 066 g1 052 g2 076, rate 1/2 K 5 g0 046 g1 066, rate 1/6 K 5 g0 066 g1 052 g2 076 g3 066 g4 052 g5 076, rate 1/2 K 3 g0 05 g1 07	rate 1/2 K 9 g0 0753 g1 0561	enum	†
InputFrameLen	input frame length	288	int	[K, ∞)

† If K < 9 and > 6, only higher K generator bits is useful, the lower (9-K) bits is all zeros. The generator is written as octal format 0xxx. For rate 1/2 K 7 g0 0554 g1 0744, K=7. Generator g1 is $D_6 + D_5 + D_4 + D_3 + 1$, written as 111100100 (that is, 0744).If K < 6 and > 3, the generator is written as 0xx; it contain 6 bits, the lower(6-K) is 0 and is not useful.

Pin Inputs

Pin	Name	Description	Signal Type
1	input	the symbols to be decoded.	real

Pin Outputs

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

Notes/Equations

1. This component is used to Viterbi-decode convolutional code with tail.
   InputFrameLen×rate (specified by CCType) output tokens are produced when InputFrameLen input tokens are consumed.
   For example, in CDMA access channel, CC(3,1,9) is used in which the convolutional code rate is 1/3 and the frame length is 288. CCType is set to *rate 1/3 K 9 g0 0557 g1 0663 g2 0711* and InputFrameLen is 288. 96 output tokens are produced when 288 input tokens are consumed.
2. Implementation
   Viterbi Decoding Algorithm
   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
The branch metric $m_j^{(\alpha)}$, 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 $r_{j1}r_{j2}...r_{jn}$ conditioned on the estimated transmitted n-bit symbol $c_{j1}^{(\alpha)}\ c_{j2}^{(\alpha)}\ ...\ c_{jn}^{(\alpha)}$

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

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

for the α path. That is,
If Rake receiver is regarded as a 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 instant 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 from the paths $\alpha_1, \alpha_2, ... ,\alpha_{2^k}$, the one having the largest metric, namely,

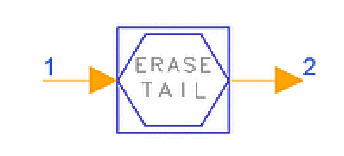
$$max(M^{(\alpha_1)}, M^{(\alpha_2)}, ... , M^{(\alpha_{2^k})})$$

and this path is known as the survivor.
Decoder Output
When the two survivors have been 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. S. Lin and D. J. Costello, Jr., *Error Control Coding Fundamentals and Applications*, Prentice Hall, Englewood Cliffs NJ, 1983.
2. R. Steele (Editor), *Mobile Radio Communication*, IEEE Press, June 1995.

CDMA_EraseTail



Description Tail bits eraser. This module deletes the tail bits added in the transmitting end.
Library CDMA, Channel Codecs
Class SDFCDMA_EraseTail

Parameters

Name	Description	Default	Type	Range
TailLength	tail length	8	int	(0, ∞)
InputFrameLen	input frame length	96	int	(TailLength, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	input	The input block.	int

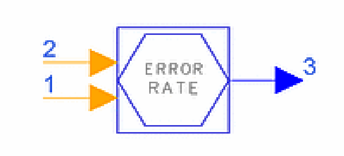
Pin Outputs

Pin	Name	Description	Signal Type
2	output	The output block.	int

Notes/Equations

1. This component is used to erase the tail bits added in the transmitting end. InputFrameLen−TailLength output tokens are produced when InputFrameLen input tokens are consumed. For example, in CDMA access channel, 88 output tokens are produced when 96 input tokens are consumed.

CDMA_ErrorRate



Description Error Rate Estimation. This model compares the two input blocks to estimate the BER.
Library CDMA, Channel Codecs
Class SDFCDMA_ErrorRate

Parameters

Name	Description	Default	Type	Range
TestLength	test length	192	int	(0, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	in1	The first channel signal.	int
2	in2	The second channel signal.	int

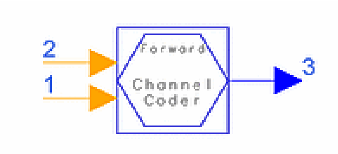
Pin Outputs

Pin	Name	Description	Signal Type
3	output	The error rate in this block.	real

Notes/Equations

1. This component is used to compare the two input blocks and estimate the error rate in this block.
   One output token is produced for each set of TestLength input tokens consumed.

CDMA_FwdChCoder



Description CDMA Forward Traffic Channel Encoder
Library CDMA, Channel Codecs
Class SDFCDMA_FwdChCoder

Pin Inputs

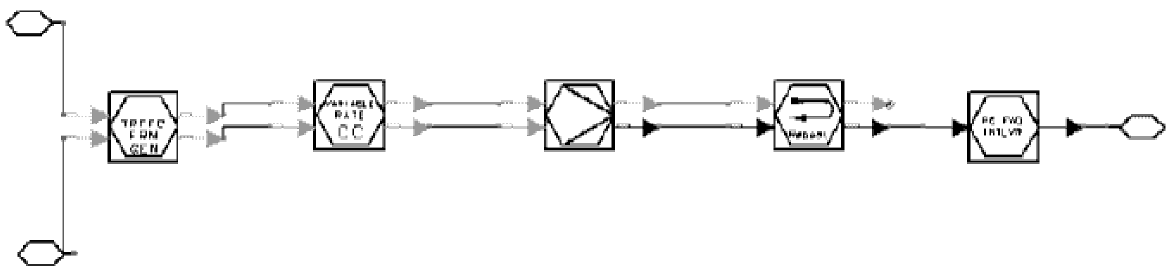
Pin	Name	Description	Signal Type
1	in1	input frame data	int
2	in2	input frame data rate	int

Pin Outputs

Pin	Name	Description	Signal Type
3	output	data	int

Notes/Equations

1. This subnetwork is used to implement forward traffic channel encoding. It is a combination of frame generator, Viterbi encoder, mapping bits to NRZ, and interleaver.
2. Implementation
   Refer to the following figure. The CDMA_FwdChCoder subnetwork includes CDMA_TrffcFrmGen, CDMA_VariableRateCC, CDMA_Repeat, CDMA_LogicToNRZ, and CDMA_PgFwdIntlvr.

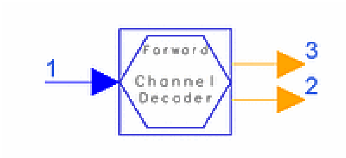


Forward Traffic Channel Encoder

References

1. TIA/EIA/IS-95-A, Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System, May 1995.

CDMA_FwdChDecoder



Description CDMA Forward Traffic Channel Deoder
Library CDMA, Channel Codecs
Class SDFCDMA_FwdChDecoder

Pin Inputs

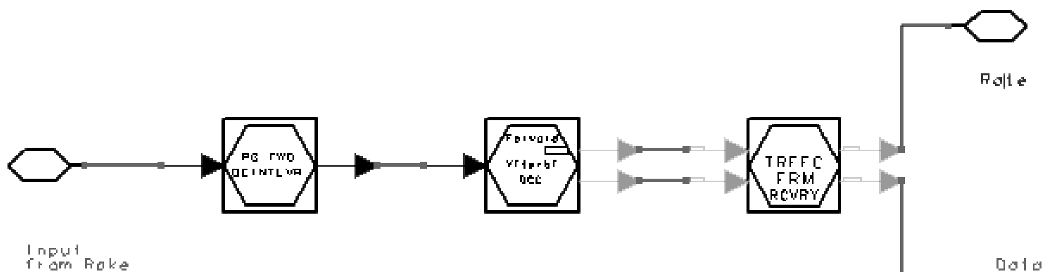
Pin	Name	Description	Signal Type
1	input	soft decision value	real

Pin Outputs

Pin	Name	Description	Signal Type
2	output	decoded data	int
3	rate0	transmit data rate	int

Notes/Equations

1. This subnetwork is used to implement forward traffic channel decoding. It is a combination of Viterbi decoder, rate detector and frame recovery.
2. Implementation
   Refer to the following figure. The CDMA_FwdChDecoder subnetwork includes CDMA_PgFwdDeintlvr, CDMA_FwdViterbiDCC, and CDMA_TrffcFrmRcvry.
   Input data from CDMA_FwdRake is soft decision values for the Viterbi decoder.
   CDMA_PgFwdIntlvr deinterleaves the input data. CDMA_FwdViterbiDCC completes the rate detection and Viterbi decoding. CDMA_TrffcFrmRcvry recovers the frame that is same as the source.

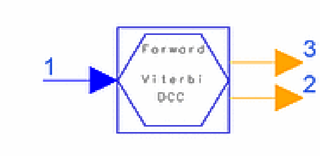


Forward Traffic Channel Decoder

References

1. TIA/EIA/IS-95-A, Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System, May 1995.

CDMA_FwdViterbiDCC



Description CDMA Forward Traffic Channel 4-way Viterbi Decoder
Library CDMA, Channel Codecs
Class SDFCDMA_FwdViterbiDCC

Pin Inputs

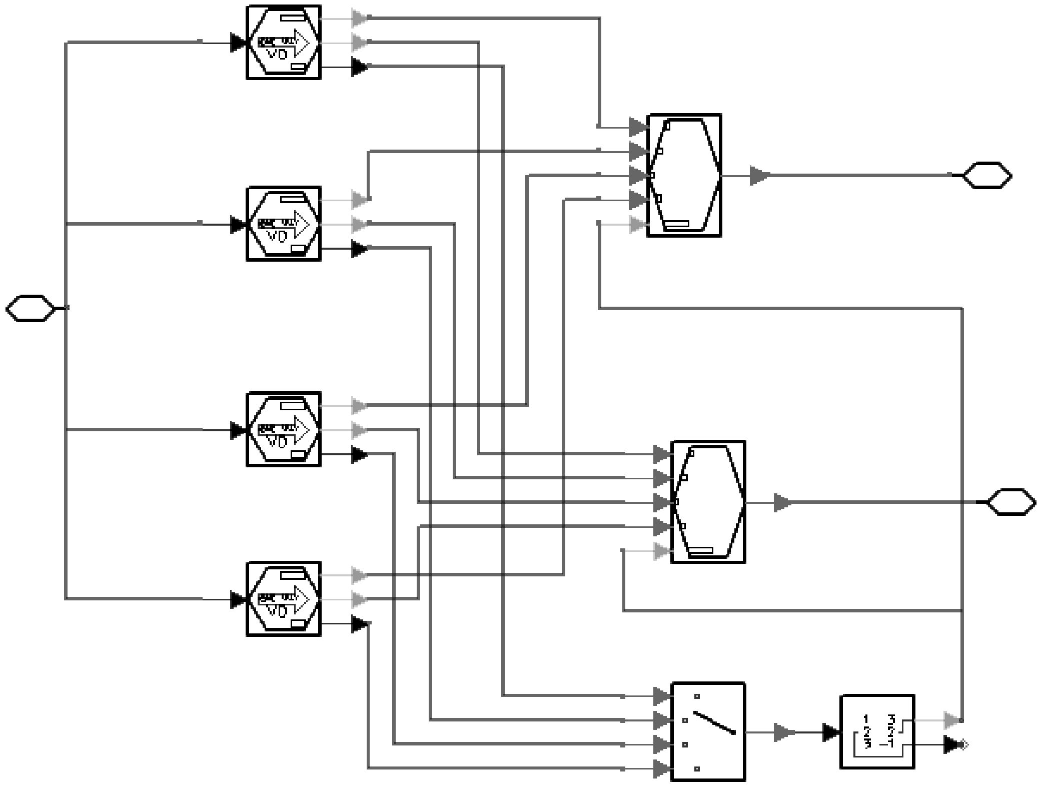
Pin	Name	Description	Signal Type
1	input	soft decision value after deinterleaving	real

Pin Outputs

Pin	Name	Description	Signal Type
2	output	decoded data	int
3	rateO	transmit data rate	int

Notes/Equations

1. This subnetwork is used to implement forward traffic channel Viterbi decoding.
2. Implementation
   Refer to the following figure. The CDMA_FwdViterbiDCC subnetwork includes CDMA_OneWayVD and CDMA_Select1in4.
   Input data from CDMA_FwdRake and CDMA_PgFwdDeintlvr is soft decision values for Viterbi decoding.
   In CDMA_OneWayVD, decoding is performed according to data rates. After decoding, data is encoded again using the same generator function; results are compared with the data before decoding, and the bit error rate is calculated. The date rate with minimum BER is used as the transmit data rate.

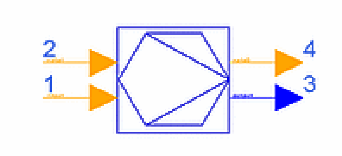


Forward Traffic Channel Viterbi Decoder

References

1. TIA/EIA/IS-95-A, Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System, May 1995.

CDMA_LogicToNRZ



Description Logic-to-NRZ Converter for CDMA systems. This model maps the logic data into the NRZ Binary Signaling.
Library CDMA, Channel Codecs
Class SDFCDMA_LogicToNRZ

Parameters

Name	Description	Default	Type	Range
Amplitude	amplitude of NRZ binary signaling	1.0	real	(-∞, -1e-6) (1e-6, ∞)
ChannelType	channel type:CDMA Forward Traffic Channel, CDMA Reverse Traffic Channel, Others: CDMA Forward Traffic Channel, CDMA Reverse Traffic Channel, Others	Others	enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	input	The input logic data.	int
2	rateI	Only used in Forward Traffic Channel. If not used, please connect constant 0.	int

Pin Outputs

Pin	Name	Description	Signal Type
3	output	The output NRZ Binary Signaling data.	real
4	rateO	data rate .	int

Notes/Equations

1. This component is used to map logic data into NRZ binary signaling and adjust symbol amplitude by data rate.
   For CDMA Forward Traffic Channel, 384 output tokens are produced when 384 input tokens are consumed; for CDMA Reverse Traffic Channel, 576 input tokens are produced when 576 input tokens are consumed; for Others, one output token is produced when one input token is consumed (rateI is not useful for Others, it can be connected to any bits).
2. Implementation
   For CDMA Forward Traffic Channel, all repeated symbols will be transmitted. The amplitude of logic-to-real mapping is inversely proportional to the data rate. The input and output block structure for CDMA Forward Traffic Channel or CDMA Reverse Traffic Channel is shown in the following table.

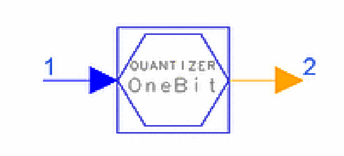
Variable Rate Frame Block Structure

Data Rate	Block Length	Block Structure	
		Valid DataInteger/Block	PaddingInteger/Block
full rate (9600 bps)	MaxFrameLen	MaxFrameLen	0
half rate (4800 bps)	MaxFrameLen	MaxFrameLen/2	MaxFrameLen/2
1/4 rate (2400 bps)	MaxFrameLen	MaxFrameLen/4	3×MaxFrameLen/4
1/8 rate (1200 bps)	MaxFrameLen	MaxFrameLen/8	7×MaxFrameLen/8

References

1. TIA/EIA/IS-95-A, Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System, May 1995.

CDMA_OneBitQuantizer



Description One-Bit Quantizer. This module maps the input real data into logic.
Library CDMA, Channel Codecs
Class SDFCDMA_OneBitQuantizer

Pin Inputs

Pin	Name	Description	Signal Type
1	input	the input data.	real

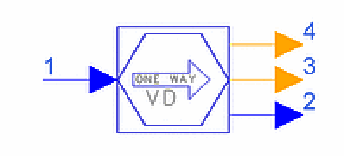
Pin Outputs

Pin	Name	Description	Signal Type
2	output	the output data.	int

Notes/Equations

1. This component is used to map real data into logic. If data > 0, output data is 0; else output data is 1.
   One output token is produced when one input token is consumed.

CDMA_OneWayVD



Description CDMA Forward One Rate Decoder
Library CDMA, Channel Codecs
Class SDFCDMA_OneWayVD

Parameters

Name	Description	Default	Type	Range
Times	number of times to repeat input data	1	int	{1, 2,4,8}
datarate	transmit data rate frame: 0=full, 1=1/2, 2=1/4, 3=1/8	0	int	{0, 1,2,3}

Pin Inputs

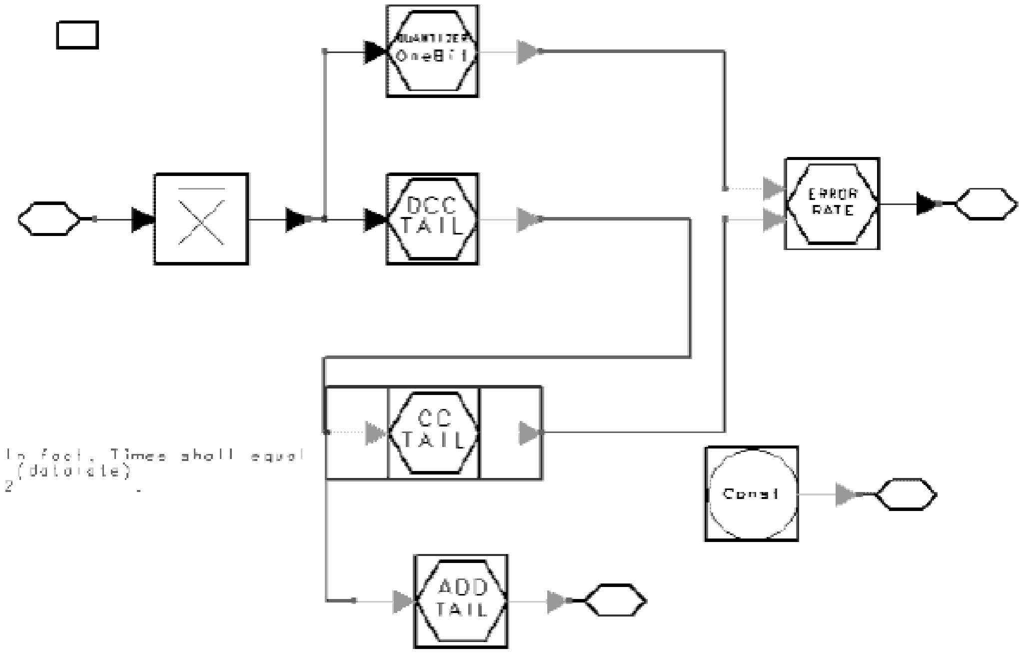
Pin	Name	Description	Signal Type
1	input	soft decision value	real

Pin Outputs

Pin	Name	Description	Signal Type
2	Err	bit error rate	real
3	output	recovered data	int
4	rate0	data rate of this decoder	int

Notes/Equations

1. This subnetwork is used to implement channel decoding of a data rate. It is a combination of deinterleaving, Viterbi decoder, encoder and BER calculator.
2. Implementation:
   Refer to the following figure. The CDMA_OneWayVD subnetwork includes CDMA_OneBitQuantizer, CDMA_DCC_WithTail, CDMA_CC_WithTail, CDMA_Erasetail, CDMA_ErrorRate and CDMA_AddTail.
   Input data is soft decision values with a certain rate for Viterbi decoder.
   Deinterleaving and decoding are performed according to the data rate. After decoding data is encoded again with the same code; results are compared with the data before decoding, and the bit error rate is calculated.

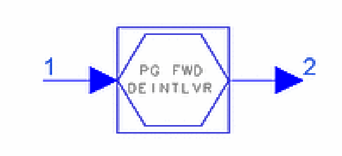


Forward One Rate Channel Decoder

References

1. TIA/EIA/IS-95-A, Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System, May 1995.

CDMA_PgFwdTrfDeintlvr



Description Paging Channel and Forward Traffic Channel Deinterleaver. This module de-interleaves the code symbol for CDMA Paging and Forward Traffic Channel.
Library CDMA, Channel Codecs
Class SDFCDMA_PgFwdTrfDeintlvr
Derived From CDMA_Interleaver

Pin Inputs

Pin	Name	Description	Signal Type
1	input	the input symbol to be interleaved.	real

Pin Outputs

Pin	Name	Description	Signal Type
2	output	the interleaved symbol.	real

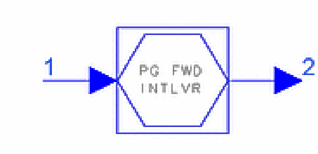
Notes/Equations

1. This component is used to deinterleave the input coded symbol for CDMA Paging Channel and Forward Traffic Channel.
   384 output tokens are produced when 384 input tokens are consumed.
2. Implementation
   Deinterleaving is the reverse function of interleaving (described in CDMA_PgFwdTrfIntlvr). This channel deinterleaver is also a 64×6 matrix. The symbol is written into the deinterleaver by row; row numbers are bit-reversed and read by the deinterleaver by column.
   Bit-reversal rearranges the input array, of which length N is a power of 2. The index (decimal) is converted into a binary number. For example, for a 32-length array, the index i of the number of this array can be denoted as binary number cdma-3-16-061.gif!, with a range of 0 to 31, and n is a 5-bit binary number, $i = a_4 a_3 a_2 a_1 a_0$, where $a_4 = i_0$, $a_3 = i_1$, $a_2 = i_2$, $a_1 = i_3$, $a_0 = i_4$.
   Then the number n is the bit-reversal index of index i. This function rearranges the input array by exchanging the number of index i
   for the number of bit reversal index n.

References

1. TIA/EIA/IS-95-A, Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System, May 1995.

CDMA_PgFwdTrfIntlvr



Description Paging Channel and Forward Traffic Channel Interleaver. This module interleaves the coded symbol for CDMA Paging and Forward Traffic Channel.
Library CDMA, Channel Codecs
Class SDFCDMA_PgFwdTrfIntlvr
Derived From CDMA_Interleaver

Pin Inputs

Pin	Name	Description	Signal Type
1	input	the input symbol to be interleaved.	real

Pin Outputs

Pin	Name	Description	Signal Type
2	output	the interleaved symbol.	real

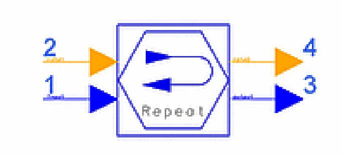
Notes/Equations

1. This component is used to interleave the input coded symbol for CDMA Paging Channel and Forward Traffic Channel.
   384 output tokens are produced when 384 input tokens are consumed.
2. Implementation
   This interleaver can also be implemented using bit-reversal.
   A 64×6 matrix is formed and is written by column, left to the right. The matrix is read by row in the order of bit reversal index.
   Bit-reversal rearranges the input array, of which length N is a power of 2. The index (decimal) is converted into binary numbers. For a 32-length array, i can be denoted as binary number $i_4 i_3 i_2 i_1 i_0$, with a range of 0 to 31, and n is a 5-bit binary number, $n = a_4 a_3 a_2 a_1 a_0$, where $a_4 = i_0$, $a_3 = i_1$, $a_2 = i_2$, $a_1 = i_3$, $a_0 = i_4$. n is the bit reversal index of i. This function rearranges the input array by exchanging the number of index i for the number of bit reversal index n.

References

1. TIA/EIA/IS-95-A, Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System, May 1995.

CDMA_Repeat



Description Repeater for CDMA systems. This model repeats the variable rate frame data to get the same symbol rate in CDMA system.
Library CDMA, Channel Codecs
Class SDFCDMA_Repeat

Parameters

Name	Description	Default	Type
Channel	channel type:Forward Traffic Channel ,Reverse Traffic Channel: Forward Traffic Channel, Reverse Traffic Channel	Forward Traffic Channel	enum

Pin Inputs

Pin	Name	Description	Signal Type
1	input	the input stream.	real
2	rateI	the data rate of frame.	int

Pin Outputs

Pin	Name	Description	Signal Type
3	output	the repeated symbol.	real
4	rateO	the data rate of frame.	int

Notes/Equations

1. This component repeats the variable data rate frame to get the same symbol rate in CDMA systems.
   For Forward Traffic Channel, 384 output tokens are produced when 384 input tokens are consumed. For Reverse Traffic Channel, 576 output tokens are produced when 576 input tokens are consumed.
2. Implementation
   The input block structure is given in the following table. For Reverse Traffic Channel MaxFrameLen is 576; for Forward Traffic Channel MaxFrameLen is 384. The Reverse Traffic Channel output block structure includes 576 symbols; the Forward Traffic Channel output block structure includes 384 symbols.

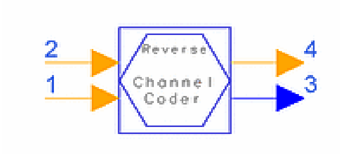
Input Block Structure

Data Rate	Block Length	Block Structure	
		Valid Data Integer/Block	Padding Integer/Block
full rate (9600 bps)	MaxFrameLen	MaxFrameLen	0
half rate (4800 bps)	MaxFrameLen	MaxFrameLen/2	MaxFrameLen/2
1/4 rate (2400 bps)	MaxFrameLen	MaxFrameLen/4	3×MaxFrameLen/4
1/8 rate (1200 bps)	MaxFrameLen	MaxFrameLen/8	7×MaxFrameLen/8

References

1. TIA/EIA/IS-95-A, Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System, May 1995.

CDMA_RevChCoder



Description CDMA Reverse Traffic Channel Encoder
Library CDMA, Channel Codecs
Class SDFCDMA_RevChCoder

Parameters

Name	Description	Default	Type	Range
preamble	preamble frame number	0	int	[0, ∞)

Pin Inputs

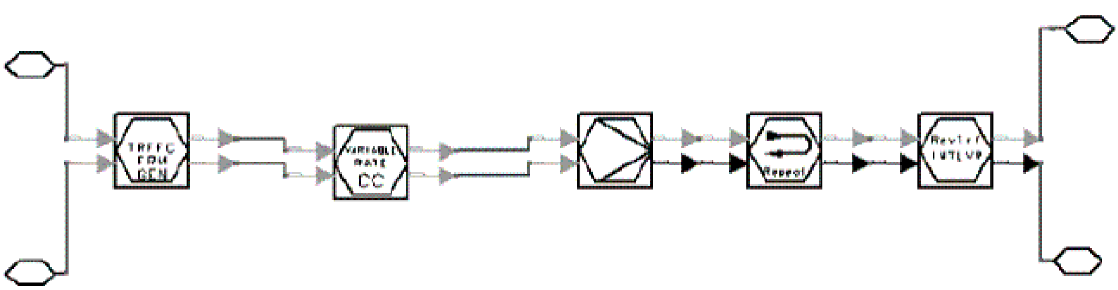
Pin	Name	Description	Signal Type
1	input	input frame data	int
2	rateI	input frame data rate	int

Pin Outputs

Pin	Name	Description	Signal Type
3	output	output data	real
4	rate0	output frame data rate	int

Notes/Equations

1. This subnetwork is used to implement reverse traffic channel encoder. It is a combination of frame generator, Viterbi encoder, mapping bits to NRZ, and interleaver.
2. Implementation
   Refer to the following figure. The CDMA_RevChCoder subnetwork includes CDMA_TrffcFrmGen, CDMA_VariableRateCC, CDMA_Repeat, CDMA_LogicToNRZ, and CDMA_RevTrfIntlvr.

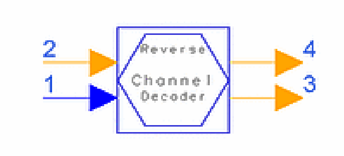


Reverse Traffic Channel Encoder

References

1. TIA/EIA/IS-95-A, Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System, May 1995.

CDMA_RevChDecoder



Description CDMA Reverse Traffic Channel Decoder
Library CDMA, Channel Codecs
Class SDFCDMA_RevChDecoder

Pin Inputs

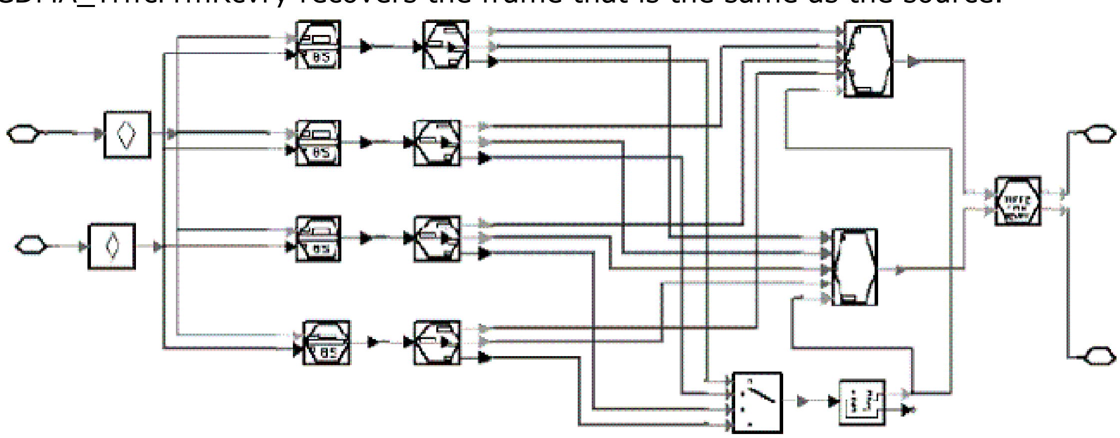
Pin	Name	Description	Signal Type
1	input	soft decision value	real
2	LgCode	long PN code	int

Pin Outputs

Pin	Name	Description	Signal Type
3	output	recovered data	int
4	rate0	transmit data rate	int

Notes/Equations

1. This subnetwork is used to implement channel decoding. It is a combination of Viterbi decoder, rate detector and frame recovery.
2. Implementation
   Refer to the following figure. The CDMA_RevChDecoder subnetwork includes CDMA_BSRateconverter, CDMA_RevOneway, CDMA_Select1In4, CDMA_TrffcFrmRcvry.
   Input data is soft decision values for Viterbi decoding. CDMA_BSRateconverter recovers the transmitted frame according to the data burst randomizing algorithm. The recovered frame is output to CDMA_RevOneway where deinterleaving and decoding are performed according to the data rate; decoded data is encoded again with the same code; results are compared with the data before decoding and the BER is calculated. The data rate with the minimum BER is the transmit data rate. CDMA_TrffcFrmRcvry recovers the frame that is the same as the source.

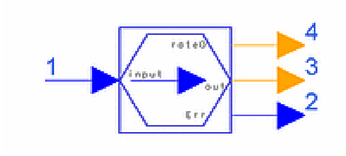


Reverse Channel Decoder

References

1. TIA/EIA/IS-95-A, Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System, May 1995.

CDMA_RevOneway



Description CDMA Reverse One Rate Decoder
Library CDMA, Channel Codecs
Class SDFCDMA_RevOneway

Parameters

Name	Description	Default	Type	Range
rate	transmit data rate:0=full, 1=1/2, 2=1/4, 3=1/8	0	int	{0, 1, 2, 3}
Times	number of times to repeat input data	0	int	{1, 2, 4, 8}

Pin Inputs

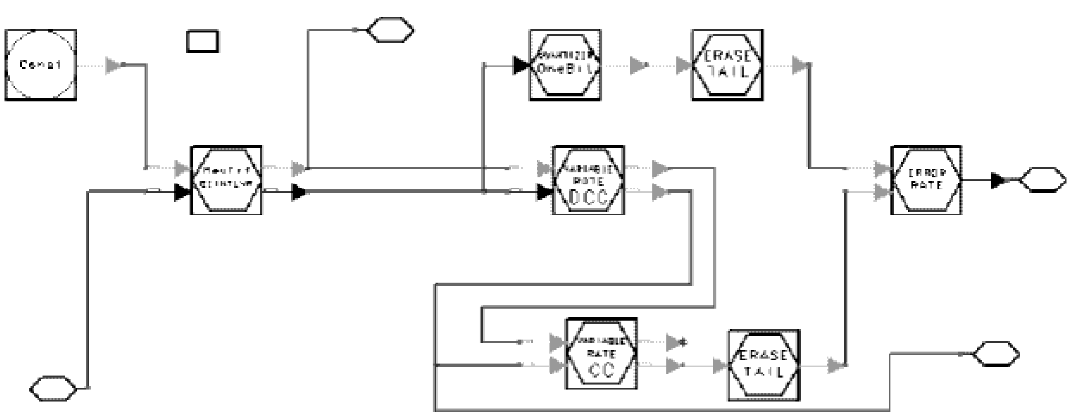
Pin	Name	Description	Signal Type
1	input	soft decision value	real

Pin Outputs

Pin	Name	Description	Signal Type
2	Err	bit error rate	real
3	output	recovered data	int
4	rate0	data rate of this decoder	int

Notes/Equations

1. This subnetwork is used to implement channel decoding of a data rate. It is a combination of deinterleaving, Viterbi decoder, encoder and BER calculator.
2. Implementation
   Refer to the following figure. The CDMA_RevOneway subnetwork includes CDMA_RevTrfDeintlvr, CDMA_OneBitQuantizer, CDMA_VariableRateDCC, CDMA_VariableRateCC, CDMA_Erasetail, and CDMA_ErrorRate.
   Input data is soft decision values with a rate for Viterbi decoding. Deinterleaving and decoding are performed according to the date rate. After decoding, data is encoded again with the same code; results are compared with the data before decoding, and the BER is calculated.

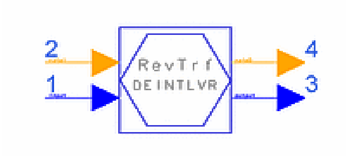


One Rate Reverse Channel Decoder

References

1. TIA/EIA/IS-95-A, Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System, May 1995.

CDMA_RevTrfDeintlvr



Description Reverse Traffic Channel Deinterleaver. This module deinterleaves the input symbol for
Library CDMA, Channel Codecs
Class SDFCDMA_RevTrfDeintlvr

Pin Inputs

Pin	Name	Description	Signal Type
1	input	The input code symbol.	real
2	rateI	The input code symbol rate.	int

Pin Outputs

Pin	Name	Description	Signal Type
3	output	The output code symbol.	real
4	rateO	The output code symbol rate.	int

Notes/Equations

1. This component is used to deinterleave the input coded symbol for CDMA Reverse Traffic Channel.
   576 output tokens are produced when 576 input tokens are consumed.
2. Implementation
   Since the rate-decision of Reverse Traffic Channel is done in Rake Receiver, the input block of Reverse Traffic Channel deinterleaver is a variable data rate frame. Since the valid data is changed according to the data rate, the deinterleaver is also changed according to the data rate. The number of columns is a constant 18 according to the Reverse Traffic Channel interleaver; the row number is the current frame length divided by the column number. The input and output block structures are the same and are given in the following table. The algorithm of this deinterleaver is to write into the deinterleaver by row and read by column.

Input and Output Block Structure

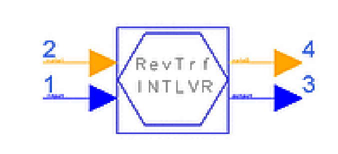
Data Rate	Block Length	Structure	
		Valid Data Integer/Block	**Padding Integer/Block**
full rate (9600 bps)	576	576	0
half rate (4800 bps)	576	288	288
1/4 rate (2400 bps)	576	144	432
1/8 rate (1200 bps)	576	72	504

References

1. TIA/EIA/IS-95-A, Mobile Station-Base Station Compatibility Standard for Dual-Mode

Wideband Spread Spectrum Cellular System, May 1995.

CDMA_RevTrfIntlvr



Description Reverse Traffic Channel Interleaver. This module interleaves the input code symbol for
Library CDMA, Channel Codecs
Class SDFCDMA_RevTrfIntlvr

Pin Inputs

Pin	Name	Description	Signal Type
1	input	the input code symbols to be interleaved	real
2	rateI	the data rate of frame	int

Pin Outputs

Pin	Name	Description	Signal Type
3	output	the interleaved code symbols.	real
4	rateO	the data rate of frame	int

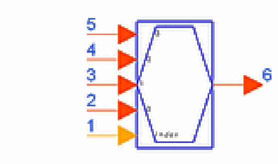
Notes/Equations

1. This component is used to interleave the input coded symbol for CDMA Reverse Traffic Channel. 576 output tokens are produced when 576 input tokens are consumed.
2. Implementation
   The Reverse Traffic Channel symbol is interleaved in a unit of power control group; the burst randomizer algorithm is used to discard the repeated power control group. A power control group includes the symbols in two rows of the interleaver. Since the algorithm is concerned with the repetition times, data rate information is transmitted in rateI.

References

1. TIA/EIA/IS-95-A, Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System, May 1995.

CDMA_Select1In4



Description Data Selector. This module selects data of one way out of the four way.
Library CDMA, Channel Codecs
Class SDFCDMA_Select1In4

Parameters

Name	Description	Default	Type	Range
BlockSize	size of input block	192	int	(0, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	index	the index used to control which data to be exported.	int
2	input0	the channel 0.	anytype
3	input1	the channel 1.	anytype
4	input2	the channel 2.	anytype
5	input3	the channel 3.	anytype

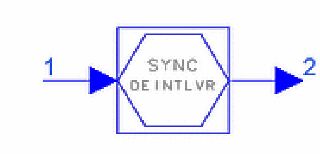
Pin Outputs

Pin	Name	Description	Signal Type
6	output	the output data.	anytype

Notes/Equations

1. This component is used to select data from one of four channels.
   BlockSize output tokens are produced for one index token and each set of BlockSize input tokens consumed.

CDMA_SyncDeintlvr



Description Sync Channel Deinterleaver. This module deinterleaves the input code symbol for CDMA Sync Channel.
Library CDMA, Channel Codecs
Class SDFCDMA_SyncDeintlvr
Derived From CDMA_Interleaver

Pin Inputs

Pin	Name	Description	Signal Type
1	input	The input data to be de-interleaved.	real

Pin Outputs

Pin	Name	Description	Signal Type
2	output	The output interleaved symbol.	real

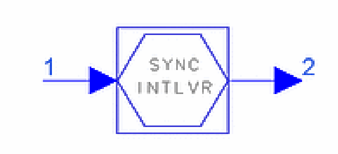
Notes/Equations

1. This component is used to deinterleave the input coded symbol for CDMA Sync Channel.
   128 output tokens are produced when 128 input tokens are consumed.
2. Implementation
   Deinterleaving is the reverse function of interleaving (described in CDMA_SyncIntlvr). The bit reversal function rearranges the input array, of which length N is a power of 2. The index (decimal) is converted into a binary number. For a 32-length array, the index i of the number of this array can be denoted as a binary number $i_4 i_3 i_2 i_1 i_0$, with a range of 0 to 31, and n is a 5-bit binary number, $n = a_4 a_3 a_2 a_1 a_0$, where $a_4 = i_0$, $a_3 = i_1$, $a_2 = i_2$, $a_1 = i_3$, $a_0 = i_4$.
   The number n is the bit reversal index of index i . This function rearranges the input array by exchanging the number of index i
   for the number of bit reversal index n .

References

1. TIA/EIA/IS-95-A, Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System, May 1995.

CDMA_SyncIntlvr



Description Sync Channel Interleaver. This module interleaves the input coded symbol for CDMA Sync Channel.
Library CDMA, Channel Codecs
Class SDFCDMA_SyncIntlvr
Derived From CDMA_Interleaver

Pin Inputs

Pin	Name	Description	Signal Type
1	input	The input code symbol to interleaved.	real

Pin Outputs

Pin	Name	Description	Signal Type
2	output	The output interleaved symbol.	real

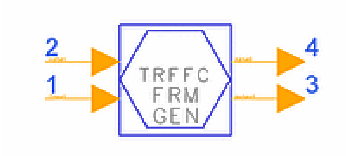
Notes/Equations

1. This component is used to interleave the input coded symbol for CDMA Sync Channel. 128 output tokens are produced when 128 input tokens are consumed.
2. Implementation
Sync Channel symbols are interleaved by a bit-reversal technique.
Bit-reversal rearranges the input array, of which length N is a power of 2. The index (decimal) is converted into a binary number. For example, for a 32-length array, the index i of the number of this array can be denoted as binary number $i_4 i_3 i_2 i_1 i_0$, with a range of 0 to 31, and n is a 5-bit binary number $n = a_4 a_3 a_2 a_1 a_0$, where $a_4 = i_0$, $a_3 = i_1$, $a_2 = i_2$, $a_1 = i_3$, $a_0 = i_4$.
Then the number n is the bit reversal index of index i. This function rearranges the input array by exchanging the number of index i for the number of bit reversal index n.

References

1. TIA/EIA/IS-95-A, Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System, May 1995.

CDMA_TrffcFrmGen



Description CDMA Traffic Channel Frame Generator. This module generates the frame of Traffic Channel.
Library CDMA, Channel Codecs
Class SDFCDMA_TrffcFrmGen

Parameters

Name	Description	Default	Type	Range
PreambleNumber	preamble frame number in CDMA Reverse Traffic Channel	0	int	[0, ∞)
Type	type of channel:CDMA Forward Traffic Channel, CDMA Reverse Traffic Channel: CDMA Forward Traffic Channel, CDMA Reverse Traffic Channel	CDMA Forward Traffic Channel	enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	input	The input stream	int
2	rateI	The data rate of CDMA Traffic Channel frame.	int

Pin Outputs

Pin	Name	Description	Signal Type
3	output	The output stream.	int
4	rateO	The data rate of CDMA Traffic Channel frame.	int

Notes/Equations

1. This component is used to generate the traffic channel frame.
   In CDMA systems, 192 *output* and 1 *rateO* tokens are produced when 171 *input* and 1 *rateI* tokens are consumed.
2. Implementation

Data Rate Index	Packet Type	Bits per Packet
0	Rate 1	171
1	Rate 1/2	80
2	Rate 1/4	40
3	Rate 1/8	16
4	Reserved	Reserved
5	Rate 1 with errors	171
6	Insufficient frame quality(erasure)	0

IS-95A Traffic Channel Frame Structure

Data Rate	**Frame Length**	**Frame Structure**			
		Reserved (Bit/Frame)	**Information (Bit/Frame)**	**CRC (Bit/Frame)**	**Tail(Bit/Frame)**
full rate (9600 bps)	192	1 (value=0)	171	12	8
half rate (4800 bps)	96	0	88	8	8
1/4 rate (2400 bps)	48	0	40	0	8
1/8 rate (1200 bps)	24	0	16	0	8

Input Block Structure

Data Rate	**Input Block Structure**		
	Block Length	**Valid Data Integer/Block**	**PaddingInteger/Block**
full rate (9600 bps)	171	171	0
half rate (4800 bps)	171	80	91
1/4 rate (2400 bps)	171	40	131
1/8 rate (1200 bps)	171	16	155

Output Block Structure

Data Rate	**Output Block Structure**		
	Block Length	**Valid Data Integer/Block**	**PaddingInteger/Block**
full rate (9600 bps)	192	192	0
half rate (4800 bps)	192	96	96
1/4 rate (2400 bps)	192	48	144
1/8 rate (1200 bps)	192	24	168

Algorithm of CDMA CRC

There are two parameters in this function: *feedbackMask* and *modulo* .
For example, if the generator polynomial of a CRC is

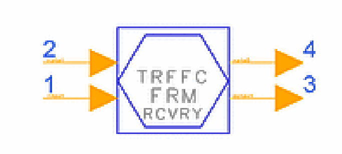
$$G(x) = x^{12} + x^{11} + x^{10} + x^{9} + x^{8} + x^{4} + x + 1$$

we let *feedbackMask* = 111, 100, 010, 011 (binary), noting that we discard the coefficient of the first item.
modulo is maximum number the encoder register can store plus one.

References

1. TIA/EIA/IS-95-A, Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System, May 1995.
2. S. Lin and D. J. Costello, Jr., *Error Control Coding Fundamentals and Applications* , Prentice Hall, Englewood Cliffs NJ, 1983.

CDMA_TrffcFrmRcvry



Description CDMA Traffic Channel Frame Recovery. This module recovers the voice data from CDMA Traffic Channel Frame.
Library CDMA, Channel Codecs
Class SDFCDMA_TrffcFrmRcvry

Pin Inputs

Pin	Name	Description	Signal Type
1	input	the data of input frame.	int
2	rateI	The frame length of CDMA Traffic Channel frame.	int

Pin Outputs

Pin	Name	Description	Signal Type
3	output	The voice data.	int
4	rateO	The data rate of CDMA Traffic Channel frame.	int

Notes/Equations

1. This component is used to recover voice data from the CDMA traffic channel frame. In CDMA systems, 171 *output* and 1 *rateO* tokens are produced when 192 *input* and 1 *rateI* tokens are consumed.
2. Implementation
   IS-95A recommends the CELP voice source, which varies the voice source data rate frame by frame. IS-95A does not recommend how to transfer the data rate from the source to the end. For ease of implementation in the SDF domain, we select the full rate frame length as the block length to process; the padding bits are appended after the valid data for the lower data rate frame in order to keep the block length constant. The CELP frame data rate is given in the following table.

   #### CELP Codec Packet Type

Data Rate Index	Packet Type	Bits per Packet
0	Rate 1	171
1	Rate 1/2	80
2	Rate 1/4	40
3	Rate 1/8	16
4	Reserved	Reserved
5	Rate 1 with errors	171
6	Insufficient frame quality(erasure)	0

   Input and output block structures are given in the following tables.

   #### Input Block Structure

Data Rate	Input Block Structure		
	Block Length	**Valid Data Integer/Block**	**PaddingInteger/Block**
full rate (9600 bps)	192	192	0
half rate (4800 bps)	192	96	96
1/4 rate (2400 bps)	192	48	144
1/8 rate (1200 bps)	192	24	168

Output block structure

Data Rate	Output Block Structure			
	full rate (9600 bps)	171	171	0
half rate (4800 bps)	171	80	91	
1/4 rate (2400 bps)	171	40	131	
1/8 rate (1200 bps)	171	16	155	

In accordance with IS-95A, the frame quality indicator bit is used to determine the quality of a full- or half-rate frame; the erroneous frame count is used to estimate the FER for reverse power control. The erroneous frames are determined according to the data rate index in *CELP Codec Packet Type*.

CDMA CRC Algorithm

There are two parameters in this function: *feedbackMask* and *modulo.*

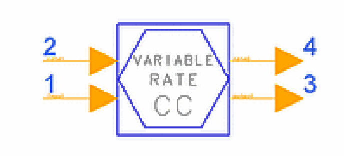
For *feedbackMask*, for example, if the generator polynomial of a CRC is $G(x) = x^{12}+x^{11}+x^{10}+x^{9}+x^{8}+x^{4}+x+1$, we let *feedbackMask* equal 111, 100, 010, 011 (binary) (note that we discard the coefficient of the first item).

modulo is the maximum number the encoder register can store plus one.

References

1. TIA/EIA/IS-95-A, Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System, May 1995.
2. S. Lin and D. J. Costello, Jr., *Error Control Coding Fundamentals and Applications*, Prentice Hall, Englewood Cliffs NJ, 1983.

CDMA_VariableRateCC



Description Variable Data Rate Convolutional Encoder. This model convolutionally encodes the input frame. esp. for variable rate system like IS-95A.
Library CDMA, Channel Codecs
Class SDFCDMA_VariableRateCC
Derived From CDMA_CnvlCoder

Parameters

Name	Description	Default	Type	Range
CCType	convolutional code type: rate 1/2 K 9 g0 0753 g1 0561, rate 1/3 K 9 g0 0557 g1 0663 g2 0711, rate 1/2 K 7 g0 0554 g1 0744, rate 1/3 K 7 g0 0554 g1 0624 g2 0764, rate 1/2 K 5 g0 046 g1 072, rate 1/3 K 5 g0 066 g1 052 g2 076, rate 1/2 K 5 g0 046 g1 066, rate 1/6 K 5 g0 066 g1 052 g2 076 g3 066 g4 052 g5 076, rate 1/2 K 3 g0 05 g1 07	rate 1/2 K 9 g0 0753 g1 0561	enum	†
MaxInFrameLen	maximum input frame length	192	int	[K+1, ∞)

† If K< 9 and > 6, only higher K generator bits is useful, the lower (9-K) bits is all zeros.The generator is written in octal format 0xxx. For rate 1/2 K 7 g0 0554 g1 0744, K=7.Generator g1 is $D_6 + D_5 + D_4 + D_3 + 1$ is written as 111100100 (that is, 0744).If K < 6 and > 3, the generator is written as 0xx; it contain 6 bits, the lower(6-K) is 0 and is not useful.

Pin Inputs

Pin	Name	Description	Signal Type
1	input	The input stream.	int
2	rateI	The data rate of input frame.	int

Pin Outputs

Pin	Name	Description	Signal Type
3	output	The output encoded symbol stream.	int
4	rateO	The data rate	int

Notes/Equations

1. This component is used to convolutionally encode the input tailed frame, especially for variable rate systems like IS-95A.
   MaxInFrameLen/rate (specified by CCType) output tokens are produced when MaxInFrameLen input tokens are consumed.
   For CDMA Forward Traffic Channel, CC(2,1,9) is used in which the rate of convolutional code is 1/2 and the length of full rate frame is 192. In this case, CCType is set to *rate 1/2 K 9 g0 0753 g1 0561* and MaxInFrameLen is 192. 384 output tokens are produced when 193 input tokens are consumed.
   For CDMA Reverse Traffic Channel, CC(3,1,9) is used. 576 output tokens are produced when 192 input tokens are consumed.

2. Implementation
   The input and output block structures are given in the following tables.

Input Block Structure

Data Rate	Input Block Structure		
	Block Length	**Valid Data Integer/Block**	**PaddingInteger/Block**
full rate (9600 bps)	192	192	0
half rate (4800 bps)	192	96	96
1/4 rate (2400 bps)	192	48	144
1/8 rate (1200 bps)	192	24	168

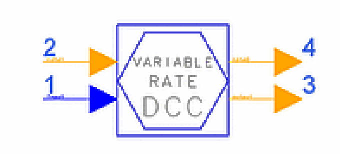
Output block structure

Data Rate	Output Block Structure			
	full rate (9600 bps)	384	384	0
half rate (4800 bps)	384	192	192	
1/4 rate (2400 bps)	384	96	288	
1/8 rate (1200 bps)	384	48	336	

References

1. S. Lin and D. J. Costello, Jr., *Error Control Coding Fundamentals and Applications* , Prentice Hall, Englewood Cliffs NJ, 1983.

CDMA_VariableRateDCC



Description Variable Data Rate Viterbi Decoder for Convolutional Code. This Model decodes Convolutional Code using Viterbi algorithm. esp. In variable rate system like IS-95A.
Library CDMA, Channel Codecs
Class SDFCDMA_VariableRateDCC
Derived From CDMA_ViterbiDecoder

Parameters

Name	Description	Default	Type	Range
CCType	convolutional code type: rate 1/2 K 9 g0 0753 g1 0561, rate 1/3 K 9 g0 0557 g1 0663 g2 0711, rate 1/2 K 7 g0 0554 g1 0744, rate 1/3 K 7 g0 0554 g1 0624 g2 0764, rate 1/2 K 5 g0 046 g1 072, rate 1/3 K 5 g0 066 g1 052 g2 076, rate 1/2 K 5 g0 046 g1 066, rate 1/6 K 5 g0 066 g1 052 g2 076 g3 066 g4 052 g5 076, rate 1/2 K 3 g0 05 g1 07	rate 1/2 K 9 g0 0753 g1 0561	enum	†
MaxInFrameLen	maximum input frame length	384	int	[K+1, ∞)
Note: If K< 9 and > 6, only higher K generator bits is useful, the lower (9-K) bits is all zeros. The generator is written in octal format 0xxx. For *rate 1/2 K 7 g0 0554 g1 0744*, K=7. Generator g1 is $D_6 + D_5 + D_4 + D_3 + 1$, written as 111100100 (that is, 0744).If K < 6 and > 3, the generator is written as 0xx; it contain 6 bits, the lower(6-K) is 0 and is not useful.				

Pin Inputs

Pin	Name	Description	Signal Type
1	input	The symbol frame to be decoded.	real
2	rateI	The input code symbol rate.	int

Pin Outputs

Pin	Name	Description	Signal Type
3	output	The decoded bits.	int
4	rateO	The output code symbol rate.	int

Notes/Equations

1. This component is used to decode the convolutional code using Viterbi algorithm, especially for variable rate systems such as IS-95A.
   MaxInFrameLen × rate (specified by CCType) output tokens are produced when MaxInFrameLen input tokens are consumed.
   For CDMA Forward Traffic Channel, CC(2,1,9) is used in which the rate of convolutional code is 1/2 and the length of full rate frame is 384. In this case, CCType is set to *rate 1/2 K 9 g0 0753 g1 0561* and MaxInFrameLen is 384. 192

output tokens are produced when 384 input tokens are consumed.
For CDMA Reverse Traffic Channel, CC(3,1,9) is used. 192 output tokens are produced when 576 input tokens are consumed.

2. Implementation
The input and output block structures are given in the following tables.

Input Block Structure

Data Rate	**Input Block Structure**		
	Block Length	**Valid Data Integer/Block**	**PaddingInteger/Block**
full rate (9600 bps)	384	384	0
half rate (4800 bps)	384	192	192
1/4 rate (2400 bps)	384	96	288
1/8 rate (1200 bps)	384	48	336

Output block structure

Data Rate	**Output Block Structure**			
	full rate (9600 bps)	192	192	0
half rate (4800 bps)	192	96	96	
1/4 rate (2400 bps)	192	48	144	
1/8 rate (1200 bps)	192	24	168	

Viterbi Decoding Algorithm
To make a general component, the following algorithm is used with CC(2,1,9) as an example. The generator functions of the code are g0, which equals 753 (octal), and g1, which equals 561 (octal).
Because the constraint length is 9, there are 256 possible states in the encoder. In the Viterbi decoder all states are represented by a single column of nodes in the trellis at every symbol instant. At each node in the trellis, there are 2 merging paths; the path with the shortest distance is selected as the survivor.
In CDMA systems, the encoded packets are very long; it is 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 the 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 CDMA systems, L=45.
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
The branch metric $m_j^{(\alpha)}$, 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 $r_{j1}r_{j2}...r_{jn}$ conditioned on the estimated transmitted n-bit symbol $c_{j1}^{(\alpha)} c_{j2}^{(\alpha)} \dots c_{jn}^{(\alpha)}$ 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 Rake receiver is regarded as a 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 instant 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 from the paths $\alpha_1, \alpha_2, \ldots, \alpha_{2^k}$, the one having the largest metric, namely,

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

and this path is known as the survivor.

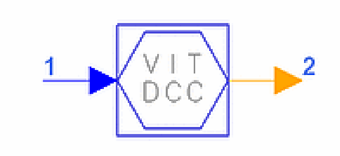
Decoder Output

When the two survivors have been 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.2).

References

1. S. Lin and D. J. Costello, Jr., *Error Control Coding Fundamentals and Applications*, Prentice Hall, Englewood Cliffs NJ, 1983.
2. R. Steele (Editor), *Mobile Radio Communication*, IEEE Press, June 1995.

CDMA_ViterbiBitDCC



Description Bit-By-Bit Viterbi Decoder for Covolutional Code.
Library CDMA, Channel Codecs
Class SDFCDMA_ViterbiBitDCC
Derived From CDMA_ViterbiDecoder

Parameters

Name	Description	Default	Type	Range
CCType	convolutional code type: rate 1/2 K 9 g0 0753 g1 0561, rate 1/3 K 9 g0 0557 g1 0663 g2 0711, rate 1/2 K 7 g0 0554 g1 0744, rate 1/3 K 7 g0 0554 g1 0624 g2 0764, rate 1/2 K 5 g0 046 g1 072, rate 1/3 K 5 g0 066 g1 052 g2 076, rate 1/2 K 5 g0 046 g1 066, rate 1/6 K 5 g0 066 g1 052 g2 076 g3 066 g4 052 g5 076, rate 1/2 K 3 g0 05 g1 07	rate 1/2 K 9 g0 0753 g1 0561	enum	†

† If K < 9 and > 6, only higher K generator bits is useful, the lower (9-K) bits is all 0s.The generator is written in octal format 0xxx. For rate 1/2 K 7 g0 0554 g1 0744, K=7. Generator g1 is $D_6 + D_5 + D_4 + D_3 + 1$, written as 111100100 (that is, 0744). If K <6 and >3, the generator is written as 0xx; it contain 6 bits; the lower (6-K) is 0 and is not useful.

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 component is used to Viterbi-decode the input code words. There is a delay, the length of which is equal to the memory length of convolutional code (due to the convolutional code constraint length. Padding bits are needed to detect when the codewords end.
   One output token is produced when 1/rate (specified in CCType) input tokens are consumed.
   For example, in CDMA Sync channel, CC(2,1,9) is used in which the convolutional code rate is 1/2. CCType is set to *rate 1/2 K 9 g0 0753 g1 0561* and one output token is produced when two input tokens are consumed.
2. Implementation
   Viterbi Decoding Algorithm
   To make a general component, the following algorithm is used, with CC(2,1,9) as an example. The generator functions of the code are g0, which equals 753 (octal), and g1, which equals 561 (octal).

Because the constraint length is 9, there are 256 possible states in the encoder. In the Viterbi decoder all states are represented by a single column of nodes in the trellis at every symbol instant. At each node in the trellis, there are 2 merging paths; the path with the shortest distance is selected as the survivor.
In CDMA systems, the encoded packets are very long; it is 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 the 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 CDMA systems, L=45.
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 $m_j^{(\alpha)}$, 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 $r_{j1}r_{j2}\dots r_{jn}$ conditioned on the estimated transmitted n-bit symbol
$c_{j1}^{(\alpha)} c_{j2}^{(\alpha)} \dots c_{jn}^{(\alpha)}$ 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 Rake receiver is regarded as a 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 instant 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 from the paths $\alpha_1, \alpha_2, \dots, \alpha_{2^k}$, the one having the largest metric, namely,

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

and this path is known as the survivor.
Decoder Output
When the two survivors have been 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.

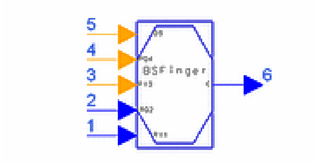
References

1. S. Lin and D. J. Costello, Jr., *Error Control Coding Fundamentals and Applications*, Prentice Hall, Englewood Cliffs NJ, 1983.
2. R. Steele (Editor), *Mobile Radio Communication*, IEEE Press, June 1995.

Receivers for CDMA Design Library

- *CDMA BSFinger* (cdma)
- *CDMA BSRake* (cdma)
- *CDMA BSRateconverter* (cdma)
- *CDMA BSSearcher* (cdma)
- *CDMA CoherentRake* (cdma)
- *CDMA FreqErrEstimate* (cdma)
- *CDMA FreqShifter* (cdma)
- *CDMA FwdChnlSounder* (cdma)
- *CDMA FwdRake* (cdma)
- *CDMA FwdRcvwithAFC* (cdma)
- *CDMA FwdRcvwithoutAFC* (cdma)
- *CDMA PathCombiner* (cdma)
- *CDMA PnCodeAcq* (cdma)
- *CDMA PnCodeTrack* (cdma)
- *CDMA RevAGC* (cdma)

CDMA_BSFinger



Description Base Station Rake Finger
Library CDMA, Receivers
Class SDFCDMA_BSFinger

Parameters

Name	Description	Default	Type	Range
MaxPathNum	maximum number of paths in Rake combination	3	int	[1, 10]
MaxChannelPathNum	range for searching stronger paths	30	int	[12, 50]
FingerIndex	finger number	0	int	[0, 9]

Pin Inputs

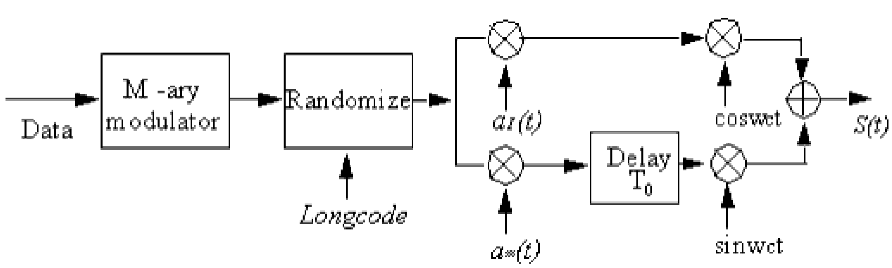
Pin	Name	Description	Signal Type
1	RI_in1	This port inputs the user in-phase sequence.	real
2	RQ_in2	This port inputs the user quadrature-phase sequence.	real
3	PI_in3	This port inputs the in-phase synchronized spreading code including PN short code and user long code.	int
4	PQ_in4	This port inputs the quadrature-phase synchronized spreading code including PN short code and user long code.	int
5	D_in5	This port inputs the path idex of this finger	int

Pin Outputs

Pin	Name	Description	Signal Type
6	C_out1	This port outputs the detection signal correlation value.	real

Notes/Equations

1. This component is used to implement the path tracking and demodulator function in the reverse channel, which demodulates the lth path signals using noncoherent demodulation. 6×64 outputs of C_out1 are produced when 6144 inputs of RI_in1, 6144 inputs of RQ_in2, 1536 inputs of PI_in3 and PQ_in4, and 6×MaxPathNum outputs of D_in5 are consumed.
2. Implementation
Transmitted Signal
In the CDMA reverse channel, the transmitter structure is illustrated in the following figure.



IS-95 Transmitter Model Using M-ary Modulation

The transmitted signal of the target transmission link for the ith user can be represented as

$$s_i(t) = \sqrt{P}W^j(t)a_I^i(t)\cos w_c t + j\sqrt{P}W^j(t-T_0)a_Q^i(t-T_0)\sin w_c t$$
$$i = 1, 2, \ldots, K \qquad 0 \le t \le T_w$$

where P is the signal power, $W^j(t)$ is the jth orthogonal Walsh function, T_0 is the time offset of OQPSK and $T_0 = T_c/2$, T_w is the symbol duration, K is the user number, and w_c is the carrier frequency. $a_I(t)$ and $a_Q(t)$ are the pseudo noise sequence of the I and Q branches and can be described as:

$$a_I^i(t) = \sum_{n=-\infty}^{\infty} a_n^{I,i} p(t - nT_c)$$

$$a_Q^i(t) = \sum_{n=-\infty} a_n^{Q,i} p(t - nT_c).$$

where $a_n^{I,i}$ and $a_n^{Q,i}$ are assumed to be i.i.d. random variables taking values +1 and −1 with probability 1/2. T_c is the chip duration, and *p(t)* is the chip pulse shape. Here we specifically use rectangular chip pulse shapes.

Channel

The transmitted signal reaches the receiver via a channel that may have one or more propagation paths, so the received signal consists of several reflected and scattered multipath components. A frequency nonselective multipath fading channel introduces a time-variant amplitude fluctuation, carrier phase jitter, and propagation delay to the transmitted signal waveform. The complex impulse response of a Rayleigh fading channel at baseband can be represented as

$$h_i(t) = \sum_{l=1}^{L} \alpha_l^i(t) e^{j\phi_l^i(t)} \delta(t - \tau_l),$$

where $\alpha_l(t)$, $\phi_l(t)$, and τ_l are the lth path amplitude, phase, and delay, respectively. L is the total number of multipath components. We assume that the multipath parameters value is small compared to symbol duration, so $\alpha_l(t)$ and $\phi_l(t)$ can be considered to be constant over the symbol duration.

Received Signal

The received signal can be represented as

$$y_i(t) = \sum_{l=1}^{L} \sqrt{P}\alpha_l^i \left[W^j(t-\tau_l^i)a_I^i(t-\tau_l^i)\cos(w_c t) + jW^j(t-T_0-\tau_l^i)a_Q^i(t-T_0-\tau_l^i)\ \sin(w_c t)\right]e^{j\theta_l^i}$$

where

y(t) is the convolution with the transmitted signal and the channel complex impulse response

$\theta_l^i = \phi_l^i + w_c(\tau_l + \Gamma_l)$

$\tau_l^i = \tau_l + \Gamma_i$

Γ_l is the *i* th user's random delay of a non-synchronized system.

In the receiver, the received signal is the sum of *K* users signals, which can be expressed as

$$r(t) = \sum_{i=1}^{K} y_i(t) + n(t),$$

$$n(t) = Re\left\{\tilde{n}(t)e^{jw_c t}\right\}$$

where

$\tilde{n}(t) = n_c(t) + jn_s(t)$ is additive white Gaussian noise

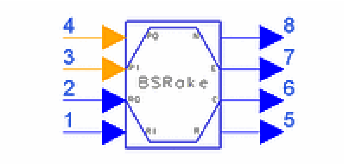
n_c (t) and n_s (t) are lowpass Gaussian random processes.

The received signal is converted into the baseband signal. For user information demodulation, signals of I, Q phases are despread and then combined using the square-law combination algorithm. Refer to [1].
The output of this component is input to the CDMA_PathCombiner component for equal gain combining.

References

1. L. M.A. Jalloul and J. M. Holtzman, "Performance analysis of DS/CDMA with noncoherent M-ary orthogonal modulation in multipath fading channels," *IEEE JSAC* , Vol. 12, No. 5, June 1994.

CDMA_BSRake



Description Base Station Rake Receiver
Library CDMA, Receivers
Class SDFCDMA_BSRake

Parameters

Name	Description	Default	Type	Range
FingerNum	number of fingers in Rake combination	3	int	[1, 3]
MaxSearchChNum	range for searching stronger paths	40	int	[12, 50]

Pin Inputs

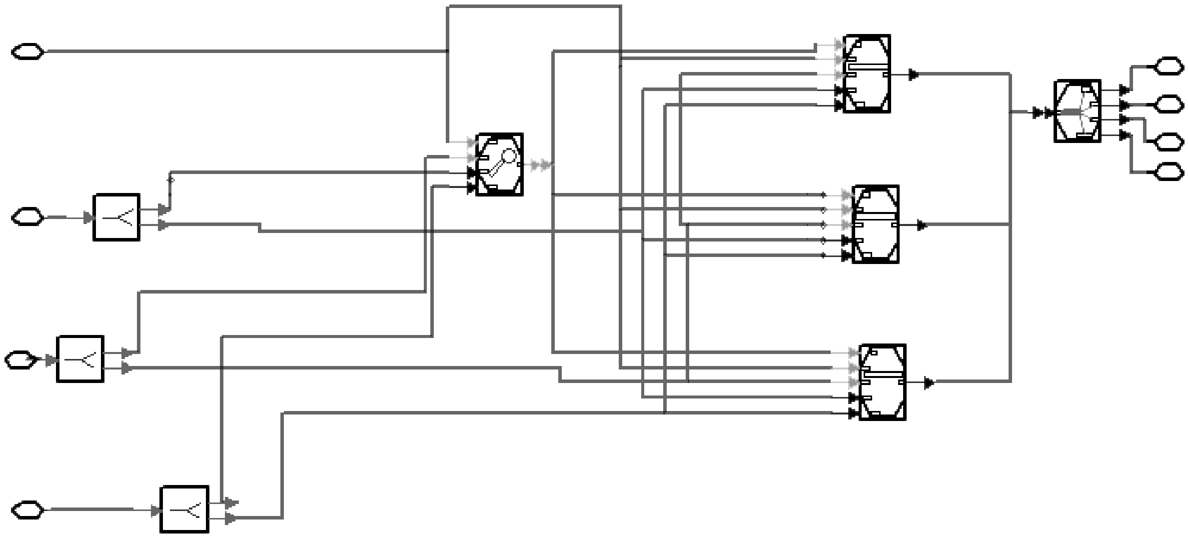
Pin	Name	Description	Signal Type
1	RI_in1	in-phase signal of base station receiver finger	real
2	RQ_in2	quadrature-phase signal of base station receiver finger	real
3	RI_in2	in-phase synchronized spreading code including PN short code and user long code	int
4	PQ_in4	quadrature-phase synchronized spreading code including PN short code and user long code	int

Pin Outputs

Pin	Name	Description	Signal Type
5	R_out1	soft decision variables for Viterbi decoder	real
6	C_out2	detected signal correlation value outputs	real
7	E_out3	bit energy estimation of base station Rake receiver	real
8	N_out4	interference plus noise estimation of base station Rake receiver	real

Notes/Equations

1. This subnetwork is used to implement Rake receiving. It is a combination of channel estimation, noncoherent demodulation, and square-law combination.
2. Implementation
   Refer to the following figure. This subnetwork includes CDMA_BSSearcher, CDMA_BSFinger, CDMA_PathCombiner.
   Input data is PN code and I and Q phase signal data. CDMA_BSSearcher implements the multipath search function on the reverse channel to find *L* maximum-strength path signals. The duration between two adjacent paths is one chip. Delay values of selected paths are output to each noncoherent receiver finger. CDMA_BSFinger implements path tracking and demodulation, which demodulates the lth path signals using noncoherent demodulation. CDMA_PathCombiner implements the path combining function, which combines *L* path signals using equal gain combining. The soft decision variables for Viterbi decoder are then calculated.

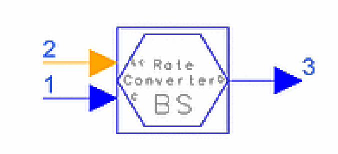


CDMA_BSRake

References

1. L. M.A. Jalloul and J. M. Holtzman, "Performance analysis of DS/CDMA with noncoherent M-ary orthogonal modulation in multipath fading channels," *IEEE JSAC* , Vol. 12, No. 5, June 1994.

CDMA_BSRateconverter



Description Rake Receiver Output Converter for Sending to Viterbi Decoder.
Library CDMA, Receivers
Class SDFCDMA_BSRateconverter

Parameters

Name	Description	Default	Type	Range
DataRate	data rate	1	int	{0, 1,2,3}

Pin Inputs

Pin	Name	Description	Signal Type
1	C_in1	The soft decision value inputs	real
2	Lc_in2	The long code inputs	int

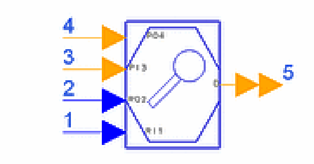
Pin Outputs

Pin	Name	Description	Signal Type
3	D_out1	The detected sequence outputs.	real

Notes/Equations

1. This component is used to convert the frame format of the input sequence according to the data burst randomizing algorithm provided in IS-95. The data burst randomizer generates a masking pattern of zeros and ones that randomly masks the redundant data generated by code repetition. The masking pattern is determined by frame data rate and by a block of 14 bits from the long code. These bits will be the last 14 bits of long code used for spreading in the previous to the last power control group of the previous frame. 576 outputs of D_out1 are generated when 96 inputs of C_in1 and 24576 inputs of Lc_in2 are consumed.

CDMA_BSSearcher



Description Base Station Rake Searcher
Library CDMA, Receivers
Class SDFCDMA_BSSearcher

Parameters

Name	Description	Default	Type	Range
MaxPathNum	maximum number of paths in Rake combination	3	int	[1, 10]
MaxChannelPathNum	range for searching strongest paths	30	int	[9, 50]

Pin Inputs

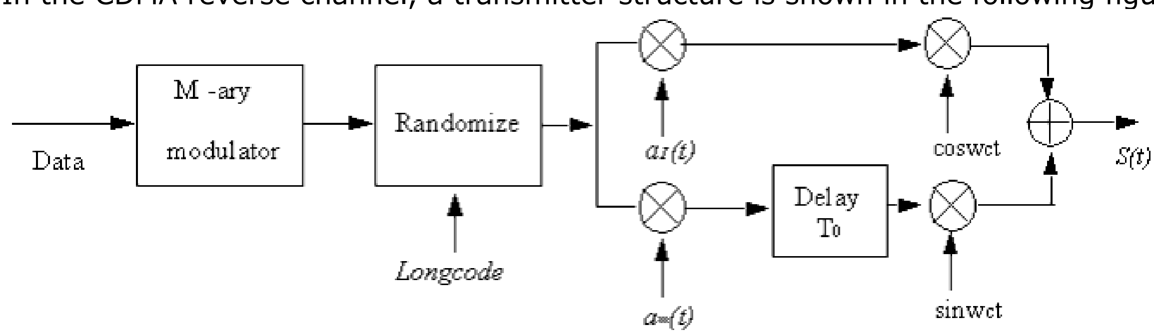
Pin	Name	Description	Signal Type
1	RI_in1	This port inputs the user in-phase sequence.	real
2	RQ_in2	This port inputs the user quadrature-phase sequence.	real
3	PI_in3	This port inputs the in-phase synchronized spreading code including PN short code and user long code.	int
4	PQ_in4	This port inputs the quadrature-phase synchronized spreading code including PN short code and user long code.	int

Pin Outputs

Pin	Name	Description	Signal Type
5	D_out1	This port outputs the delay values of each selected path	multiple int

Notes/Equations

1. This component performs the multipath searching function on the reverse channel to find *L* maximum-strength path signals. The duration between two adjacent paths is one-fourth chip. Delay values of selected paths are output to each noncoherent receiver finger. 6×MaxPathNum outputs of D_out1 are produced when 6144 RI_in1, 6144 RQ_in2, 1536 PI_in3, and 1536 PQ_in4 inputs are consumed.
2. Implementation
   Transmitted Signal
   In the CDMA reverse channel, a transmitter structure is shown in the following figure.



The transmitted signal of the target transmission link for the ith user can be represented as

$$s_i(t) = \sqrt{P}W^j(t)a_I^i(t)\cos w_c t + j\sqrt{P}W^j(t-T_0)a_Q^i(t-T_0)\sin w_c t.$$
$$i = 1, 2, \dots, K \qquad 0 \le t \le T_w$$

where P is signal power, $W^j(t)$ is jth orthogonal Walsh function, T_0 is OQPSK time offset, and $T_0 = T_c/2$, T_W is symbol duration, K is user number, and w_c is the carrier frequency. $a_I(t)$ and $a_Q(t)$ are the I and Q branch pseudo noise sequences and can be described as

$$a_I^i(t) = \sum_{n=-\infty}^{\infty} a_n^{I,i} p(t - nT_c)$$
$$a_Q^i(t) = \sum_{n=-\infty}^{\infty} a_n^{Q,i} p(t - nT_c).$$

where $a_n^{I,i}$ and $a_n^{Q,i}$ are assumed to be i.i.d. random variables taking values +1 and −1 with probability 1/2. T_c is the chip duration, and *p(t)* is the chip pulse shape. Here we specifically use rectangular chip pulse shapes.

Channel

The transmitted signal reaches the receiver via a channel that may include one or more propagation paths, so the received signal consists of several reflected and scattered multipath components. A frequency nonselective multipath fading channel introduces a time-variant amplitude fluctuation, carrier phase jitter, and propagation delay to the transmitted signal waveform. The complex impulse response of a Rayleigh fading channel at baseband can be represented as

$$h_i(t) = \sum_{l=1}^{L} \alpha_l^i(t) e^{j\phi_l^i(t)} \delta(t - \tau_l),$$

where $\alpha_l(t)$, $\phi_l(t)$, and τ_l are lth path amplitude, phase, and delay, respectively. L is the total number of multipath components. We assume that the multipath parameters value is small compared to symbol duration, so that $\alpha_l(t)$ and $\phi_l(t)$ can be considered to be constant over the symbol duration.

Received Signal

The received signal can be represented as

$$y_i(t) = \sum_{l=1}^{L} \sqrt{P}\alpha_l^i [W^j(t-\tau_l^i)a_I^i(t-\tau_l^i)\cos(w_c t) + jW^j(t-T_0-\tau_l^i)a_Q^i(t-T_0-\tau_l^i) \sin(w_c t)]e^{j\theta_l^i}$$

where

y(t) is the convolution with the transmitted signal and the channel complex impulse response

$\tau_l^i = \tau_l + \Gamma_i$

$\theta_l^i = \phi_l^i + w_c(\tau_l + \Gamma_l)$

Γ_l is the *i* th user's random delay of a non-synchronized system.

In the receiver, the received signal is the sum of K users signals, which can be expressed as:

$$n(t) = Re\left\{\tilde{n}(t)e^{jw_c t}\right\}$$

where

$\tilde{n}(t) = n_c(t) + jn_s(t)$ is additive white Gaussian noise

n_c (t) and n_s (t) are lowpass Gaussian random processes.

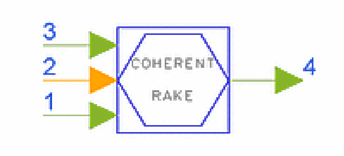
The received signal is converted into the baseband signal, then the I- and Q-phase signals are despread. Non-coherent demodulation with square-law combination is used to find the channel with the strongest paths.
Path Searching in the Rake Receiver
In the reverse link, according to the IS-98 Standard, maximum channel delay is 14.5 μ (which is approximately 18 T_c), and the delay caused by filters in transceivers is 12 T_c. So, in this component the path search range should be >30 T_c. Path resolution is one chip time (T_c = 0.813 μ) and search accuracy is 1/4 chip. Suitable paths with the strongest signals from all paths in the CDMA channel are selected and signals on the weaker paths are ignored.
In IS-95 systems, path selection in the reverse link differs from the forward link. In forward link, each path strength can be estimated through the pilot channel and coherent receiver can be used. In reverse link, no pilot channel exists, so the non-coherent receiving technique is used.
In the reverse Rake receiver, the signal is despread by PN code, then correlated with 64 Walsh codes. The maximum correlation value among all 64 correlations is considered to be the path strength.
After all path strengths are estimated, the first L(L<10, default value 3) paths with maximum strength are selected. Path indexes of *L* maximum paths are output to CDMA_BSFinger.

References

1. TIA/EIA/IS-95-A, Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System, May 1995.
2. L. M.A. Jalloul and J. M. Holtzman, "Performance analysis of DS/CDMA with noncoherent M-ary orthogonal modulation in multipath fading channels," *IEEE JSAC* , Vol. 12, No. 5, June 1994.
3. W. Zhuang, "Noncoherent Hybrid Parallel PN Code Acquisition for CDMA Mobile Communications," *IEEE Transaction on Vehicular Technology* , Vol 45, No. 4, Nov, 1996.
4. R. A. Birgenheier, "Overview of Code-Domain Power, Timing, and Phase

Measurements," *Hewlett-Packard Journal* , Feb 1996.
5. W. Y. C. Lee, "Overview of cellular CDMA," *IEEE Trans. Vehic. Tech* ., Vol. VT-40, No. 2, pp. 291-3-2, May 1991.
6. R. F. W. Coates, G. J. Janacek, and K. V. Keverm, "Monte Carlo simulation and random number generation," *IEEE J. Select. Area Commun* ., Vol. 6, No. 1, pp 58-66, Jan. 1988.
7. R. Padovani, "Reverse link performance of IS-95 based cellular systems," *IEEE personal Commun* ., Vol. 1, No. 3, pp. 28-34, 1994.
8. A. J. Viterbi, CDMA: Principles of Spread Spectrum Communication, Wesley Publishing Company, Apr. 1995.
9. J. G. Proakis, *Digital Communications* , McGraw-Hill, 3rd edition, 1995.
10. TIA/EIA/IS-98, *Recommended Minimum Performance Standards for Dual-Mode Wideband Spread Spectrum Cellular Mobile Stations* , Dec. 1994.

CDMA_CoherentRake



Description Coherent Rake Receiver.
Library CDMA, Receivers
Class SDFCDMA_CoherentRake
Derived From CDMA_FwdChnlSounder

Parameters

Name	Description	Default	Sym	Type	Range
NSymblChE	number of consumed symbols for channel estimation in each firing	8	N	int	2^n, n=0,...,9
NSymblIni	number of initial ineffective input symbols from the preceding model	0		int	NSymblChE * n, n=0,2
NFinger	number of Rake receiver finger	3	L	int	[1, 3] (up to the channel)
PN_Offset	offset (in terms of chips) of PN code between base and mobile stations	0		int	64 * n, n=0,...,512
SampleRatio	number of samples per chip	4	R	int	4
WalshIndex	Walsh code index	3		int	[0, 63]

Pin Inputs

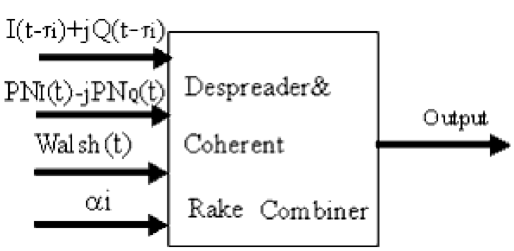
Pin	Name	Description	Signal Type
1	sigIn	equivalent baseband received signal.	complex
2	dlIdx	multipath delays for every finger.	int
3	chPrm	multipath channel parameters for every finger.	complex

Pin Outputs

Pin	Name	Description	Signal Type
4	sigOut	multipath channel parameters for every finger.	complex

Notes/Equations

1. This component is used to implement coherent Rake receiver for IS95 forward link. It despreads the signal and coherently combines the signal despread from multipaths using maximum ratio combining. Each firing, *N* output tokens are produced for ($N \times 64 \times R$) input tokens consumed. The real part of the output complex signal can be used as the decision variable or input to the decoder.
2. Implementation



Principle Diagram of Coherent Rake Receiver

For implementation refer to CDMA_FwdChnlSounder.
The CDMA_CoherentRake output is implemented by

$$r_q(k) = R_e\{\underline{Y}_q[k]\} = R_e\left\{\sum_{l=1}^{L} \underline{Y}_{ql}[k]\right\} = R_e\left\{\sum_{l=1}^{L} \underline{y}_{ql}[k]\underline{\alpha}_l^*[k]\right\}$$

where R_e denotes taking real part.

For BPSK the bit error probability after combining for a known channel is

$$P_e = \frac{1}{2} erfc\left(\sqrt{\frac{E_b}{N_0}}\alpha_\Sigma\right)$$

For MPS, the bit energy is generally denoted by

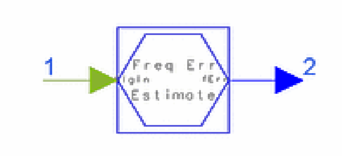
$$E_b = E_{sq}/(\log_2 M)$$

For BPSK the energy equals symbol energy E_{sq}.

References

1. V. Barnasconi, *Receiver Architectures for the Down-link in a DS-CDMA Mobile System*, IEEE CD-ROM 1994.
2. U. Fawer, "A Coherent Spread-Spectrum Diversity-Receiver with AFC for Multipath Fading Channels," *IEEE Trans. on Comm*. Vol.42, pp. 1300-1311, 1994.

CDMA_FreqErrEstimate



Description Carrier Frequency Error Estimation of Received Signal Relative to BS Transmitter.
Library CDMA, Receivers
Class SDFCDMA_FreqErrEstimate
Derived From CDMA_FwdChnlSounder

Parameters

Name	Description	Default	Sym	Unit	Type	Range
NSymblChE	number of consumed symbols for channel estimation in each firing	8	N		int	2^n, n=0,...,9
NSymblIni	number of initial ineffective input symbols from the preceding model	0			int	NSymblChE * n, n=0,2
NFinger	number of Rake receiver finger	3	L		int	[1, 3] (up to the channel)
PN_Offset	offset (in terms of chips) of PN code between base and mobile stations	0			int	64 * n, n=0,...,512
Distance	distance between transmit and receive antennas	7.0	D	m	int	[0.0, ∞)
SampleRatio	number of samples per chip	4	R		int	4

Pin Inputs

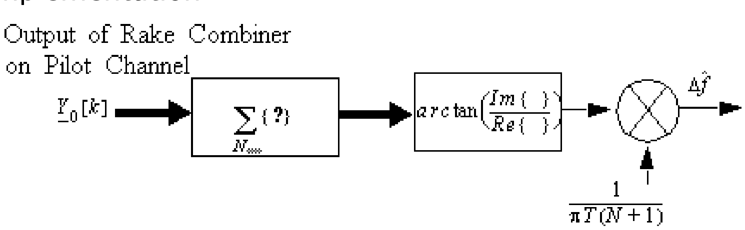
Pin	Name	Description	Signal Type
1	sigIn	equivalent baseband received signal.	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	fErr	estimated digital angle frequency error.	real

Notes/Equations

1. This component is used to estimate carrier frequency error of the received signal relative to the BS transmitter. Frequency error is caused by Doppler effect or local oscillator inaccuracy. Each firing, 2 *N* output tokens are produced for 2 *N* × *WalshCodeLength* × *R* input tokens consumed.
2. Implementation



Carrier Frequency Error Estimation

The frequency offset estimate at time t = kT is:

$$\widehat{\Delta f}[k] = \frac{1}{\pi T(N+1)} arc\tan\left(\frac{\sum_{l=0}^{N_{\Delta f}-1} Im\{\underline{Y}_0[k-l]\}}{\sum_{l=0}^{N_{\Delta f}-1} Re\{\underline{Y}_0[k-l]\}}\right)$$

where $N_{\Delta f}$ denotes the number of symbols forming the observation interval.
Or, let $N_{\Delta f}$ =1 and use a loop filter to implement tracking of small frequency offset.
The loop filter transfer function is:

$$H_{LF}(z) = \frac{K}{1-z^{-1}}$$

where 0<K<<1. Frequency estimation for this type of scheme is written as:

$$\widehat{\Delta f}^{out}[k] = K\widehat{\Delta f}[k]\big|_{N_{\Delta f}=1} + \widehat{\Delta f}^{out}[k-1]$$

The algorithm for frequency offset (Δ *f*) detector is shown in the previous equations for initial acquisition and tracking, respectively.
Angle frequency is used to avoid operation with п, which is shown as:

$$\Delta\Omega[k] = 2\pi\widehat{\Delta f}[k] = \frac{2\pi}{\pi T(N+1)} arc\tan\left(\frac{\sum_{l=0}^{N_{\Delta f}-1} Im\{\underline{Y}_0[k-l]\}}{\sum_{l=0}^{N_{\Delta f}-1} Re\{\underline{Y}_0[k-l]\}}\right)$$

$$= \frac{2}{T(N+1)} arc\tan\left(\frac{\sum_{l=0}^{N_{\Delta f}-1} Im\{\underline{Y}_0[k-l]\}}{\sum_{l=0}^{N_{\Delta f}-1} Re\{\underline{Y}_0[k-l]\}}\right)$$

To further simplify the operation, digital angle frequency Δω[k] at time t = kT with T as sampling interval is used as output of the frequency offset detector:

$$\Delta\omega[k] = \Delta\Omega[k]T = \frac{2}{N+1} arc\tan\left(\frac{\sum_{l=0}^{N_{\Delta f}-1} Im\{\underline{Y}_0[k-l]\}}{\sum_{l=0}^{N_{\Delta f}-1} Re\{\underline{Y}_0[k-l]\}}\right)$$

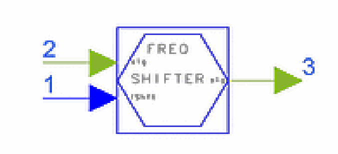
The detected range of the digital angle frequency error Δω should be:

$$|\Delta\omega| < \frac{\pi}{N+1}$$

References

1. V. Barnasconi, Receiver Architectures for the Down-link in a DS-CDMA Mobile System, IEEE CD-ROM 1994.
2. U. Fawer, "A Coherent Spread-Spectrum Diversity-Receiver with AFC for Multipath Fading Channels," *IEEE Trans. on Comm*., Vol.42, pp. 1300-1311, 1994.
3. Z. Wenan and Z. Xiaoguang, "Approach on AFC of mobile station in vehicle for IS-95A CDMA cellular mobile communication system," *The Proceedings of the fifth China Youth Communication Academic Conference*, pp. 483-486, 1997.

CDMA_FreqShifter



Description Carrier Frequency Offset Shifter.
Library CDMA, Receivers
Class SDFCDMA_FreqShifter

Parameters

Name	Description	Default	Sym	Type	Range
NConsume	number of received signal tokens consumed in one firing (in terms of samples for this model)	4096	Ns	int	†
NfshftInputPeriod	number of input signal tokens to be shifted based on the frequency shift value	256	N_T	int	256
NIniFire	number of initial ineffective firings, =3 if used after AFC part	3		int	[0, ∞)
† 2^n*R*WalshCodeLength, where n = 0, ... , 9					

Pin Inputs

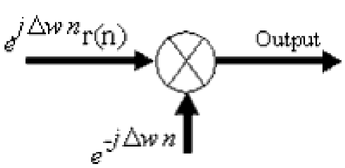
Pin	Name	Description	Signal Type
1	fShft	digital angle frequency value (in terms of radians) to be shifted per data.	real
2	sigIn	equivalent baseband received signal.	complex

Pin Outputs

Pin	Name	Description	Signal Type
3	sigOut	signal after frequency correcting.	complex

Notes/Equations

1. This component is used to adjust the frequency offset. It can correct the frequency error in the receiver input according to the fShft value produced by CDMA_FreqErrEstimate. Each firing, Ns output tokens are produced for Ns input tokens consumed.
2. Implementation



Principle Diagram of Frequency Error Shifter

The principle of the frequency shifter used in the receiver can be shown as:

$$r_{out}^{\dagger}(t) = r_{in}(t)e^{j2\pi f_{shift}t}$$

In IS-95, the sample interval of the received signal

$$T_s = \frac{1}{SampleRatio}T_c = \frac{1}{4}T_c$$

where T $_c$ denotes the length of a code chip. Thus the discrete expression of the equation above is

$$r_{out}^{\dagger}(n) = r_{in}(n)e^{jw_{shift}n}$$

where the digital angle frequency $w_{shift} = 2\pi f_{shift}T_s$ and N_T denotes the number of samples for duration T.

$$N_T = T/T_s = G \times SampleRatio$$

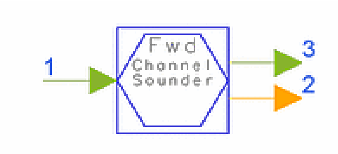
As mentioned, the output of the frequency offset (Δf) detector uses the digital angle frequency Δω[k] at time t = kT with T as sampling interval. For coordination between connected components, the equation above is rewritten as:

$$\begin{aligned} r_{out}^{\dagger}(n) &= r_{in}(n)e^{j\omega_{in}[k]nT_s/T} \\ &= r_{in}(n)e^{j\omega_{in}[k]n\frac{1}{N_T}} \end{aligned}$$

where

$$\begin{aligned} \omega_{in}[k] &= 2\pi f_{shift}[k]T = -\Delta\omega[k] \\ &= -2\pi\widehat{\Delta f}[k]T \end{aligned}$$

CDMA_FwdChnlSounder



Description Channel Sounder on Pilot Channel for IS95 CDMA System Forward Link Receiver.
Library CDMA, Receivers
Class SDFCDMA_FwdChnlSounder

Parameters

Name	Description	Default	Sym	Unit	Type	Range
NSymblChE	number of consumed symbols for channel estimation in each firing	8	N		int	2^n, n=0,...,9
NSymblIni	number of initial ineffective input symbols from the preceding model	0			int	NSymblChE * n, n=0,2
NFinger	number of Rake receiver finger	3	L		int	[1, 3] (up to the channel)
PN_Offset	offset (in terms of chips) of PN code between base and mobile stations	0			int	64 * n, n=0,...,512
Distance	distance between transmit and receive antennas	7.0	D	m	int	[0.0, ∞)
Mode	model mode function: MultipathSearcher and Test: MultipathSearcher, Test	MultipathSearcher			enum	
SampleRatio	number of samples per chip	4	R		int	4
MaxChSpread	maximum multipath channel delay spread	1.45e-5	T_{max}	sec	real	14.5e-6
ChipRate	transmitted chip rate, in terms of chips per second	1.2288e6	S		real	1.2288e6

Pin Inputs

Pin	Name	Description	Signal Type
1	sigIn	equivalent baseband received signal.	complex

Pin Outputs

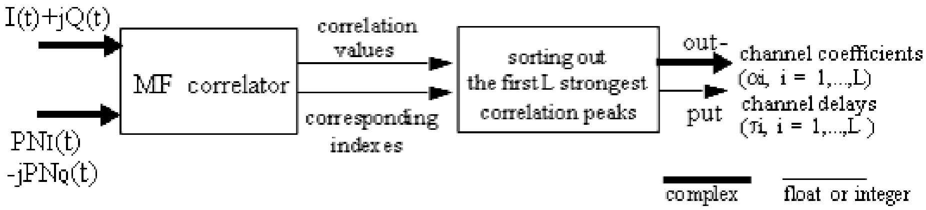
Pin	Name	Description	Signal Type
2	dlOut	multipath delays for every finger.	int
3	sigOut	multipath channel parameters for every finger.	complex

Notes/Equations

1. This model is used for channel estimation for IS-95 forward link pilot channel. When Mode=MultipathSearcher, *L* dlOut and *L* sigOut tokens are produced for *Ncp* ($Ncp = N \times WalshCodeLength \times R$) sigIn tokens consumed each firing. The output multipath delays and channel coefficients are selected by sorting correlation values for each possible delay position in the search window. Search window width is determined by MaxChSpread and Distance.
   When Mode=Test, *W* dlOut and *W* sigOut tokens are produced for *Ncp* sigIn tokens consumed each firing, where *W* denotes search window width (in terms of samples).

The total channel profile (multipath delays and channel coefficients) is output.
For channel estimation, *N* must be small enough to track channel change, and large enough to determine accuracy; *N* =8 is recommended for a 3-path CDMA channel with 50km/hr speed.
CDMA_CoherentRake, CDMA_FreqErrEstimate, and CDMA_FreqShifter components related to forward link Rake receiver are used with CDMA_FwdChnlSounder.

2. Implementation
The following figure represents the basic forward channel sounder block diagram.



Forward Channel Sounder Block Diagram

In IS-95, the phase noise sequence period *Q* is 32768. The total phase range is denoted by *D*.

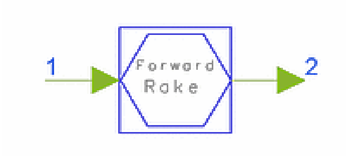
$$D = Q \times SampleRatio = 4\ Q$$

L path delays (T_i, i = 1, 2, ..., *L*) with the strongest energy are chosen; path energy is based on the pilot channel.
Because the maximum multipath delay is much smaller than symbol duration *T* (64 chips), the detection range of the multiple searcher should be smaller than *T*.
CDMA_FwdChnlSounder estimates the energy of paths in the range, selects *L* strongest paths, obtains their delays, and stores their correlation values as the corresponding channel coefficients used by the receiver.

References

1. F. Li and H. Xiao and J. Yang, *On Channel Estimation for Rake Receiver in a mobile multipath fading channel*, IEEE CD-ROM, 1994.
2. W. Zhuang, "Noncoherent Hybrid Parallel PN Code Acquisition for CDMA Mobile Communications," *IEEE Transaction on Vehicular Technology*, Vol.45, No.4, pp. 643-656, Nov. 1996.
3. U. Fawer, "A Coherent Spread-Spectrum Diversity-Receiver with AFC for Multipath Fading Channels," *IEEE Trans. on Comm.*, Vol.42, pp. 1300-1311, 1994.
4. A. J. Viterbi, *Principles of Spread Spectrum Communication*, The Peoples Posts & Telecommunications Publishing, 1995.
5. TIA/EIA/IS-95-A, *Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System*, May 1995.

CDMA_FwdRake



Description IS95A CDMA Forward Link Rake Receiver
Library CDMA, Receivers
Class SDFCDMA_FwdRake

Parameters

Name	Description	Default	Sym	Type	Range
NSymblChEst	number of symbols for channel estimation	8	N	int	2^n, n=0,...,9
NSymblInputIni	initial symbol number	0		int	NSymblChEst * n, n=0,2
FingerNumber	number of Rake receiver finger	3	L	int	[1, 3] (up to the channel)
PilotPN_Offset	offset (in terms of chips) of PN code between base and mobile stations	0		int	64 * n, n=0,...,512
Distance	maximum distance between transmit and receive antennas, in km	7.0	D	real	[0.0, ∞)
UserChannelIndex	Walsh code index	3		int	[0, 63]

Pin Inputs

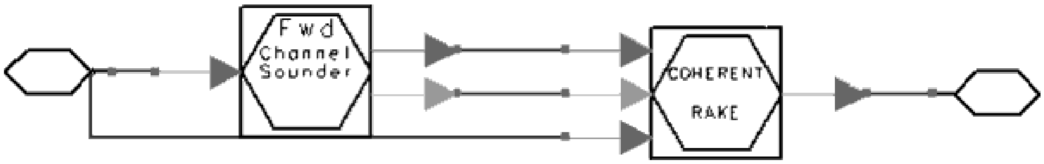
Pin	Name	Description	Signal Type
1	sigIn	complex signal received from channel	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	sigOut	recovered traffic data bit	complex

Notes/Equations

1. The basic function of this subnetwork is to implement the IS-95A forward link receiver, which includes demodulating and despreading signal coherently by Rake receiver using maximum ratio combining and multipath delay estimation, and channel coefficient estimation (attenuation and phase).
2. Implementation
   As shown in the following figure, this subnetwork includes CDMA_FwdChnlSounder, CDMA_CoherentRake.



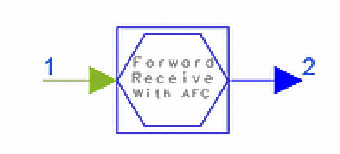
CDMA_FwdRake Network

CDMA_FwdChnlSounder is used to implement channel sounding for IS95A forward link using a pilot channel. Output multipath delays and channel coefficients are sorted by correlation values for each possible delay position in the search window; search window width is determined by the system parameter. For channel estimation, *N* must be small enough to track channel change, and large enough to determine accuracy; *N* =8 is recommended for a 3-path CDMA channel with 50 km/hr speed.
CDMA_CoherentRake is used to implement coherent Rake receiver for IS95A forward link. It despreads the signal using multipath delays and channel coefficients output from CDMA_FwdChnlSounder, and coherently combines the signal despread from multipaths using maximum ratio combining. The real part of the output complex signal can be used as the decision variable or input to the decoder.

References

1. TIA/EIA/IS-95-A, Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System, May 1995.

CDMA_FwdRcvwithAFC



Description IS95A Forward Link Receiver with AFC Function
Library CDMA, Receivers
Class SDFCDMA_FwdRcvwithAFC

Parameters

Name	Description	Default	Sym	Type	Range
ChEstLen	number of symbols for channel estimation	8	N	int	2^n, n=0,...,9
FingerNumber	number of Rake receiver finger	3	L	int	[1, 3] (up to the channel)
PilotPN_Offset	offset, in terms of chips, of PN code between base and mobile stations	0		int	64 * n, n=0,...,512
Distance	maximum distance between transmit and receive antennas, in km	7.0	D	real	[0.0, ∞)
UserChannelIndex	Walsh code index	3		int	[0, 63]

Pin Inputs

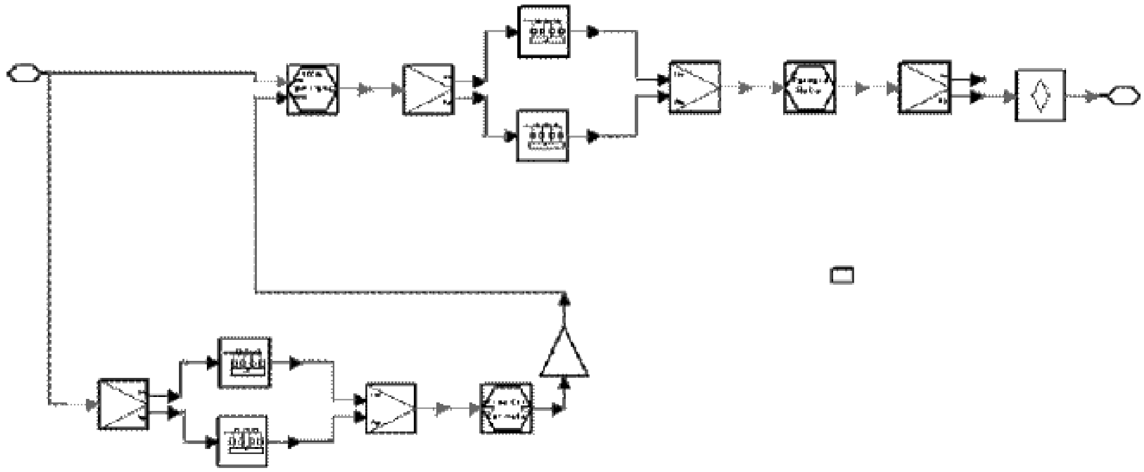
Pin	Name	Description	Signal Type
1	sigIn	comples signal received from channel	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	sigOut	recovered traffic data bit	real

Notes/Equations

1. The basic function of this subnetwork is to implement the total IS-95 forward link receiver with the AFC function, which includes baseband filtering, demodulating and despreading signal coherently by Rake receiver using maximum ratio combining and multipath delay estimation, channel coefficient estimation (attenuation and phase), frequency offset estimation, and frequency offset correction.
2. Implementation
   Refer to the following figure. This subnetwork includes CDMA_FreqErrEstimate, CDMA_FreqShifter and CDMA_FwdRake.



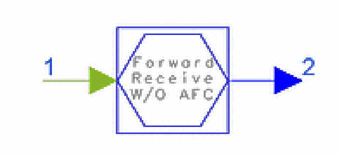
CDMA_FwdRcvwithAFC Network

The channel input signal is input into CDMA_FreqErrEstimate; here it is used to estimate the carrier frequency error of the received signal relative to the base station transmitter caused by Doppler effect or local oscillator inaccuracy. The estimation result is input into CDMA_FreqShifter to adjust frequency offset of the original signal. The corrected complex signal is then input into subnetwork CDMA_FwdRake for despreading.

References

1. TIA/EIA/IS-95-A, Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System, May 1995.

CDMA_FwdRcvwithoutAFC



Description IS95 Forward Link Receiver without AFC Function
Library CDMA, Receivers
Class SDFCDMA_FwdRcvwithoutAFC

Parameters

Name	Description	Default	Sym	Type	Range
ChEstLen	number of symbols for channel estimation	8	N	int	2^n, n=0,...,9
FingerNumber	number of Rake receiver fingers	3	L	int	[1, 3] (up to the channel)
PilotPN_Offset	offset, in terms of chips, of PN code between base and mobile stations	0		int	64 * n, n=0,...,512
Distance	maximum distance between transmit and receive antennas, in km	7.0	D	real	[0.0, ∞)
UserChannelIndex	Walsh code index	3		int	[0, 63]
NSymblInputIni	number of initial ineffective input symbols from preceding components	0		int	[0, ∞)

Pin Inputs

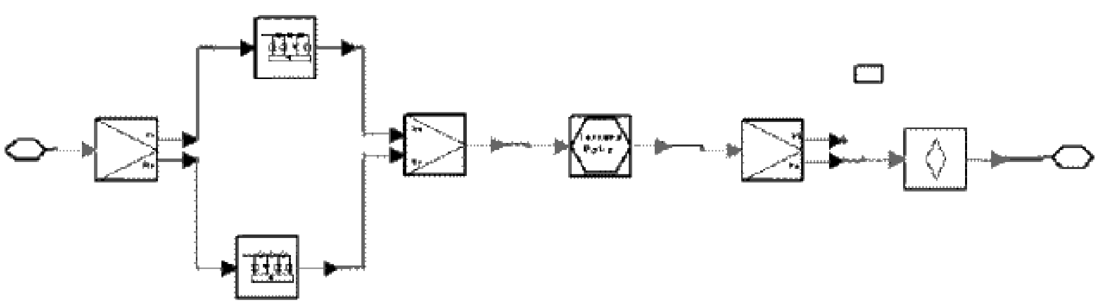
Pin	Name	Description	Signal Type
1	sigIn	comples signal received from channel	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	sigOut	recovered traffic data bit	real

Notes/Equations

1. The basic function of this subnetwork is to implement the total IS-95 forward link receiver without AFC function, which includes baseband filtering, demodulating and despreading signal coherently by Rake receiver using maximum ratio combining and multipath delay estimation, channel coefficient estimation (attenuation and phase).
2. Implementation
   Refer to the following figure. This subnetwork includes CDMA_FwdRake.



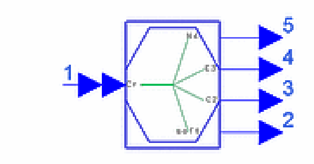
CDMA_FwdRcvwithoutAFC Network

The complex channel signal is baseband filtered, then input into CDMA_FwdRake for despreading.

References

1. TIA/EIA/IS-95-A, Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System, May 1995.

CDMA_PathCombiner



Description Base station Path Combiner
Library CDMA, Receivers
Class SDFCDMA_PathCombiner

Parameters

Name	Description	Default	Type	Range
MaxPathNum	maximum number of paths in rake combination	3	int	[1, 10]

Pin Inputs

Pin	Name	Description	Signal Type
1	Cr_in1	This port inputs the user in-phase sequence.	multiple real

Pin Outputs

Pin	Name	Description	Signal Type
2	soft_decision_var_out	This port outputs the soft decision variables for Viterbi decoder.	real
3	C_out2	This port outputs the detection signal correlation value.	real
4	E_out3	This port outputs the Bit Energy estimation.	real
5	N_out4	This port outputs the Interference plus Noise estimation.	real

Notes/Equations

1. This component is used to implement the path combining function in the reverse channel, which combines *L* path signals using equal gain combining. Soft decision variables for Viterbi decoder are calculated.
2. Implementation
   Path Combining
   The selected L multipath signals are combined using equal gain combining.
   In Rake receiver, each finger demodulates a different propagation of the signal. In each finger, the signal is correlated with each possible mapping of data to produce a corresponding correlation energy value. Associated with each correlation energy value is an index value of Walsh code. Correlation energy values of the same index from multiple fingers are then summed.
   In this equal gain combining Rake receiver, the hard decision variables of kth user are

$$s^k(m) = \sum_{l=1}^{L} S^k(m,l) \qquad m = 1, 2, \ldots, M.$$

   where

$$S^k(m,l) = \left|Z^k_{II}(m,l) + Z^k_{QQ}(m,l)\right|^2 + \left|Z^k_{IQ}(m,l) - Z^k_{QI}(m,l)\right|^2$$

In this component, the receiver uses a maximum-likelihood decision rule.
Decision Output Unit
The maximum signal among 64 Walsh correlator outputs is selected. According to maximum-likelihood decision, the binary code of the number of the Walsh function is the recovered data of Rake receiver for Viterbi decoder using hard-decision algorithm.
Soft Decision Data Calculation
Soft decision data for Viterbi decoder is calculated according to the method in [1]. It searches for a maximum energy level value in each of two subsets of a given set of Walsh symbol indexes and associated energy level values and calculates the difference of the two maximum energy level values to form a soft decision output value. For example, for ith bit of a sequence a1a2...aj, the soft decision value is

$$\Lambda^{(i)}(s) = \underset{m \in M_i}{Max} S(m) - \underset{m \in \overline{M}_i}{Max} S(m)$$

where

M_i = {all of m: a_i =0},

$\overline{M}_i$ = {all if m: a_i =1}

The two subsets are identified by the binary value (0 or 1) of a given digital of the binary equivalent of the Walsh symbol index. The soft decision output value reflects a measure of confidence of the value of the corresponding digit of the original signal.
SINR Measurement
For SINR measurement, signal power, interference, and noise power must be calculated in a fixed time interval. A frame time interval is used to obtain the desired signal power, interference, and noise power.
Signal power can be acquired as:

$$P_s = \sum_{j=1}^{N_n} \left|S_{max}\right|^2$$

where Nn expresses the SINR measurement symbol number, S_{max} is the symbol detection variable, max corresponds to the Walsh code index that is the maximum correlation value among the 64 Walsh correlation values.
So the interference plus noise power is:

$$P_I = \sum_{j=1}^{N_n} \sum_{\substack{i=0 \\ i \neq max}}^{63} \left|S_i\right|^2$$

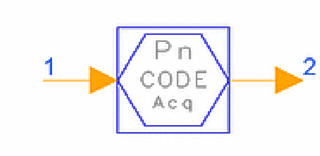
where P_I is the sum of all Walsh code correlation values excluding the maximum value. Therefore,

$$SINR = \frac{P_s}{P_I}$$

References

1. A. J. Viterbi, *CDMA: Principles of Spread Spectrum Communication*, Wesley Publishing Company, 1995.

CDMA_PnCodeAcq



Description PN Code Acquisition
Library CDMA, Receivers
Class SDFCDMA_PnCodeAcq

Pin Inputs

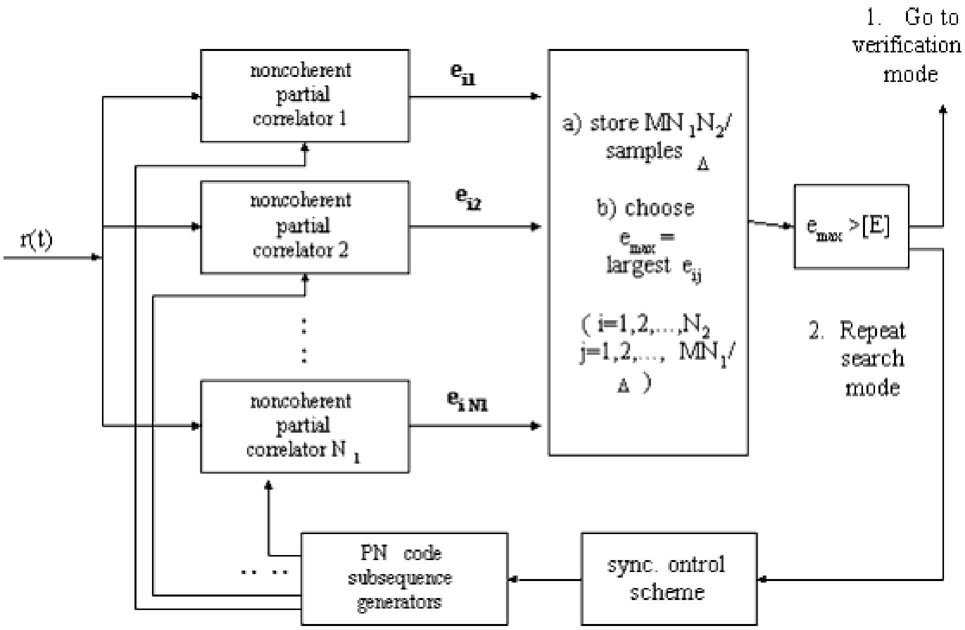
Pin	Name	Description	Signal Type
1	in1	input sequence	int

Pin Outputs

Pin	Name	Description	Signal Type
2	out1	output sequence phase	int

Notes/Equations

1. This component is used to perform the acquisition function of the pseudo noise sequence (PN code) of the input signal, which includes the matched filter correlator, local pseudo-noise subsequence generator, synchronization control scheme unit, and decision unit. Each firing, one output token is generated when 1280 input tokens are consumed.
2. Implementation
   Generally, PN code synchronization consists of acquisition and tracking. PN code acquisition finishes the coarse synchronization of PN code; tracking accurately modifies the synchronization.
   The noncoherent partial parallel PN code acquisition method is used (see the following figure), which can reduce acquisition time.



Noncoherent Partial Parallel PN Code Acquisition System

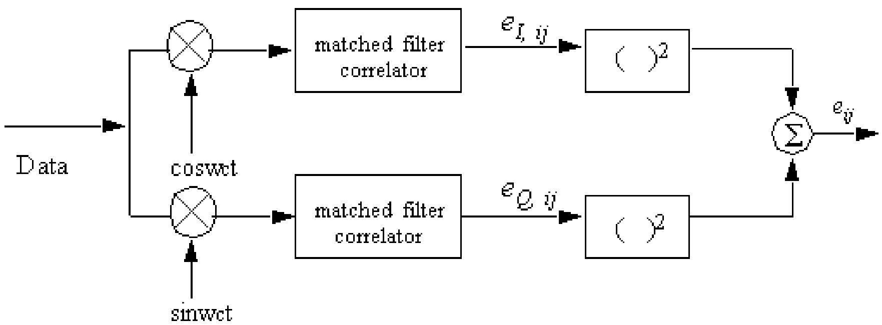
Assuming input signal is r(t), and the local PN code subsequence can be defined as:

$$a_I^{i,j}(t) = \sum_{m=0}^{M-1} a_{I,m}^{i,j} p(t - mT_c) \qquad a_Q^{i,j}(t) = \sum_{m=0}^{M-1} a_{Q,m}^{i,j} p(t - mT_c).$$

where $a_I\ (t)$ and $a_Q\ (t)$ are the PN sequence of I and Q branches, p(t) is the PN code waveform defined as a unit rectangular pulse over [0, T_c]. M is the length of the local PN code subsequence as well as the correlation scope.
The previous sequence are correlated in the matched filter correlator; the correlation expressions are

$$e_{ij}^I = \int_0^T r(t) a_{I,m}^{i,j}(t) dt \qquad e_{ij}^Q = \int_0^T r(t) a_{Q,m}^{i,j}(t) dt.$$

where the matched filter uses the tapped delay line structure shown in the following figure, the input signal shifts in the tapped delay line unit and multiply with the PN code subsequence, and then summed to export.



I-Q Noncoherent Correlator Structure

Partial correlation of the incoming and locally generated codes is performed at baseband in the in-phase and quadrature arms, each arm is squared and added as a decision variable e_{ij} for the ith searching in the jth branch over duration T=MT$_c$.

An input code length L (L= M×N1×N2) is assumed. The uncertainty region of the input code phase is divided into sub-regions each having length *M* with *N* 1and *N* 2 being integers. *N* 1 and *N* 2 are design parameters describing the numbers of parallel and serial acquisition searches, respectively. Each correlator has one of the subcodes of length *M* as a reference code input. The code uncertainty region of each subsequence is discretized with a Δ step size, which is normalized to chip interval T_c, and each subsequence contains *M* /Δ discrete PN code phases.

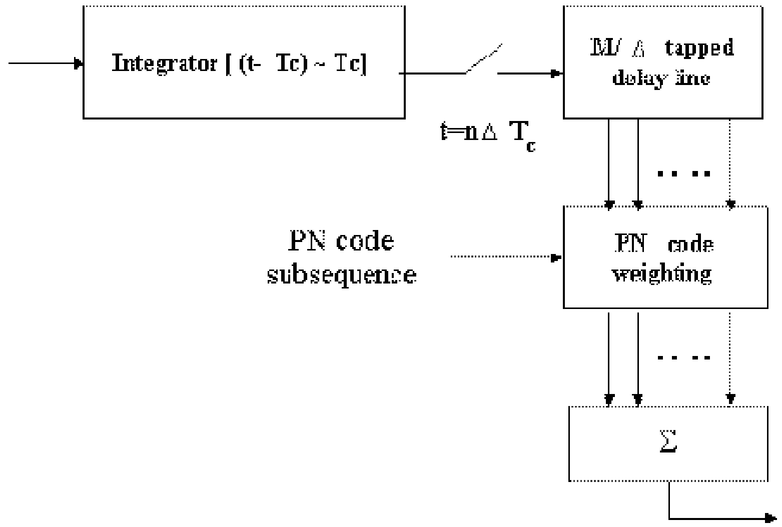
In the partial noncoherent correlation at each correlator, the number of taps on the delay line is *M* /Δ with a Δ Tc delay between successive taps. The incoming code phase uncertainty region is searched in discrete steps.

Over each noncoherent correlation period T there are MT_c /Δ input data samples.

Each new input data sample is collected with *N* 1 subcodes simultaneously loaded in *N* 1 parallel correlators. The process repeats *M* /Δ times, each time with a unique code phase offset between the incoming PN code and the subcode loaded in any correlator, until all possible PN code phases corresponding to *N* 1 subcodes are tested once. The correlators generate *MN* 1/Δ decision variables over the period, corresponding to *MN* 1/Δ possible phases.

In the next period of duration *T*, the *N* 1 noncoherent correlators are loaded with a new group of PN subcodes corresponding to other *MN* 1/Δ possible input code phases; the correlation process continues until a coarse code phase alignment is detected.

In this way, over a period of *N* 2 *T*, the *N* 1 parallel noncoherent correlators generate *L* /Δ decision variables corresponding to all possible discrete PN code phases of the input signal.



Matched Filter Correlator Structure

After correlation, each noncoherent partial correlation value is squared and summed as follows:

$$e_{ij} = \left(e^{I}_{ij}\right)^2 + \left(e^{Q}_{ij}\right)^2 \qquad \begin{array}{l} i = 1, 2, \ldots, M/\Delta \\ j = 1, 2, \ldots, N_1 \end{array}$$

where e_{ij} is the output to enter into the decision unit, which is according to the threshold value to determine whether the acquisition action goes to verification mode *H* 1 or to the repeated search mode *H* 0. Selection of the largest e_{ij} is shown as.

$$e_{max} = max(e_{ij}) \qquad \begin{array}{l} i = 1, 2, \ldots, M/\Delta \\ j = 1, 2, \ldots, N_1 \end{array}$$

On the other hand, the decision expression is

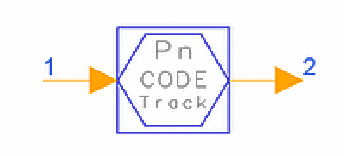
$$e_{max} > TH_1.$$

In PN code acquisition, a coarse alignment decision is made after *MN* 1/Δ discrete code phases are tested once. In other words, after each interval of length *T*, the decision is made according to *MN* 1/Δ decision variables. The decision device stores [E], the corresponding phase of the subcode that is tentatively assumed to be coarsely aligned with the received PN code signal (*H* 1); otherwise, coarse alignment is not achieved (*H* 0). In the next period *T*, the search process is repeated with the next group of possible references subdued until a tentative *H* 1 state is assumed. The verification mode begins.

References

1. W. Zhuang, "Noncoherent Hybrid Parallel PN Code Acquisition for CDMA Mobile Communications," *IEEE Transaction on Vehicular Technology*, Vol. 45, No. 4, Nov. 1996.

CDMA_PnCodeTrack



Description PN Code Tracking
Library CDMA, Receivers
Class SDFCDMA_PnCodeTrack

Pin Inputs

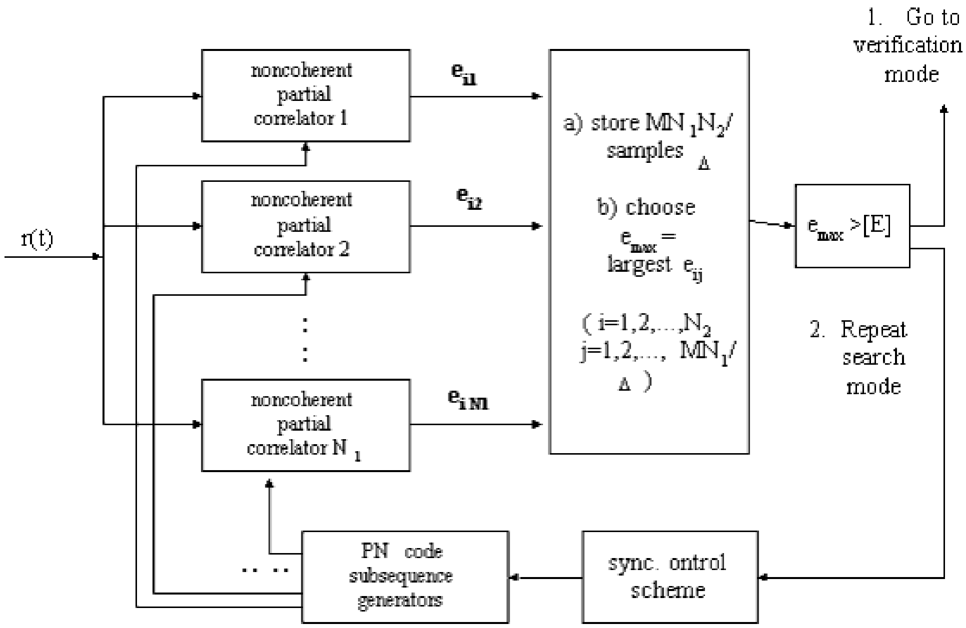
Pin	Name	Description	Signal Type
1	in1	input sequence	int

Pin Outputs

Pin	Name	Description	Signal Type
2	out1	user_desc	int

Notes/Equations

1. This component is used to perform the tracking function of the pseudo noise sequence (PN code) of the input signal, which includes the matched filter correlator, local pseudo-noise subsequence generator, synchronization control scheme unit, and decision unit.
   Each firing, one output token is generated when 5120 output tokens are consumed.
2. Implementation
   The tracking algorithm is the same as the PN code acquisition method, except PN code tracking uses the sample in one chip to correlate, while the acquisition method uses the chip to count the correlation values.
   PN code synchronization generally consists of acquisition and tracking. PN code acquisition finishes the coarse synchronization of PN code; tracking accurately modifies the synchronization.
   CDMA_PnCodeTrack uses noncoherent partial parallel PN code acquisition (see the following figure), which can reduce acquisition time.



Noncoherent Partial Parallel PN Code Acquisition System

Assuming input signal is r(t), and the local PN code subsequence can be defined as:

$$a_I^{i,j}(t) = \sum_{m=0}^{M-1} a_{I,m}^{i,j} p(t - mT_c)$$

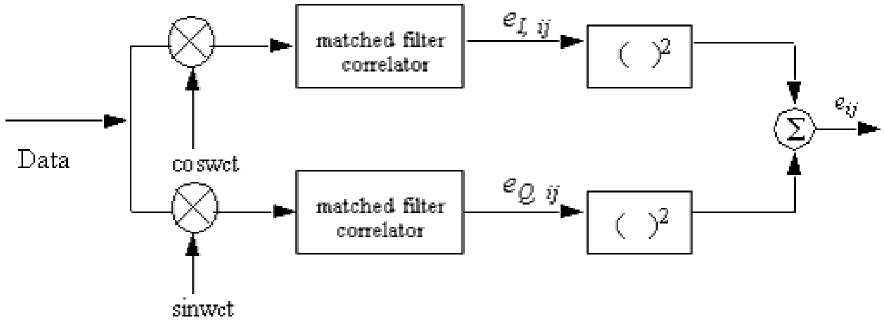
$$a_Q^{i,j}(t) = \sum_{m=0}^{M-1} a_{Q,m}^{i,j} p(t - mT_c).$$

where a_I *(t)* and a_Q *(t)* are the pseudo noise sequence of I and Q branches, p(t) is the PN code waveform defined as a unit rectangular pulse over [0, T_c]. M is the length of the local PN code subsequence as well as the correlation scope.
The previous two sequence are correlated in the matched filter correlator; the correlation expressions are

$$e_{ij}^I = \int_0^T r(t) a_{I,m}^{i,j}(t) dt \qquad e_{ij}^Q = \int_0^T r(t) a_{Q,m}^{i,j}(t) dt.$$

where the matched filter uses the tapped delay line structure shown in the following figure, the input signal shifts in the tapped delay line unit and multiply with the PN code subsequence, and then summed to export.
Partial correlation of the incoming and locally generated codes is performed at baseband in the in-phase and quadrature arms, square each arm and add as a decision variable e_{ij} for the ith searching in the jth branch over duration T=MTc.

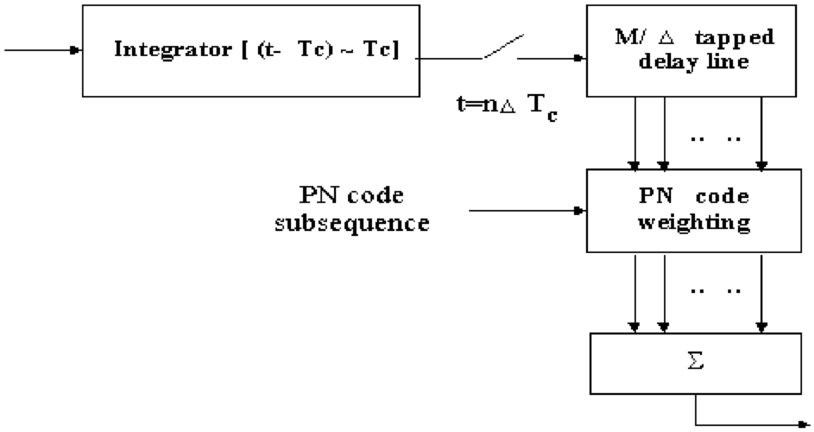
An input code length L, L= M×N1×N2 is assumed. The uncertainty region of the input code phase is divided into sub-regions each having length *M* with *N* 1and *N2* being integers. *N* 1 and N2 are design parameters describing the numbers of parallel and serial acquisition searches, respectively. Each correlator has one of the subcodes of length M as a reference code input. The code uncertainty region of each subsequence is discretized with a Δ step size, which is normalized to chip interval T_c, and each subsequence contains M/Δ discrete PN code phases.



I-Q Noncoherent Correlator Structure

In the partial noncoherent correlation at each correlator, the number of taps on the delay line is M/Δ with a $\Delta\ T_c$ delay between successive taps. The incoming code phase uncertainty region is searched in discrete steps.
Over each noncoherent correlation period T there are MT_c/Δ input data samples.

Each new input data sample is collected with the N 1 subcodes simultaneously loaded in the N 1 parallel correlators. The process repeats M/Δ times, each time with a unique code phase offset between the incoming PN code and the subcode loaded in any correlator, until all possible PN code phases corresponding to N 1 subcodes are tested once. The correlators generate MN 1/Δ decision variables over the period, corresponding to MN 1/Δ possible phases.
In the next period of duration T, the N 1 noncoherent correlators are loaded with a new group of PN subcodes corresponding to other MN 1/Δ possible input code phases; the correlation process continues until a coarse code phase alignment is detected.
In this way, over a period of N 2 T, the N 1 parallel noncoherent correlators generate L /Δ decision variables corresponding to all possible discrete PN code phases of the input signal.



Matched Filter Correlator Structure

After correlation, each noncoherent partial correlation value is squared and summed:

$$e_{ij} = \left(e_{ij}^{I}\right)^2 + \left(e_{ij}^{Q}\right)^2 \qquad \begin{aligned} i &= 1, 2, \ldots, M/\Delta \\ j &= 1, 2, \ldots, N_1 \end{aligned}$$

where *eij* is the output to enter into the decision unit, which is according to the threshold value to determine whether the acquisition action goes to verification mode *H* 1 or to the repeated search mode *H* 0. Selection of the largest e_{ij} is shown as.

$$e_{max} = max(e_{ij}) \qquad \begin{aligned} i &= 1, 2, \ldots, M/\Delta \\ j &= 1, 2, \ldots, N_1 \end{aligned}$$

On the other hand, the decision expression is

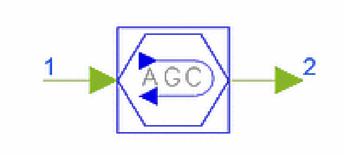
$$e_{max} > TH_1.$$

In PN code acquisition, a coarse alignment decision is made after MN_1 /Δ discrete code phases are tested once. In other words, after each interval of length *T*, the decision is made according to *MN* 1/Δ decision variables. The decision device stores [E], the corresponding phase of the subcode that is tentatively assumed to be coarsely aligned with the received PN code signal (*H* 1); otherwise, coarse alignment is not achieved (*H* 0). In the next period *T*, the search process is repeated with the next group of possible references subdued until a tentative *H* 1 state is assumed. The verification mode begins.

References

1. W. Zhuang, "Noncoherent Hybrid Parallel PN Code Acquisition for CDMA Mobile Communications," *IEEE Transaction on Vehicular Technology*, Vol. 45, No. 4, Nov. 1996.

CDMA_RevAGC



Description Base Station Automatic Gain Control
Library CDMA, Receivers
Class SDFCDMA_RevAGC

Pin Inputs

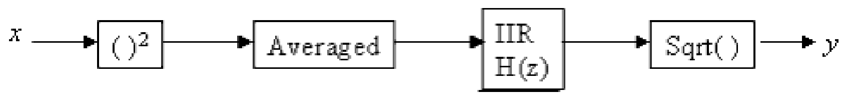
Pin	Name	Description	Signal Type
1	N_in1	Input sequence	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	N_out1	Normalized output sequence.	complex

Notes/Equations

1. This component is used as automatic gain control (AGC) for the signal received from channel. The amplitude of the signal will be suited for processing components that follow AGC.
   The basic AGC method follows:
   Output y is the AGC factor; that is, output is (input signal x/y).



where

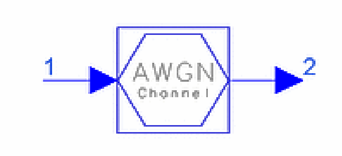
$$H(z) = \frac{a}{1-(1-a)z^{-1}}$$

and a is determined by time duration. The averaged module of the input signal in a frame is used as the AGC factor.

Test Components for CDMA Design Library

- *CDMA AWGN Ch* (cdma)
- *CDMA BER* (cdma)
- *CDMA BER Sink* (cdma)
- *CDMA CC 215* (cdma)
- *CDMA Channel* (cdma)
- *CDMA Cyc* (cdma)
- *CDMA CycCodeEncoder* (cdma)
- *CDMA Cyc R12* (cdma)
- *CDMA DeOQPSK* (cdma)
- *CDMA FreqOffset* (cdma)
- *CDMA Fwd* (cdma)
- *CDMA FwdFadingCh* (cdma)
- *CDMA FwdTrfCh* (cdma)
- *CDMA GNoise* (cdma)
- *CDMA IncSource* (cdma)
- *CDMA OQPSK* (cdma)
- *CDMA PN Code* (cdma)
- *CDMA RnXOR* (cdma)
- *CDMA Sounder Statistic* (cdma)
- *CDMA TimeAverage* (cdma)
- *CDMA TrfER* (cdma)
- *CDMA TriffERR* (cdma)
- *CDMA TstSrc* (cdma)

CDMA_AWGN_Ch



Description AWGN Channel
Library CDMA, Test
Class SDFCDMA_AWGN_Ch

Parameters

Name	Description	Default	Type	Range
EbNoRatio	initial Eb/No of AWGN	0.0	real	[0.0, ∞)
FrameNumberA	first frame in which Eb/No interval is to remain constant	100	int	
FrameNumberB	second frame in which Eb/No interval is to remain constant	100	int	
FrameSymbolNum	number of symbols in each frame	576	int	[1, ∞)
SymbolPerBit	number of symbols per bit	2.0	real	[1, ∞)
Step	step for increasing Eb/No, in dB	1.0	real	(0.0, ∞)
† The product of FrameNumberA and FrameNumberB is the test length for computing an error rate value.				

Pin Inputs

Pin	Name	Description	Signal Type
1	input		real

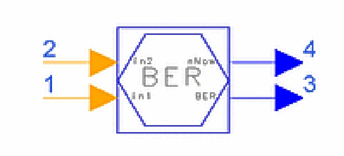
Pin Outputs

Pin	Name	Description	Signal Type
2	output		real

Notes/Equations

1. This component is used as the AWGN channel for ease of plotting the BER curve. The ratio of Eb/No can be changed based on the parameters. Each firing, one output token is produced when one input token is consumed.

CDMA_BER



Description Real Time Error Rate Estimation. This model is to Estimate BER averged on all time from system running to present observation instant.
Library CDMA, Test
Class SDFCDMA_BER

Parameters

Name	Description	Default	Type	Range
Ini	number of initial ineffective symbols not accounted for in BER calculation	8	int	[0, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	in1	The first channel signal.	int
2	in2	The second channel signal.	int

Pin Outputs

Pin	Name	Description	Signal Type
3	BER	The error rate.	real
4	nNow	Current Statistic Times.	real

Notes/Equations

1. This component is used to estimate the BER in real-time.
2. Implementation

$$A_N = \frac{1}{N}\sum_{n=1}^{N} a_n = \frac{1}{N}[(N-1)A_{N-1} + a_N]$$

$$= A_{N-1}\left(1 - \frac{1}{N}\right) + \frac{a_N}{N}$$

where

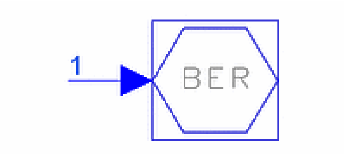
A_N is the current BER output

N is the effective number of symbols accounted for in the BER
a_N is the current bit error value

when in1=in2, a_N =0, otherwise a_N =1

As shown in the equation, a recursive method is used in this component.

CDMA_BER_Sink



Description BER Sink
Library CDMA, Test
Class SDFCDMA_BER_Sink

Parameters

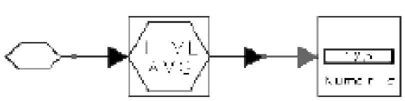
Name	Description	Default	Type	Range
Test	test length for computing one bit error rate value	10000	int	[1, ∞)
Dot	number of dots to draw a bit error rate curve	5	int	[1, ∞)
Group	index of data storage	1	int	[1, ∞)
IniLen	initial points not counted in bit error rate	0	int	[0, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	input	bit error rate value	real

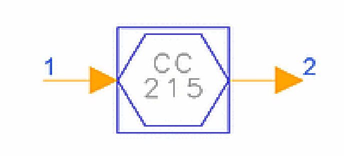
Notes/Equations

1. This subnetwork estimates the bit error rate and draws a bit error rate curve. Each firing, one input token is consumed.
2. Implementation
   Refer to the following figure. This subnetwork includes CDMA_TimeAverage and NumericSink. CDMA_TimeAverage averages input data and outputs the average value. Only the last data saved in the sink is used.



CDMA_BER_Sink Subnetwork

CDMA_CC_215



Description Convolutional Encoder, Rate 2, Constraint Length 5
Library CDMA, Test
Class SDFCDMA_CC_215

Pin Inputs

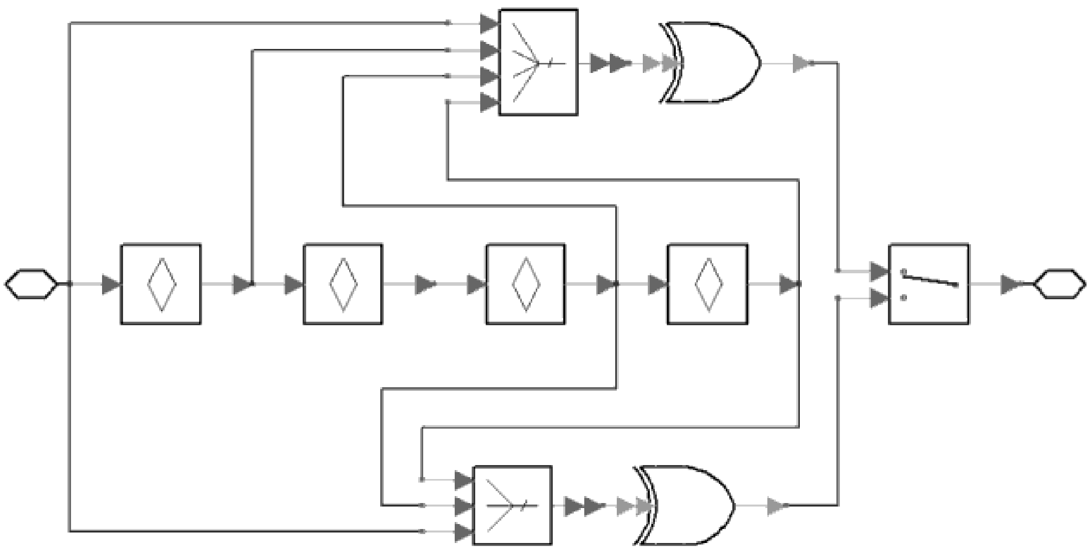
Pin	Name	Description	Signal Type
1	input	data	int

Pin Outputs

Pin	Name	Description	Signal Type
2	output	encoded data	int

Notes/Equations

1. This subnetwork is a convolutional encoder with rate 2, constraint length of 5, and generator function g0 046, g1 066. It is used to check the convolutional encoder algorithm in the CDMA library.
   Two tokens are produced when one token is consumed.
2. Implementation
   Refer to the following figure. This subnetwork is built by passing the information sequence to be transmitted through a linear finite-state shift register and module 2 adder.

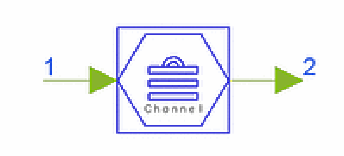


Structure of (2,1,5) Encoder

References

1. A. J. Viterbi, CDMA: Principles of Spread Spectrum Communication, Wesley Publishing Company, 1995.

CDMA_Channel



Description CDMA Reverse Fading Channel
Library CDMA, Test
Class SDFCDMA_Channel

Parameters

Name	Description	Default	Type	Range
X_Position	mobile station position	1.0	real	[0, ∞)
Y_Position	mobile station position	1.0	real	[0, ∞)
Vx_Speed	mobile station speed, km/hr	0.0	real	[0, ∞)
Vy_Speed	mobile station speed, km/hr	0.0	real	[0, ∞)
PathLoss	channel path loss: No, Yes	No	enum	
ChannelType	channel path type: NoMultipath, OnePath, TwoPath, ThreePath	NoMultipath	enum	

Pin Inputs

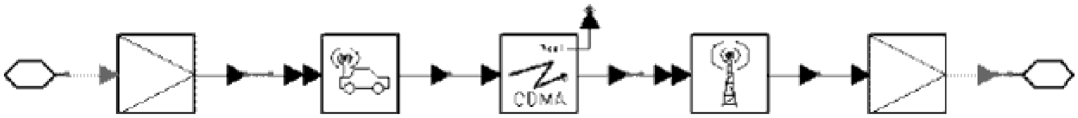
Pin	Name	Description	Signal Type
1	input	data	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	output	data	complex

Notes/Equations

1. The subnetwork is used for simulating the transmission condition of CDMA Reverse Channel.
   One output token is produced when one input token is consumed.
2. Implementation
   Refer to the following figure. This subnetwork includes CxToTimed, AntBase, PropNADCcdma, AntMobile, and TimedToCx.



CDMA Reverse Channel

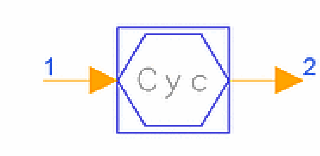
CxToTimed is used to convert the SDF signal to a time domain signal; TStep is the time interval between 2 data chips.
AntBase is the base station antenna. PropNADCcdma is the CDMA channel according to channel model defined in IS-97 [1].
AntMobile is the mobile station antenna; its position and speed can be set in subnetwork parameters.

CxToTimed converts the time domain signal to SDF signals.

References

1. TIA/EIA/IS-97, Recommended Minimum Performance Standards for Base Station Supporting Dual-Mode Wideband Spread Spectrum Cellular Mobile Station, Dec. 1994.

CDMA_Cyc



Description 12-bit Cyclic Encoder
Library CDMA, Test
Class SDFCDMA_Cyc

Parameters

Name	Description	Default	Type	Range
K	length of data signal	172	int	[1, ∞)

Pin Inputs

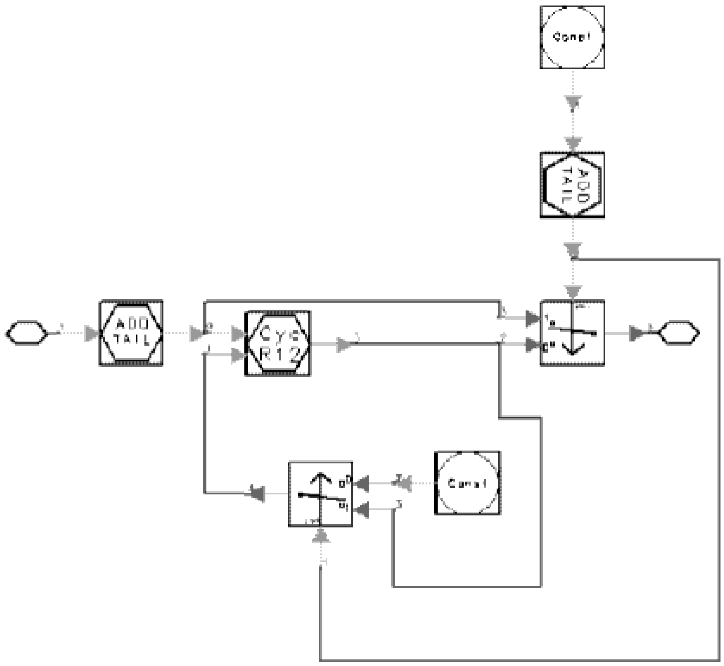
Pin	Name	Description	Signal Type
1	DataIn	input data	int

Pin Outputs

Pin	Name	Description	Signal Type
2	DataOut	encoded data	int

Notes/Equations

1. This subnetwork is a CDMA cyclic encoder designed to check the algorithm of the CRC generator.
   One output token is produced when one input token is consumed.
2. Implementation
   Refer to the following figure. This subnetwork is built by CDMA_Cyc_R12 and other components. CDMA_Cyc_R12 is the shift register array of the encoder; the other components are used as the switch. The initial value 1 of registers cannot be set in the subnetworks, and the initial value is 0.

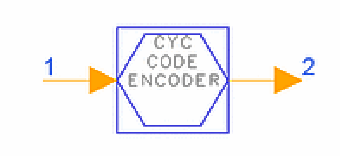


12-bit Cyclic Encoder Structure

References

1. TIA/EIA/IS-95-A, Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System, May 1995.
2. S. Lin and D. J. Costello, Jr., *Error Control Coding Fundamentals and Applications* , Prentice Hall, Englewood Cliffs NJ, 1983.

CDMA_CycCodeEncoder



Description Cyclic Code Encoder.
Library CDMA, Test
Class SDFCDMA_CycCodeEncoder

Parameters

Name	Description	Default	Sym	Type	Range
Polynomial	generator polynomial	0x1f13	P	int	†
InitialState	initial state of encoder: all 0's, all 1's	all 0's		enum	
Vn	length of data to be encoded	172	V	int	[1, ∞)
† If the polynomial is x8+x7+x4+x3+x+1, the coefficient is {1,1,0,0,1,1,0,1,1}; in hex it is 0x19b.					

Pin Inputs

Pin	Name	Description	Signal Type
1	input	The input stream	int

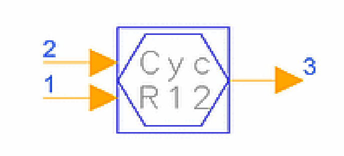
Pin Outputs

Pin	Name	Description	Signal Type
2	output	The output stream.	int

Notes/Equations

1. This component is a cyclic code encoder. Each firing, (V+m) tokens are produced for V tokens consumed, where m = lgP/lg2.

CDMA_Cyc_R12



Description Registers of 12-bit Cyclic Encoder
Library CDMA, Test
Class SDFCDMA_Cyc_R12

Pin Inputs

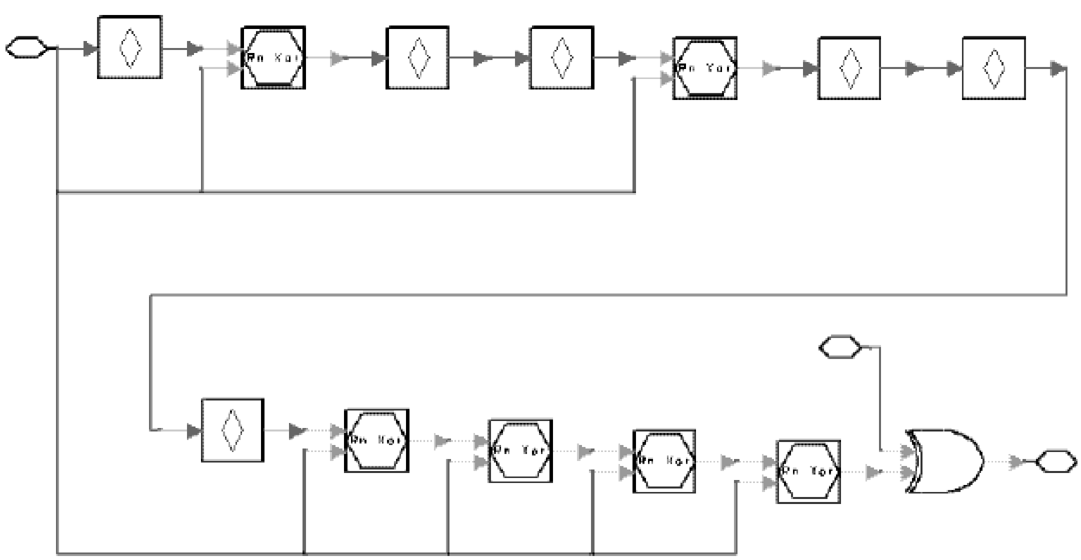
Pin	Name	Description	Signal Type
1	input1	feedback data	int
2	input2	data to be encoded	int

Pin Outputs

Pin	Name	Description	Signal Type
3	output1	encoded data	int

Notes/Equations

1. This subnetwork is used as the shift register of a cyclic code encoder. One output token is produced when one input token is consumed.
2. Implementation
Refer to the following figure. This subnetwork is built by register and module 2 adder. The generator polynomial of CDMA_Cyc_R12 is
$G(x) = x^{12} + x^{11} + x^{10} + x^{9} + x^{8} + x^{4} + x + 1$.
In the subnetwork, the initial value of registers is 0 and cannot be set as 1.

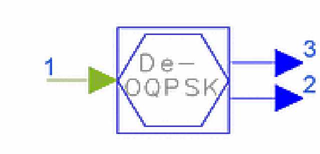


12-bit Cyclic Encoder Register Array

References

1. TIA/EIA/IS-95-A, Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System, May 1995.
2. S. Lin and D. J. Costello, Jr., *Error Control Coding Fundamentals and Applications*, Prentice Hall, Englewood Cliffs NJ, 1983.

CDMA_DeOQPSK



Description CDMA OQPSK Demodulator
Library CDMA, Test
Class SDFCDMA_DeOQPSK

Pin Inputs

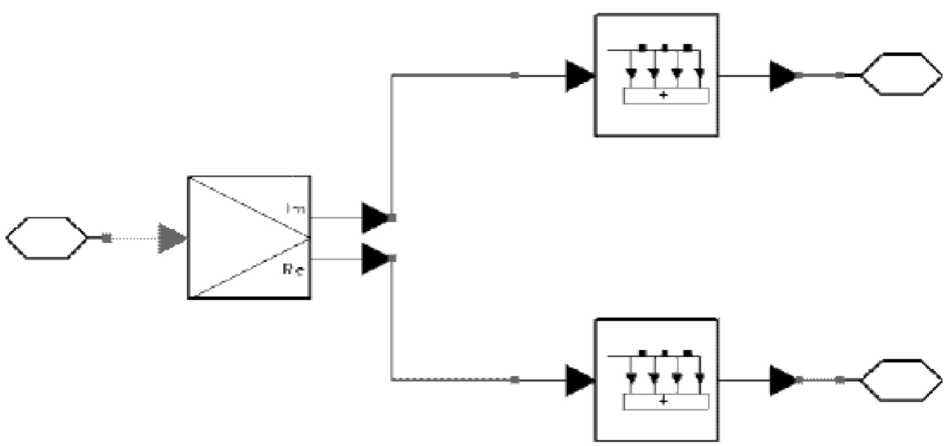
Pin	Name	Description	Signal Type
1	Input	data received from channel	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	output1	in-phase data after demodulation	real
3	output2	quad-phase data after demodulation	real

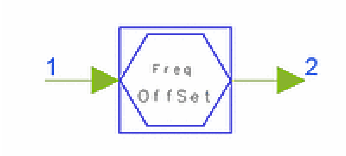
Notes/Equations

1. This subnetwork is used to implement OQPSK demodulation. It is a combination of phase mapping and filtering.
2. Implementation
   Refer to the following figure. This subnetwork includes CxToRect and FIR.
   Input data is signal information received from channel. The input complex data is converted to real values of in-phase and quad-phase. After baseband filtering, the I and Q data are output to Rake receiver.



OQPSK Demodulator

CDMA_FreqOffset



Description Frequency Shifter
Library CDMA, Test
Class SDFCDMA_FreqOffset

Parameters

Name	Description	Default	Type	Range
SampleRate	sample Frequency	4 * 1.2288e6	real	[0.0, ∞)
FrequencyOffsetHz	frequency Offset, in Hz	0.0	real	[0.0, ∞)

Pin Inputs

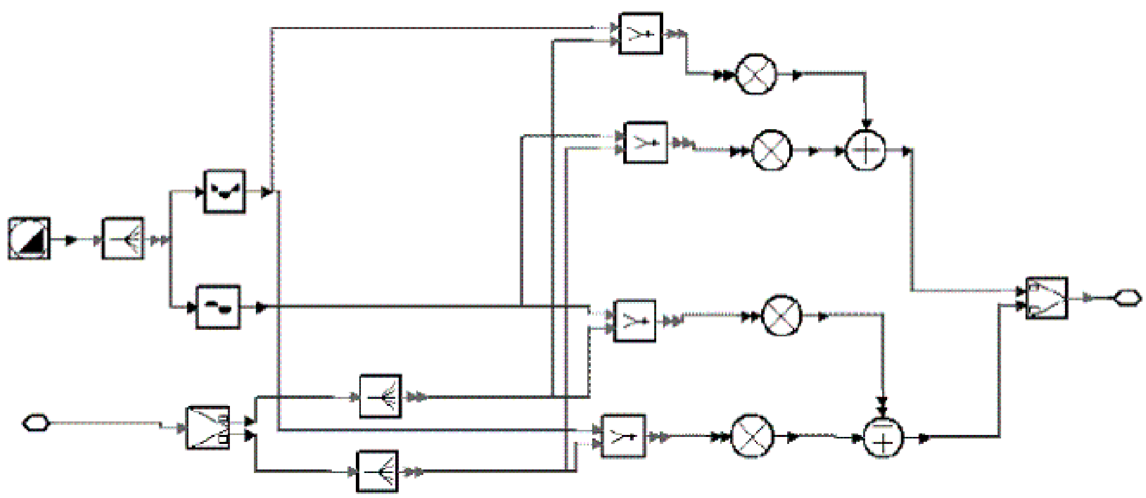
Pin	Name	Description	Signal Type
1	sigIn	signal	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	sigOut	complex signal after frequency shifting	complex

Notes/Equations

1. The basic function of this subnetwork is to produce the frequency offset of the complex input signal.
2. Implementation
   Refer to the following figure. This subnetwork is implemented by basic Advanced Design System components.

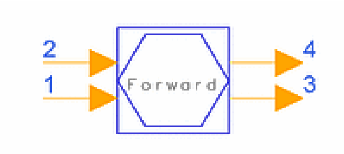


CDMA_FreqOffset Network

References

1. TIA/EIA/IS-95-A, Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System, May 1995.

CDMA_Fwd



Description CDMA Forward Link
Library CDMA, Test
Class SDFCDMA_Fwd

Parameters

Name	Description	Default	Type	Range
ChannelNumber	Walsh index of traffic channel	3	int	[0, 63]

Pin Inputs

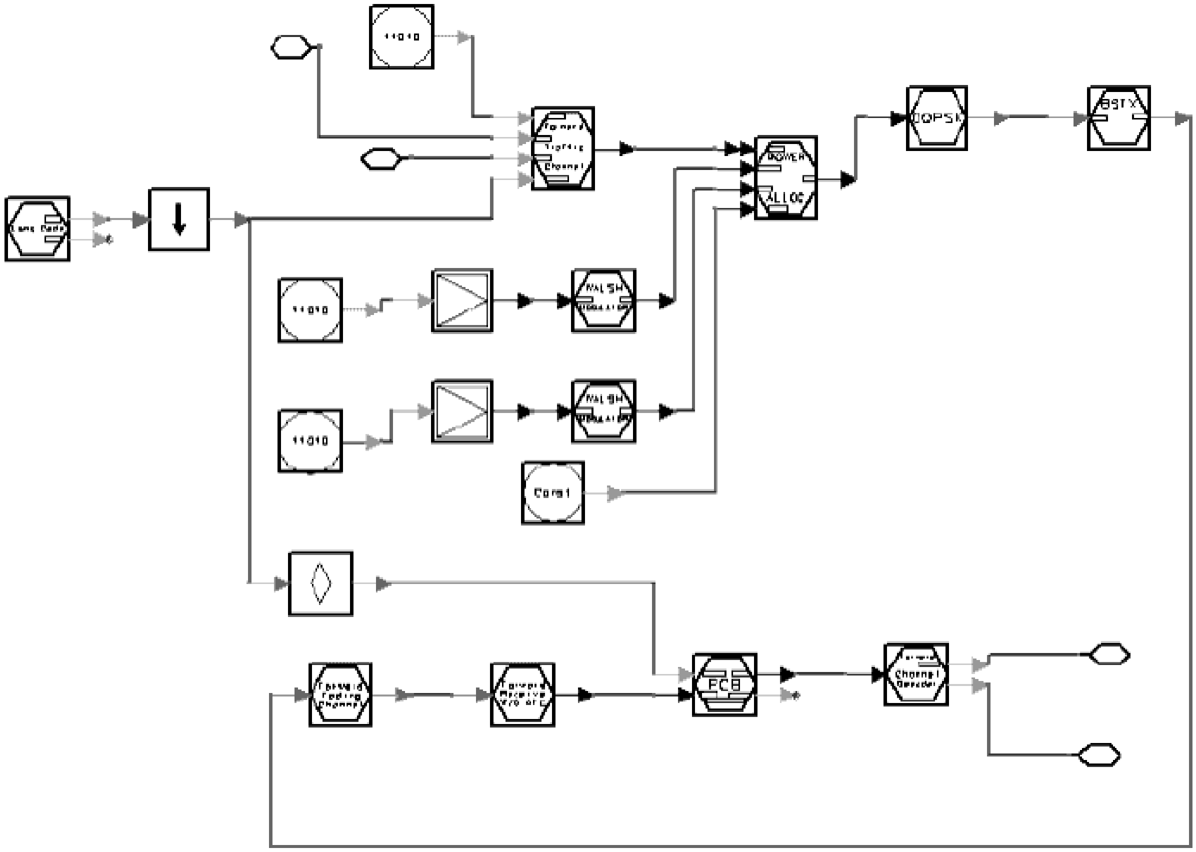
Pin	Name	Description	Signal Type
1	input	data	int
2	rateI	data rate of input frame	int

Pin Outputs

Pin	Name	Description	Signal Type
3	output	data	int
4	rate0	data rate of output frame	int

Notes/Equations

1. This component is used as the whole CDMA forward link.
2. Implementation
   Refer to the following figure. This subnetwork includes forward traffic channel encoder and decoder, CDMA forward transmission, CDMA forward fading channel and CDMA forward Rake receiver.

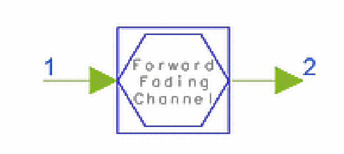


CDMA Forward Link

References

1. TIA/EIA/IS-95-A, Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System, May 1995.

CDMA_FwdFadingCh



Description CDMA Forward Fading Channel
Library CDMA, Test
Class SDFCDMA_FwdFadingCh

Parameters

Name	Description	Default	Type	Range
Vx	mobile station speed	8	real	[0, ∞)
Vy	mobile station speed	0	real	[0, ∞)
X_Position	mobile station position	3	real	[0, ∞)
Y_Position	mobile station position	3	real	[0, ∞)
Variance	gauss noise variance	1	real	[0, ∞)
PathLoss	channel path loss: No, Yes	No	enum	
ChannelType	channel path type: NoMultipath, OnePath, TwoPath, ThreePath	NoMultipath	enum	

Pin Inputs

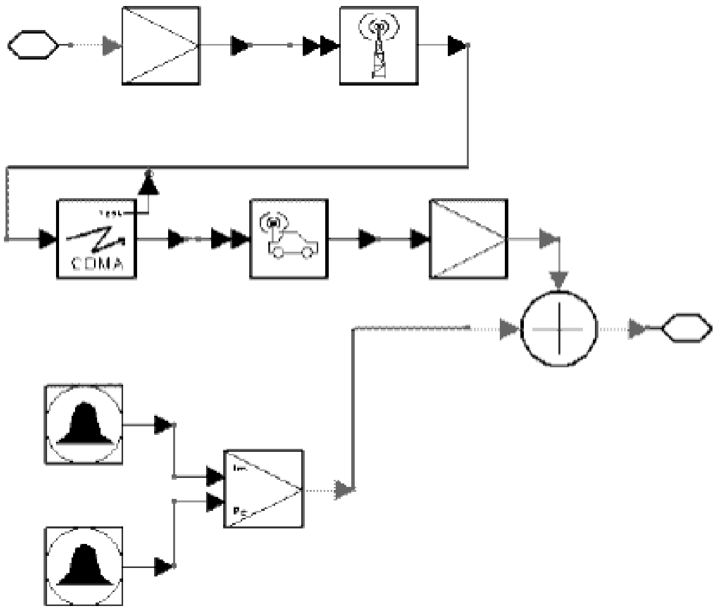
Pin	Name	Description	Signal Type
1	input	data	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	output	data	complex

Notes/Equations

1. This subnetwork is used for simulating the transmission condition of a CDMA forward fading channel.
   One output token is produced when one input token is consumed.
2. Implementation
   Refer to the following figure. This subnetwork includes CxToTimed, AntBase, PropNADCcdma, AntMobile and TimedToCx.



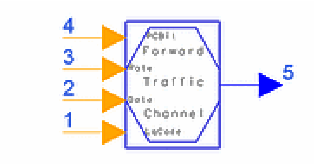
CDMA Forward Fading Channel

CxToTimed converts the SDF signal to a time domain signal; TStep is the time interval between 2 data chips.
AntBase is the base station antenna. PropNADCcdma is the CDMA channel according to the channel model defined in IS-97 [1].
AntMobile is the mobile station antenna, its position and speed can be set in the subnetwork parameters.
TimedToCx converts the time domain signal to an SDF signal.

References

1. TIA/EIA/IS-97, Recommended Minimum Performance Standards for Base Station Supporting Dual-Mode Wideband Spread Spectrum Cellular Mobile Station, Dec. 1994, page 3-3.

CDMA_FwdTrfCh



Description CDMA Forward Traffic Channel
Library CDMA, Test
Class SDFCDMA_FwdTrfCh

Parameters

Name	Description	Default	Type	Range
Channel	Walsh code index of traffic channel	3	int	[0, 63]

Pin Inputs

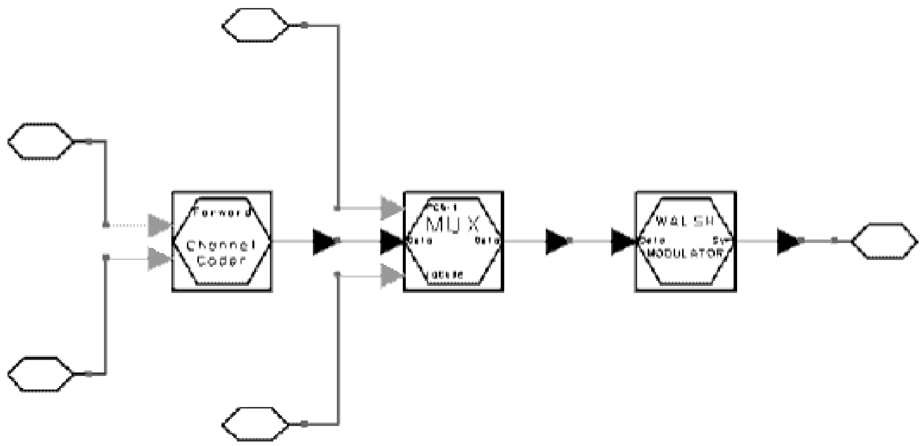
Pin	Name	Description	Signal Type
1	LgCode	long code	int
2	Data	source data	int
3	Rate	input frame data rate	int
4	PCBit	power control bit	int

Pin Outputs

Pin	Name	Description	Signal Type
5	output	data	real

Notes/Equations

1. This component is a CDMA forward traffic channel that includes forward encoder and transmitter.
2. Implementation
   Refer to the following figure. This subnetwork includes CDMA_FwdChCoder, CDMA_MUX and CDMA_WalshModulator.
   CDMA_FwdChCoder is used to implement forward traffic channel encoding.
   CDMA_MUX is used to implement two functions: long code scramble data and insert power control bits (2 successive identical bits) into one power control group.
   CDMA_WalshModulator is used to generate 64-bit long Walsh Symbol (index 0 ~ 63; each symbol has 64 bits) and spread one input symbol to 64 chips.

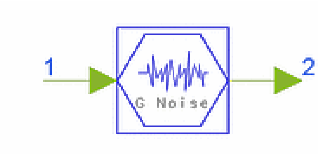


CDMA Forward Traffic Channel

References

1. TIA/EIA/IS-95-A, Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System, May 1995.

CDMA_GNoise



Description CDMA Gaussin Noise Generator
Library CDMA, Test
Class SDFCDMA_GNoise

Parameters

Name	Description	Default	Type	Range
Noise_Mean	noise mean value	0.0	real	[0.0, ∞)
Noise_Variance	noise variance value	0.0	real	[0.0, ∞)

Pin Inputs

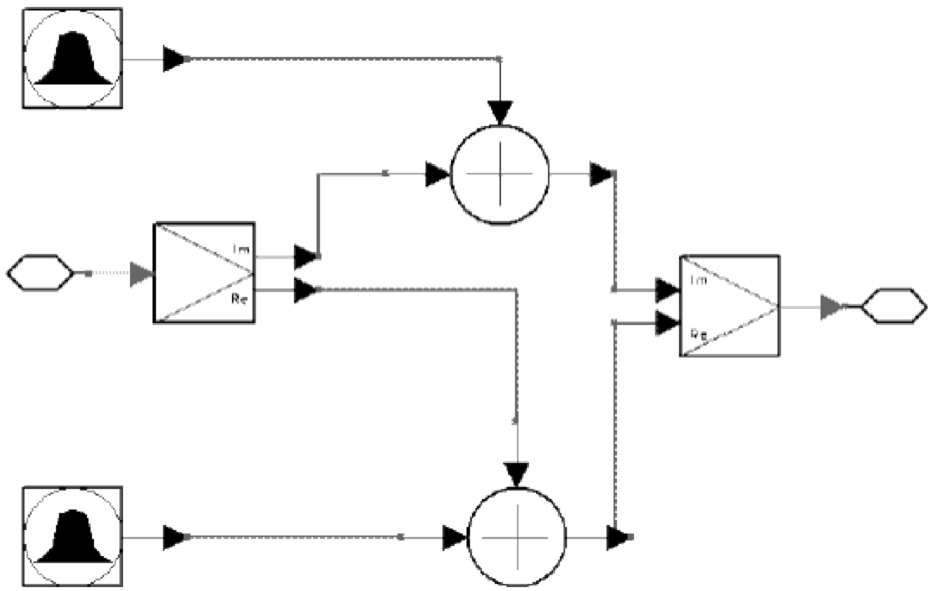
Pin	Name	Description	Signal Type
1	input	data	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	output	output signal with noise	complex

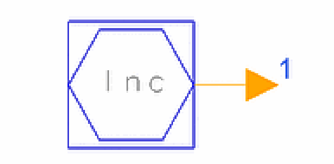
Notes/Equations

1. This subnetwork is used to add complex Gaussian distributed noise to signal.
   One output token is produced when one input token is consumed.
2. Implementation
   Refer to the following figure. This sub-network includes IID_Gaussian, CxToRect, and RectToCx.
   IID_Gaussian is a Gaussian noise generator, its mean and variance parameters can be set in sub-network parameters.
   CxToRect converts a complex input to real and imaginary parts.
   RectToCx converts real and imaginary inputs to a complex output.



Complex Gaussian Noise Generator

CDMA_IncSource



Description Signal Source with Progressively Increasing Amplitude .
Library CDMA, Test
Class SDFCDMA_IncSource

Parameters

Name	Description	Default	Type	Range
Step	increasing step	1	int	[1, ∞)
RepeaTime	symbol repeat times	1	int	[1, ∞)
InitValue	initial signal level	1	int	[1, ∞)
Max	maximum signal level	576	int	[1, ∞)

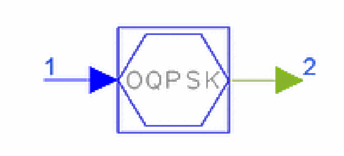
Pin Outputs

Pin	Name	Description	Signal Type
1	output		int

Notes/Equations

1. This component is used to generate an integer that starts at 1 and increases step-by-step to the maximum value as an auxiliary component to test the CDMA system interleaver.
   One output token is produced when one input token consumed.
2. The interleaver block length varies for different channels. In the CDMA access channel, the symbol is repeated two times before it is placed into the interleaver; so data can be repeated if specified.

CDMA_OQPSK



Description CDMA OQPSK Modulator
Library CDMA, Test
Class SDFCDMA_OQPSK

Parameters

Name	Description	Default	Type	Range
PN_Offset_Value	offset of PN code	0	int	[0, 512)
Delay	phase offset of OQPSK, 1/4 chip	2	int	
NormalFactor	power normalization factor	1	real	

Pin Inputs

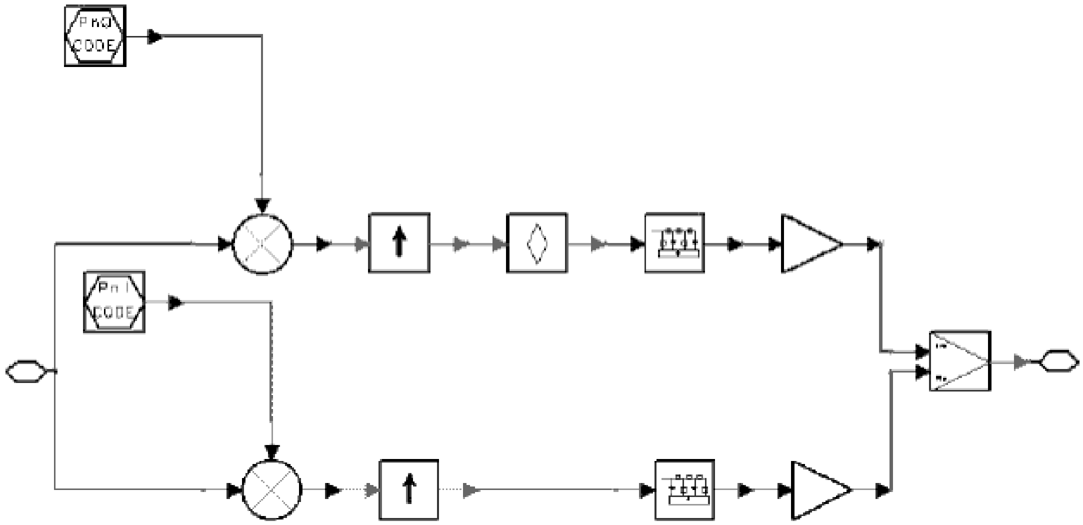
Pin	Name	Description	Signal Type
1	input	data source	real

Pin Outputs

Pin	Name	Description	Signal Type
2	output	data after modulation	complex

Notes/Equations

1. This subnetwork is used to implement OQPSK modulation. It is a combination of spreading by PN codes of I and Q phases, upsampling, phase offsetting, filtering, and gaining.
2. Implementation
   Refer to the following figure. This subnetwork includes CDMA_PnICode, CDMA_PnQCode, UpSample, Delay, FIR, Gain, and RectToCx.
   Input data is signal information after encoder and Walsh code modulation. The input data is spread by a quadrature pair of PN sequences (I, Q); data spread by the Q PN sequence is delayed by one-half PN chip time with regard to the data spread by the I PN sequence. After baseband filtering, the data of I and Q are converted to complex value.

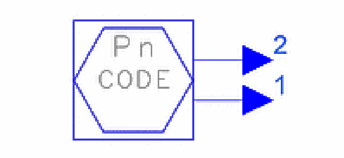


OQPSK Modulator

References

1. TIA/EIA/IS-95-A, Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System, May 1995.

CDMA_PN_Code



Description Generating In-Phase and Quadrature Phase PN Code for Despreading
Library CDMA, Test
Class SDFCDMA_PN_Code

Parameters

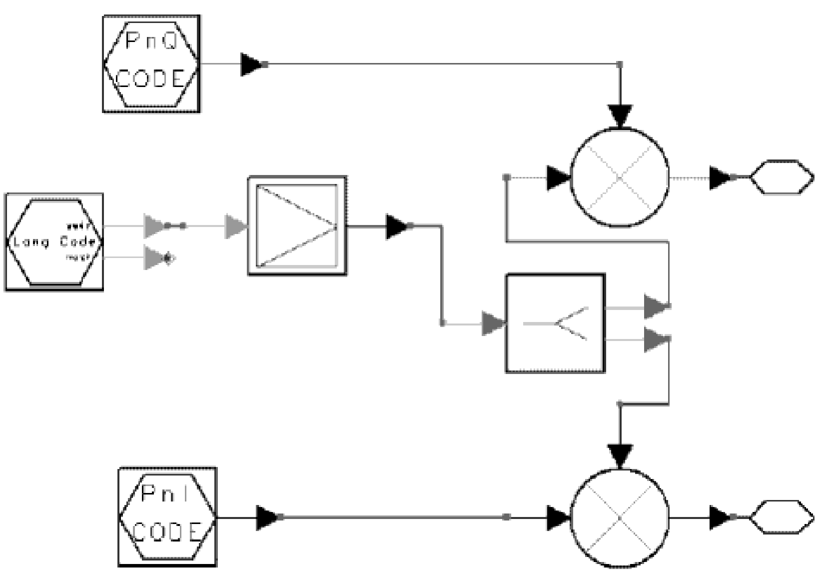
Name	Description	Default	Type	Range
PN_Offset_Value	base station PN code offset	0	int	[0, 512)
LongCodeMask1	first 16 bits of serial number for long code generator	00000000	int	[0, 65535]
LongCodeMask2	last 16 bits of serial number for long code generator	00000000	int	[0, 65535]

Pin Outputs

Pin	Name	Description	Signal Type
1	output1	in-phase path PN code	real
2	output2	quadrature path PN code	real

Notes/Equations

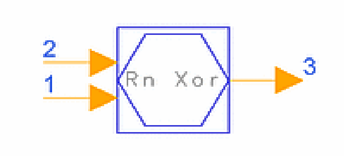
1. This subnetwork is used to generate PN code for despreading a reverse link. It combines long code and quadrature spreading PN code generating process as shown in the following figure. CDMA_PnICode, CDMA_PnQCode, and CDMA_LongCodeGenerator are used; refer to these components for more details.
2. Implementation
   After NRZ transformation, the long code is multiplied by I- and Q-path PN code and output for the respective paths.



References

1. TIA/EIA/IS-95-A, Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System, May 1995.

CDMA_RnXOR



Description Shift Register and Modulo 2 Adder
Library CDMA, Test
Class SDFCDMA_RnXOR

Pin Inputs

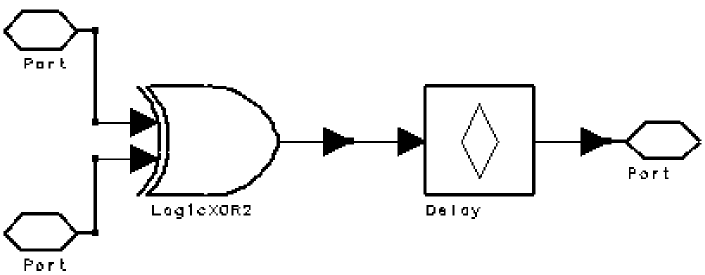
Pin	Name	Description	Signal Type
1	input1	first input	int
2	input	second input	int

Pin Outputs

Pin	Name	Description	Signal Type
3	output	output	int

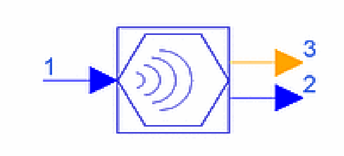
Notes/Equations

1. This subnetwork is composed of LogicXOR2 and Delay; the schematic is shown in the following figure.
   One output token is produced when one input token is consumed.



CDMA_RnXOR Subnetwork

CDMA_Sounder_Statistic



Description Estimation of Probability for Channel Sounder Output
Library CDMA, Test
Class SDFCDMA_Sounder_Statistic

Parameters

Name	Description	Default	Type	Range
Ini	number of ineffective firings to be ignored	1	int	[0, ∞)
Thresholds	quantization thresholds, in increasing order	0.0	real array	(-∞, ∞)
Levels	output levels		real array	

Pin Inputs

Pin	Name	Description	Signal Type
1	input		real

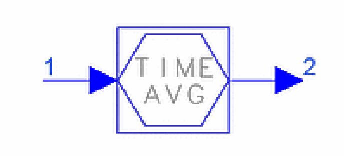
Pin Outputs

Pin	Name	Description	Signal Type
2	output		real
3	Statistic		int

Notes/Equations

1. This component is used to estimate the number of inputs for each level in order to provide input probability statistics. Frequency error is caused by Doppler effect or local oscillator inaccuracy.
   Each firing, 1 output token and *N* +1 statistic tokens are produced for 1 input token consumed, where *N* equals the array size of Thresholds.
2. Implementation
   This component is based on the Quant component (in the ADS Numeric Special Functions library) to quantize the input value to *N* +1 possible output levels using *N* Thresholds. It adds one output statistic to record the result of statistics (the number of points that fall in every level) and adds one Ini parameter to count the noneffective points.
   - For input ≤ *n* th threshold, but > all previous thresholds, the output will be the *n* th level.
   - For input > all thresholds, the output is the *N+1* th level.
   - For input < all thresholds, then the output is the *0* th level.
     The default value for level is 0, 1, 2, ... *N*. This star takes on the order of log *N* steps to find the correct level.

CDMA_TimeAverage



Description Average in Time Domain. This module add the input with the previous value and average it.
Library CDMA, Test
Class SDFCDMA_TimeAverage

Parameters

Name	Description	Default	Type	Range
TestLength	number of frames for BER estimate	10000	int	[1, ∞)
DotNumber	number of dots needed to draw BER curve.	8	int	[1, ∞)
IniLength	number of ineffective firings to be ignored	0	int	[0, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	input	The input datum.	real

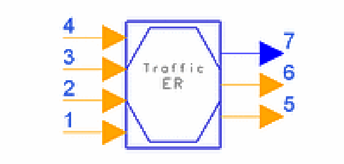
Pin Outputs

Pin	Name	Description	Signal Type
2	output	The time averaged datum.	real

Notes/Equations

1. This component is used to average the input data and avoid the multirate. One output token is produced when one input token is consumed.

CDMA_TrfER



Description Estimating Traffic Channel Bit Error
Library CDMA, Test
Class SDFCDMA_TrfER

Parameters

Name	Description	Default	Type	Range
InitialFrame	number of frames to be ignored	0	real	[0, ∞)

Pin Inputs

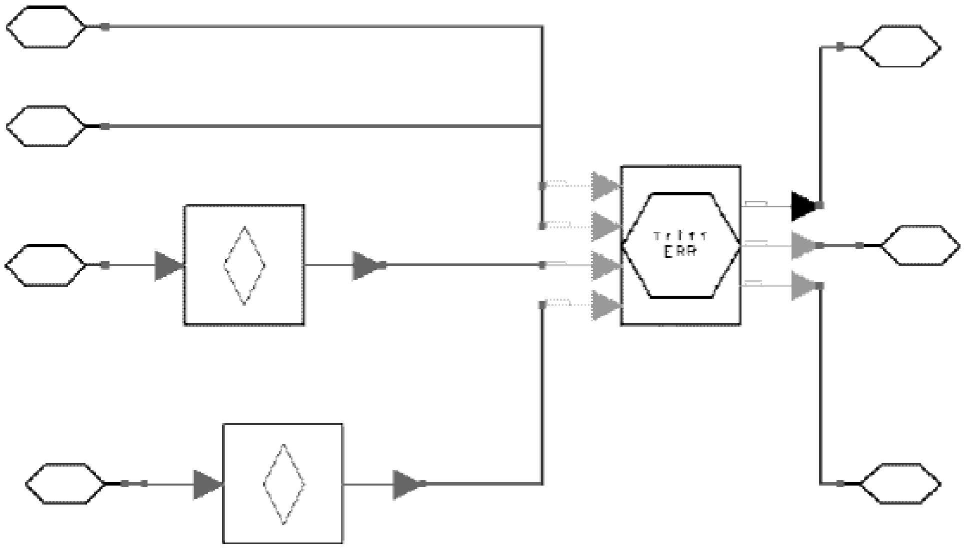
Pin	Name	Description	Signal Type
1	input1	block one	int
2	rate1	data rate of block one	int
3	input2	block two	int
4	rate2	data rate of block two	int

Pin Outputs

Pin	Name	Description	Signal Type
5	RDER	error rate decision	int
6	FEROut	error frame	int
7	BEROut	bit error rate	real

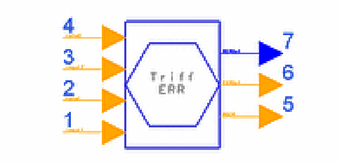
Notes/Equations

1. This component is used to estimate the BER, FER and error data rate in CDMA traffic channel.
2. Refer to the following figure. This subnetwork includes CDMA_TriffERR and Delay. Delay sets the initial frame of input data. In the CDMA library, the 9600 bps frame length of CDMA source is 171.



CDMA_TrfER Subnetwork

CDMA_TriffERR



Description Estimating the Rate-Decision Error of the forward Traffic Channel.
Library CDMA, Test
Class SDFCDMA_TriffERR

Parameters

Name	Description	Default	Type	Range
InitialFrame	number of frames to be ignored	0	int	[1, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	Input1	the input block one.	int
2	rate1	the input block one.	int
3	Input2	the input block two.	int
4	rate2	the input block two.	int

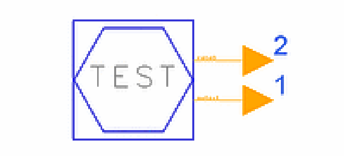
Pin Outputs

Pin	Name	Description	Signal Type
5	RDER	specify if it is a error rate-decision.	int
6	FEROut	specify if it is a error frame.	int
7	BEROut	the bit error rate.	real

Notes/Equations

1. This component is used to estimate the BER, FER and decision error rate of data rate in CDMA traffic channel. One output token is produced when L input sink and source tokens are consumed.

CDMA_TstSrc



Description Test Data Source.
Library CDMA, Test
Class SDFCDMA_TstSrc

Parameters

Name	Description	Default	Type
My_random	type of bit source:ALL 0s, ALL 1s, ALTERNATE 0 1, RANDOM BIT: ALL 0s, ALL 1s, ALTERNATE 0 1, RANDOM BIT	RANDOM BIT	enum
Order	frame order: RANDOM, SEQUENTIAL, CONSTANT9600, CONSTANT4800, CONSTANT2400, CONSTANT1200: RANDOM, SEQUENTIAL, CONSTANT9600, CONSTANT4800, CONSTANT2400, CONSTANT1200	SEQUENTIAL	enum

Pin Outputs

Pin	Name	Description	Signal Type
1	output	output data	int
2	rateO	output data rate	int

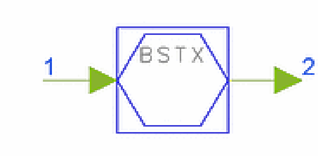
Notes/Equations

1. This component is a test source for CDMA systems. It can generate the variable data rate and fixed data rate source for CDMA Traffic Channel (it is still a general random bit source). Each firing, 171 output tokens are produced. The framelength full rate frame is 171.
2. A rateO value of 0, 1, 2 or 3 denotes a data rate of 9600, 4800, 2400 or 1200, respectively.

Transmission Components

- *CDMA BSTX* (cdma)
- *CDMA DataRandomizer* (cdma)
- *CDMA LongCodeGenerator* (cdma)
- *CDMA M aryModulator* (cdma)
- *CDMA MSTX* (cdma)
- *CDMA MUX* (cdma)
- *CDMA PCBitExtraction* (cdma)
- *CDMA PnICode* (cdma)
- *CDMA PnQCode* (cdma)
- *CDMA PowerAllocation* (cdma)
- *CDMA ReversePowerControl* (cdma)
- *CDMA WalshModulator* (cdma)

CDMA_BSTX



Description Base Station Transmitter
Library CDMA, Transmission
Class SDFCDMA_BSTX

Parameters

Name	Description	Default	Unit	Type	Range
BS_Power	base station transmission power	10.0	W	real	[0, ∞)
BlockLength	number of chips for each control group	24		int	[1, ∞)
SignalType	type of input signal: BaseBand, IntermidiateFrequency	BaseBand		enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	DataIn	combined information chips	complex

Pin Outputs

Pin	Name	Description	Signal Type
2	DatOut	transmission data	complex

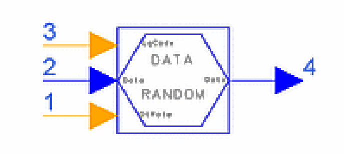
Notes/Equations

1. This component is used to allocate power for transmission data. Each firing, one token is produced and one token is consumed.
2. Implementation
   Multiply an amplitude value to the normalized baseband signal, where amplitude is the square root of transmission power. Maximum base station power is 4.0W.

References

1. TIA/EIA/IS-97, Recommended Minimum Performance Standards for Base Station Supporting Dual-Mode Wideband Spread Spectrum Cellular Mobile Station, Dec. 1994, page 3-3.

CDMA_DataRandomizer



Description Data Burst Randomizer and Long Code Spreader for Forward Link
Library CDMA, Transmission
Class SDFCDMA_DataRandomizer

Pin Inputs

Pin	Name	Description	Signal Type
1	DtRate	base band data rate	int
2	DataIn	data after M_ary modulation	real
3	LgCode	Long Code	int

Pin Outputs

Pin	Name	Description	Signal Type
4	DataOut	data after randomizing and spread apectrum	real

Notes/Equations

1. This component is used to puncture bits of the reverse traffic channel to decrease output power, then long code spread the output data. Block length will be one frame. Each firing, 6144 DataIn, 1 DtRate, and 24576 LgCode tokens are consumed and 24576 DataOut tokens are produced.
2. Implementation
   A masking pattern of 0s and 1s is generated that randomly masks out the redundant data generated by code repetition. The masking pattern is determined by DtRate and 14 bits of LgCode. These 14 bits will be the last 14 bits of the Long code used for spreading in the previous to the last power control group of the previous frame; they are denoted as:

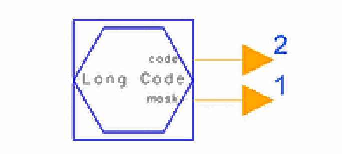
   b0,b1,b2,b3,b4,b5,b6,b7,b8,b9,b10,b11,b12,b13

   One frame can be divided into 16 power control groups 0 through 15 (one power control group consists of 24 bits); the transmission will occur on power control groups numbered:
   Spread Spectrum is also implemented by multiplying long code (1-bit multiples of 4-bit Long Code).
   Refer to [1].
   Long code is used to spread the output data; process gain is 4.

References

1. TIA/EIA/IS-95-A, Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System, May 1995, pp. 6-19 to 6-22.

CDMA_LongCodeGenerator



Description Generation of Long Code with 42-bit Regster Status
Library CDMA, Transmission
Class SDFCDMA_LongCodeGenerator

Parameters

Name	Description	Default	Type	Range
ChannelType	channel type:TrafficChannel, AccessChannel, PagingChannel: TrafficChannel, AccessChannel, PagingChannel	TrafficChannel	enum	
ACN	access channel number	0	int	[0, 31]
PCN	paging channel number	0	int	[0, 7]
BASE_ID	base station Identification	0	int	[0, 65535]
PILOT_PN	PN code offset for forward CDMA channel	0	int	[0, 511]
ESN1	first 16-bit electronic serial number	0	int	[0, 65535]
ESN2	last 16-bit electronic serial number	0	int	[0, 65535]

Pin Outputs

Pin	Name	Description	Signal Type
1	T_Mask	Mask value for test	int
2	LgCode	Long Code	int

Notes/Equations

1. This component is used to generate m-sequence bits with the period of 2^{42-1} bits long. The initial register status is:

   {00,0000000000,0000000000,0000000000,0000000001}

   (from the 42nd register to the first one) and shift 41 times.
   Each firing, 1 LgCode and 42 T_Mask output tokens are produced.
2. Implementation
   The long code period will be 2^{42-1} chips and will satisfy the linear recursion specified by the characteristic polynomial:

$$p(x) = x^{42} + x^{35} + x^{33} + x^{31} + x^{27} + x^{26} + x^{25} + x^{22} + x^{21} + x^{19} + x^{18} + x^{17} + x^{16} + x^{10} + x^{7} + x^{6} + x^{5} + x^{3} + x^{2} + x^{1} + 1$$

   There are three kinds of masks in IS-95A. Each PN chip of the long code will be generated by the modulo-2 inner product of a 42-bit mask and the 42-bit state vector of the sequence generator (refer to [1] page 6-23).
   Access Channel Long Code Mask

41	33, 32	28, 27	25, 24	9, 8	0
110001111	ACN	PCN	BASE_ID	PILOT_PN	

ACN - Access Channel Number
PCN - Paging Channel Number
BASE_ID - Base Station Identification
PILOT_PN - PN offset for the forward CDMA Channel

Traffic Channel Long Code Mask
When transmitting on the Reverse Traffic Channel, the mobile station uses a public long code mask:

41	32, 31	0
1100011000	Permuted ESN	

where

ESN = (E31,E30,E29,......E2, E1, E0)
permuted ESN = (E0, E31, E22, E13, E4, E26, E17, E8, E30, E21, E12, E3, E25, E16, E7, E29, E20, E2, E24, E15, E6, E28, E19, E10, E1, E23, E14, E5, E27, E18, E9)

refer to [1] page 6-24.
Paging Channel Long Code Mask

41	29 28	24 23	21 20	9 8	0
1100011001101	00000	PCN	000000000000	PILOT_PN	

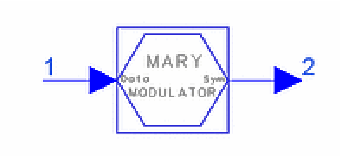
PCN - Paging Channel Number
PILOT_PN - Pilot PN code offset index for the Forward CDMA Channel

refer to [1] page 7-27.
In this component, the binary number must be converted to two 7-place octal Masks and add one 0 before each mask.

References

1. TIA/EIA/IS-95-A, Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System, May 1995.

CDMA_M_aryModulator



Description M-ary Modulator for Non-Coherent Detection
Library CDMA, Transmission
Class SDFCDMA_M_aryModulator

Pin Inputs

Pin	Name	Description	Signal Type
1	DataIn	the input data bit to be modulated	real

Pin Outputs

Pin	Name	Description	Signal Type
2	SymOut	the data chip after M_ary modulation	real

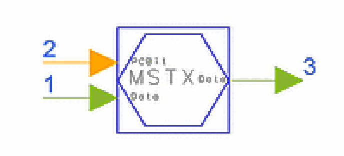
Notes/Equations

1. This component is used to convert 6-bit information sequence to 1 Walsh code (64 chips).
   Each firing 6 DataIn tokens are consumed; 64 SymOut 64 tokens are produced.
2. Implementation
   The 6-bit information sequence is converted to one decimal number that is used as the Walsh code index. The 6-bit information is then replaced by one Walsh symbol. The *n* th chip of the *m* th Walsh symbol W[n] is derived from:

   W[n]={m[5](and)n[5]} xor {m[5](and)n[5]} .... xor {m[0](and)n[0]}

   where, m[5] ~ m[0] is the input data, n is the *n* th output data, which is converted from decimal to binary.

CDMA_MSTX



Description Mobile Station Transmitter
Library CDMA, Transmission
Class SDFCDMA_MSTX

Parameters

Name	Description	Default	Unit	Type	Range
PowerControl	enable the Power Control: Yes, No: Yes, No	Yes		enum	
MS_Power	mobile station maximum output power	4.0	W	real	[0, ∞)
Init_Power	mobile station initial transmission power	1.0	W	real	[0, ∞)
PowerStep	Mobile Station power adjustmnet step, unit: dB	1.0		real	(-∞, ∞)
BlockLength	number of chips for each power control group	24		int	[1, ∞)
SignalType	type of input signal:BaseBand, IntermediateFrequency: BaseBand, IntermidiateFrequency	BaseBand		enum	

Pin Inputs

Pin	Name	Description	Signal Type
1	DataIn	MS Traffic Channel	complex
2	PCBit	Power Control Bit	int

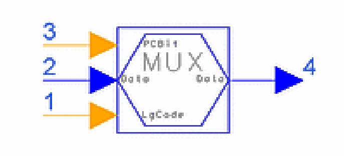
Pin Outputs

Pin	Name	Description	Signal Type
3	DataOut	Transmission Data	complex

Notes/Equations

1. This component is used to allocate real transmission for the mobile station and adjust output power according to the power control bit.
2. Each firing, DataIn consumes BlockLength tokens, PCBit consumes 1 token, and DataOut produces BlockLength tokens.
3. Implementation
   It is equal to assign amplitude for the normalized baseband signal, the amplitude is the power.
   Then if the power control bit is 0 the mobile station will increase its power at a PowerStep value; otherwise, the mobile station will decrease its power at a PowerStep value.

CDMA_MUX



Description MUX for Power Control Bit Pucture and Long Code Scrambling
Library CDMA, Transmission
Class SDFCDMA_MUX

Pin Inputs

Pin	Name	Description	Signal Type
1	LgCode	long code bits after decimator	int
2	DataIn	information data flow	real
3	PCBit	power contol bit from mearurement part	int

Pin Outputs

Pin	Name	Description	Signal Type
4	DataOut	combined information signal	real

Notes/Equations

1. This component is used to long code scramble the data and insert power control bits (2 successive identical bits) into one power control group.
   Each firing, 24 DataIn tokens, 24 LgCode tokens, and 24 PCBit tokens are consumed, and 24 DataOut tokens are produced.
2. Implementation
   MUX uses long codes to scramble data. MUX then replaces two information bits with power control bit (2 bits with the same value) at the place that the long code indicates. The power control bit initial position (first bit position) can be derived from the LgCode value:

   one power control group contains 24-bit long code (Long Code after decimator) denoted as
   b0, b1, b2, b3, ... b20, b21, b22, b23

   where

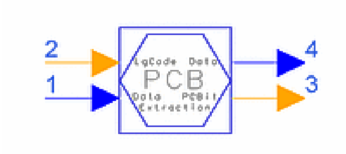
   b0 is the first one, and b23 is the latest one. Thus the initial position for power control bit is
   position= $2^3 \times b23 + 2^2 \times b22 + 2 \times b21 + b20$

   Refer to [1].

References

1. TIA/EIA/IS-95-A, Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System, May 1995.

CDMA_PCBitExtraction



Description Extract Power Control Bit and Descramble Data
Library CDMA, Transmission
Class SDFCDMA_PCBitExtraction

Pin Inputs

Pin	Name	Description	Signal Type
1	DataIn	input data	real
2	LgCode	long code	int

Pin Outputs

Pin	Name	Description	Signal Type
3	PCBit	power control bit	int
4	DatOut	data after extracting and de-scrambling	real

Notes/Equations

1. This component is used to extract the power control bit from decoded traffic bits, replace it with 0, and use long code to de-scramble the data. This component processes one power control group as a block (24 bits).
   Each firing 24 DataIn tokens and 24 LgCode tokens are consumed, and 1 PCBit token and 24 DataOut tokens are produced.
2. Implementation
   This component extracts the power control bit at every power control group and sends it to the mobile station power controller; it replaces the power control bits (2 successive identical bits) with 0. Two analogy values will be combined into one power control integer bit.
   The power control bit initial position (first bit position) can be derived from the LgCode value:

   one power control group contains 24-bit long codes (Long Code after deciminator) denoted as:
   b0, b1, b2, b3, ... , b20, b21, b22, b23

   where

   b0 is the first one, and b23 is the latest one.

   Thus the initial position for power control bit is:

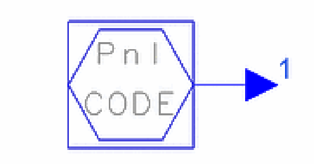
   $$\text{position} = 2^3 \times b23 + 2^2 \times b22 + 2 \times b21 + b20$$

   It then uses long codes to descramble the data.

References

1. TIA/EIA/IS-95-A, Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System, May 1995.

CDMA_PnICode



Description I-Path PN Code Generator for IS95A QPSK and OQPSK
Library CDMA, Transmission
Class SDFCDMA_PnICode

Parameters

Name	Description	Default	Type	Range
PN_Offset	base station PN code offset	0	int	[0, 512)

Pin Outputs

Pin	Name	Description	Signal Type
1	I_Code	I channel PN code	real

Notes/Equations

1. This component is used to generate PN code for in-phase path scrambling data. Each firing, one I_Code token is produced.
2. Implementation
   I-channel PN code is a 2^{15-1} bits M-sequence inserted by another 0, the polynomial is:

   $$P_I(x) = x^{15} + x^{13} + x^9 + x^8 + x^7 + x^5 + 1$$

   The maximum length linear feedback shift register sequence {i(n)} based on the above polynomials are of length 2^{15-1} and can be generated by linear recursions:

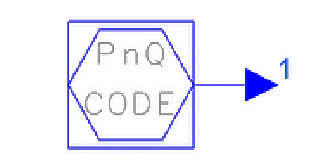
   $$i(n) = i(n-15) \oplus i(n-10) \oplus i(n-8) \oplus i(n-7) \oplus i(n-6) \oplus i(n-2)$$

   where additions are modulo-2. To obtain I sequences of period 2^{15}, 0 is inserted in {i(n)} after 14 consecutive 0 outputs.
   Refer to [1].

References

1. TIA/EIA/IS-95-A, Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System, May 1995, p 7-18.

CDMA_PnQCode



Description Q-Path PN Code Generator for IS95A QPSK and OQPSK
Library CDMA, Transmission
Class SDFCDMA_PnQCode

Parameters

Name	Description	Default	Type	Range
PN_Offset	base station PN code offset	0	int	[0, 512)

Pin Outputs

Pin	Name	Description	Signal Type
1	Q_Code	Q channel PN code	real

Notes/Equations

1. This component is used to generate PN code for quadrature path scrambling data. Each firing, 1 Q_Code token is produced.
2. Implementation
   Q-channel PN code is a 2^{15-1} -bit M-sequence inserted by another 0, the polynomial is:

   $$P_Q(x) = x^{15} + x^{12} + x^{11} + x^{10} + x^6 + x^5 + x^4 + x^3 + 1$$

   The maximum length linear feedback shift register sequence {q(n)} based on the above polynomials are 2^{15-1} and can be generated by linear recursions:

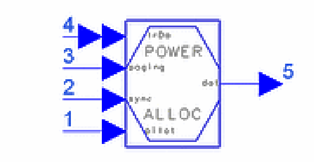
   $$q(n) = q(n-15) \oplus q(n-12) \oplus q(n-11) \oplus q(n-10) \oplus q(n-9) \oplus q(n-5) \oplus q(n-4) \oplus q(n-3)$$

   where additions are modulo-2.
   To obtain the I sequences of period 2^{15}, 0 is inserted in {q(n)} after 14 consecutive 0 outputs.

References

1. TIA/EIA/IS-95-A, Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System, May 1995, page 7-18.

CDMA_PowerAllocation



Description Power Allocation for Different Base Station Channel
Library CDMA, Transmission
Class SDFCDMA_PowerAllocation

Parameters

Name	Description	Default	Type	Range
PilotPowerRatio	ratio of pilot channel power to total power	0.2	real	[0, 1)
SyncRelativeDB	sync channel power relative to one traffic channel power, in dB	-3.0	real	(- ∞, ∞)
PagingRelativeDB	paging channel power relative to one traffic channel power, in dB	3.0	real	(- ∞, ∞)

Pin Inputs

Pin	Name	Description	Signal Type
1	Pilot	Pilot Channel Data	real
2	Sync	Sync Channel Data	real
3	Paging	Paging Channel Data	real
4	TrData	multi user data	multiple real

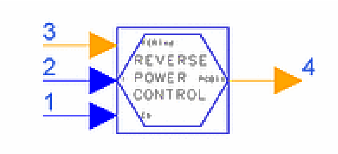
Pin Outputs

Pin	Name	Description	Signal Type
5	DatOut	output data	real

Notes/Equations

1. This component is used to allocate power for the forward transmission link (including pilot channel, sync channel, paging channel, and three forward traffic channels).
   The traffic channel data is multiple input; connected traffic users can automatically be detected and corresponding parts calculated.
   Each firing, BlockLength output tokens are consumed and BlockLength tokens are produced.
2. Implementation
   Assume each traffic channel has the same power and
   $CombinedSignalPower = \Sigma(EachChannel \times RelativeRatio)$

CDMA_ReversePowerControl



Description Reverse Power Control for Base to Mobile Transmission
Library CDMA, Transmission
Class SDFCDMA_ReversePowerControl

Parameters

Name	Description	Default	Type	Range
SIR_Threshold	minimum signal-to-interference ratio	4.5	real	[0, ∞)
SIR_AdjustStep	signal-to-interference ratio adjustment step	0.2	real	(- ∞, ∞)
FER_Threshold	threshold of frame error rate: if detected FER > the threshold, transmission power increased, and vice versa	0.01	real	[0, 1]

Pin Inputs

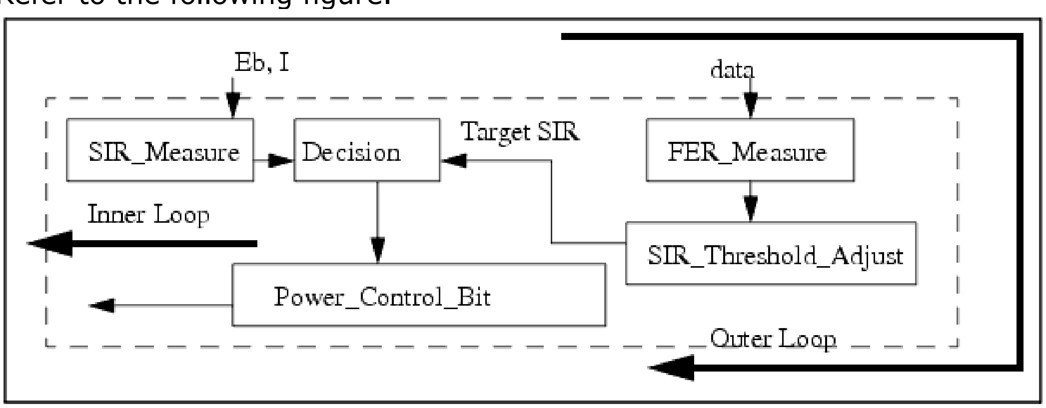
Pin	Name	Description	Signal Type
1	Eb	bit energy	real
2	I	interference	real
3	Rate	If Rate=5 or 6, it is a bad Frame	int

Pin Outputs

Pin	Name	Description	Signal Type
4	PCBit	Power Control Bit	int

Notes/Equations

1. This component is used to control base station transmission power to the mobile station to overcome the near-far effect and increase system capacity.
   Each firing, 1 token is consumed for each input and one token is produced for the output.
2. Implementation
   Refer to the following figure.



CDMA_ReversePowerControl Block Diagram

SIR_Measure is used to calculate the signal-to-interference ratio (SIR) for the Eb and I inputs:

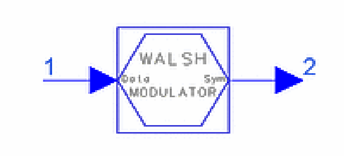
$$SIR = \frac{E_b}{I}$$

FER_Measure is used to calculate the frame error rate (FER). CRC determines whether or not a frame is good.

FER= number of good frames / number of total frames

Since high-rate frames (9600 bps or 4800 bps) have CRC, low rate frames (2400 bps and 1200 bps) are considered good. If the full rate frame is not good, the rate will be 5 to indicate an error frame; if the half rate frame is not good, the rate will be 6 to indicate an error frame.
SIR_Threshold_Adjust is used to calculate the actual SIR and adjust the SIR threshold according to the environmental requirement. If FER > FER_Min, the SIR threshold will be increased, otherwise it will be decreased. The new SIR threshold cannot be < SIR_Min.
Decision is used to compare the two current SIR and required SIR_Min.
Power_Control_Bit sets PCBit. If the current SIR > required SIR_Min, the output is set to 0, otherwise it is set to 1. Power_Control_Bit will be repeated, so the Power_Control_Bit will be 2 repeated bit values.

CDMA_WalshModulator



Description Walsh Modulator for 64-Bit Spread
Library CDMA, Transmission
Class SDFCDMA_WalshModulator

Parameters

Name	Description	Default	Type	Range
WalshCodeIndex	Walsh code index	0	int	[0, 63]

Pin Inputs

Pin	Name	Description	Signal Type
1	DataIn	the input data bit to be modulated	real

Pin Outputs

Pin	Name	Description	Signal Type
2	SymOut	the data chip after Walsh modulation	real

Notes/Equations

1. This component is used to generate 64-bit long Walsh symbols (0 ~ 63, each symbol has 64 bits) and spread one input data from forward channels with one Walsh symbol to 64 bits. Each firing, 1 DataIn token is consumed and 64 SymOut tokens are produced.
2. Implementation
   The *n* th chip of the *m* th Walsh symbol W[m][n] is derived from

   W[m][n]={m[5](and)n[5]} xor {m[5](and)n[5]} .... xor {m[0](and)n[0]}

   where, array m, n is a 6-dimension binary-number array that is converted from decimal number m, n.
   Walsh symbol (convert to bi-polar code) is used to multiply the input data, and one input data is spread. The process gain is 64.