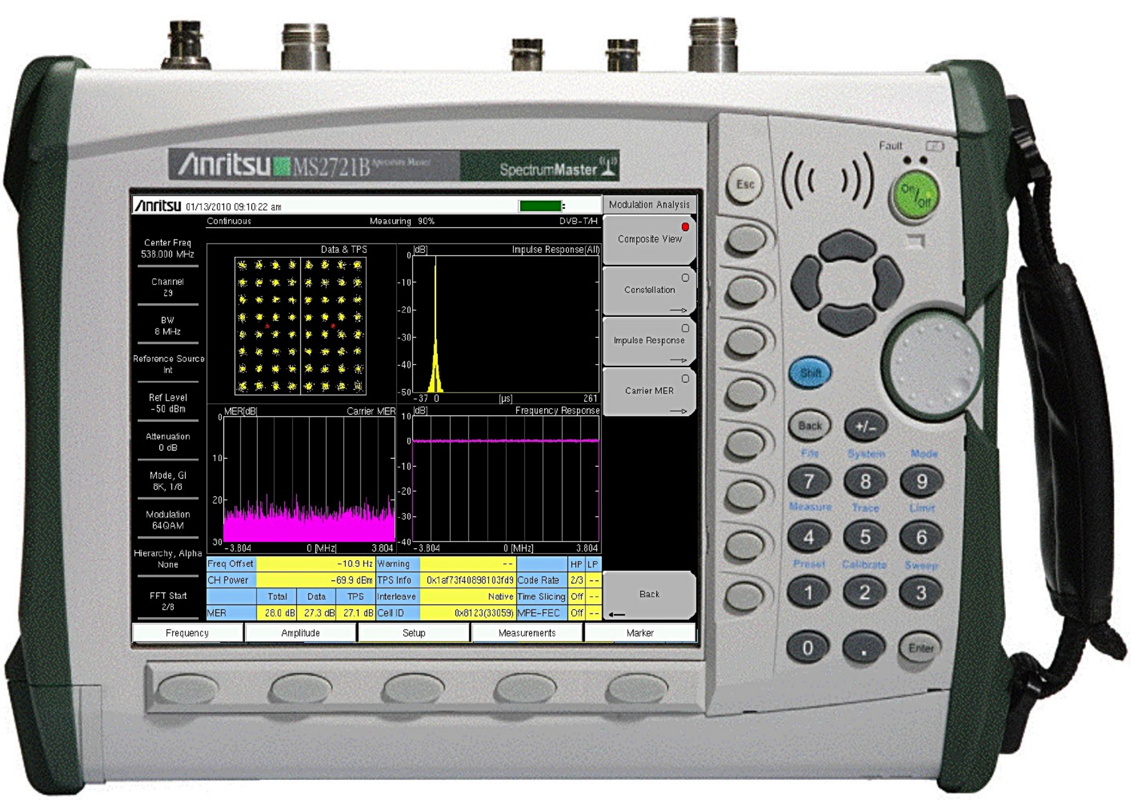
Application Note

DVB-T/H Field Measurements

MS2721B Spectrum Master™
MT8222A BTS Master™

Introduction

This application note describes the key measurements to perform on DVB-T/H digital terrestrial television transmitters during installation, commissioning and maintenance. It also describes how to monitor transmissions within the coverage area of a transmitter and how to interpret some typical measurement data and results. It focuses specifically on measurements pertaining to the DVB-T/H technology but occasionally references other digital television technologies where comparisons will aid understanding. The emphasis is very much towards the field measurement aspects of DVB-T/H and, as such, discusses the measurements as would be performed on Anritsu's handheld field test instruments, notably the **MS2721B Spectrum Master** and the **MT8222A BTS Master**. No prior knowledge of these instruments is necessary to review this application note. However, full details, including specification data sheets, instrument **User Guides** and the **Digital Television Measurement Guide** can be found at the www.us.anritsu.com website.



Brief History of Digital Television

For most of the last century, analogue techniques were used for television transmission. Slight modifications were implemented when black and white pictures were replaced with color in the 1960s and later, too, when stereo sound was transmitted digitally. Essentially, though, the RF television channel had not changed much for many decades. A single channel of, typically, 5, 6, 7 or 8 MHz bandwidth was required to transmit the content of one television station.

This worked reasonably well when the number of television stations was small. There was plenty of available bandwidth in the VHF and UHF spectrum and large geographical areas and, indeed, complete countries, could be served with judicious placement of transmitters and the re-use of channels at transmitter sites whose relative distances were likely to cause minimal or no interference.

However, towards the end of last century the number of television stations was growing rapidly. In many countries, the VHF part of the spectrum had been reallocated for other uses and so it was recognized that, going forward, it would become more difficult to squeeze the growing number of services into a smaller available spectrum.

About the same time, digital transmission technologies were being researched and developed and advances in data compression techniques on digitized video and audio information meant that it would be possible to transmit content from multiple program sources (stations) multiplexed together in the same RF channel. This improvement in bandwidth efficiency coupled with capacity needs being continuously variable depending on the level of compression and resolution of the required image meant that broadcasters could provide, say, a high definition television service or multiple standard definition services, multimedia or interactivity, all in the same bandwidth space. This was very exciting and the advance in transmission efficiency, in terms of information (bits) per second per Hertz of bandwidth, was obvious and compelling.

Figure 1. The chronology of television.

However, broadcasters could not just install new digital transmitters and immediately switch off the analogue ones. There would likely be a lag in the consumer industry before new receivers would be readily available and at a price that consumers themselves would feel comfortable adopting the new technology.

So, in every country where digital television has been adopted there has been, or is ongoing, a transition period usually lasting some years where both analogue and digital transmissions co-exist at the same transmitter sites. It's somewhat ironic that in trying to find more efficient transmission of an increasing number of television channels, broadcasters first have to accommodate the transmission of both analogue and digital versions of the same program material in the same limited spectrum, without causing interference between them.

From the late 1990s and continuing today, the transition to digital is progressing. Some countries have completed the transition and achieved Analogue Switch Off (ASO), whereas others have not started yet. However, by far the majority of countries are in transition and will each have a target date for ASO. Some of those dates have been determined not only by the desire to offer digital television services but also by governments' needs to re-use some of the spectrum traditionally used for public service broadcasting for other digital services unrelated to the broadcast field. Spectrum is a valuable commodity and the UHF spectrum in particular has long been coveted by other service providers.

Digital Television Basics

As in analogue terrestrial television where there are many standards around the world (PAL, SECAM and NTSC), so there are in digital terrestrial television. The vast majority use multiple carrier Coded Orthogonal Frequency Division Multiplexing (COFDM) techniques. The two most prevalent technologies using this technique are DVB-T/H and ISDB-T. Other technologies are used and, in particular, the ATSC system used in North America and South Korea is a single carrier system using 8VSB modulation. Figure 2 shows the extent of various digital terrestrial television technologies.

Digital Video Broadcast – Terrestrial (DVB-T) and Digital Video Broadcast - Handheld (DVB-H) were developed by the DVB Project. There is much commonality between the two standards which is why they are often lumped together as DVB-T/H. However, DVB-H has some extra features which improve its robustness in mobile reception environments. DVB-T is the most widely adopted digital terrestrial television standard.

Integrated Services Digital Broadcast – Terrestrial (ISDB-T) was developed and maintained by the Association of Radio Industries and Businesses (ARIB) in Japan. The technology, with minor modifications, is also used in Brazil and adopted extensively now throughout the rest of South America.

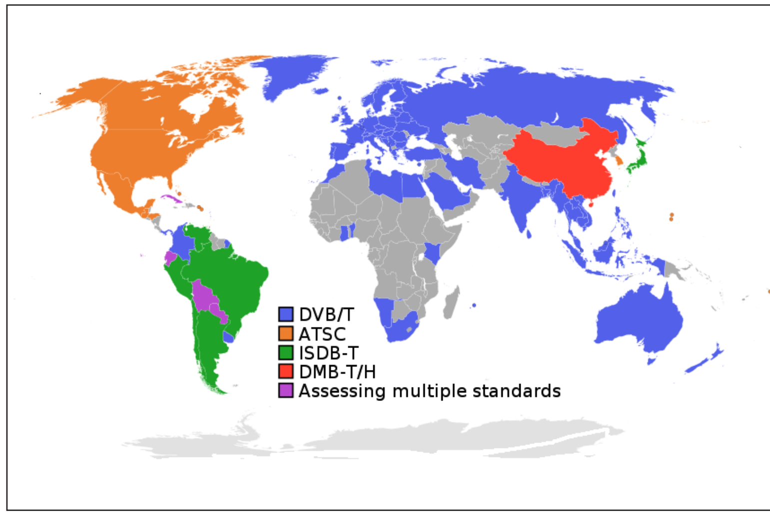


Figure 2. Global digital terrestrial television technology adoption Feb 2010.

Orthogonal Frequency Division Multiplexing (OFDM)

OFDM takes a serial data stream to be transmitted and spreads it over a large number of carriers, typically more than a thousand and sometimes many thousands. The data rate conveyed by each carrier is correspondingly reduced and the symbol length is in turn extended. These modulation symbols on each of the carriers are arranged to occur simultaneously.

The carrier spacing is uniform and deliberately chosen so that it is the inverse of each symbol duration. This choice of carrier spacing ensures orthogonality (the 'O' of OFDM) of the carriers which means that the influence of adjacent carriers (in fact all other carriers) on the demodulation of a particular carrier is zero. It ensures there is no crosstalk between carriers, even though there is no explicit filtering and their spectra overlap. Figure 3 illustrates this.

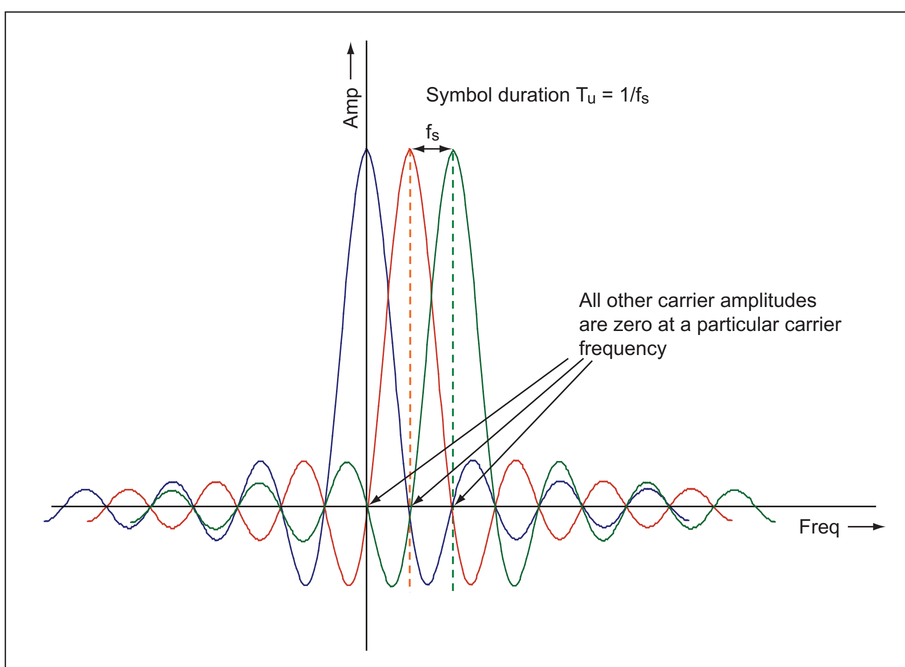


Figure 3. Orthogonality.

A further refinement adds the concept of a guard interval. Each modulation symbol is transmitted for a duration which is longer than the active symbol period by a period called the guard interval. It is generated by copying the last fraction of the active symbol and placing it at the front of the active symbol period as shown in Figure 4. This means that a receiver will experience neither inter-symbol nor inter-carrier interference provided that any multi-path echoes present in the signal have a delay which does not exceed the guard interval. Naturally, the data throughput is reduced by an amount determined by the guard interval length. With both DVB-T/H and ISDB-T, the number of carriers is scalable so that it is possible to protect against echoes with prolonged delay simply by choosing a larger number of carriers such that the guard interval need not form too great a fraction of the active symbol period. Both can specify a guard interval which is no greater than 1/4 of the active symbol period, but can protect against echo delays in excess of 200 μs depending on the mode chosen.

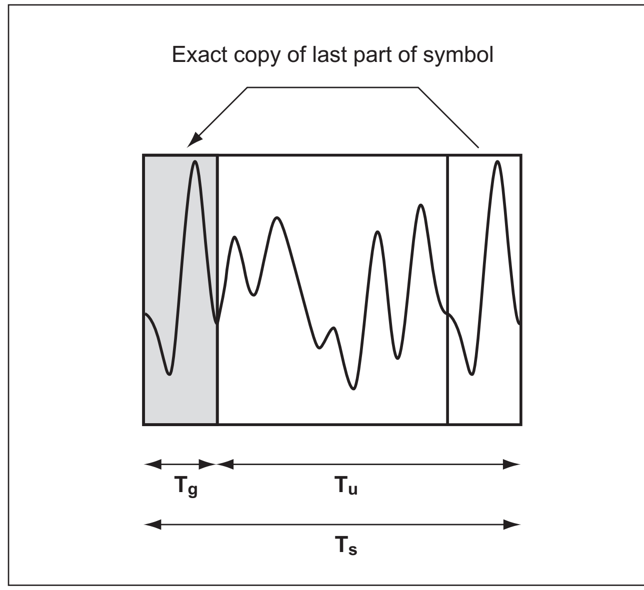


Figure 4. Guard interval generation.

In DVB-T there are two carrier modes, 2K and 8K modes. DVB-H has an extra 4K mode possibility. The total number of carriers and all associated parameters for an 8 MHz channel bandwidth are shown in Table 1.

	Mode		
OFDM Parameter	2K	4K	8K
FFT size	2048	4096	8192
Modulated carriers	1705	3409	6817
Data carriers	1512	3024	6048
OFDM symbol duration μs	224	448	896
Guard interval durations μs	7,14,28,56	14,28,56,112	28,56,112,224
Guard interval proportions	1/32, 1/16, 1/8, 1/4		
Carrier spacing Hz	4464	2232	1116

Table 1. DVB-T/H parameter choices for 8 MHz channel bandwidth.

COFDM

To enhance the reliability of transmission the data are coded with Forward Error Correction (FEC), specifically an outer Reed-Solomon (RS) correction for correcting erroneous bytes and a variable inner convolutional code for correcting erroneous bits. It should be noted that the FEC reduces the useful data throughput rate. The RS coding reduces it by a fixed amount but the variable convolutional coding provides scalability from highly robust but lower net rate transmissions to highest rate transmissions with minimal robustness depending on the particular transmission requirements.

By far the most common and potentially problematic occurrence during transmission is an interference burst, as could be caused by a lightning event for example, which may corrupt a continuous block of sequential data. To reduce the detrimental effects of such an event, data are also subjected to both byte- and bit-wise interleaving before transmission. In ISDB-T systems, it is also interleaved in time where original consecutive data are transmitted in different symbols. Figure 5 shows the location of the byte interleaver in DVB-T/H.

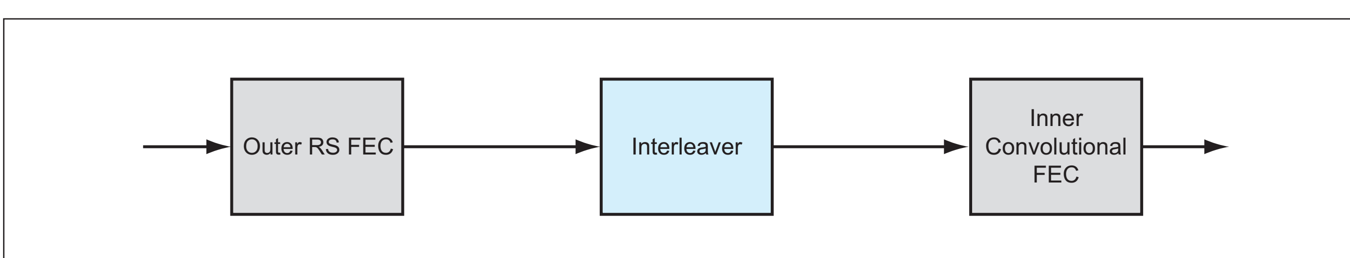


Figure 5. Forward error correction order for transmission.

However, this “coding” of the OFDM structure only makes limited improvement in the transmission robustness. Also transmitted in the OFDM structure are pilot signals, some continuous and some discontinuous or “scattered”. Figure 6 shows a portion of the OFDM frame showing the configuration of the pilot signals. The data conveyed by these pilot signals are known by the receiver and can therefore use this information to derive the channel state information. This can vary significantly across the channel and also over time but knowledge by the receiver of the channel state can greatly improve the performance of the forward error correction in the receiver.

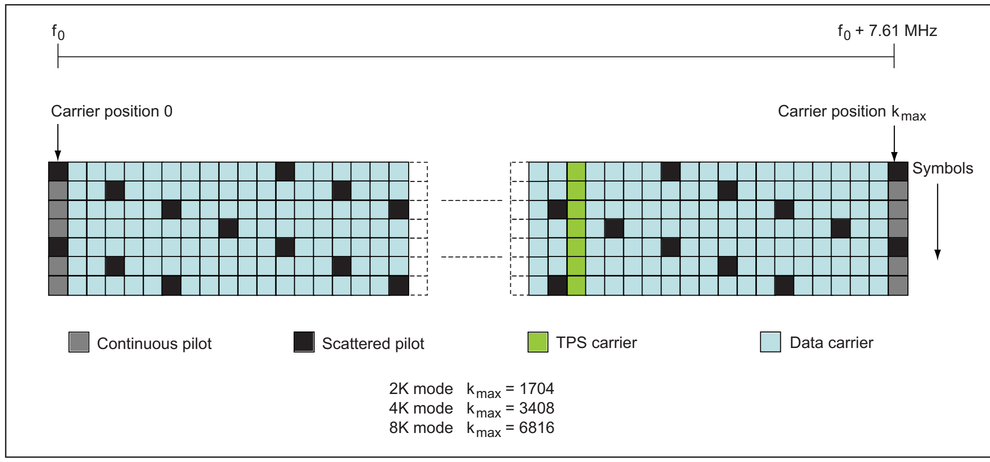


Figure 6. OFDM structure with pilot and TPS carrier positions.

Transmission Parameter Signaling (TPS)

In addition to the data and pilot carriers, DVB-T/H also transmits TPS carriers. They are used for the purpose of signaling parameters related to the transmission scheme including, among other information, channel coding and modulation. The TPS is transmitted in parallel on 17 TPS carriers for the 2K mode and on 68 carriers for the 8K mode. Every TPS carrier in the same symbol conveys the same differentially encoded information bit.

Modulation and Hierarchical Transmission

In DVB-T/H, each data carrier is modulated with QPSK, 16QAM or 64QAM. However, the broadcaster may want to transmit services simultaneously aimed at different types of receiver. For example, it may want to target fixed receivers with roof-top antenna installations at the same time as portable receivers. Clearly, the signal to portable receivers would need more robust FEC protection because of the poorer reception conditions. Alternatively, a broadcaster may want to transmit both high definition and standard definition services but to different coverage areas.

Both these scenarios can be realized using hierarchical transmission. Basically, the transport stream or TS (packets of the multiplexed programs’ video and audio data) is split into a high-priority (HP) and low-priority (LP) stream and coded separately. The HP stream would be subjected to the more robust FEC.

Additionally, scalable non-uniform constellations can be employed to further improve signal to noise reception conditions of the HP stream but to the detriment of the LP stream. Figure 7 shows a hierarchical transmission with non-uniformity (α-factor) of 4 giving the best signal to noise conditions for the HP stream.

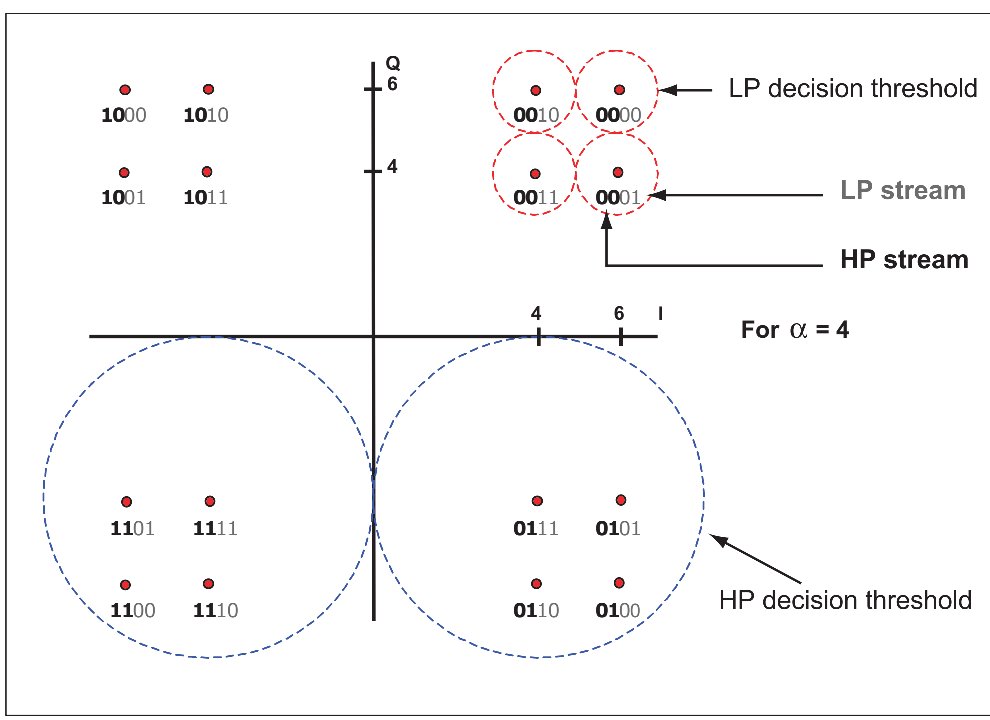


Figure 7. Hierarchical modulation with α factor 4.

Making and Understanding DVB-T/H Measurements

Verifying digital television transmission performance requires broadcast technicians to measure many types of parameters, some unique to the broadcast industry. They can be broadly split into three types:

- RF measurements
- Modulation Analysis measurements
- Bit Error Ratio (BER) measurements

Some measurements may require a direct physical connection to the transmitter and others will require an indirect connection or "over the air" measurement via an antenna. Some can be performed in either configuration. However, care must be taken when connecting directly to a transmitter output since the high powers associated with television transmitters will damage the test equipment. Usually, at transmitter installations, there is a directional coupler connected in line with the main RF signal. It provides a decoupled test point typically 30 to 60 dB down on the main transmitted signal which can be connected to the RF In port of the BTS Master or Spectrum Master. Note that the maximum input damage level of the RF In port is +43 dBm.

To measure a DVB-T/H signal over the air, connect an appropriate frequency band antenna to the BTS Master or Spectrum Master RF In connector.

Before commencing, press the Shift key and then the Mode (9) key. Use the directional arrows or rotary knob to highlight DVB-T/H Signal Analyzer and press Enter to select.

RF Measurements

Unless a user has extensive experience or is only intending to make specific measurements, it's always good practice to start with RF measurements. All measurements require a certain amount of setting up and the RF measurement section ensures the user is tuned to the correct channel for analysis before progressing further.

The frequency accuracy can be improved by using an optional internal GPS receiver. It is recommended that this option be specified to improve the accuracy of frequency offset measurements especially when working with single frequency networks. As well as establishing a very accurate frequency reference for measurement, it also enables measurements to be logged against geographical position.

To set up the GPS, connect the GPS antenna (supplied with the option) to the GPS receiver input. Place the antenna with a clear view to the sky so that it can detect the satellite signals. On the BTS Master or Spectrum Master, press the Shift key and then the System (8) key. Press the GPS soft key and turn on the GPS function. After a few minutes, GPS synchronization will be achieved and the high accuracy frequency reference established. Once established, the GPS antenna can be removed and the high accuracy will be maintained for 24 hours.

To set the frequency of operation, press the Frequency hard key. Select the frequency using the Frequency soft keys either by selecting a signal standard and channel number or setting the frequency manually. The DVB-T/H application supports 5, 6, 7 and 8 MHz bandwidths which will be selected automatically for the specified signal standard or can be manually set.

During the transition period from analogue to digital, sometimes standard offset frequencies from the normal channel frequencies are used for the digital channels to prevent interference with adjacent analogue channels. Standard offset frequencies of ±166.666 kHz, ±333.333 kHz and ±499.999 kHz can be chosen from the Frequency menu to aid tuning if required.

Press the Amplitude hard key to set the reference level for the measurement. For manual setting press the Reference Level soft key and set an appropriate reference level and press the Pre Amp soft key to set the internal preamplifier On if required. For automatic setting according to the total signal input power, press the Auto Reference Level soft key. This sets the reference level, preamplifier status and input attenuation automatically and is the method recommended for most measurements.

Spectrum Monitor

This measurement displays the frequency response over the selected channel and the channel power in dBm. It can be performed directly connected or over the air using an antenna. For over the air connection, the variable span supports the display of up to 51 channels simultaneously, so that the broadcast service signals can be checked at a glance. It is also a convenient method to select a particular channel for measurement.

1. Press the Measurements hard key.
2. Press the RF Measurements soft key.
3. Press the Spectrum Monitor soft key to select the spectrum monitor measurement. The red dot on the soft key indicates it is selected.
4. Press the Spectrum Monitor soft key again to display the Spectrum Monitor menu soft keys.
5. Press the Span soft key.
6. Use the directional arrow keys or the rotary knob to highlight the required span. Press Enter.
7. Use the rotary knob to move the green zone marker to the desired signal. Press the Zone Position to Center soft key or the Enter key to move the selected signal to the center of the screen.
8. Press the Span soft key and select an appropriate span setting to zoom in to the desired signal.

Figure 8a and 8b show the spectrum monitor displays with channel power measurement.

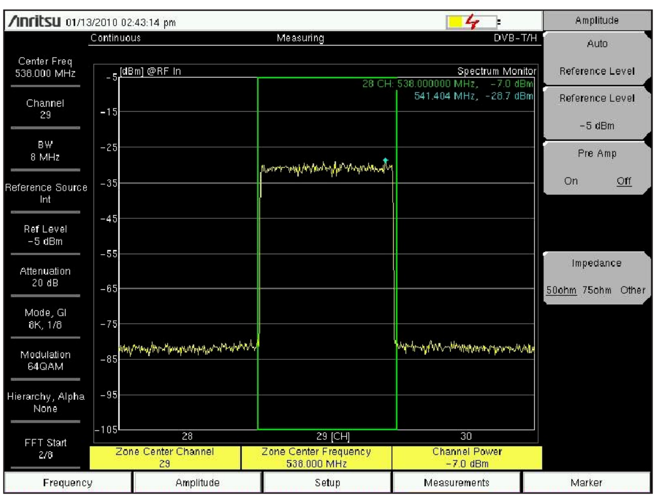


Figure 8a. Spectrum Monitor of a transmitter output.

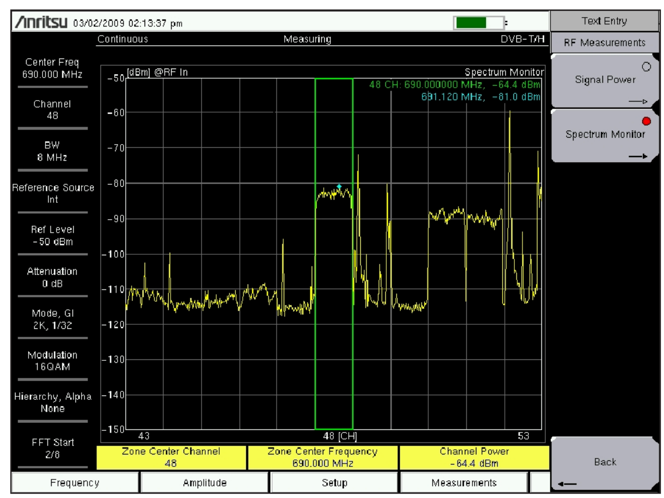


Figure 8b. Over the air measurement.

Signal Power

This measurement can be performed with either a direct connection to the transmitter or over the air. When connected directly, the channel power in dBm of the transmitter output can be measured. In over the air measurement configuration using an antenna, in addition to the channel power, the termination voltage in dBμV, open terminal voltage in dBμV (emf) and field strength in dBμV/m can also be measured. This configuration allows broadcast technicians to assess the received signal strength at various locations in the coverage area to determine the likely quality of reception. At some locations, because of the natural or man-made topography, the signal may be masked giving a poor signal strength measurement. Consequently, it would be necessary to install an additional repeater or gap-filler to provide appropriate coverage.

The measurement of field strength requires that the antenna factors of the antenna connected to the test instrument are known and applied to the termination voltage to derive the field strength. As standard, the antenna factor curves for many Anritsu supplied antennas are already downloaded to the BTS Master and Spectrum Master for selection. Other antennas, whose antenna factors are known, can be added to the list using Anritsu's Master Software Tools pc program provided free with the instrument. The procedure to do this is outside the scope of this application note but full details are available in the BTS Master and Spectrum Master User Guides or at www.us.anritsu.com.

1. Follow steps 1 and 2 in the Spectrum Monitor section.
2. Press the Signal Power soft key to select the signal power measurement. The red dot on the soft key indicates it is selected.
3. Press the Signal Power soft key again to display the Signal Power menu soft keys.
4. Press the Antenna soft key.
5. Use the directional arrow keys or the rotary knob to highlight the antenna used. Highlight None for direct connection measurements at the transmitter. Press Enter.

Figure 9 is a signal power measurement display showing the key parameters measured and the antenna used with its antenna (correction) factor at the frequency of operation. The yellow line on the termination voltage bar graph is the maximum voltage detected during the measurement and is useful for aligning a directional antenna to the transmitter.

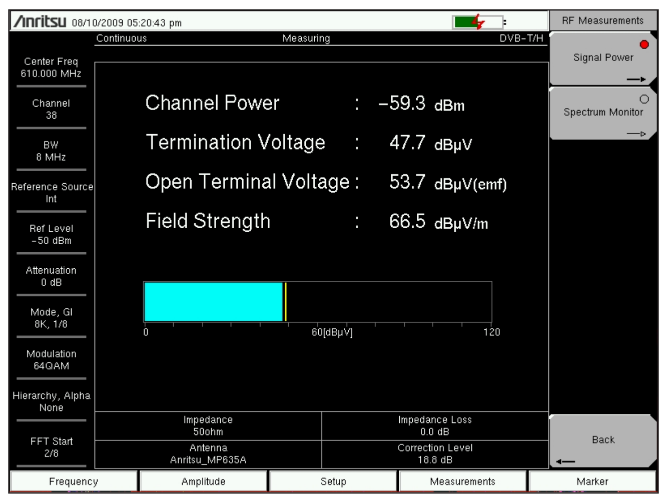


Figure 9. Signal Power measurement.

Modulation Analysis Measurements

Whereas the previous RF measurements section looked at the parameters measured on the overall envelope of the RF signal, the modulation analysis measurements determine the parameters of the content of the signal.

When connected directly to the transmitter, the combination of RF and modulation analysis measurements provides full characterization of the transmitter performance.

Modulation analysis measurements may also be performed over the air and, again, in combination with RF measurements, can determine any degradation in signal quality caused by external factors and the likely reception quality at various locations.

Modulation Error Ratio (MER)

A fundamental measurement parameter to understand in digital broadcast is Modulation Error Ratio (MER). It has some similarities with Error Vector Magnitude (EVM) which is often used in other digital modulation systems. MER is a “figure of merit” for the carrier transmission quality.

MER is expressed as follows:

$$MER = 10 \times \log_{10} \left\{ \frac{\sum_{j=1}^{N} \left(I_j^2 + Q_j^2 \right)}{\sum_{j=1}^{N} \left(\delta I_j^2 + \delta Q_j^2 \right)} \right\}$$

where I_j and Q_j are the ideal coordinates of the j^{th} symbol, δI_j and δQ_j are the errors in the received j^{th} symbol point and N is the number of symbols in the measurement sample. Figure 10 shows a diagrammatic representation.

An empirical analysis of the equation reveals that as errors reduce (better received quality), the MER tends towards a large number and vice versa.

MER is preferred over EVM in broadcasting because the range of typical values and sensitivity of the measurement give MER an immediate familiarity for those having experience of Carrier-to-Noise (C/N) or Signal-to-Noise ratio (SNR) measurement. In fact, MER can be regarded as a form of Signal-to-Noise ratio measurement that will give an accurate indication of a receiver’s ability to demodulate the signal because it includes all uncorrectable impairments of the received constellation. Indeed, if the only significant impairment present in the signal is Gaussian noise then MER and SNR are equivalent.

Another useful property of MER is that the value is independent of the modulation scheme so that for the same absolute error values, the MER is the same for QPSK, 16QAM or 64QAM making comparison of measurements straightforward.

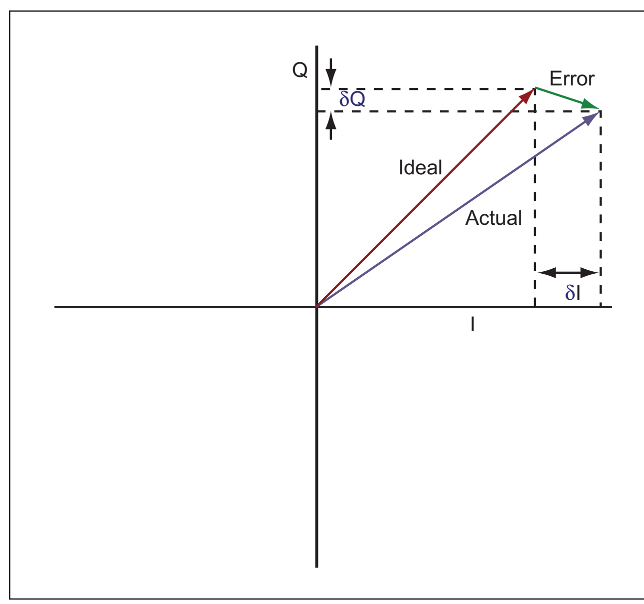


Figure 10: Modulation Error Ratio.

As described earlier when discussing COFDM, the transmissions are protected with forward error correction (FEC). The net effect of this is that signals will continue to be received error-free with worsening MER. In fact, the range of MER values over which the bit error ratio (BER) starts to degrade from zero to a value which causes a loss of picture in the receiver is very small (figure 11). Therefore, measuring BER alone will give little indication as to how close the received signal is to this threshold. On the other hand, MER will give an accurate measurement of the quality of the received signal and, hence, the margin that a receiver has to be able to demodulate the signal error-free.

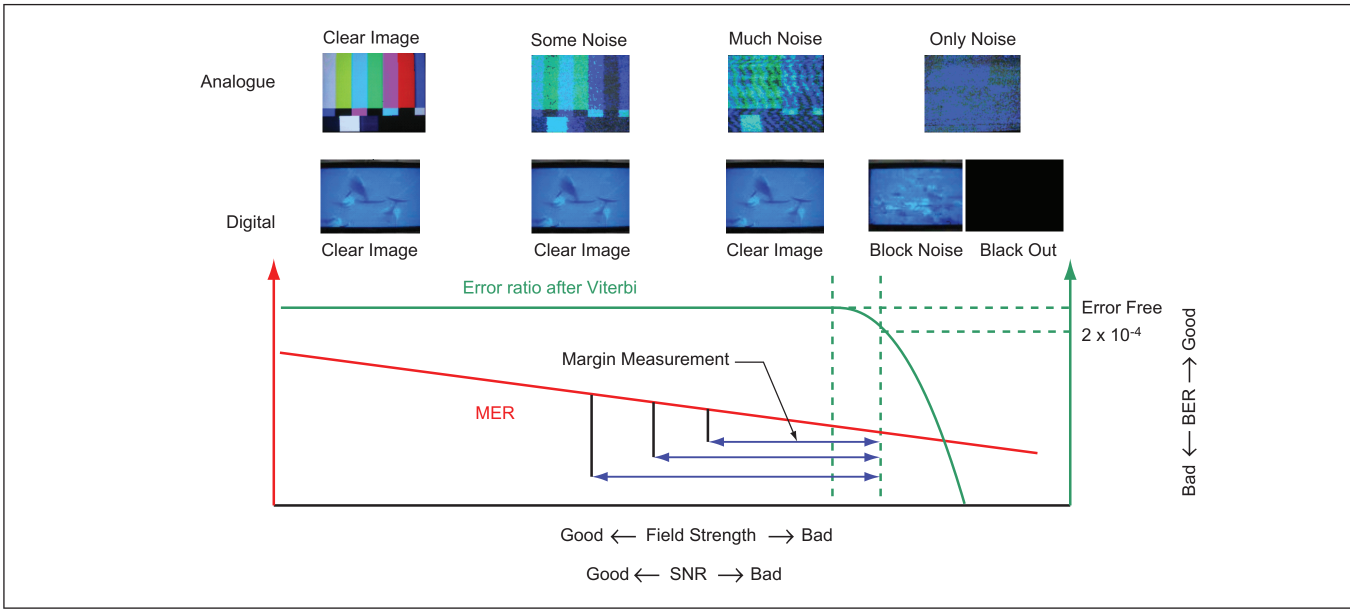


Figure 11. Relationship between BER and MER.

Constellation

In DVB-T/H, data are modulated onto the OFDM carriers using QPSK, 16QAM or 64QAM. The TPS carriers are modulated using differential BPSK (DBPSK). The constellation measurement allows the constellations of both the data and TPS carriers to be viewed on one screen. Additional measurement data are also shown in a summary area at the bottom of the display which is common to all modulation analysis measurement screens. These measurements are discussed later.

When connected directly to the transmitter, the constellation measurement can analyze the effects of various components (for example, the modulator, power amplifiers, output channel filters, etc) on the modulation constellation.

Constellation measurement in over the air configuration is also useful for checking received signal quality at key reception sites.

For the following measurement steps it is assumed that the Spectrum Master or BTS Master is already tuned to the frequency channel of interest and the reference level has been set appropriately according to the procedure explained at the start of the RF Measurements section.

1. Press the Measurements hard key.
2. Press the Modulation Analysis soft key.
3. Press the Constellation soft key to select the constellation measurement. The red dot on the soft key indicates it is selected.
4. Press the Constellation soft key again to display Constellation menu soft keys.
5. Press the Graph Annotation soft key to set the constellation symbol decision lines to be drawn on the graph if required.
6. Press the Setup hard key to display the Meas Setup menu soft keys.
7. Press the Detect Parameters Once soft key. Alternatively, press the Auto Detect Parameter soft key to set this function On.

Either of these functions has a similar effect in that they will both interrogate the TPS carriers and decode the relevant transmission parameters. The mode, guard interval, modulation and hierarchy will be set automatically according to the decoded data so that the signal can be demodulated correctly.

If measurements will continue on the same channel frequency and the signal reception is stable, use the Detect Parameters Once method. The detected parameters will remain relevant for all other modulation analysis measurements.

If measurements will be performed on many channels or the signal reception conditions are variable, it will be more convenient to use the Auto Detect Parameters method. A TPS interrogation will be triggered automatically each time the channel frequency is changed or the received signal level changes considerably.

If the TPS parameters are known they can be set manually if desired by pressing the Advanced Settings soft key in the Meas Setup menu and selecting each parameter setting in turn.

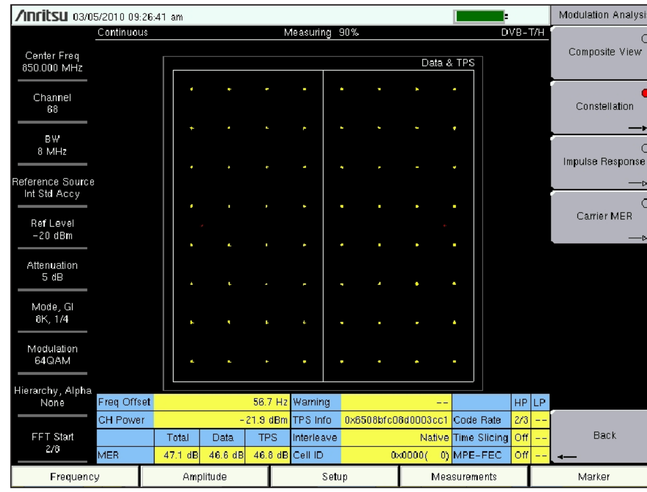


Figure 12. 64QAM constellation also showing TPS modulation.

8. Press Meas Mode soft key and use the directional arrow keys or the rotary knob to highlight the required mode (Single, Continuous, Average or Moving Average). Press Enter.

9. Press Trigger Sweep to restart the measurement if required.

Figure 12 shows a typical constellation measurement obtained directly connected to a transmitter test point. Note the DBPSK modulated TPS data in red.

Carrier MER

The carrier MER measurement is used to measure the MER of each individual carrier. When connected directly to the transmitter, it will show any carrier or group of carriers which have poor or suspect MER. A normal transmitter should have a MER around 40 dB or more across all carriers (figure 13a).

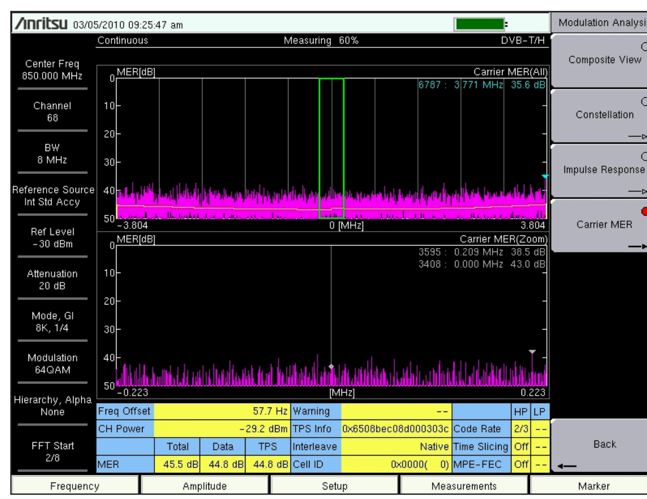


Figure 13a. Carrier MER measurement.

Over the air carrier MER can be used to assess the likely reception quality and can also be used to detect narrowband interfering signals. Figure 13b shows the effect of an interfering signal in the position of carrier 292 depicted by the marker on the top trace. Depending on the type of scenario from indoor to high-gain rooftop reception, carrier MERs from 12 to 30 dB should be expected.

Ensure the channel frequency and reference level have been set appropriately.

1. Follow steps 1 and 2 in the Constellation measurement section.

2. Press the Carrier MER soft key to select the carrier MER measurement. The red dot on the soft key indicates it is selected.

3. Press the Carrier MER soft key again to open the Carrier MER soft key menu.

4. Press the Vertical Range soft key. Select the appropriate vertical range for the measurement and then press the Back soft key.

5. Press the Measurement Type soft key to select either Speed or Accuracy. The selected type is underlined.

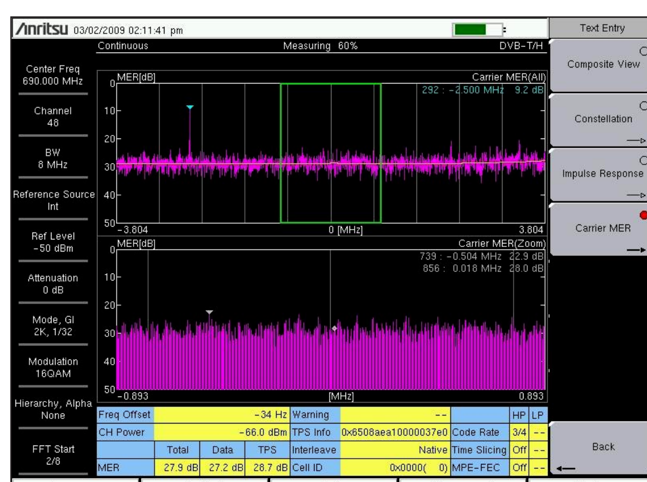


Figure 13b. Over the air carrier MER showing narrowband interfering signal.

Accuracy measurement type integrates the measurement over a greater number of symbols and consequently takes longer to update the measurement but has improved accuracy. Speed measurement type integrates the measurement over fewer symbols but updates faster.

6. Press the Marker hard key to open the Marker soft key menu.
7. Press the Marker soft key to turn on the marker function.
8. Press the Active Marker soft key to select the active marker to be on the Zoom (lower) or All (upper) trace. The selected trace is underlined.
9. If the active marker is on the All trace a green rectangle depicts the area of the carrier MER trace which is expanded into the lower Zoom trace. Use the directional arrow keys or the rotary knob to highlight the region of the carrier MER trace to expand.
10. If the active marker is on the Zoom trace the expanded region is grayed out on the All trace. Use the directional arrow keys or the rotary knob to move the marker to the desired position on the Zoom trace.

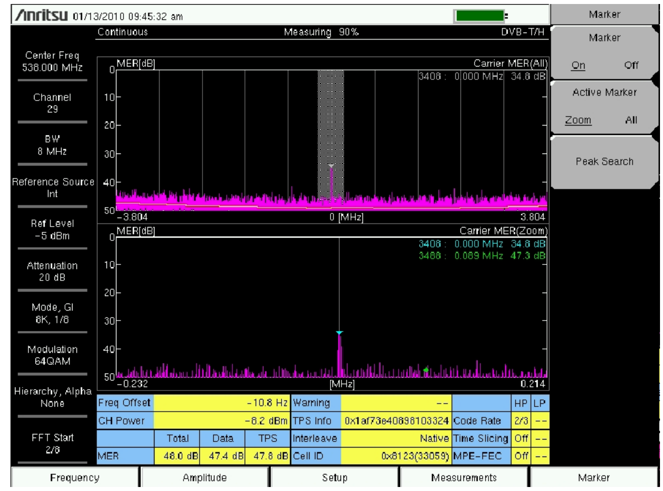


Figure 13c. Typical carrier leakage MER display.

11. Press the Peak Search soft key to position the marker to the peak (worst) carrier MER value on the Zoom trace.

Figure 13c depicts a carrier leakage problem caused by, for example, dc signal components in the I/Q modulator.

Impulse Response

This measurement is performed only over the air. It measures the relative delay and amplitude of signal echoes compared with the main signal. Echoes can be caused by signals from the transmitter reflecting off mountains or buildings and can also be transient in nature as would be caused by reflections from a moving vehicle. It is important for good reception that all echoes arrive at the reception point within the guard interval period.

In single frequency networks (SFN) all transmitters are set to the same frequency. In this case, signals may be received from multiple transmitters as well as echoes of each transmitted signal. Again, for good reception, all signals, main or echo, must arrive within the guard interval period.

Ensure the channel frequency and reference level have been set appropriately.

1. Follow steps 1 and 2 in the Constellation measurement section.
2. Press the Impulse Response soft key to select the impulse response measurement. The red dot on the soft key indicates it is selected.
3. Press the Impulse Response soft key again to open the Impulse Response soft key menu.
4. Press the Vertical Range soft key to select a suitable range. Press the Back soft key.
5. Press the 0 μs Position soft key and use the directional arrow keys or the rotary knob to highlight the position required. Press Enter.

The measurement always sets the largest received signal at 0 μs and the default position is at the left of the trace. This is acceptable for most scenarios as the largest signal is usually the main line-of-sight received signal. This becomes the 0 dB, 0 μs reference response. All echoes have smaller amplitudes and will be received later and consequently appear to the right of the main response.

If the largest received signal is not the least delayed so that there appear pre-echoes, the 0 μs position can be moved to show the pre-echo responses.

6. If necessary, press the Path_Posn_Keep soft key to set this function On. This will fix the signal path at the 0 μs position.

If the largest received response changes, as may happen from a transient reflection, so that the response at 0 μs also changes, a specific response can be fixed at this position to stabilize the trace.

7. Press the Marker hard key to open the Marker soft key menu.
8. Press the Marker soft key to turn on the marker function.
9. Press the Active Marker soft key to select the active marker to be on the Zoom (lower) or All (upper) trace. The selected trace is underlined.
10. If the active marker is on the All trace a green rectangle depicts the area of the impulse response trace which is expanded into the lower Zoom trace. Use the directional arrow keys or the rotary knob to highlight the region of the impulse response trace to expand.
11. If the active marker is on the Zoom trace the expanded region is grayed out on the All trace. Use the directional arrow keys or the rotary knob to move the marker to the desired position on the Zoom trace.

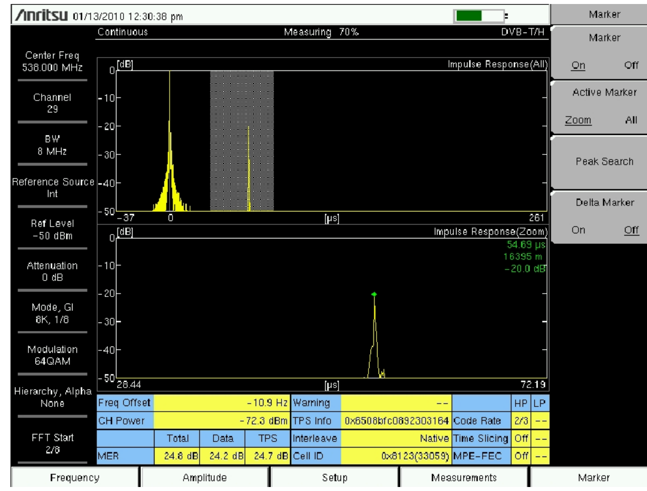


Figure 14. Impulse Response measurement.

12. Press the Peak Search soft key to position the marker to the peak value on the Zoom trace.
13. Press the Delta Marker soft key to turn on the delta marker. Use the directional arrow keys or the rotary knob to move the delta marker to the desired position on the Zoom trace and read the delta time, distance and level.

Figure 14 shows an echo signal delayed by about 55 μs, equivalent to about 16.5 km distance.

Composite View

A unique feature of the BTS Master and Spectrum Master is the composite view display which encapsulates on one screen the constellation measurement, carrier MER measurement and impulse response measurement. An additional frequency response measurement completes the modulation analysis summary.

1. Follow steps 1 and 2 in the Constellation measurement section.
2. Press the Composite View soft key to select the composite view measurement. The red dot on the soft key indicates it is selected.

Figure 15a shows a composite view measurement.

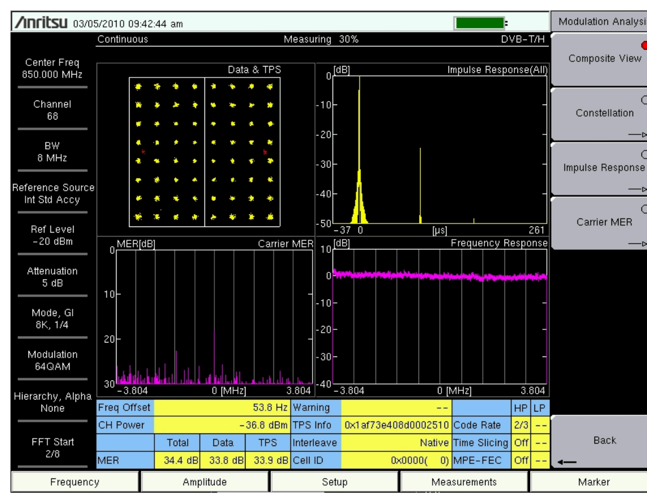


Figure 15a. Composite View screen.

The composite view is a very useful diagnostic tool that can be used to identify some common transmission problems and effects which may not be so obvious when looking at each modulation analysis measurement in isolation. For example, the combination of constellation and carrier MER measurements can reveal specific transmitter impairments.

Figure 15b shows the effect of amplitude instability as may be caused by an unstable amplifier, for example. Note the “exploding” constellation and the uniform worsening MER across the channel.

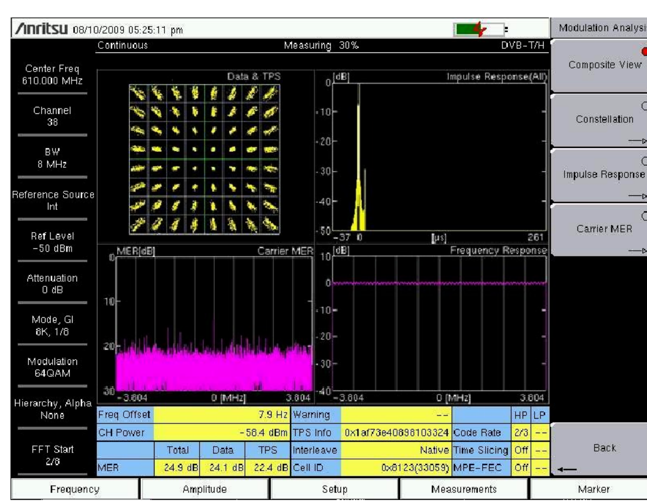


Figure 15b. Amplitude instability.

In contrast, figure 15c shows a rotational blurring of the constellation data and a general deterioration of the carrier MER evenly across the channel. There are two main causes: signal timing jitter in the IQ modulator in the transmitter or frequency instability of the RF signal. If the frequency offset reading in the results panel beneath the traces is stable the cause if more likely to be the former.

Another common and potentially serious phenomenon especially in single frequency networks (SFN), is FFT sampling frequency error. The FFT sampling clock governs the frequency spacing between the carriers and consequently the length of the symbols (excluding the guard interval). Therefore, any error will affect the overall bandwidth of the modulated signal and also the symbol rate. In SFNs, where signals from two or more transmitters are received simultaneously, if their respective FFT clock frequencies differ, each signal will potentially interfere with the others. It may be intuitively understood that, if there is an error in the FFT sampling frequency, the frequencies of the carriers towards the extremes of the channel bandwidth differ from their norm more than those nearer the center of the channel. Figure 15d shows this effect by the V-shaped carrier MER trace, with worse MER away from the channel center. The corresponding angular smearing of the constellation confirms the phenomenon.

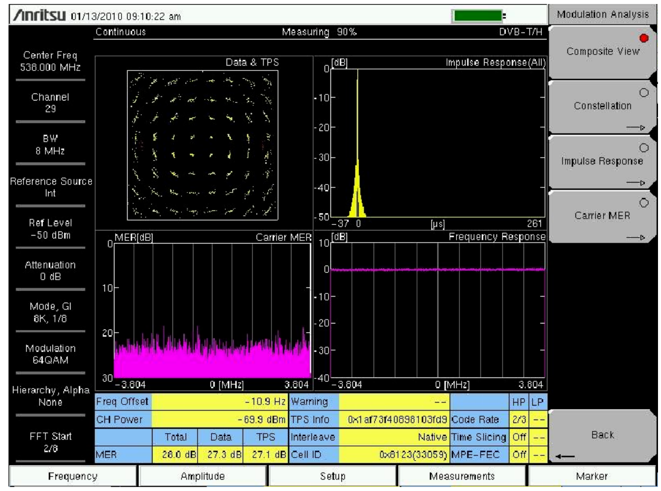


Figure 15c. Jitter or frequency instability.

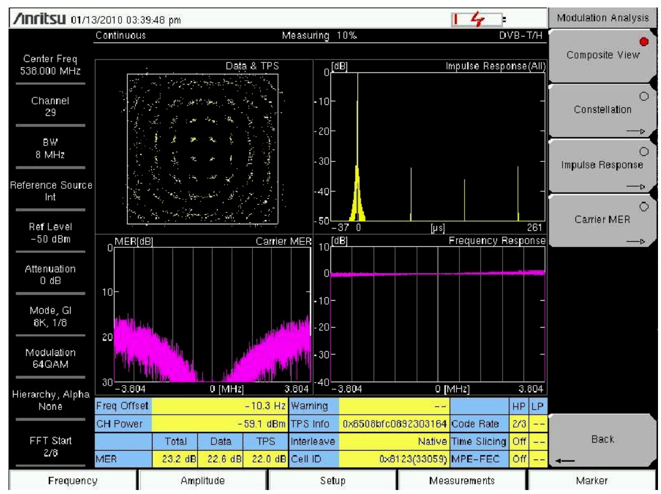


Figure 15d. FFT sampling clock frequency error.

Freq Offset			54.6 Hz	Warning	--		HP	LP
CH Power			-21.0 dBm	TPS Info	0x1af73e408d0002510	Code Rate	2/3	--
	Total	Data	TPS	Interleave	Native	Time Slicing	Off	--
MER	23.0 dB	22.4 dB	21.8 dB	Cell ID	0x0000(0)	MPE-FEC	Off	--

Figure 16. Additional measurement data table in modulation analysis screens.

Additional Measurement Data

Displayed in a table at the bottom of all modulation analysis measurement screens are a number of additional measurement parameters (figure 16).

Freq Offset. The difference between the measured frequency and the desired frequency.

CH Power. The absolute received channel power in dBm.

MER. Three MER values representing the RMS MER of:

- All carriers
- Data carriers
- TPS carriers

Warning. Any corrupted or incompatible TPS byte information is reported here. The full message can be viewed from the Advanced Settings menu.

TPS info. Byte information representing the 68 symbol TPS data.

Interleave. A DVB-H specific function where Native or In-depth symbol interleaving can be used.

Cell ID. Sometimes the transmitter identification is included in the TPS information and decoded here.

Code Rate. The convolutional code rate decoded from the TPS data. If hierarchical transmission is used it will be detected for both high and low priority streams.

Time Slicing. A DVB-H specific function used to save battery power in a handheld receiver and its use conveyed in the TPS data. If hierarchical transmission is used it will be detected for both high and low priority streams.

MPE-FEC. Multi-Protocol Encapsulation Forward Error Correction. An additional layer of forward error correction used in DVB-H providing more robust error protection and a degree of time interleaving. Its use is conveyed in the TPS data. If hierarchical transmission is used it will be detected for both high and low priority streams.

Bit Error Ratio (BER) Measurements

As discussed earlier, in DVB-T/H the transmitted data are protected by forward error correction (FEC). Specifically, an outer Reed-Solomon (RS) block code and an inner convolutional code (Figure 5). In the receiver, a Viterbi decoder and Reed-Solomon decoder attempt to recover the original data. Therefore, it is necessary to measure the following three error ratios:

- BER before Viterbi
- BER before RS (equivalent to BER after Viterbi)
- BER after RS

Since the data are reconstituted back into 188-byte TS packets after the RS decoder and the RS decoder reports erroneous packets, the final error ratio is described as Packet Error Ratio (PER) after RS.

There are three main scenarios for BER measurements.

The first, when connected directly to the transmitter for commissioning or acceptance testing, only minimal errors before Viterbi are acceptable. The smaller the error ratio to be measured, the longer the test time will be. For acceptance testing, this can be many hours.

Second, when monitoring a transmitter with an antenna at a location with good reception conditions. Again, the BER before Viterbi should be minimal (1×10^{-9} or less) but the test time need only be a few minutes to check this.

Third, to predict the performance of a receiver at various reception locations. The antenna used should fit the likely reception scenario. In this case, all interferences in the transmission path will cause errors and will be reported as BER before Viterbi. The Viterbi decoder will correct some or all errors. The properties of the RS decoder are such that if the BER after Viterbi is better than 2×10^{-4}, then the final PER after RS is likely to be zero. Of course, to prove absolutely that the error ratio is zero would require an infinite amount of time. Clearly, this is impractical so it is deemed to be "quasi error free" if the BER after RS is better than 1×10^{-11}, equivalent to a PER of approximately 6×10^{-7} (Figure 17).

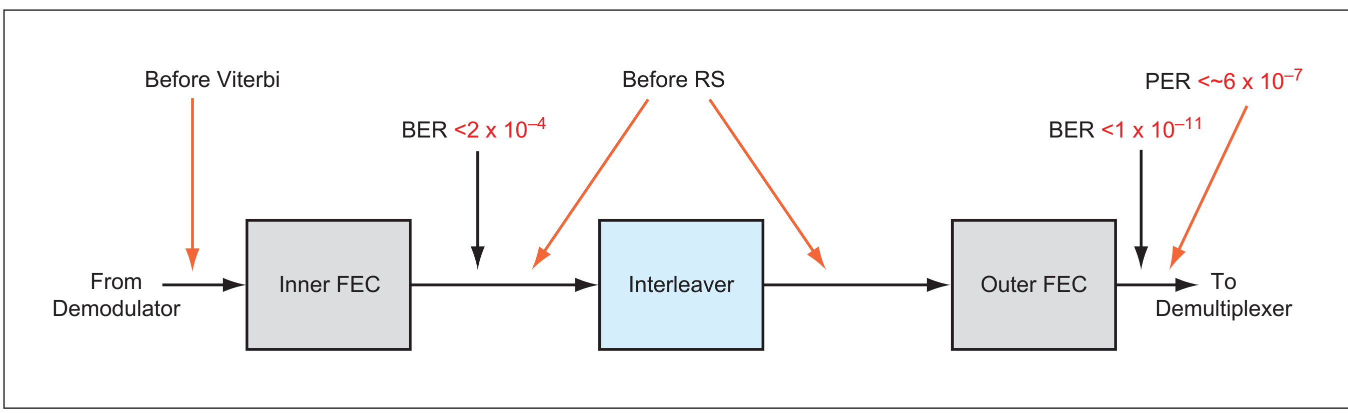


Figure 17. Receiver FEC arrangements.

Ensure the channel frequency and reference level have been set appropriately.

1. Press the Measurements hard key.
2. Press the BER soft key to select BER measurements. The red dot on the soft key indicates it is selected.
3. Press the Setup hard key to open the Meas Setup soft key menu.
4. Press the Bit Count Setting soft key.
5. Press the Mantissa and Exponent soft keys in turn and use the directional arrow keys, the rotary knob or numeric entry keys to set the number of bits for analysis. Press Enter.
6. Press the Meas Mode soft key. Use the directional arrow keys or the rotary knob to select Single or Continuous mode. Press Enter.
7. Press the Stream soft key if the transmission is hierarchical. Use the directional arrow keys or the rotary knob to select HP (High Priority) or LP (Low Priority) stream for analysis. Press Enter.
8. Press the Result Disp soft key to select either the Current or Last measurement. The selected result is underlined.

The Last result display fixes the previous measurement on screen while the next measurement is integrating.When the next measurement is ready, the display updates. The Current result display shows the progress of the current measurement and is useful to see the measurement progress when high bit counts have been set.

In addition to the various error ratios, the BER measurement also displays the instantaneous, maximum, minimum and moving average values of the channel power and MER. Full TPS decoding is also shown.

Figure 18 shows a BER measurement.

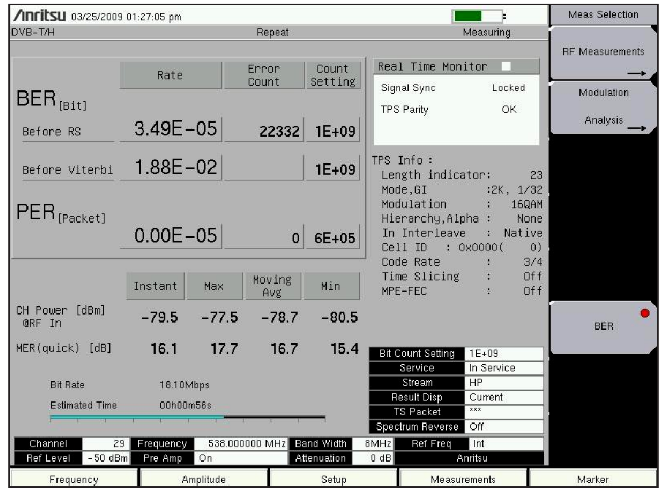


Figure 18. BER measurement.

Single Frequency Networks (SFN)

To improve the efficiency of spectrum use, it may be convenient for areas to be serviced by a single frequency network (SFN). An SFN is a network where all transmitters are tuned to the same frequency. Sometimes, whole countries are serviced by SFNs where each broadcaster uses the same frequency channel at all transmitter sites.

At first glance, this type of network configuration may seem highly complex and fraught with potential interference issues. Indeed, there are extra considerations but the use of OFDM and scalable guard intervals really lends DVB-T/H technology (and other OFDM-based systems) to the SFN environment.

All measurements described so far are relevant to SFNs also. For measurements made with direct transmitter connections, the fact that the transmitter is part of an SFN is irrelevant. Even for most of the over the air measurements, SFNs can be regarded as a special case of a multi-frequency network (MFN) with multiple echo and multi-path signal reception.

The impulse response measurement is the key test. The procedure described earlier allows for delay measurements slightly in excess of the longest allowable guard interval for the respective OFDM mode. This is usually adequate for MFNs to ensure there are no wayward echo responses. However, for SFNs, especially during their installation, it is necessary to check for relative signal delays over a much longer period.

Part of the installation process is to set the signal delay through each transmitter so that at all reception sites within the coverage area, the relative delays of all significant signals received - not just the main transmitter signals but their echoes also – are within the guard interval period.

During this procedure it is likely that signals will be delayed well beyond the guard interval. It is necessary to measure these delays so that transmission delays at the transmitter sites can be adjusted accurately.

Figure 19 shows a basic SFN configuration. Assuming there are no programmed delays through the transmitters themselves so that each transmits the same symbol at the same time, then receiver "A" does not suffer any inter-symbol interference if the delay difference between the signals from transmitters T1 and T2 is less than the guard interval. Indeed, in this case, the energy from each is accumulated. The phase difference of the two signals received at "A" will likely cause some fading effects across the channel which can be compensated by the information supplied with the pilot carriers.

SFNs usually specify the 8K mode since the symbols, and therefore the corresponding guard intervals, are longer. Large SFNs use the maximum guard interval of 1/4 symbol length to support larger distances. For smaller regional SFNs and for gap-fillers, smaller guard intervals may be used.

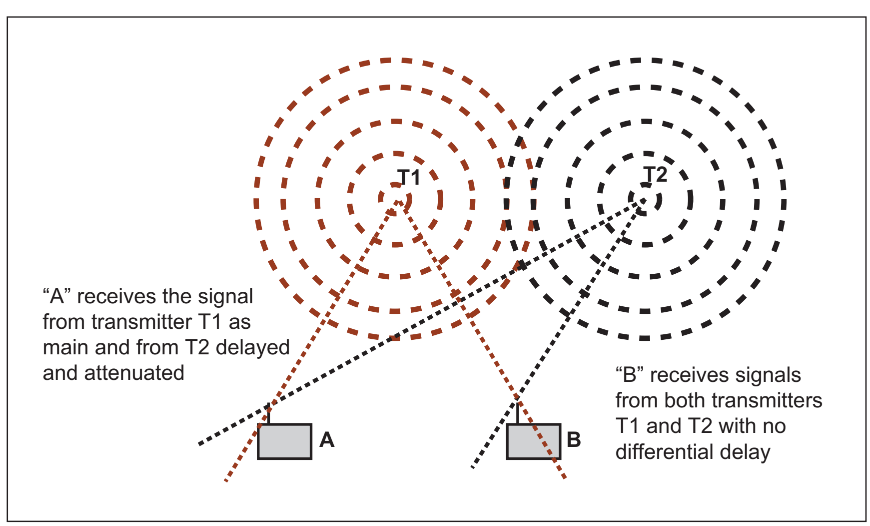


Figure 19. Single Frequency Network configuration.

Single Frequency Network Measurements

An optional SFN Field Measurement mode (option 78) is available for the BTS Master and Spectrum Master which allows the measurement of delay ranges of ±896 μs for 8 MHz bandwidth signals and correspondingly longer for smaller bandwidth signals. The option uses advanced algorithms and two different delay profile measurement methods simultaneously which enable it to discriminate many delayed signals, compute accurately their absolute power levels and dramatically reduce the possibility of producing aliased responses. The latter is crucial to the efficient installation of SFNs since much time can be wasted tracking aliased signals and is where Anritsu's anti-aliasing methodology has significant advantages and time-saving benefits.

Before commencing, press the Shift key and then the Mode (9) key. Use the directional arrows or rotary knob to highlight DVB-T/H SFN Analyzer and press Enter to select.

Connect an appropriate antenna to the unit and ensure the channel frequency and reference level have been set accordingly.

Impulse Response

1. Press the Measurements hard key.
2. Press the Impulse Response soft key to select the impulse response measurement. The red dot on the soft key indicates it is selected.
3. Press the Impulse Response soft key again to open the Impulse Response soft key menu.
4. Press the Vertical Range soft key to select a suitable range. Press the Back soft key.
5. Press the Setup hard key to open the setup soft key menu.
6. Press the Meas Mode soft key. Use the directional arrow keys or the rotary knob to select Single or Continuous mode. Press Enter.
7. Press the Detect Parameters soft key to detect automatically the TPS parameters.

If the TPS parameters are known they can be set manually if desired by pressing the Advanced Settings soft key in the Setup menu and selecting each parameter setting in turn.

8. Press the Advanced Settings soft key.
9. Press the Antenna soft key. Use the directional arrow keys or the rotary knob to highlight the antenna used. Press Enter.
10. Press the Marker hard key to open the marker soft key menu.
11. Press the Unit soft key to select measurement in dBμV/m (field strength) or dBμV (terminal voltage).
12. Press the Marker soft key to select Move or Fix marker function. The active selection is underlined.
13. With Move marker function selected, press the Active Marker soft key to select the active marker to be on the Zoom (lower) or All (upper) trace. The selected trace is underlined.

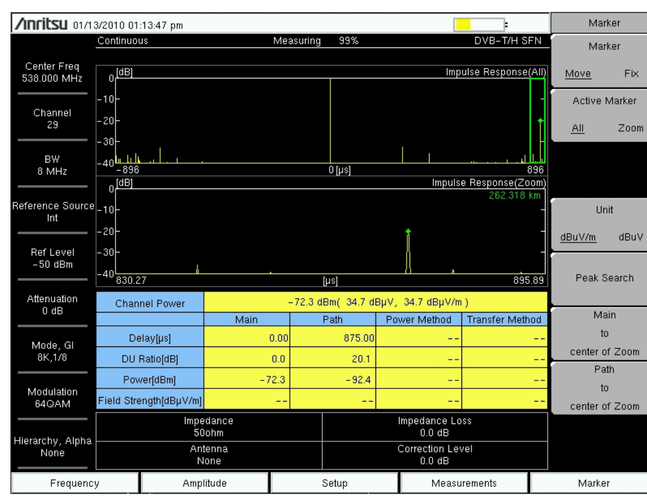


Figure 20. SFN impulse response.

14. With the active marker on the All trace, a green rectangle on the All trace depicts the area of the impulse response trace which is expanded into the Zoom trace. Use the directional arrow keys to highlight the region of the impulse response trace to expand. Use the rotary knob to move a spot marker to the signal to be measured. Read the spot marker measurement details in the results table. The distance at the spot marker in km is shown on the Zoom trace.
15. Press the Active Marker soft key to set the active marker to the Zoom trace.
16. Press the Marker Mode soft key to select Normal or Zone. The active selection is underlined. Use the directional arrow keys or the rotary knob to move the selected marker to the required signal response. Normal marker mode allows precise setting of the spot marker on the Zoom trace. Zone marker mode automatically selects the peak response within the zone. Read the spot marker measurement details in the results table. The distance at the spot marker in km is shown on the Zoom trace.

The markers are used to pick out different delayed signals. The results table shows the following measurement:

- Channel Power (combined power of all received signals)
- Delay
- DU Ratio (relative level between the main and delayed signal)
- Power (absolute power of main and delayed signal)
- Field Strength or Terminal Voltage of main and delayed signal

Figure 20 shows an SFN impulse response measurement showing an 875 μs delayed response about 20 dB down from the main signal.

In-band Spectrum

The reception of many delayed signals can affect the in-band frequency response causing severe fading in extreme cases. The In-band Spectrum function can measure these effects.

Connect an appropriate antenna to the unit and ensure the channel frequency and reference level have been set accordingly.

1. Press the Measurements hard key.
2. Press the In-band Spectrum soft key to select the in-band spectrum measurement. The red dot on the soft key indicates it is selected.
3. Press the In-band Spectrum soft key again to open the in-band spectrum soft key menu.
4. Press the Vertical Range soft key. Select the appropriate vertical range for the measurement.
5. Press the Marker hard key to open the marker soft key menu.
6. Press the Marker soft key to turn on the marker. Use the directional arrow keys or the rotary knob to move the marker to the desired position.
7. Press the Delta Marker soft key. Use the directional arrow keys or the rotary knob to move the delta marker to the desired position.
8. Read the marker values of relative frequency, level and distance.

Figure 21 shows an in-band spectrum measurement.

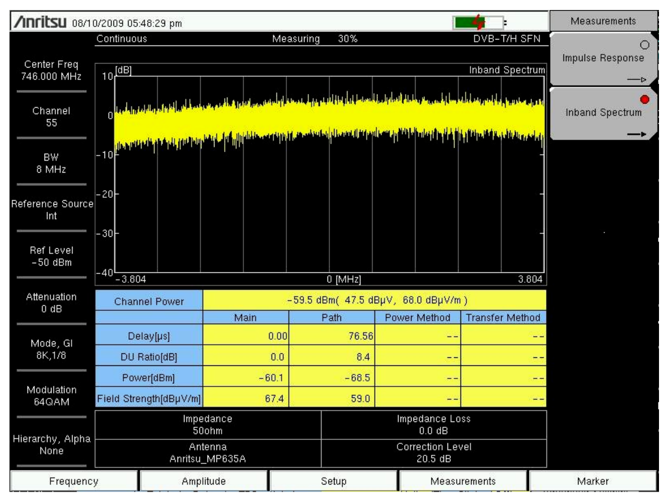


Figure 21. SFN In-band Spectrum measurement.

Conclusion

This application note has described the key field measurements to perform on DVB-T/H digital terrestrial television transmitters with the MS2721B Spectrum Master and MT8222A BTS Master during installation, commissioning and maintenance. It has also shown how some common problems can be interpreted from the measurement displays so that broadcast technicians can be more productive in the field. Further incite can be obtained by visiting www.us.anritsu.com and downloading the product specification sheets and Digital Television Measurement Guide.

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