ISDB-T Transmitter Measurements for Acceptance, Commissioning and Maintenance
Application Note

Product:

- R&S®ETL

Broadcasting transmitters are subject to particularly stringent standards with respect to broadcast signal quality, because even small faults can lead to service disruptions for many viewers.

A single instrument, the R&S®ETL TV analyzer, performs all required ISDB-T transmitter measurements, from the initial acceptance testing for the transmitter, to measurements performed during commissioning and preventive maintenance.

ROHDE&SCHWARZ

Application Note

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12.2013 - 7BM103_1E

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1 Overview

Broadcasting transmitters are subject to particularly stringent standards with respect to broadcast signal quality, because even small faults can lead to service disruptions for many viewers.

A single instrument, the R&S®ETL TV analyzer, performs all required ISDB-T transmitter measurements, from the initial acceptance testing for the transmitter, to measurements performed during commissioning and preventive maintenance.

The measurements described here satisfy many country-specific and customer-specific test specifications. Users need only set the limit values accordingly.

Section 2 describes the preparatory steps. These include the necessary test equipment and setup, as well as steps to protect the T&M equipment against destructively high input power. This is followed by a description of typical default configurations for the R&S®ETL.

Section 3 lists the various measurements. For every reserve system in the transmitter, these measurements should be repeated at least once during commissioning testing. Maintenance measurements, on the other hand, can initially be limited to power, MER and BER, and then expanded only as needed.

Because not all measurements need to be repeated during regular maintenance, Rohde & Schwarz offers the R&S®ETC and the R&S®ETH as cost-effective alternative to the R&S®ETL (see Fig. 1). These compact TV analyzers can perform most of the measurements described here with a high degree of accuracy.

***Fig. 1**: From left to right: R&S®ETL, R&S®ETH and R&S®ETC*.

Appendix D describes how these measurements can be automated using the R&S®TxCheck Software provided with the R&S®ETL.

Additional background information on this topic can be found in the book "Digital Video and Audio Broadcasting Technology" by Walter Fischer [1].

2 Preparatory Steps

2.1 Required Equipment

Basic configuration

R&S®ETL TV analyzer with:

- options as needed (see Section 7)
- current firmware (available at no cost at www.rohde-schwarz.com/product/ETL.html)

Application- or measurement-specific configurations

Transmitter operation without signal broadcasting for transmitter acceptance testing or commissioning

Dummy antenna

For Transmitter Output Level measurements (3.1.1) with an inaccuracy of < 0.1 dB

Additional power sensor, e.g. R&S®NRP-Z91

For Shoulder Attenuation and Adjacent Channel Emissions measurements (3.3.1) using the variant "after mask filter"

Notch filter to attenuate the wanted signal by 40 dB or more

For Harmonics measurements (3.3.2)

Highpass filter with at least 40 dB wanted signal attenuation or more

2.2 Test Setup

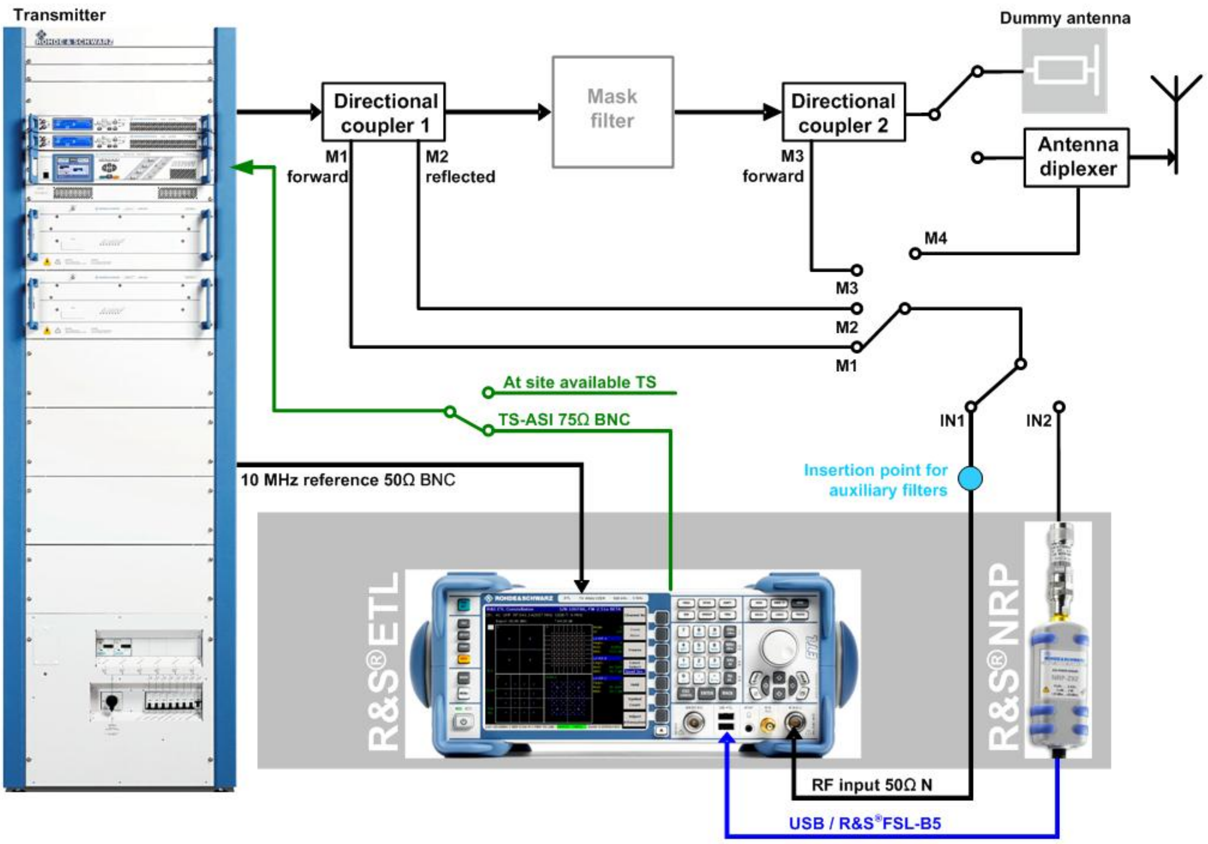


***Fig. 2*: Test Setup.**

For the transmitter acceptance test, the built-in R&S®ETL TS generator (see Appendix A) feeds an ISDB-T-compliant MPEG-2 transport stream (TS) to the TS input on the ISDB-T transmitter. It is also possible to use another TS generator such as the R&S®DVSG. The transmitter output is connected to a dummy antenna.

During commissioning, the TS feed present at the transmitter station is used. The measurements are initially performed using a dummy antenna, before the broadcast signal is applied to the antenna combiner. As a result, the test port at the antenna combiner (M4) is available as an additional measurement point.

The TS feed present at the transmitter station is likewise used for maintenance measurements. The signal is applied to the transmit antenna via the antenna combiner for broadcasting.

The RF input of the R&S®ETL (IN1) or the optional power sensor (IN2) is connected as follows for the various measurements:

- to the test port on the transmitter output (M1=forward, M2=reverse)
- to the test port behind the mask filter (M3)

If installed, the mask filter is located between the transmitter output and the dummy antenna or the antenna combiner. Some measurements can be taken at the test port before or after the mask filter (M1 / M3). The port to be used depends on which ports are available and which influencing factors are to be measured.

Some out-of-band emission measurements (see 3.3) require auxiliary filters, such as an adjustable notch filter. If they are required, these filters are added at the insertion point for auxiliary filters.

The EXT REF reference input located at the rear of the R&S®ETL TV analyzer is used to connect the instrument to the 10 MHz GPS time reference available at the transmitter station. The optional power sensor can be connected to the R&S®ETL via USB or via the sensor input on the R&S®ETL hardware option R&S®FSL-B5.

2.3 Operating Mode of the ISDB-T Transmitter for Acceptance and Commissioning

The ISDB-T standard (Japan) is significantly more complex than the terrestrial DVB-T and ATSC standards. ISDB-T uses coded orthogonal frequency division multiplex (COFDM) in the 2k, 4k and 8k mode (mode I, II, III). The channel (typically 6 MHz for ISDB-T) is divided into 13 subbands (segments).

A maximum of three different layers (A, B, C) are formed from these 13 segments. Each of these three layers can use a different number of segments and exhibit different transmission parameters. The various transmission parameters include a variety of modulation modes (DQPSK, QPSK, 16QAM, 64QAM) and error control methods (code rates, time interleaving). The same transmission parameters apply to all segments of a layer.

Only one layer is needed for acceptance and commissioning of a transmitter. The measurements described in this document are based on the following transmitter operating parameters:

- Mode III
- Guard interval = 1/4
- Layer A = 13 segments
- Coherent modulation
- 64QAM
- Code rate = 2/3
- Time interleaving = 2

It is important to ensure that the applied MPEG-2 TS is compliant with ISDB-T and includes the transmitter operating parameters. It is similarly important to note that, when used in this system, differential modulation (DQPSK) will result in a MER that is 3 dB worse than that of coherent modulation.

2.4 Protection Against Destructive Input Power

The R&S®ETL allows maximum input power peaks of 36 dBm (short-term, < 3 s), while the recommended, separate R&S®NRP-Z91 power sensor can handle up to 23 dBm.

It is therefore recommended that additional attenuators be used as needed to limit the average total power at the individual test ports to a range from 0 dBm to 10 dBm. This range provides adequate protection against short-term power peaks, while having a negligible effect on the instrument accuracy. The resulting attenuation must of course be taken into consideration during the measurements.

2.5 R&S®ETL Default Configuration

The following conventions are used in these procedures:

- Terms in all caps refer to key labels, e.g. "FREQ" for 
- Bulleted lists (for example, ● TV Standard: OFDM ISDB-T) identify settings made in the currently displayed configuration dialog box
- All other terms refer to the softkeys that are currently displayed along the right-hand side of the screen. Arrows (→) separate the keys to be pressed in sequence

The following default settings apply to the R&S®ETL unless explicitly stated otherwise:

Spectrum analyzer mode
SETUP→Reference Ext: Use the external 10 MHz reference frequency
MODE→Spectrum Analyzer
FREQ→Center: Set to center frequency at mid-channel
SPAN→Span Manual: Set to 20 MHz
TRACE→Detector Manual Select→Detector RMS
BW→Res BW Manual: Set to 30 kHz
SWEEP→Sweeptime Manual: Set to 2 s
AMPT→More→Preselector: Off[1]
AMPT→RF Atten Manual: Select the lowest possible setting without overloading[2]
AMPT→Ref Level: Set the reference level so that the entire signal is clearly visible; if necessary, go to AMPT→Range Log and change the grid scale

TV/radio analyzer/receiver mode
SETUP→Reference Ext: Use the external 10 MHz reference frequency
MODE→TV/Radio Analyzer/Receiver→Digital TV
MEAS→Digital TV Settings ● TV Standard: OFDM ISDB-T
AMPT→More→Preselector: Off[1]
FREQ→Channel RF: Select based on the transmit frequency
MEAS→Special Settings→System Opt.→Slow/Laboratory

[1] Only if a preselector is provided in the instrument
[2] Overload warnings appear centered at the top of the display as "IFovl" or "Ovld".

3 Measurements

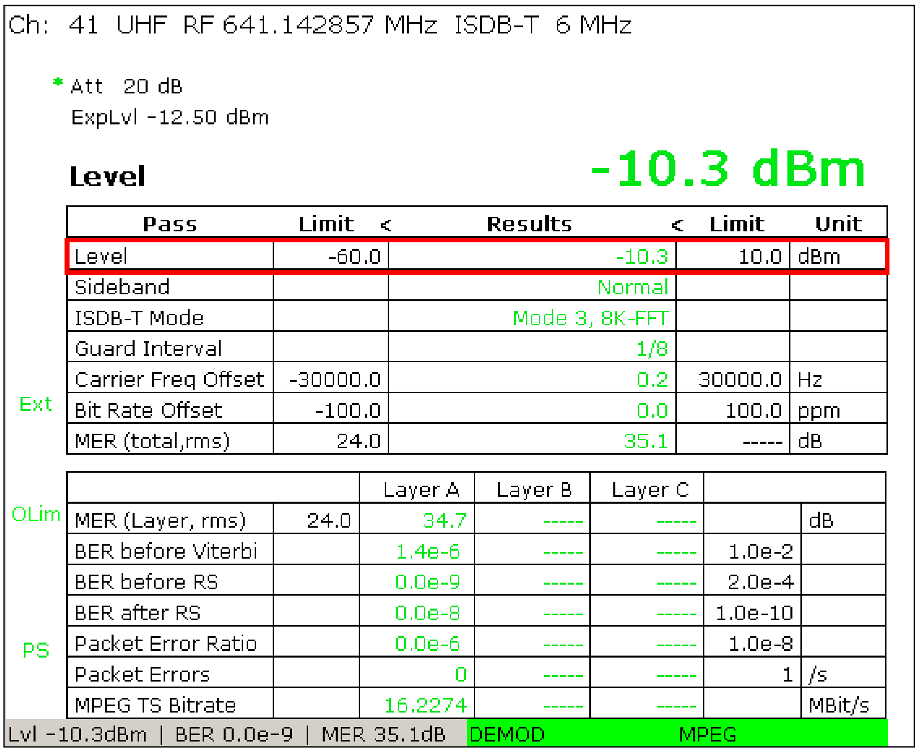
3.1 Power

3.1.1 Transmitter Output Level

The average power is constant for digital television, and not dependent on the picture contents, like it is in analog television. Because the mask filter attenuates the output power between about 0.1 dB and 0.6 dB behind the transmitter output, measurements should be taken before and after the mask filter. Note that as a default, the displayed power includes only the power that is decoupled by the directional coupler. The coupling attenuation can be input using the Ref Level Offset function on the R&S®ETL, and is then automatically calculated into the displayed value.

The R&S®ETL can measure the signal level directly via the RF input with an accuracy of 1 dB. Use of a separate power sensor allows an accuracy of 0.1 dB to be achieved.

<table>
<tr><th colspan="2">Procedure</th></tr>
<tr><td colspan="2">Perform these steps at the test port:
• M1, for forward power before the mask filter
• M2, for reverse power (see Appendix B) before the mask filter
• M3, for forward power after the mask filter</td></tr>
<tr><th>TV/radio analyzer/receiver</th><th>Power sensor</th></tr>
<tr><td colspan="2">⚠ Check that the max. input power is not exceeded, see Section 2.4</td></tr>
<tr><td colspan="2">AMPT→More→Ref Level Offset: Set to the full coupling attenuation at the test port for immediate compensation</td></tr>
<tr><td>Feed a signal into the RF input on the R&S®ETL (IN1)</td><td>Connect the power sensor (IN2) (connected to R&S®ETL via USB or sensor input) to the test port</td></tr>
<tr><td rowspan="2">Define the TV/radio analyzer/receiver default settings as described in Section 2.5</td><td>MODE→Spectrum Analyzer</td></tr>
<tr><td>FREQ→Center: Set to center frequency at mid-channel</td></tr>
<tr><td rowspan="2">MEAS→Overview→Adjust Attenuation</td><td>MENU→Power Meter→Frequency Coupling:
• Center</td></tr>
<tr><td>MENU→Power Meter→Power Meter→On</td></tr>
<tr><td>Read the measured value; see Fig. 3</td><td>Read the measured value; see Fig. 4</td></tr>
</table>



Ch: 41 UHF RF 641.142857 MHz ISDB-T 6 MHz

* Att 20 dB
ExpLvl -12.50 dBm

Level -10.3 dBm

Pass	Limit <	Results	< Limit	Unit
Level	-60.0	-10.3	10.0	dBm
Sideband		Normal		
ISDB-T Mode		Mode 3, 8K-FFT		
Guard Interval		1/8		
Carrier Freq Offset	-30000.0	0.2	30000.0	Hz
Bit Rate Offset	-100.0	0.0	100.0	ppm
MER (total,rms)	24.0	35.1	-----	dB

		Layer A	Layer B	Layer C		
MER (Layer, rms)	24.0	34.7	-----	-----		dB
BER before Viterbi		1.4e-6	-----	-----	1.0e-2	
BER before RS		0.0e-9	-----	-----	2.0e-4	
BER after RS		0.0e-8	-----	-----	1.0e-10	
Packet Error Ratio		0.0e-6	-----	-----	1.0e-8	
Packet Errors		0	-----	-----	1	/s
MPEG TS Bitrate		16.2274	-----	-----		MBit/s

Ext OLim PS

Lvl -10.3dBm | BER 0.0e-9 | MER 35.1dB DEMOD MPEG

Fig. 3: TV/radio analyzer/receiver mode, MEAS→Overview menu: The level can be read in the first table row, in the status bar on the test screen or in the zoomed view (MEAS→Overview→Zoom).

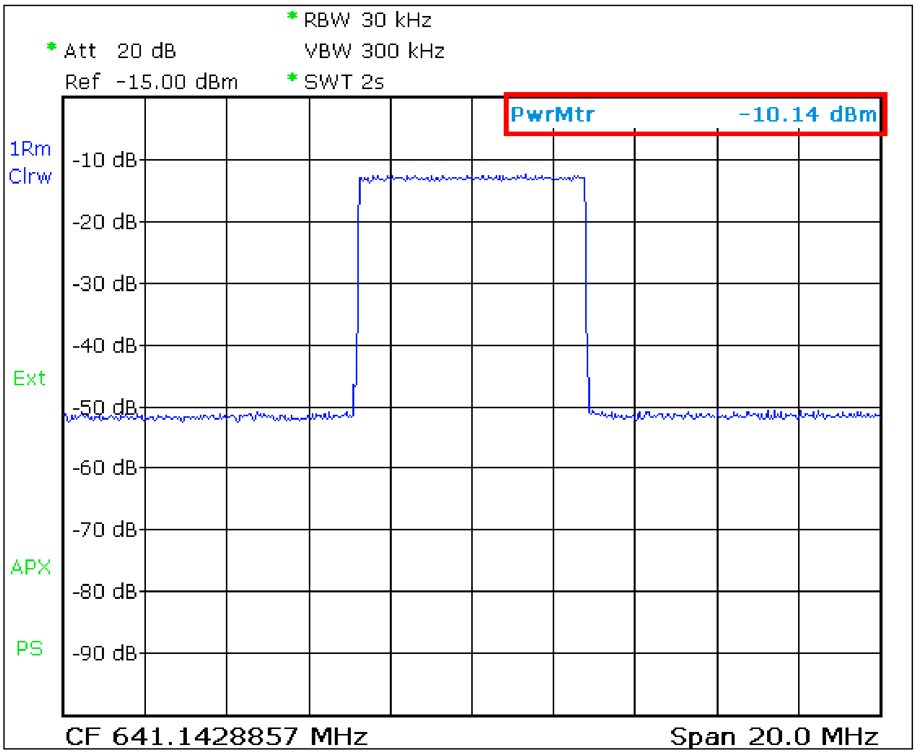


Fig. 4: Spectrum analyzer mode: ISDB-T spectrum with integrated reading from the power sensor displayed at the top right.

3.1.2 Crest Factor

It is important to know the crest factor so that the components that follow the transmitter – such as the mask filter, the antenna combiner, the coaxial cable and the antenna – can be adequately dimensioned.

The crest factor (CF) defines the relationship between the highest occurring amplitude of the modulated carrier signal (U_{Peak}) and the RMS voltage (U_{RMS}) of a signal:

$$\mathrm{CF} = 20 \cdot log \frac{U_{Peak}}{U_{RMS}}$$

More recently, however, a new way of defining the crest factor has become prevalent, in which a ratio is formed from the peak envelope power (PEP) and the average power. A crest factor calculated in this way is smaller by an amount equal to the crest factor of the sinus carrier, i.e. 3.01 dB. [2]

Orthogonal frequency division multiplex (OFDM) signals exhibit a very high crest factor because in extreme cases, all carriers could be overlaid or even eliminated at any given moment. In the case of OFDM, the following equation applies to this theoretical crest factor:

$Cf_{OFDM} = 10 \cdot \log(2N)$, where N = number of carriers

Because the signal peaks occur less frequently at high crest factors, any measurement would be valid only for the time period when the measurement was made. This is why the complementary cumulative distribution function (CCDF) includes the statistical probability that a signal peak will occur. The CCDF method determines the peak envelope power, which is why the calculated value must becorrected by a factor of $\sqrt{2}$ or 3.01 dB. [3]

For ISDB-T, a theoretical value of > 40 dB results for mode III . In practice, it is limited to about 13 dB in the transmitter.

The mask filter at the transmitter output removes intermodulation products lying outside of the useful band. However, this filtering results in a deformation of the envelope, which then increases the crest factor. This is why, when measuring the crest factor, it is important to distinguish between the crest factor of the transmitter and the crest factor of the bandwidth-limited signal (e.g. after the mask filter).

Using the R&S®ETL, the transmitter crest factor is measured in spectrum analyzer mode directly at the transmitter test port (M1).

The crest factor of the bandwidth-limited signal can be measured with the R&S®ETL in spectrum analyzer mode at the test port after the mask filter (M3). Alternatively, the measurement can be made at the transmitter test port (M1) by selecting TV/radio analyzer/receiver mode. This mode limits the channel bandwidth (e.g. 6 MHz), simulating a mask filter.

Procedure: Transmitter crest factor
⚠ Check that the max. input power is not exceeded, see Section 2.4
Connect the R&S®ETL (IN1) to the test port before the mask filter (M1)
MODE→Spectrum Analyzer
FREQ→Center: Set to center frequency at mid-channel
AMPT→RF Atten Manual: Select the lowest possible setting without overloading[3]
MEAS→More→CCDF→Res BW: 10 MHz
MEAS→More→CCDF→# of Samples: 1000 000 000
Read crest factor and add 3.01 dB

Procedure: Crest factor of bandwidth-limited signal
⚠ Check that the max. input power is not exceeded, see Section 2.4
Connect the R&S®ETL (IN1) to the test port before or after the mask filter (M1 / M3)
Define the TV/radio analyzer/receiver default settings as described in Section 2.5
MEAS→Modulation Analysis→CCDF→Adjust Attenuation
MEAS→Modulation Analysis→# of Samples: 1000 000 000
Read crest factor, see Fig. 5 and add 3.01 dB

[3] Overload warnings appear centered at the top of the display as "IFovl" or "Ovld".

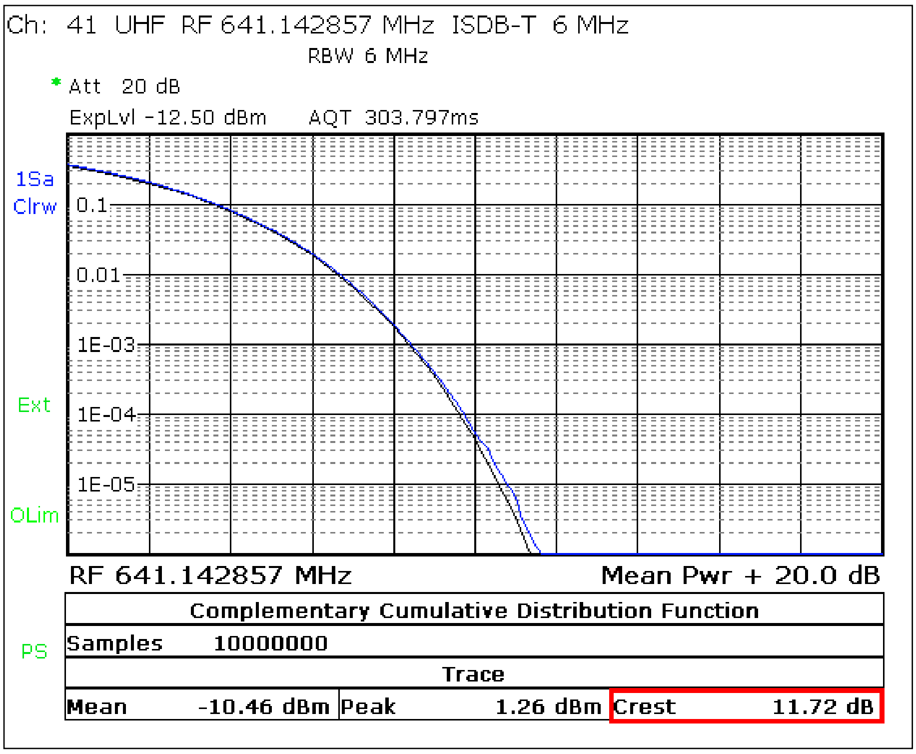


Fig. 5: TV/radio analyzer/receiver mode, MEAS→Modulation Analysis→CCDF menu: View with the calculated crest factor at the bottom right.

3.2 Modulator Characteristics

3.2.1 I/Q Imbalance

ISDB-T modulators are essentially an IFFT signal processing block followed by an I/Q modulator. This I/Q modulator can be either digital or analog. If an ISDB-T modulator uses direct modulation, then the I/Q modulator is analog. In this case, it must be aligned cleanly to minimize the following influencing factors:

- Amplitude imbalance
- Quadrature error
- Carrier suppression

Poor carrier suppression is recognizable as a notch directly at mid-band on MER(f) (see Fig. 13) and results in a contorted and compressed constellation diagram in mid-band. Amplitude imbalance and quadrature error (see Fig. 7) negatively affect the MER of all COFDM carriers. The carriers above the ISDB-T mid-band relate to the carriers under mid-band and vice versa.

Procedure
⚠ Check that the max. input power is not exceeded; see Section 2.4
Connect the R&S®ETL (IN1) to the test port before or after the mask filter (M1 / M3)
Define the TV/radio analyzer/receiver default settings as described in Section 2.5
MEAS→Modulation Analysis→Modulation Errors→Adjust Attenuation
Read the measured values; see Fig. 6
MEAS→Modulation Analysis→I/Q Imbalance
Use PRINT to print the test screen; see Fig. 7

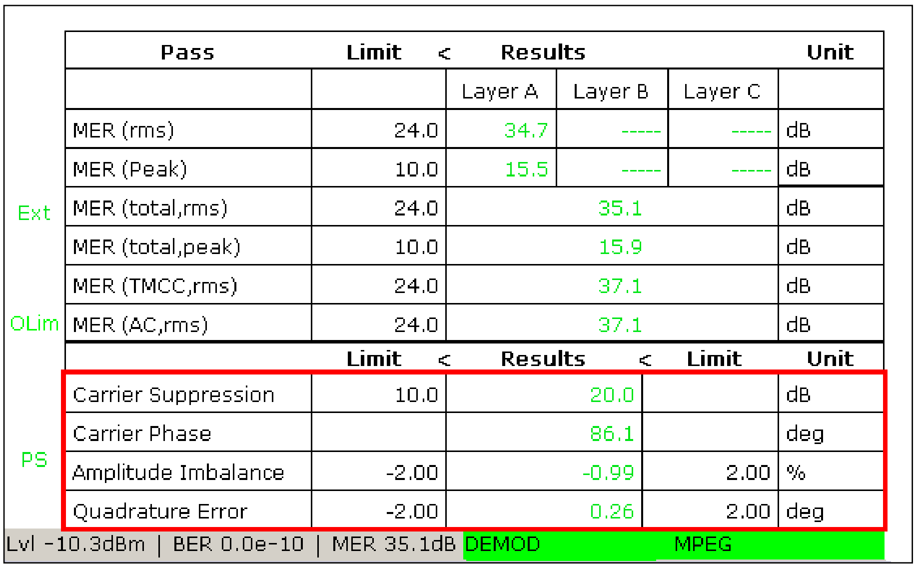


Fig. 6: TV/radio analyzer/receiver mode, MEAS→Modulation Errors menu: Carrier suppression, amplitude imbalance and quadrature error.

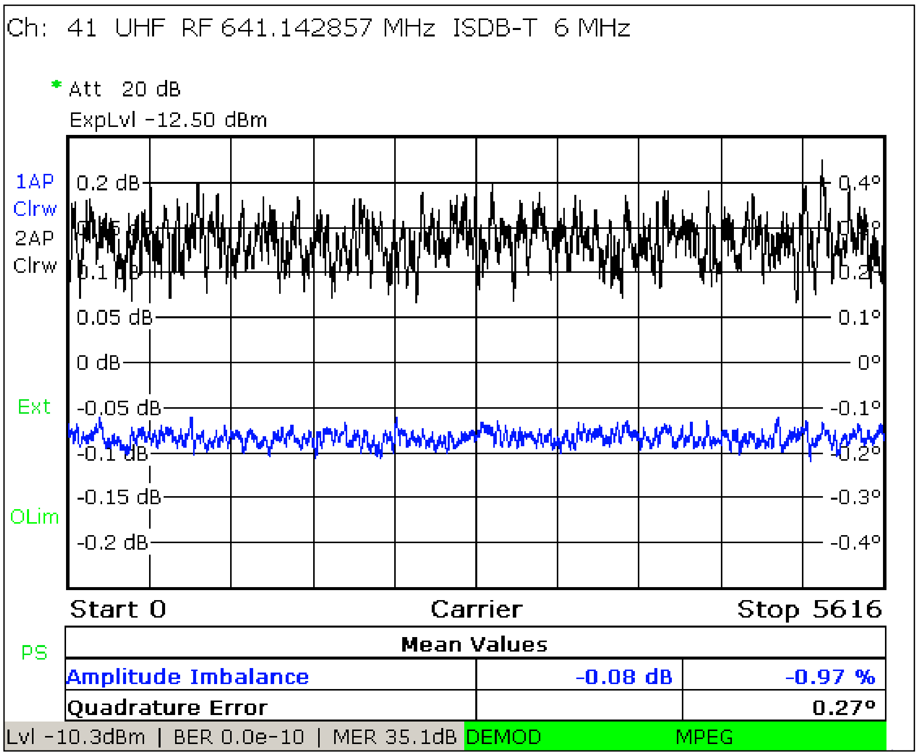


Fig. 7: TV/radio analyzer/receiver mode, MEAS→Modulation Analysis →I/Q Imbalance menu: Detailed analysis of amplitude imbalance and quadrature error over all carriers.

3.2.2 Amplitude Frequency Response and Group Delay

In analog televisions, amplitude frequency response and group delay were important parameters for a transmission path between the transmitter output and the receiver input. Because of the channel correction in the ISDB-T receiver, significantly larger tolerances can now be permitted without noticeable reductions in quality. The mask filter and antenna combiners cause linear distortions. These linear distortions can be compensated by a precorrector within the transmitter. As a result, however, the linear distortions reappear reversed directly at the transmitter output.

Therefore, the preferred method is to measure amplitude frequency response and group delay after all filter stages at a test port in the antenna combiner. Of course, the results will differ at the various measurement points.

Procedure
⚠ Check that the max. input power is not exceeded, see Section 2.4
If available, connect the R&S®ETL (IN1) to the test port (M4) on the antenna combiner, or else to (M3) after the mask filter
Define the TV/radio analyzer/receiver default settings as described in Section 2.5
MEAS→Channel Analysis→Amplitude & GroupDelay→Adjust Attenuation
MEAS→Channel Analysis→Amplitude & GroupDelay→Auto Range
Use PRINT to print the test screen; see Fig. 8

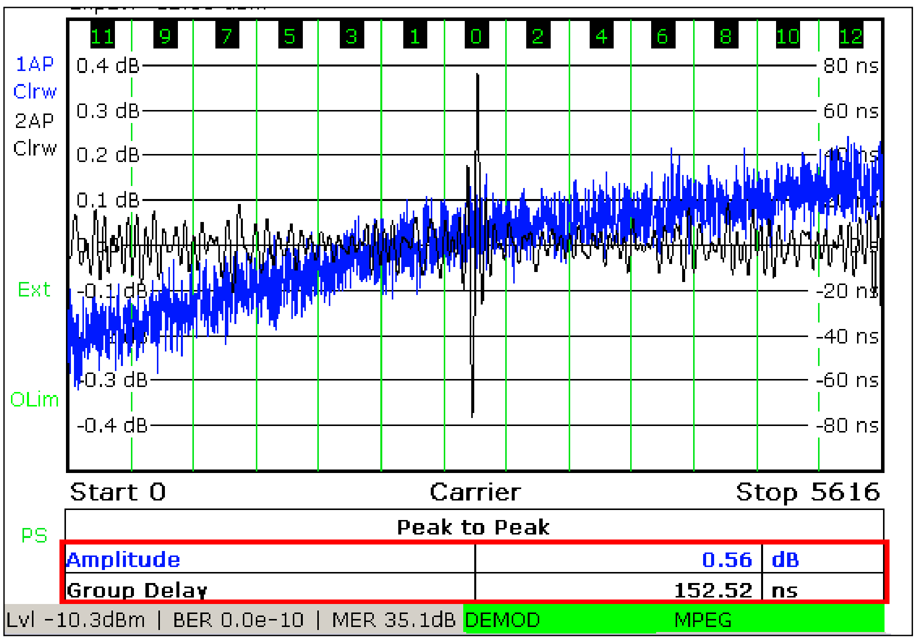


***Fig. 8: TV/radio analyzer/receiver mode, MEAS→Channel Analysis→Amplitude & Group Delay menu: Amplitude frequency response and group delay*.**

3.3 Out-of-Band Emissions

ISDB-T transmitters include very linear AB amplifiers. In spite of these, some residual nonlinearities remain. These cause intermodulation products to form from the many COFDM carriers.

On the one hand, these additional, unwanted frequency components appear in the channel itself. There, they act as additional disturbance power and therefore reduce the signal quality.

On the other hand, the intermodulation products also occur outside of the channel, and can negatively impact the signal quality of other channels. There are several distinct components:

- Shoulder attenuation
  Describes the power of the noise components in the near field of the channel boundary
- Adjacent channel emissions
  Components within several MHz of the channel boundaries
- Harmonics
  Components at multiples of the transmit frequency

3.3.1 Shoulder Attenuation and Adjacent Channel Emissions

The mask filter is used to reduce these unwanted out-of-band emissions. Critical mask filters are used when an adjacent channel requires protection, making more stringent requirements for attenuation of out-of-band emissions necessary. All other mask filters are uncritical.

The high dynamic range of the signal after the mask filter makes it impossible to check adherence to the tolerance mask directly using a spectrum analyzer. This is why an adjustable notch filter is typically used to reduce the useful band power. Before the measurement, the tracking generator on the R&S®ETL records the frequency response of the notch filter so that its influence on the measurement results **after the mask filter** can automatically be taken into consideration using the transducer function.

Another option is to use the tracking generator to log the frequency response of the mask filter itself before the measurement so that its influence can be calculated into the spectrum analysis results **before the mask filter** using the transducer function.

<table>
<tr><th colspan="2">Transducer file procedure</th></tr>
<tr><th>After mask filter using a notch filter</th><th>Before mask filter</th></tr>
<tr><td>Record the frequency response of the adjustable notch filter in a transducer file; see Appendix B</td><td>Record the frequency response of the mask filter in a transducer file; see Appendix B</td></tr>
<tr><td>Connect the R&S®ETL TV analyzer (IN1) to the test port after the mask filter (M3)</td><td>Connect the R&S®ETL TV analyzer (IN1) to the test port before the mask filter (M1)</td></tr>
</table>

The shoulder attenuation as well as the emissions within several MHz of the channel can be measured on the R&S®ETL by means of cursor measurements in spectrum analyzer mode. This is often done in practice.

The out-of-band emission function is a convenient way to perform the measurements required by the ARIB STD-B31 ver. 1.7 (Japan) and SBTVD No. 01:2007 (Brazil) standards.

<table>
<tr><th colspan="2">Procedure</th></tr>
<tr><th>Cursor measurement</th><th>Out-of-band emission function</th></tr>
<tr><td colspan="2">⚠ Check that the max. input power is not exceeded, see Section 2.4</td></tr>
<tr><td colspan="2">Follow the procedure defined in 3.3.1</td></tr>
<tr><td colspan="2">Go to SETUP→Transducer to enable the previously generated transducer file</td></tr>
<tr><td>Define the spectrum analyzer default settings as described in Section 2.5</td><td>Define the TV/radio analyzer/receiver default settings as described in Section 2.5</td></tr>
<tr><td>MKR→Marker 1: Set to center</td><td>MEAS→Spectrum→OutOfBand Emission</td></tr>
<tr><td>The following three settings must be repeated for each defined measurement point</td><td rowspan="2">Go to MEAS→Spectrum→OutOfBand Emission→Out of Band Emission Setup
● Select the country
● Select the transmitter power range</td></tr>
<tr><td>MKR→Marker 2: Set to measurement point</td></tr>
<tr><td>MKR→More→Marker 3: Set to the next measurement point</td><td>MEAS→Spectrum→Adjust Attenuation</td></tr>
<tr><td>Read the marker delta values; see Fig. 9. Use PRINT to generate a printout as needed</td><td>Use PRINT to print the results; see Fig. 10</td></tr>
<tr><td colspan="2">SETUP→Transducer→Active Off: Disable the transducer file</td></tr>
</table>

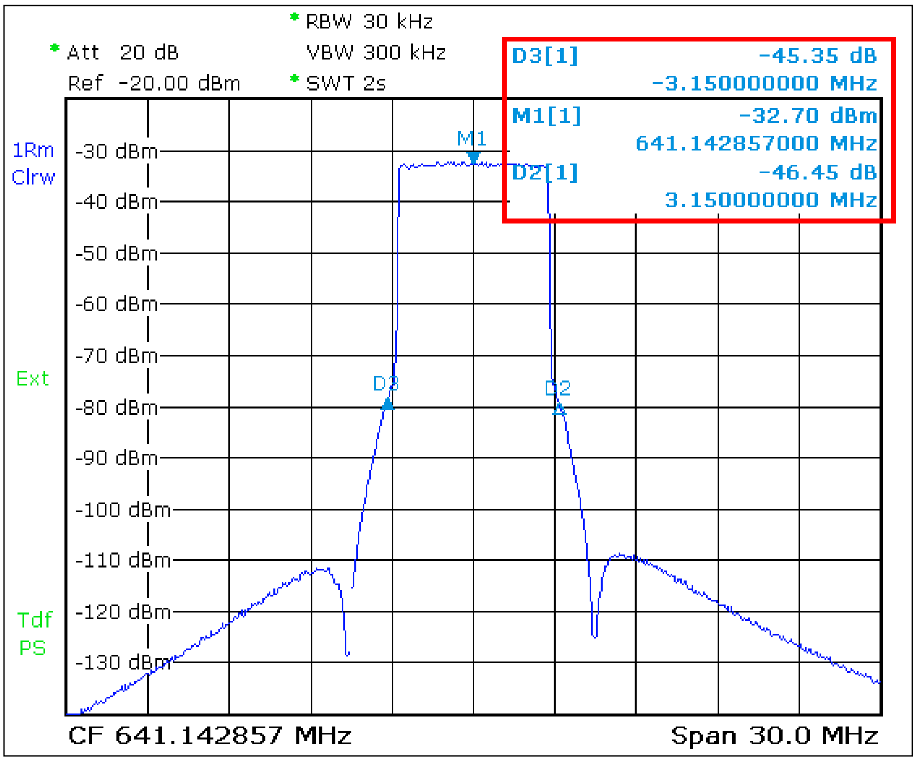


Fig. 9: Spectrum analyzer mode: Measuring the shoulder attenuation using the cursor method with active transducer file at ±3.15 kHz in the 6 MHz ISDB-T channel.

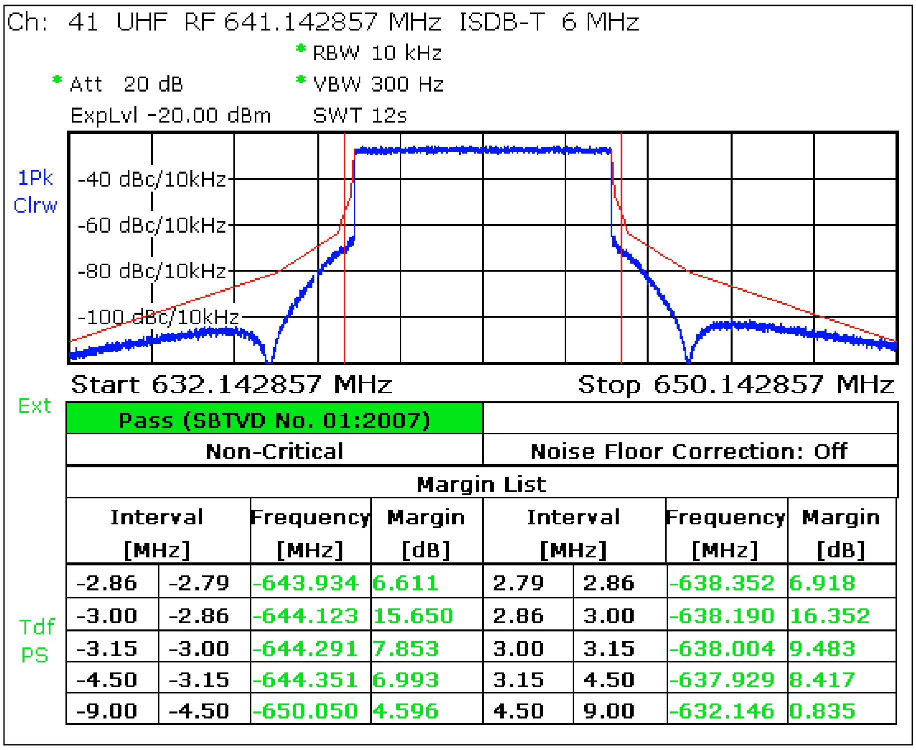


Fig. 10: TV/radio analyzer/receiver mode, MEAS→Spectrum→OutOfBandEmission menu: Adjacent channel emissions checked with Brazil/non-critical mask.

3.3.2 Harmonics

In addition to adjacent channel emissions, multiples of the transmit frequency can also result in harmonics. A harmonics filter at the transmitter output is used to suppress these harmonics. The R&S®ETL TV analyzer can be used to measure out-of-band emissions in spectrum analyzer mode. Because the mask filter does not suppress these harmonics, but rather affects only the channel near range, the harmonics can be measured directly at the test port (M1) on the transmitter output.

The high dynamic range of the signal means that a suitable highpass filter must be used to attenuate the useful channel by at least 40 dB. Notch filters (which are coaxial cavity filters that can be manually adjusted to the channel being suppressed) are not suitable here because they do not attenuate in just the useful band, but rather are repeated at multiples of the useful band. The frequency response of the highpass filter should be documented before the measurement using the tracking generator and then applied during the measurement using the transducer function.

Procedure
⚠ Check that the max. input power is not exceeded, see Section 2.4
Assess the highpass filter and save the result as a transducer file; see Appendix B
Connect the R&S®ETL (IN1) to the test port before the mask filter (M1) and add the highpass filter at the "auxiliary filter insertion point"
Define the spectrum analyzer default settings as described in Section 2.5
FREQ→Center: Set to 1.5 GHz
SPAN→Span Manual: Set to 3 GHz
Go to SETUP→Transducer to enable the previously generated transducer file for the highpass filter
Go to MKR→Marker 1 and use the marker functions to study the range around the multiples of the transmit frequency; see Fig. 11

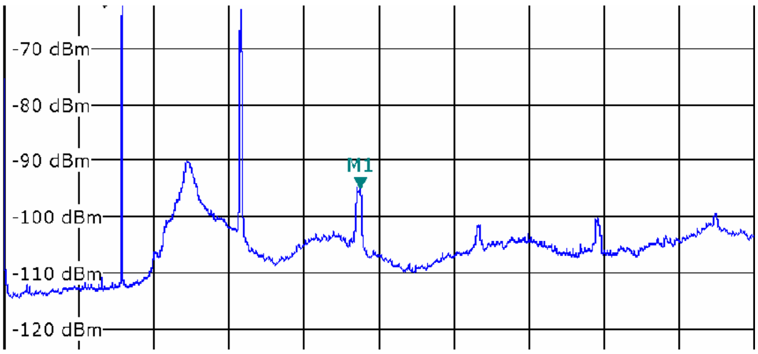


Fig. 11: Spectrum analyzer mode: Useful channel attenuated using the highpass filter; the harmonics, which can be assessed using the marker function, are clearly visible.

3.4 Signal Quality

3.4.1 Frequency Accuracy

Single-frequency networks (SFN), in particular, place very stringent requirements on the frequency accuracy of an ISDB-T transmitter of less than 10^{-9}. The carrier frequency offset is measured using the R&S®ETL in TV/radio analyzer/receiver mode at the test port (M1) of the transmitter output.

Procedure
⚠ Check that the max. input power is not exceeded, see Section 2.4
Connect the R&S®ETL TV analyzer (IN1) to the test port before the mask filter (M1)
Define the TV/radio analyzer/receiver default settings as described in Section 2.5
Press MEAS→Overview→Adjust Attenuation
Note the carrier frequency offset reading; see Fig. 12

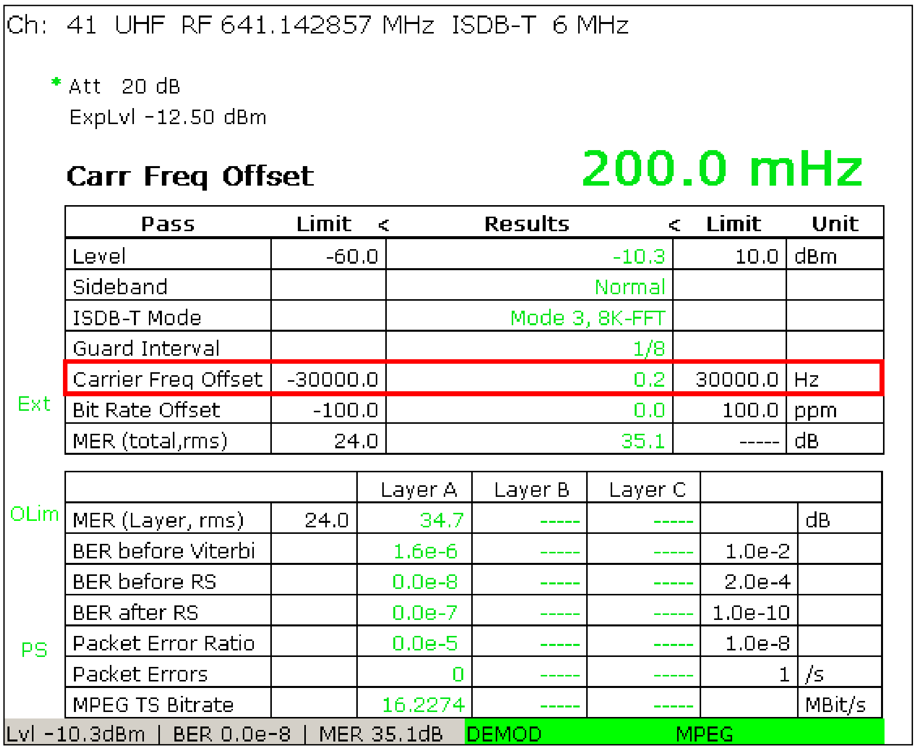


Fig. 12: TV/radio analyzer/receiver mode, MEAS→Overview menu: The frequency accuracy can be read in the 5th table row, as well as in the zoomed view (MEAS→Overview→Zoom).

3.4.2 Modulation Error Ratio

The modulation error ratio (MER) is a measure of the sum of all interference that affects a digital TV signal. The deviation of the points in the constellation diagram from their theoretical position is recorded. This makes a quantitative assessment of the signal quality possible. The MER is typically expressed in dB as a logarithmic ratio between the RMS value of the signal amplitude and the error vector magnitude.

$$MER_{RMS} = 20log_{10}\frac{\sqrt{\frac{1}{N}\sum_{n=0}^{N-1}(|error\_vector|)^2}}{U_{RMS}} \text{ [dB]}$$

A high MER value indicates good signal quality. In practice, the MER lies in the range of only a few dB to around 40 dB. A good ISDB-T transmitter has a MER in the range of approximately 35 dB. When receiving ISDB-T signals over a roof antenna with gain, a MER of 20 dB to 30 dB would be measurable at the antenna box. Values between 13 dB and 20 dB are expected for portable receivers with a room antenna.

The MER is the single most important quality parameter for an ISDB-T transmitter. A distinction is typically made between the total MER and the MER for each of the three layers. The boosted continual pilots which are typically included in the total MER, significantly affect the value of the total MER, making it somewhat better than the average value of the MERs for the layers. The MERs of the three layers represent the average values of the payload data for all COFDM subcarriers of the allocated segments.

The MER(f) measurement displays the average value of the layers being used. The graphical representation of the ISDB-T channel displays poor carrier suppression as a notch at the center of the band, see Fig. 13 .The MER(f) display also shows the presence of frequency-selective interference as well as the mixed use of differential and coherent modulation. (In this system differential modulation (DQPSK) results in a MER that is about 3 dB lower, see Fig. 14).

Procedure
⚠ Check that the max. input power is not exceeded, see Section 2.4
Connect the R&S®ETL (IN1) to the test port before or after the mask filter (M1 / M3)
Define the TV/radio analyzer/receiver default settings as described in Section 2.5
MEAS→Modulation Analysis→MER(f)→Adjust Attenuation
SPAN→Full Span
MEAS→Modulation Analysis→MER(f)→Auto Range
Use PRINT to print the test screen; see Fig. 13

High-efficiency transmitters can cause the MER(f) to display a slight distortion after the equalizer.

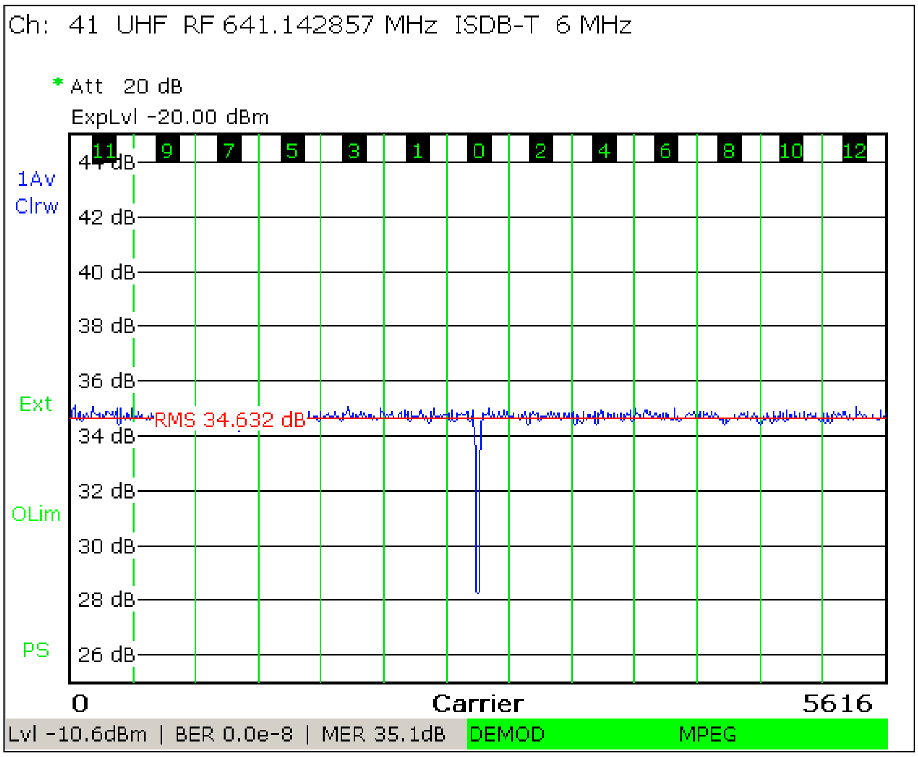


Fig. 13: TV/radio analyzer/receiver mode, MEAS→Modulation Analysis→MER(f) menu: MER as a function of the frequency and integration of the MER averaged over the channel (RMS).

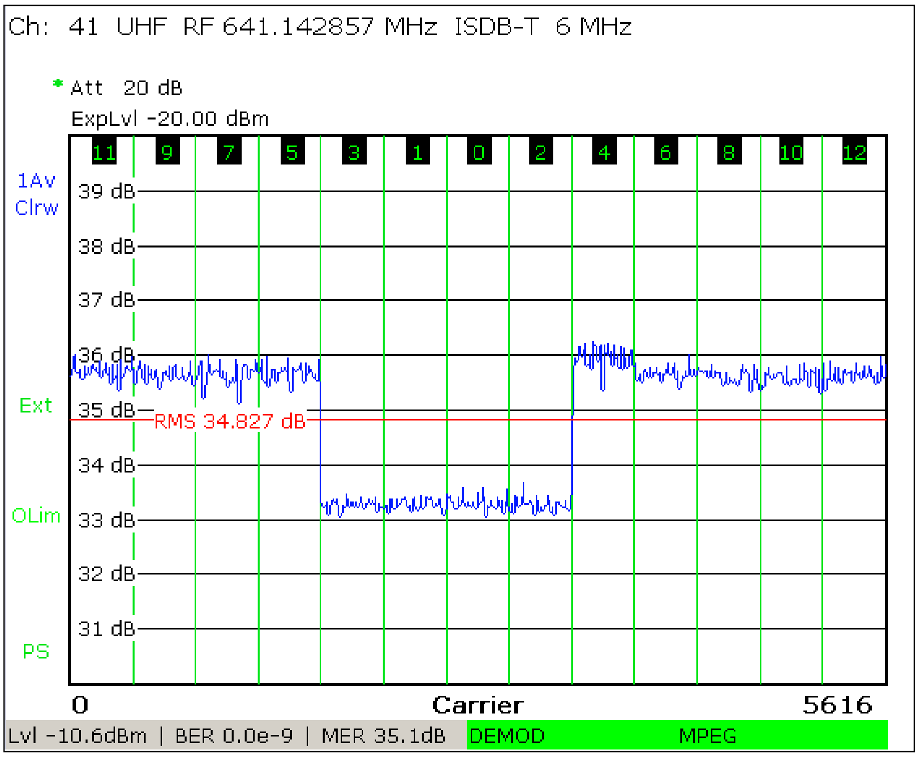


Fig. 14: MER development for coherent and differential modulation in the various layers.

3.4.3 Constellation Diagram

The constellation diagram makes it possible to display all the signal states that occurred in quadrature modulation at discrete time intervals at the same time. The constellation diagram is a graphical representation of the in-phase and quadrature components of the QAM signal in the x- and y-axes. In the case of modulation with multiple carriers, the constellation diagram typically forms the sum of the signal states of all the carriers. A noisy or disrupted DAB signal will exhibit cloud-like effects. The smaller the resulting points on the constellation diagram, the better the signal quality. When making measurements directly on the transmitter, only fine constellation points should be visible.

You can use the R&S®ETL to choose whether to display the constellation diagram for a specific layer or for all layers. The results for all carriers must first be recorded using FULL SPAN. The quality of the I/Q alignment (see 3.2.1) can then be checked by a targeted analysis of the center carrier frequency.

Procedure
⚠ Check that the max. input power is not exceeded, see Section 2.4
Connect the R&S®ETL (IN1) to the test port before or after the mask filter (M1 / M3)
Define the TV/radio analyzer/receiver default settings as described in Section 2.5
MEAS→Modulation Analysis→Const Diagram→Adjust Attenuation
SPAN→Full Span
Use PRINT to print the constellation diagram; see Fig. 15
Go to SPAN→Span Carrier→Carrier Span and enter the carrier number of the mid-band (carrier number 2808 in mode III, carrier number 1404 in mode II or carrier number 702 in mode I)
Use PRINT to print the constellation diagram again

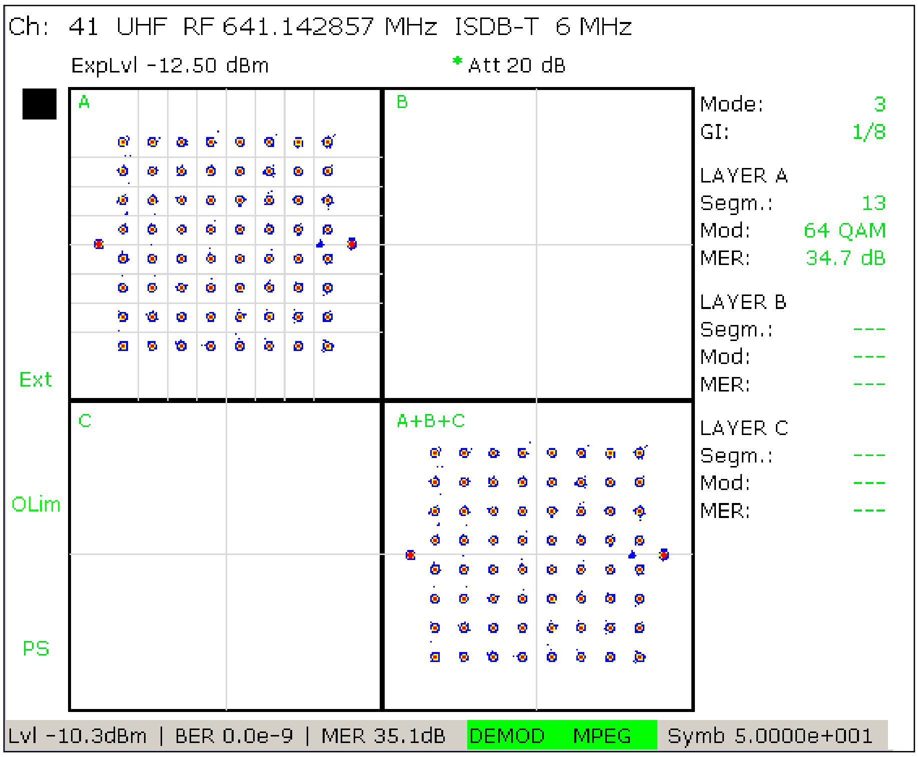


Fig. 15: TV/radio analyzer/receivermode, MEAS→Modulation Analysis→Const Diagram menu: ISDB-T constellation diagram (layer A, 64QAM).

3.4.4 Bit Error Ratio

ISDB-T provides an outer and inner error correction in the form of Reed-Solomon (RS) block coding and convolutional coding, which are assessed using a Viterbi decoder. Both methods are capable of recognizing and correcting bit errors in the data stream. As a result, the following three bit error ratios (BERs) are available:

- BER before Viterbi
- BER after Viterbi = BER before RS
- BER after RS

All interference of an ISDB-T transmission path can be expressed as bit error ratios (BER). In the case of a functional ISDB-T transmitter, only the BER before Viterbi can differ from null. It will lie in the range of 10^{-9} or less. With small BERs, it is necessary to select correspondingly long measurement times. For acceptance tests, this will be hours, while it will be minutes for monitoring tests.

In the case of ISDB-T, the R&S®ETL can be used to measure the BER of the three different layers simultaneously (TV/radio analyzer/receivermode, MEAS→Overview →Overview Meas). For acceptance testing, the development of the BERs over time for layer A should be measured, along with any loss of synchronization.

Procedure
⚠ Check that the max. input power is not exceeded, see Section 2.4
Connect the R&S®ETL (IN1) to the test port before or after the mask filter (M1 / M3)
Define the TV/radio analyzer/receiver default settings as described in Section 2.5
Open MEAS→Digital TV Settings • MPEG TS Output: Select the layer
MEAS→Overview→Adjust Attenuation
Open the MEAS→Measure Log→Configure dialog; see Fig. 16 • Select Enable Measurement Log • Select the Time Span to define the measurement time • Select Trace 1: BER before Viterbi • Select Trace 2: BER before Reed-Solomon
MEAS→Measure Log→Clear
Allow the test – lasting from several minutes to several hours – to run completely
Check the validity of the measurement: The measurement is considered valid if no synchronization loss occurs; see Fig. 17
If the measurement is valid: MEAS→Measure Log→Auto Range
If the measurement is valid: Record the max. values or use PRINT to print the results

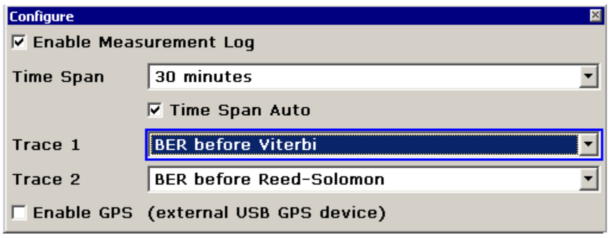


Fig. 16: TV/radio analyzer/receiver mode, MEAS→Measure Log→Configure menu: Configuration for the BER measurement.

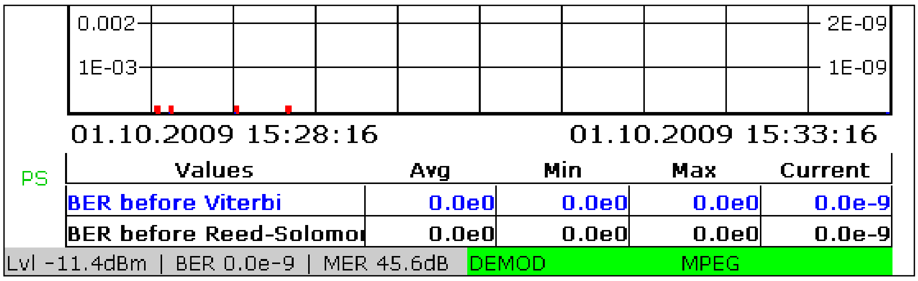


Fig. 17: TV/radio analyzer/receiver mode, MEAS→Measure Log menu: BER measurement with the measurement log. Red markers directly above the time axis (here in the 2nd and 3rd time segments) indicate a loss of synchronization. In this case, the BER measurement is invalid.

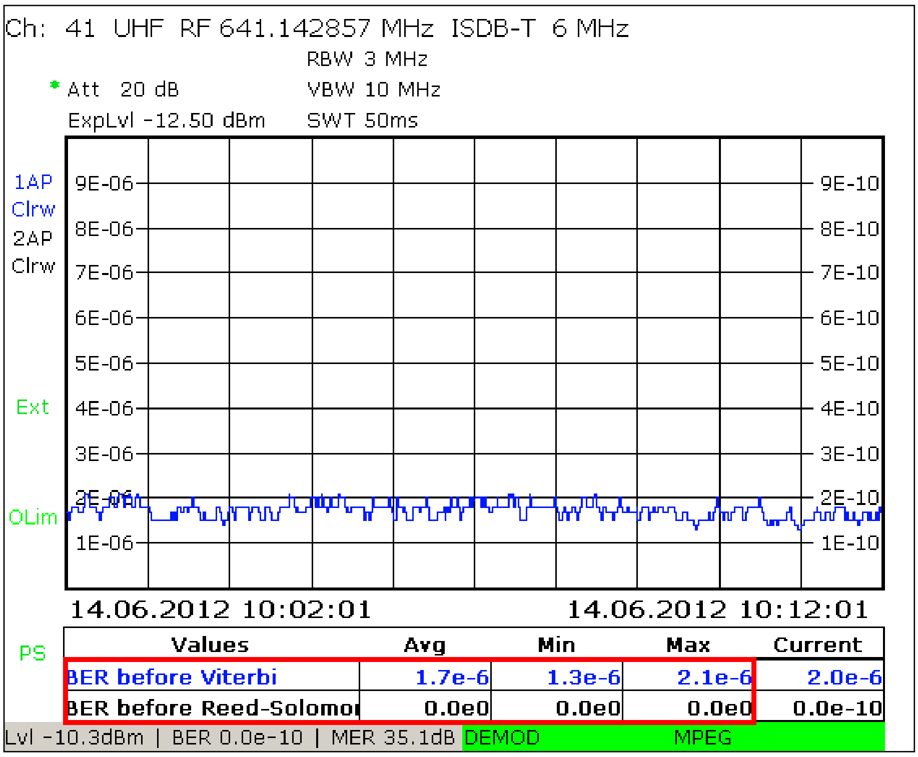


Fig. 18: TV/radio analyzer/receiver mode, MEAS→Measure Log menu: Valid BER measurement.

4 Abbreviations

ATSC	Advanced television systems committee
BER	Bit error ratio
CCDF	Complementary cumulative distribution function
DQPSK	Differential quadrature phase shift keying
ISDB-T	Integrated service digital broadcasting – terrestrial
DVB-T	Digital video broadcasting – terrestrial
MER	Modulation error ratio
MPEG	Moving Picture Experts Group
OFDM	Orthogonal frequency division multiplex
RS	Reed-Solomon
SFN	Single-frequency network
TS	Transport stream
QAM	Quadrature amplitude modulation
QPSK	Quadrature phase shift keying

5 References

[1] "Digital Video and Audio Broadcasting Technology",
Walter Fischer, Springer Verlag, 2010,
ISBN: 978-3-642-11611-7

[2] Rohde & Schwarz Application Note 7TS02

[3] "CCDF determination – a comparison of two measurement methods",
Christoph Balz, Neues von Rohde & Schwarz, Heft 172 (2001/III), S. 52 – 53

6 Additional Information

Our application notes are regularly revised and updated. Check for any changes at http://www.rohde-schwarz.com.

Please send any comments or suggestions about this application note to Broadcasting-TM-Applications@rohde-schwarz.com.

7 Ordering Information

Designation	Type	Order No.
Instrument		
TV Analyzer, 500 kHz to 3 GHz, with tracking generator	R&S®ETL	2112.0004.13
Average Power Sensor; 9 kHz to 6 GHz, 200 mW	R&S®NRP-Z91	1168.8004.02
Required options		
One of the following three power sensor interfaces		
- Additional Interfaces	R&S®FSL-B5	1300.6108.02
- Active USB Adapter	R&S®NRP-Z3	1146.7005.02
- Passive USB Adapter	R&S®NRP-Z4	1146.8001.02
Power Sensor Support with NRP	R&S®FSL-K9	1301.9530.02
80 Gbyte HD (part of the base unit starting with SN 101500)	R&S®ETL-B209	2112.0291.02
MPEG Processing Board	R&S®ETL-B280	2112.0362.02
MPEG TS Generator/ Recorder	R&S®ETL-K280	2112.0591.02
ISDB-T Firmware	R&S®ETL-K260	2112.0485.02
Measurement Log for DTV	R&S®ETL-K208	2112.0579.02
Recommended options		
Single-frequency network offset		
ISDB-T SFN frequency offset	R&S®ETL-K261	2112.0491.02
Picture display		
Video and Audio HW Decoder	R&S®ETL-B281	2112.0356.02
HDTV and Dolby Upgrade	R&S®ETL-K281	2112.0604.02
MPEG analysis		
MPEG Analysis/Monitoring	R&S®ETL-K282	2112.0610.02
In-Depth Analysis	R&S®ETL-K283	2112.0627.02
Data Broadcast Analysis	R&S®ETL-K284	2112.0633.02

A Transport Stream Generation Using the R&S®ETL

The MPEG TS generator / recorder provided with the R&S®ETL generates MPEG-2 transport stream (TS). It is applied to the transmitter via a 75 Ω cable connected to the TS ASI OUT output (at the rear of the R&S®ETLs). A full complement of transport stream files with varying data rates are available for ISDB-T, all of which can be played back without interruption in an endless loop. The following settings are required on the R&S®ETL:

TS generator settings
MODE→TS Generator / Recorder
MEAS→TS Generator→Source: Select the appropriate TS (see Fig. 19)
MEAS→TS Generator→Start

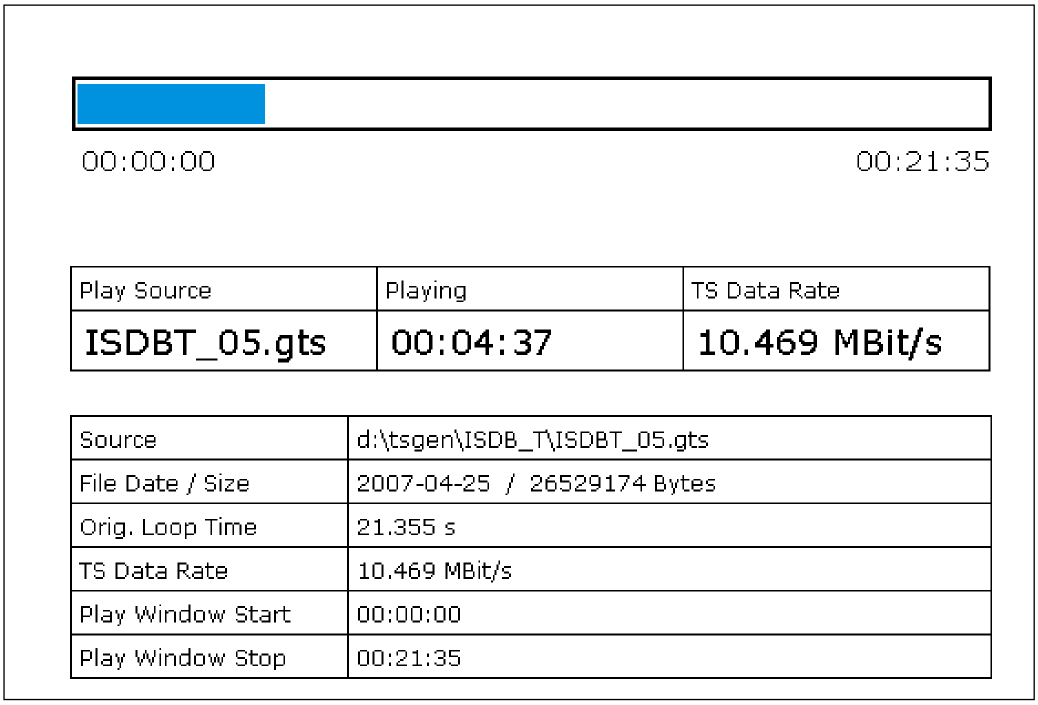


Fig. 19: TS generator mode: Generating a transport stream.

B Reverse Power Measurement Uncertainty

Measurement uncertainty occurs during scalar measurements of reverse power as a result of the directivity of measurement couplers. This directivity is an indicator of undesirable forward crosstalk on the reverse power that is being measured. The better the directivity, the less undesirable forward crosstalk is present. A typical directivity value for directional couplers is about −35 dB.

The phase of the overlapping signals must be known in order to measure reverse power exactly. This is possible only with a vector power measurement. However, the scalar measurement offered by the R&S®ETL can also be used to perform the necessary assessment. Instead of determining the precise reverse power value, the R&S®ETL ensures that the reverse power is low enough that the transmitter station self-protect function does not shut down the station. This can be determined using a scalar measurement as long as the ratio of the directional coupler directivity to the maximum permissible reverse power is large enough.

During a scalar measurement of the reverse power, the theoretical worst-case measurement errors would be from about +6 dB bis −∞ dB, see Fig. 20. In other words, the reverse power in a scalar measurement can be up to 6 dB too high or else much too low. The measurement uncertainty is dependent on the insertion loss, the directivity, and the reverse power. To simplify the evaluation, the insertion loss should be disregarded because its influence in practice is negligible.

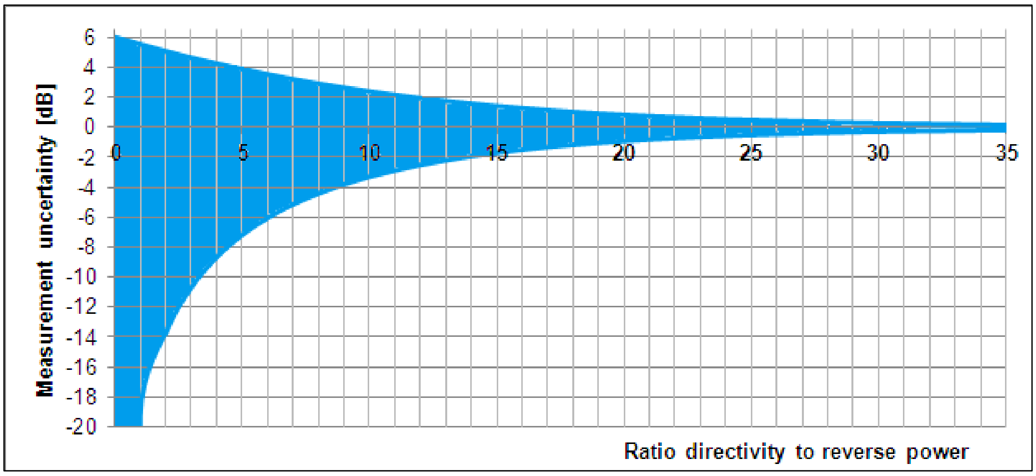


Fig. 20: Measurement uncertainty of the scalar measurement, dependent on the ratio of the directional coupler directivity to the reverse power (insertion loss of the directional coupler is disregarded).

For example, assume that the ratio of the directional coupler directivity to the reverse power is 0 dB (worst case). In this situation, the theoretical maximum measurement error would be between +6 dB and −∞ dB. However, as long as a 6 dB greater value is acceptable, it is not necessary to determine the actual value.

In another example, assume that the difference between the directional coupler directivity and the reverse power is 20 dB. In this case, the theoretical maximum measurement error would be between 0.83 dB and −0.92 dB. In other words, if the decoupled reverse power is −15 dBm, for example, and the directional coupler directivity is −35 dB, values of between –14.17 dBm and −15.92 dBm can occur at the test instrument. In this case, the measurement uncertainty varies in a range of ±1 dB. As a result, a scalar measurement would detect the critical case of a large reverse power.

The following diagram (Fig. 21) can be used to determine the maximum actually reversed power based on the measurement value that is displayed.

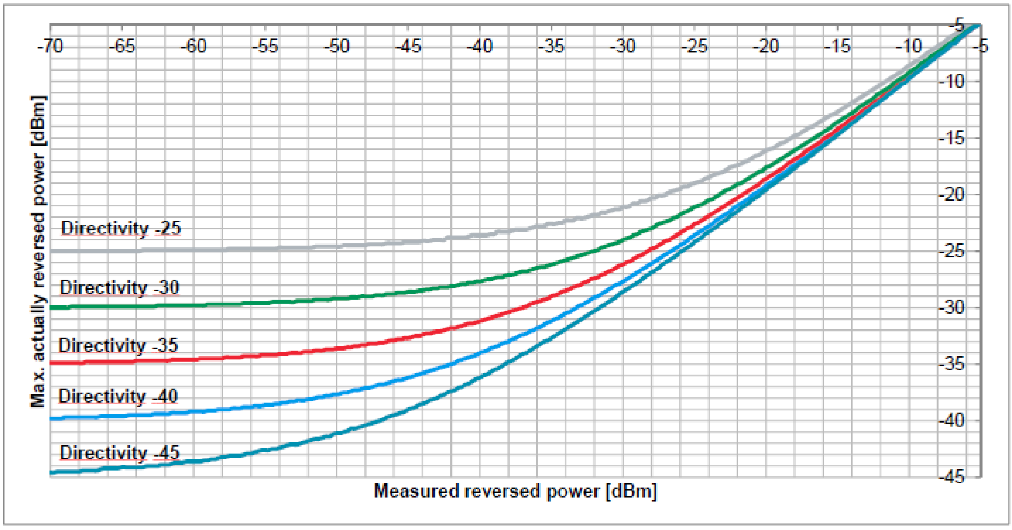


Fig. 21: Maximum actually reversed power based on measured reverse power.

In summary, a scalar measurement is sufficient as long as the maximum actually reversed power from the measured line is at an acceptable value.

C Recording a Filter Frequency Response in a Transducer File

In practice, there are two methods for assessing signals that exceed the dynamic range offered by spectrum analyzers:

- Method 1: The frequency components having the highest power are selectively attenuated using auxiliary filters, such as adjustable notch filters or a highpass filter. This reduces the dynamic range enough that the signals can be measured after the auxiliary filter. In order to display the actual dynamic range automatically, a transducer file is used to compensate by mathematically subtracting the frequency response of the auxiliary filter, which was previously assessed in a separate step.

- Method 2: If the high dynamic range of the signal is achieved by using a specific filter (for example, the mask filter on a transmitter), auxiliary filters are not absolutely required. Instead, the frequency response of the specific filter can be recorded separately as a transducer file. This transducer file is then enabled during the measurement before the filter by adding the filter frequency response, and thus automatically calculating the actual dynamic range.

The transducer file can be created directly using the tracking generator function on the R&S®ETL as long as the frequency response of the filter does not exceed the measurable dynamic range.[1]:

<table>
<tr><th colspan="2">Generating a transducer file</th></tr>
<tr><td colspan="2">MODE→Spectrum Analyzer</td></tr>
<tr><td colspan="2">FREQ→Center: Set to center frequency at mid-channel</td></tr>
<tr><td colspan="2">SPAN→Span Manual: Set to 30 MHz</td></tr>
<tr><td colspan="2">TRACE→Detector Manual Select→More→Detector Average</td></tr>
<tr><td colspan="2">BW→Res BW Manual: Set to 30 kHz</td></tr>
<tr><td colspan="2">SWEEP→Sweeptime Manual: Set to 2 s</td></tr>
<tr><td colspan="2">MENU→Tracking Generator→Source On</td></tr>
<tr><td colspan="2">MENU→Tracking Generator→Source Power: Set to 0 dBm</td></tr>
<tr><td colspan="2">Connect the cables to be used for the measurement from the Gen Out 50 Ω output on the R&S®ETL to the RF IN 50 Ω input on the R&S®ETL; see Fig. 22:</td></tr>
<tr><td colspan="2">AMPT→Ref Level: Set to –30 dBm</td></tr>
<tr><th>R&S®ETL with preselector[2]</th><th>R&S®ETL without preselector</th></tr>
<tr><td>AMPT→RF Atten Manual: Set to 15 dB</td><td>AMPT→RF Atten Manual: Set to 0 dB</td></tr>
</table>

[1] The frequency response provided in the data sheet can also be entered into the transducer file manually (SETUP→Transducer).
[2] If a preselector is provided in the instrument, the Preselector setting is available unter AMPT→More. The preselector is enabled by default.

Generating a transducer file	
If an overload occurs,[1], go to AMPT→RF Atten Manual and increase the attenuation by 5 dB.	
MENU→Tracking Generator→Source Cal→Cal Trans	
MENU→Tracking Generator→Source Cal→Normalize	
Using the previously assessed cables, connect the filter to be assessed from the Gen Out 50 Ω output on the R&S®ETL to the RF IN 50 Ω input on the R&S®ETL; see Fig. 22	
Method 1 (reduce the dynamic range using auxiliary filters)	**Method 2 (assess before increasing the dynamic range)**
MENU→Tracking Generator→Source Cal→More→Save As Neg Trd Factor	MENU→Tracking Generator→Source Cal→More→Save As Pos Trd Factor
Specify a file name and save the transducer file	
Go to SETUP→Transducer→Active On to enable the transducer file	

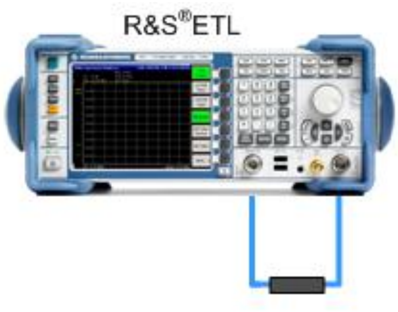


Fig. 22: Connection setup to regulate the cable.

Fig. 23: Connection setup to assess the frequency response of a mask filter.

[1] Overload warnings appear centered at the top of the display as "IFovl" or "Ovld".

D Automated Measurements Using R&S®TxCheck

The R&S®TxCheck software application is available free of charge on every R&S®ETL. This software makes it possible run measurements automatically, and includes the generation of a weighted report of the results.

This Application Note includes the file "7BM103.ETLtxi". Opening this file in R&S®TxCheck configures the software to perform all automated measurements on the transmitter:

- Transmitter Output Level (3.1.1, TV/radio analyzer/receiver variant)
- I/Q Imbalance (3.2.1)
- Amplitude Frequency Response and Group Delay (3.2.2)
- Frequency Accuracy (3.4.1)
- Modulation Error Ratio (3.4.2)
- Constellation Diagram (3.4.3)

Automated measurements using R&S®TxCheck
Copy the file 7BM103.ETLtxi to the R&S®ETL
⚠ Check that the max. input power is not exceeded, see Section 2.4
If available, connect the R&S®ETL (IN1) to the test port (M4) on the antenna combiner, or else to (M3) after the mask filter
MODE→TxCheck
In the R&S®TxCheck application, go to File/Open Profile (*.ini) and select the previously copied profile "7BM103.ETLtxi"
On the “Settings” tab, adjust the frequency and bandwidth; see Fig. 24
On the “Measurements” tab, adjust the limits for the individual measurement parameters; see Fig. 25
Go to "Measurement/Start Measurement" to start the measurement
After the measurements are complete, go to "File/Save" to save the results

The results of the automated measurement are displayed in the "Measurements" and the "Graphics" tabs. To view the saved result files on an external PC, first install the R&S®TxCheck software on the PC (in the R&S®TxCheck application, go to "Help/Installation Info…" for more information). Finally, go to "File/Print" to print the result report.

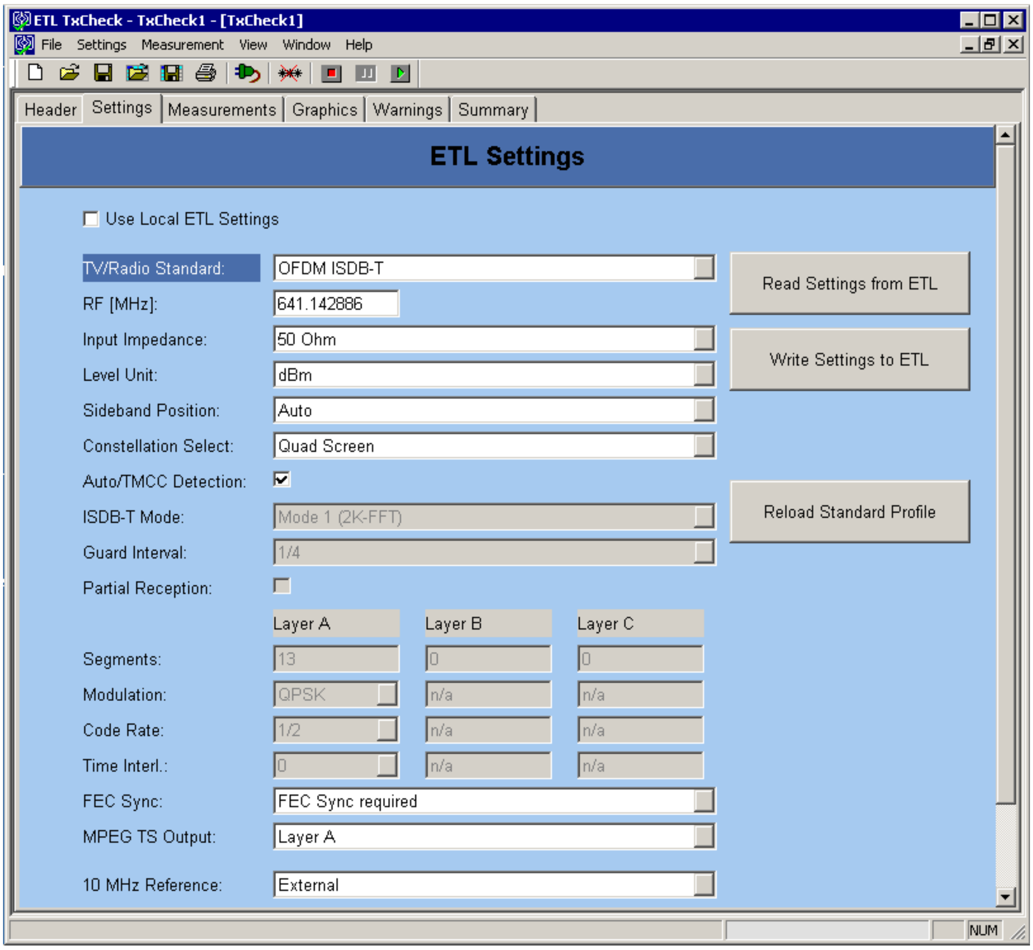


Fig. 24: R&S®TxCheck user interface, "Settings" tab.

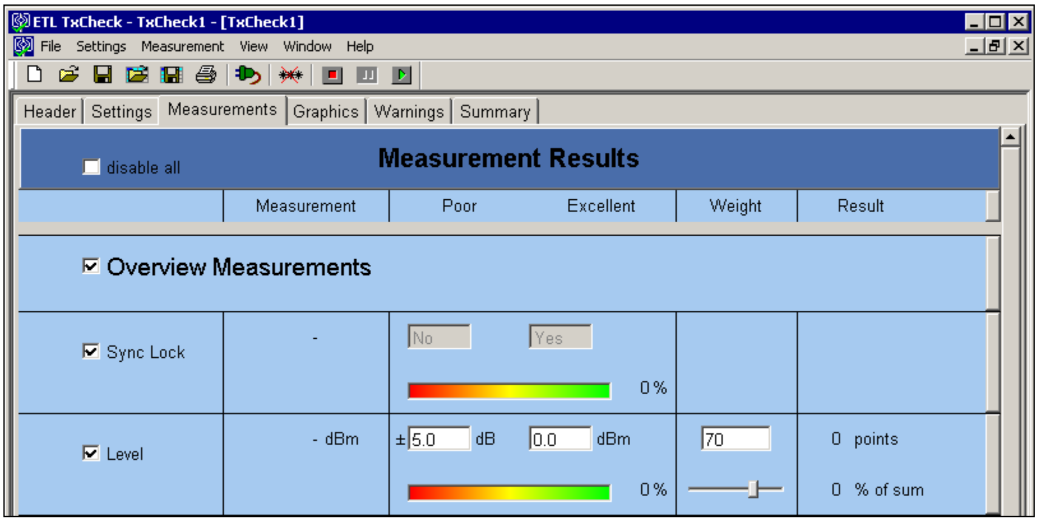


Fig. 25: R&S®TxCheck user interface, "Measurements" tab.

About Rohde & Schwarz

Rohde & Schwarz is an independent group of companies specializing in electronics. It is a leading supplier of solutions in the fields of test and measurement, broadcasting, radiomonitoring and radiolocation, as well as secure communications. Established more than 75 years ago, Rohde & Schwarz has a global presence and a dedicated service network in over 70 countries. Company headquarters are in Munich, Germany.

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Environmental commitment

- Energy-efficient products
- Continuous improvement in environmental sustainability
- ISO 14001-certified environmental management system

Certified Quality System
ISO 9001

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