ATSC Transmitter Measurements for Acceptance, Operation and Monitoring

Application Note

Products:

| R&S®ETL | R&S®DVSG

This application note describes how to perform acceptance, operational and monitoring measurements on a digital terrestrial television transmitter based on the Advanced Television Systems Committee (ATSC) standard.

As compared to analog television, digital television requires significantly fewer measurement parameters to evaluate the quality of the transmitter output signal. The most important parameters are:

- Transmitter output level
- Bit error ratio (BER)
- Modulation error ratio (MER)
- Shoulder attenuation

Application Note
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ROHDE&SCHWARZ

The following abbreviations are used throughout this document:
R&S®XYZ is abbreviated as R&S XYZ.

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1 Overview

This application note describes how to perform acceptance, operational and monitoring measurements on a digital terrestrial television transmitter based on the Advanced Television Systems Committee (ATSC) standard. As compared to analog television, digital television requires significantly fewer measurement parameters to evaluate the quality of the transmitter output signal. The most important parameters are:

- Transmitter output level
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- Modulation error ratio (MER)
- Shoulder attenuation

This document is structured as follows: Chapter 2 presents the test setup and its device requirements. Chapter 3 explains the particular measurements. Finally, ordering information is given.

2 Test Setup

The following measurement equipment is needed to perform measurements on the ATSC transmitter:

- R&S DVSG MPEG-2 transport stream generator
- R&S ETL TV analyzer with the latest firmware
- Average power sensor, e.g. R&S NRP-Z91
- Dummy antenna
- GPS receiver with 10 MHz reference output and 1 pps output, e.g. R&S ED170
- Highpass filter to supress the wanted signal by 40 dB or more (e.g. MiniCircuits)

The required device options are listed in Chapter 7.

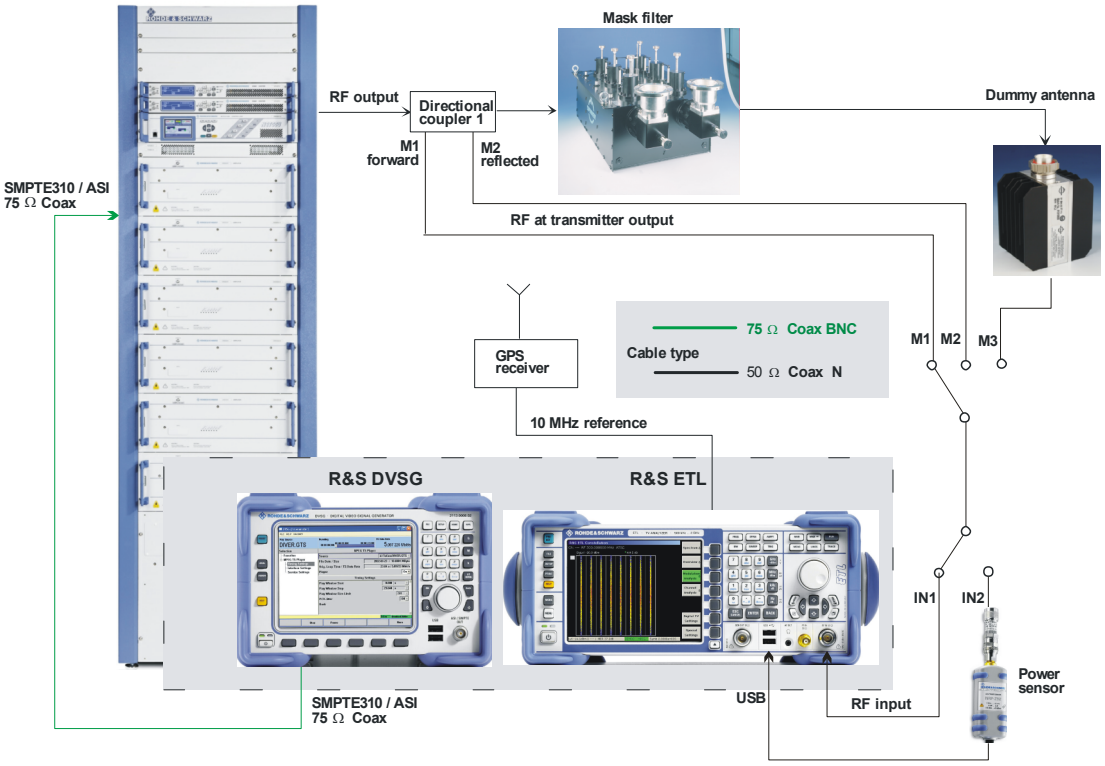


Fig. 2-1: Test setup

The R&S DVSG feeds the ATSC-compliant MPEG-2 transport stream to the transport stream input on the ATSC transmitter. The transmitter output is connected to a dummy antenna. If installed, the mask filter is located between the transmitter output and the dummy antenna. The RF input of the R&S ETL TV analyzer (IN1) or the power sensor (IN2) is connected as follows for the various measurements:

- to the test port on the transmitter output (M1 = forward, M2 = reflected)
- to the test port on the dummy antenna (M3)

The R&S ETL TV analyzer is connected to the power sensor using one of its USB ports and to the GPS receiver using its reference input.

Default settings on the R&S ETL TV analyzer

The following default settings are always used on the R&S ETL TV analyzer to perform TV transmitter measurements:

Reference frequency

Set R&S ETL SETUP:REFERENCE EXT to use the external 10 MHz reference frequency.

Spectrum Analyzer mode

- Center Frequency at mid-channel
- Span 15 MHz or 20 MHz
- Detector RMS (in the TRACE menu)
- RBW 30 kHz
- VBW 300 kHz
- Sweep Time 2 s

TV Analyzer/Receiver mode

- Digital TV Settings: 8VSB
- Special Settings: System Opt. Medium
- Important: Always press MENU:ADJUST ATTENUATION before every measurement

3 Measurements

3.1 Transmitter Output Level

The transmitter output level is defined completely differently for digital television as compared to analog television. ATSC signals are pseudo-noise signals, in contrast to vestigial sideband, AM-modulated analog TV signals. In the case of analog television, the synchronous pulse peak power is used as the power definition, while for digital television, the average power is measured over the RMS value. The average power is constant for digital television, and not dependent on the picture contents, like it is in analog television. The transmitter output is followed by the mask filter, which can be implemented in either a critical or an uncritical mask. The filter itself has an attenuation of between 0.1 dB and 0.3 dB, depending on the technology used (coaxial or dual-mode waveguide). Therefore, the power has to be recorded both before and after the mask filter. The measurement itself takes place using a power sensor. This is connected to a calibrated test port on the transmitter output or on the dummy antenna. Measurement using the power sensor provide the greatest accuracy, but of course the signal level can also be measured using the R&S ETL TV analyzer set to TV Analyzer/Receiver mode via the RF input on the R&S ETL.

Procedure:

1. Connect the power sensor (IN2) (connected to R&S ETL via USB) to the test port on the transmitter output (M1).
2. Switch transmitter ON.
3. On the R&S ETL, press MENU:POWER METER.
4. Read the measured value from the R&S ETL.
5. Alternatively, feed a signal into the RF input on the R&S ETL (50 ohm, IN1) and read the level from the MEAS:OVERVIEW menu.
6. Add to that the correction value from the test port.
7. Connect the power sensor (IN2) (connected to R&S ETL via USB) to the test port on the dummy antenna (M3).
8. Read the measured value from the R&S ETL.
9. Alternatively, feed a signal into the RF input (50 Ohm, IN1) on the R&S ETL and read the level from the MEAS:OVERVIEW menu (first press ADJUST ATTENUATION).
10. Add to that the correction value from the test port.

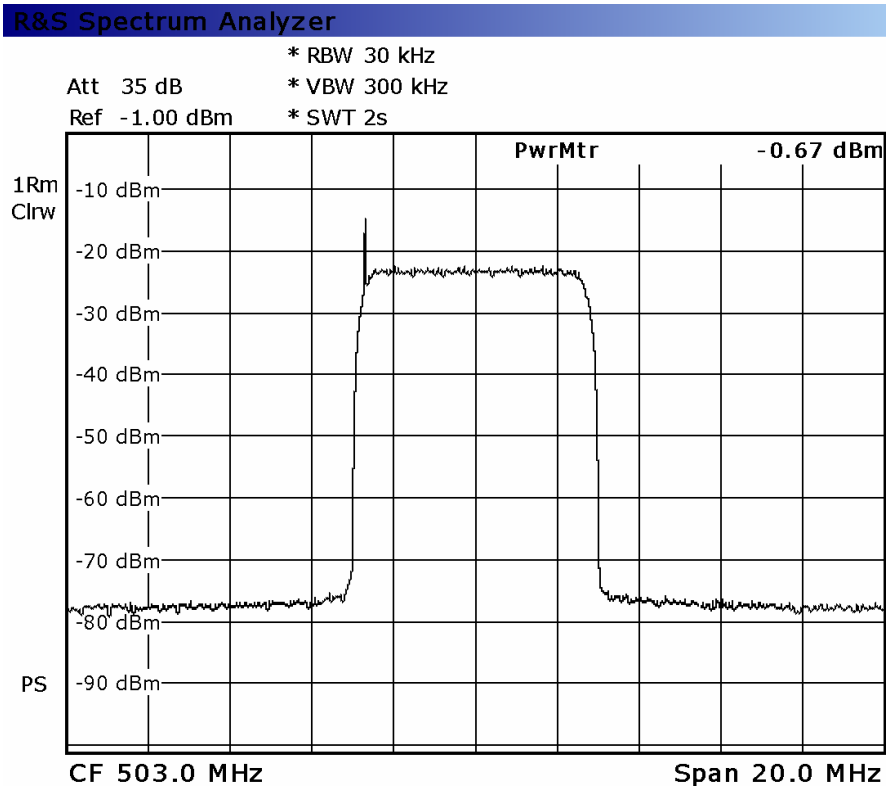


Fig. 3-1: ATSC spectrum with integrated reading from the power sensor

R&S ETL Digital Overview

Ch: 19 UHF4/5 RF 503.000000 MHz ATSC

* Att 25 dB
SigLvl -7.50 dBm

Level -0.8 dBm

	Pass	Limit <	Results	< Limit	Unit
	Level	-60.0	-0.8	10.0	dBm
	Constellation		8VSB / Normal		
	MER (rms)	24.0	48.7	-----	dB
	MER (peak)	10.0	28.9	-----	dB
	EVM (rms)	-----	0.24	4.40	%
	EVM (peak)	-----	2.34	22.00	%
	BER before RS		0.0e-9(122/1K00)	2.0e-4	
	Packet Error Ratio		0.0e-5(80/100)	1.0e-8	
	Packet Errors		0	1	/s
PS	Carrier Freq Offset	-30000.0	69.5	30000.0	Hz
	Symbol Rate Offset	-10000.0	1.7	10000.0	Symb/s
	MPEG Ts Bitrate		19.392661		MBit/s

Lvl -0.8dBm | BER 0.0e-9 | MER 48.7dB DEMOD MPEG

Fig. 3-2: MEAS:OVERVIEW menu in TV Analyzer/Receiver mode on the R&S ETL with integrated level readings (zoom level, level result in the 2nd table row and along the bottom of the test screen)

Similarly, the power sensor (IN2) can also be used to measure the reflected power at measurement point M2 at the test port on the transmitter output.

3.2 Bit Error Ratio

Error correction for ATSC is divided between the transmitter and the receiver. In the transmitter, it consists of the following:

- Scrambler
- Reed-Solomon RS(188,208) coder
- Time interleaver
- Trellis coder

In the receiver, it consists of the following:

- Viterbi decoder
- Time deinterleaver
- Reed-Solomon decoder
- Descrambler

As a result, the following are available:

- Bit error ratio before Viterbi (BER before Viterbi),
- Bit error ratio before Reed-Solomon (BER before Reed-Solomon)
- Packet error ratio

To perform this procedure, the R&S ETL must be changed to ATSC mode using the DIGITAL TV SETTINGS. The BER before Viterbi cannot be measured because of ambiguities in the Trellis re-encoding required for the measurement.

Procedure:

1. Connect the R&S ETL TV analyzer to the test port on the transmitter output (M1) or the dummy antenna (M3).
2. Switch transmitter on.
3. On the R&S ETL, select OVERVIEW from the test menu.
4. Press MENU:ADJUST ATTENUATION.
5. On the R&S ETL, press BER reset.
6. Allow the test – lasting from several minutes to several hours – to run completely.
7. Read and document the BERs.

	Pass	Limit <	Results	< Limit	Unit
	Level	-60.0	-1.2	10.0	dBm
	Constellation		8VSB / Normal		
	MER (rms)	24.0	40.0	-----	dB
	MER (peak)	10.0	40.0	-----	dB
	EVM (rms)	-----	3.00	4.40	%
	EVM (peak)	-----	5.00	22.00	%
	BER before RS		1.2e-5(123/1M00)	-----	
	Packet Error Ratio		0.0e-5(10/100)	1.0e-8	
	Packet Errors		0	1	/s
PS	Carrier Freq Offset	-30000.0	-12.6	30000.0	Hz
	Symbol Rate Offset	-----	300.0	-----	Symb/s
	MPEG Ts Bitrate		19.392658		MBit/s

Lvl -1.2dBm | BER 1.2e-5 | MER 40.0dB DEMOD MPEG

Fig. 3-3: Measuring the bit error ratios for ATSC

3.3 Modulation Error Ratio

ATSC uses a single carrier modulation. Therefore, there is only one MER value. The modulation error ratio (MER) is a measure of the overall quality of the ATSC signal that includes all interference to the ATSC signal. The MER measurement value is included in several R&S ETL menus in ATSC mode.

Procedure:

1. Connect the R&S ETL TV analyzer to the test port on the transmitter output (M1) or the dummy antenna (M3).
2. Switch transmitter on.
3. On the R&S ETL, select MEASURE:MODULATION ANALYSIS: MODULATION ERRORS.
4. Select MENU:ADJUST ATTENUATION.
5. Use PRINT to print the test screen or note the MER RMS.

Pass	Limit <	Results	< Limit	Unit
Level	-60.0	-0.7	10.0	dBm
Pilot value	1.20	1.24	1.30	
Data Signal/Pilot	11.0	11.4	11.6	dB
Pilot Amplitude Error	-0.3	-0.1	0.3	dB
MER (rms)	24.0	40.0	-----	dB
MER (peak)	10.0	40.0	-----	dB
EVM (rms)	-----	3.00	4.40	%
EVM (peak)	-----	5.00	22.00	%

PS

Lvl -0.7dBm | BER 1.2e-5 | MER 40.0dB DEMOD MPEG

Fig. 3-4: "Modulation Errors" menu on the R&S ETL in ATSC mode

3.4 I/Q Imbalance on the Modulator

I/Q imbalance on the modulator will affect the ATSC signal quality. ATSC uses single carrier vestigial sideband amplitude shift keying (8VSB). Like for analog television, the lower sideband is partially suppressed (vestigial sideband modulation). If an analog I/Q modulator is used in the transmitter, the vestigial sideband filtering is carried out by means of a Hilbert transformer in the Q branch and a subsequent I/Q modulator. If the I/Q modulator uncovers an imbalance with respect to amplitude and phase, the vestigial sideband is being insufficiently suppressed.

Carrier leakage results in a defective pilot signal because the pilot is located at the previous mid-band location. The pilot amplitude is measured using the "Modulation Errors" menu (see MER measurements). A poorly suppressed lower vestigial sideband is detected during the shoulder attenuation measurement.

3.5 Shoulder Attenuation

Shoulder attenuation is an important measurement parameter for ATSC. To determine this parameter using the cursor method with the R&S ETL in Spectrum Analyzer mode, a cursor is placed at mid-band and another cursor is then offset from mid-band by –3.25 MHz or +3.25 MHz. Alternatively, the shoulder attenuation can be determined with the R&S ETL in TV Analyzer/Receiver mode by using the tangent method.

Procedure for method 1 (cursor method):

1. Connect the R&S ETL (IN1) to the corresponding test port M1 or M3.
2. Change the R&S ETL to Spectrum Analyzer mode.
3. Select the following settings on the spectrum analyzer:
   a. Center Frequency at mid-band on the ATSC channel
   b. Span 15 MHz
   c. Detector RMS
   d. RBW 30 kHz
   e. VBW 300 kHz
   f. Sweep Time 2 s
   g. Marker 1 at center
   h. Marker 2 at + 3.25 MHz over center
   i. Marker 3 at –3.25 MHz under center
   j. Read the marker delta values.

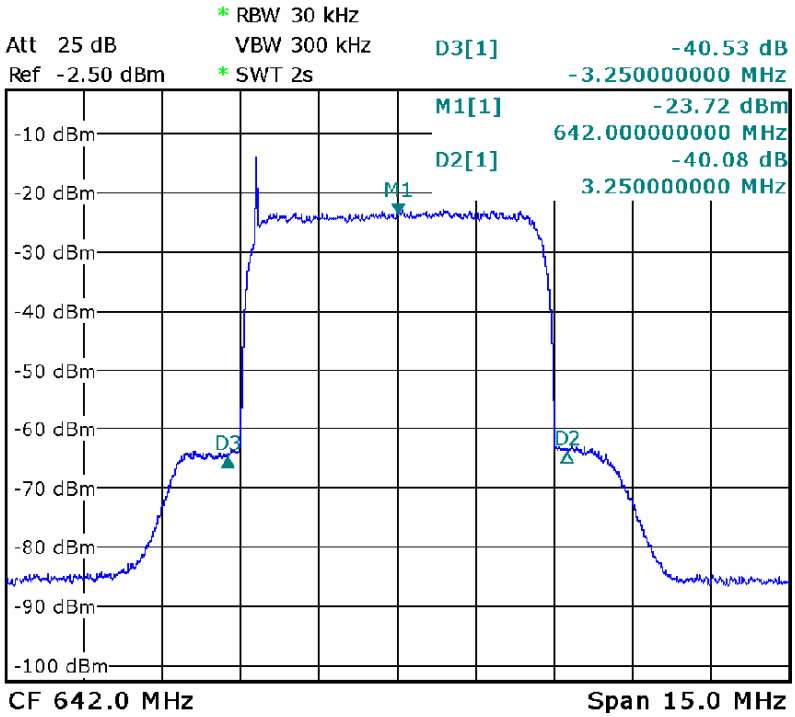
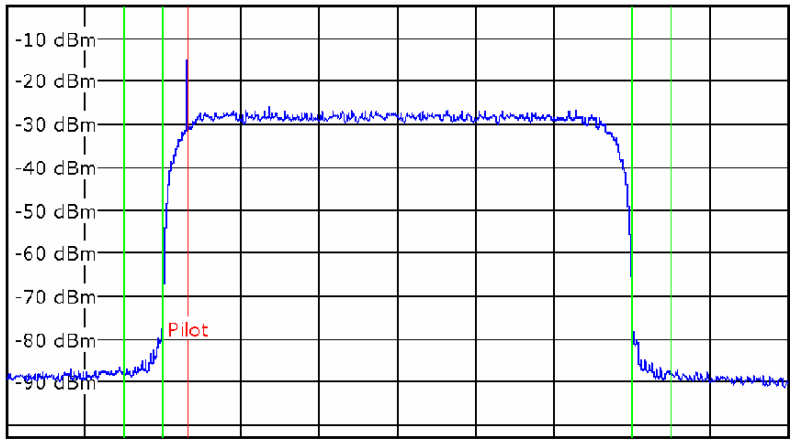


Fig. 3-5: Measuring the ATSC shoulder attenuation using the cursor method on the R&S ETL in Spectrum Analyzer mode

Procedure for method 2 (tangent method):

1. Connect the R&S ETL to the corresponding test port M1 or M3.
2. Change the R&S ETL to TV Analyzer/Receiver mode.
3. Press MENU:ADJUST ATTENUATION.
4. Select MEAS:SPECTRUM.
5. Set SHOULDER ON.
6. Print the test screen.



Shoulder Attenuation (FCC 500kHz)	Result	Unit
Lower	62.0	dB
Upper	67.4	dB

Fig. 3-6: Measuring the shoulder attenuation using the tangent method on the R&S ETL in TV Analyzer/Receiver mode

3.6 Out-of-Band Emissions

In addition to adjacent channel transmissions (shoulders), harmonics can also occur at multiples of the transmit frequency. A harmonics filter in the transmitter output ensures that these harmonics are suppressed. These out-of-band emissions can be measured using a spectrum analyzer or using the R&S ETL TV analyzer 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 at the test port on the transmitter output. However, this also requires that a suitable highpass filter be used to suppress the user channel by 40 dB or more. Notch filters have the disadvantage that they do not attenuate in just the useful band, but rather are "repeated" at multiples of the user band.

Procedure:

1. Select a highpass filter and document using the R&S ETL tracking generator.
2. Connect the highpass filter to the test port on the transmitter (M1) and to the RF input on the R&S ETL (IN1).
3. Switch transmitter on.
4. Change the R&S ETL to Spectrum Analyzer mode.
5. Select Center 1.5 GHz and Span 3 GHz.
6. Search for the out-of-band emissions.
7. Pay special attention to the range around the multiples of the transmit frequency.

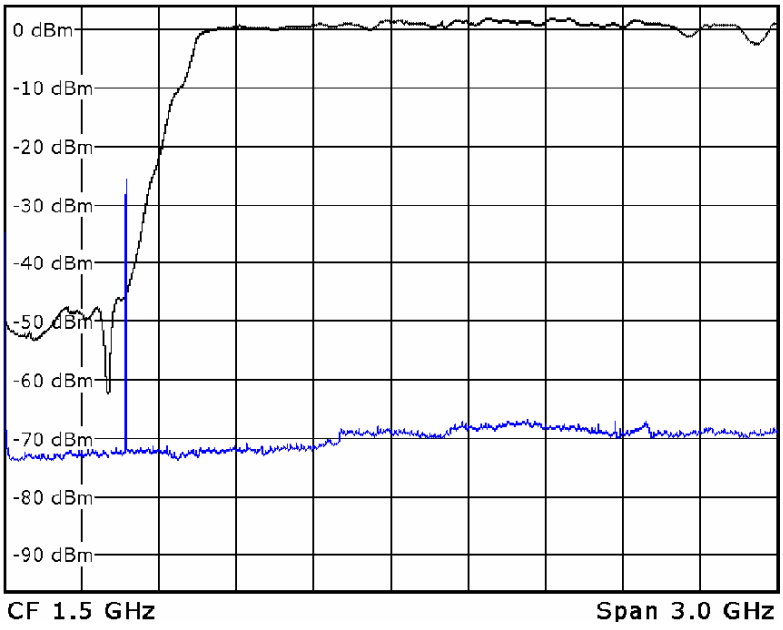


Fig. 3-7: Filter characteristics of a highpass filter compared to the useful channel

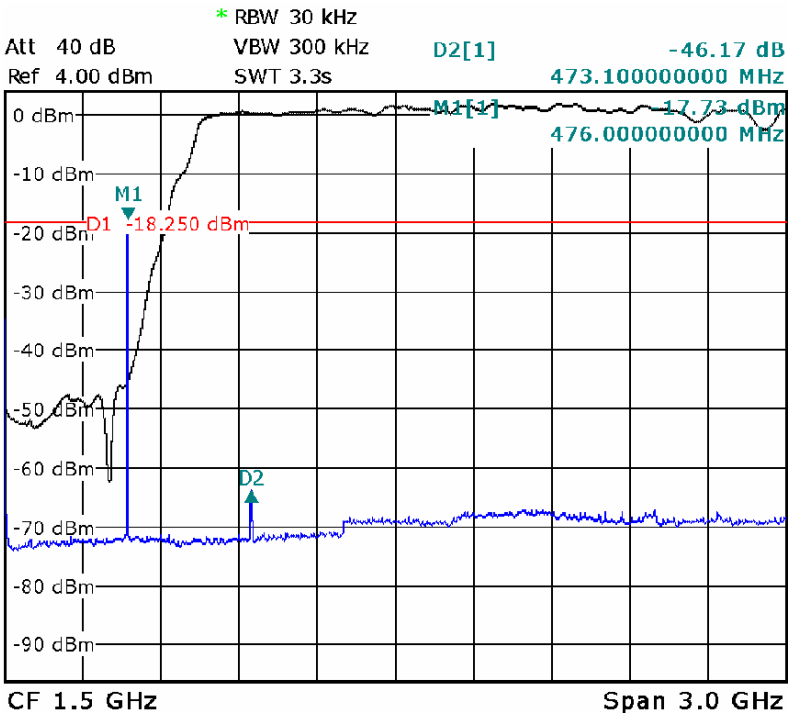


Fig. 3-8: Useful channel unattenuated compared to the first harmonic; the display line marks the level in the useful channel

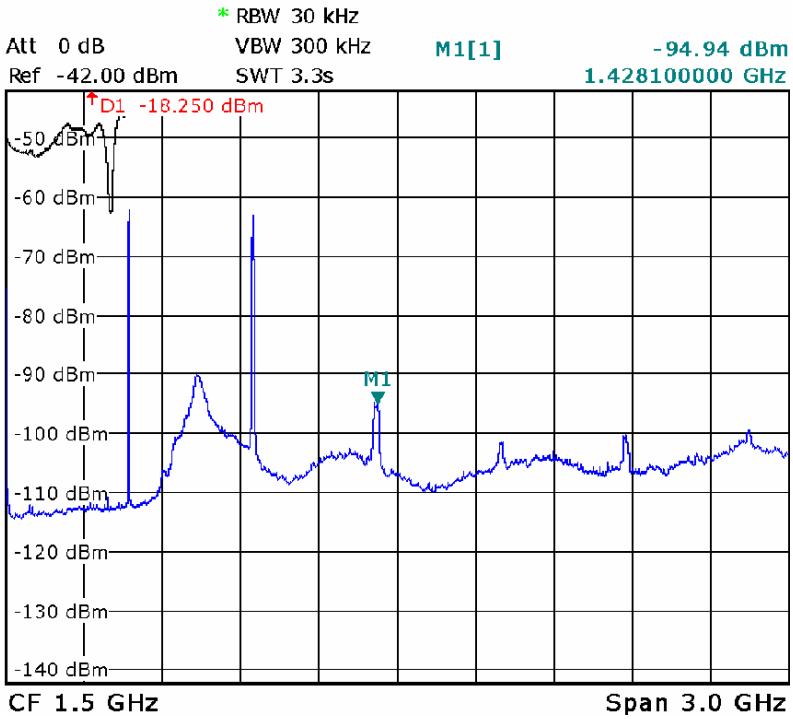


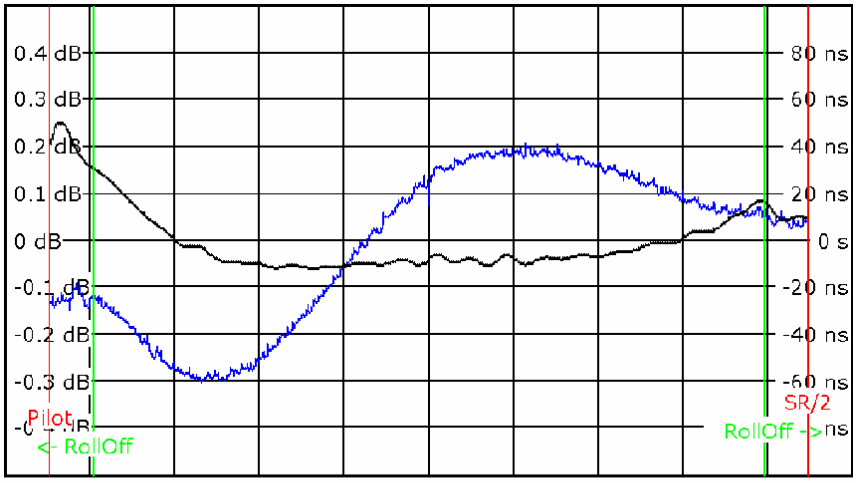
Fig. 3-9: Useful channel attenuated using the highpass filter; the display line marks the level in the useful channel; the figure shows the first and second harmonic and the attenuated useful channel (in this case: 474 MHz)

3.7 Amplitude Frequency Response and Group Delay

In analog televisions as well as in ATSC, amplitude frequency response and group delay were important parameters for a transmission path between the transmitter output and the receiver input. The mask filter and antenna combiners cause the linear distortions. These linear distortions can be compensated with the equalizer within the transmitter. As a result, however, the linear distortions reappear reversed directly at the transmitter output. Therefore, amplitude frequency response and group delay are measured at a test port in the antenna combiner.

Procedure:

1. Connect the R&S ETL to the test port.
2. Switch transmitter on.
3. Select MEAS:CHANNEL ANALYSIS:AMPLITUDE&GROUP DELAY from the menu.
4. Use MENU:ADJUST ATTENUATION.
5. Press AUTORANGE.
6. Print the test screen.



Peak to Peak (Pilot to SymbolRate/2)		
Amplitude	0.51	dB
Group Delay	62.20	ns

Fig. 3-10: Measuring amplitude frequency response and group delay with ATSC

3.8 Initial Carrier Frequency Tolerance

In single frequency networks (SFN), in particular, very stringent requirements are placed on the initial carrier frequency tolerance (ICFT) of a ATSC transmitter of less than 10^{-9}. Due to the external 10 MHz reference from the GPS receiver, the ICFT of the transmitter can be measured using the R&S ETL TV analyzer operating in TV Analyzer/Receiver mode. The measurement can take place at the test port (M1) on the transmitter output.

Procedure:

1. Connect the R&S ETL to the test port on the transmitter output.
2. Switch transmitter on.
3. Select MEAS:OVERVIEW from the menu.
4. Press MENU ADJUST ATTENUATION.
5. Note the Carrier Freq Offset reading.

Carr Freq Offset 200.0 mHz

Pass	Limit <	Results	< Limit	Unit
Level	-60.0	-0.7	10.0	dBm
Constellation		8VSB / Normal		
MER (rms)	24.0	40.0	-----	dB
MER (peak)	10.0	40.0	-----	dB
EVM (rms)	-----	3.00	4.40	%
EVM (peak)	-----	5.00	22.00	%
BER before RS		1.2e-5(123/1M00)	-----	
Packet Error Ratio		0.0e-7(1K76/10K0)	1.0e-8	
Packet Errors		0	1	/s
Carrier Freq Offset	-30000.0	0.2	30000.0	Hz
Symbol Rate Offset	-----	300.0	-----	Symb/s
MPEG Ts Bitrate		19.392658		MBit/s

Fig. 3-11: Measuring the initial carrier frequency tolerance (ICFT) using the R&S ETL (zoomed into the Carrier Frequency Offset reading)

3.9 Constellation Diagram

As a final step, the constellation diagram should also be documented. To do this, change the R&S ETL TV analyzer to TV Analyzer/Receiver mode, select MODULATION ANALYSIS:CONST from the menu, and print the test screen. The ATSC constellation diagram is made up of eight very thin vertical lines as a result of the 8ASK modulation with vestigial sideband filtering. The thinner the lines, the better the signal quality.

Procedure:

1. Connect the R&S ETL to the test port on the transmitter output (M1).
2. Switch transmitter on.
3. Change the R&S ETL to TV Analyzer/Receiver mode.
4. Select MENU:ADJUST ATTENUATION.
5. Select MEAS:MODULATION ANALYSIS:CONST DIAGRAM.
6. Print the constellation diagram.

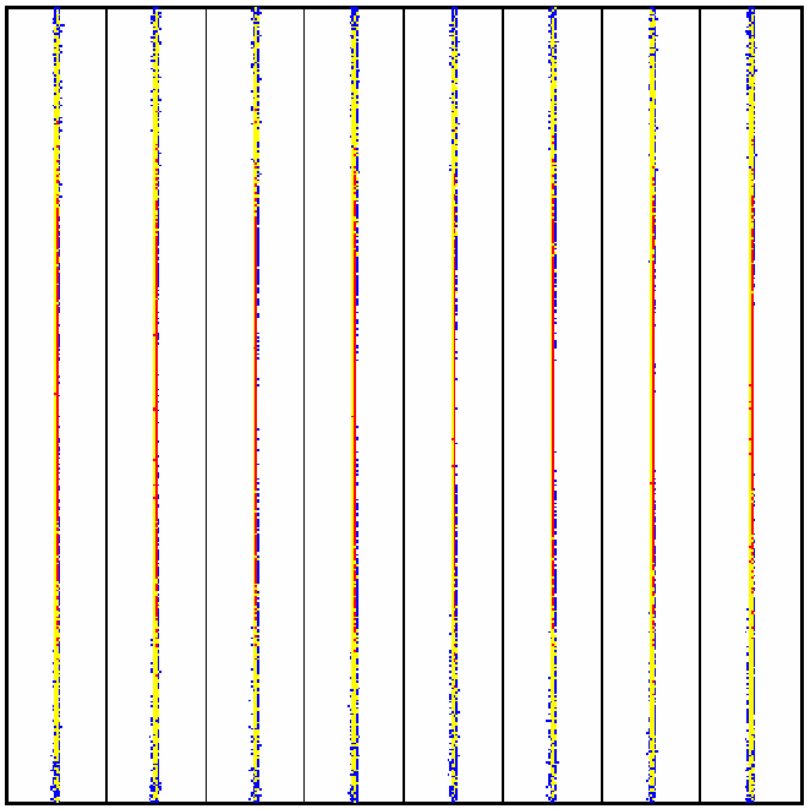


Fig. 3-12: ATSC constellation diagram

4 Abbreviations

8VSB	Single carrier vestigial sideband amplitude shift keying
ATSC	Advanced Television Systems Committee
BER	Bit error ratio
ICFT	Initial carrier frequency tolerance
MER	Modulation error ratio
RS	Reed Solomon
SFN	Single frequency network

5 Literature

[1] "Digital Video and Audio Broadcasting Technology",
Walter Fischer, Springer, 2008,
ISBN: 978-3-540-76357-4

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@rsd.rohde-schwarz.com.

7 Ordering Information

Instrument

Designation	Type	Order number
TV Analyzer, 500 kHz to 3 GHz, with tracking generator	R&S ETL	2112.0004.13
Digital Video Signal Generator	R&S DVSG	2113.0008.02
GPS Receiver	R&S ED170	2105.5856.02

Required options

Designation	Type	Order number
ATSC Firmware	R&S ETL-K220	2112.0456.02
Power Sensor Support with R&S NRP	R&S FSL-K9	1301.9530.02
Average Power Sensor; 9 kHz to 6 GHz, 200 mW	R&S NRP-Z91	1168.8004.02
MPEG Processing Board	R&S ETL-B280	2112.0362.02
Measurement Log for DTV	R&S ETL-K208	2112.0579.02
80 Gbyte Hard Disk	R&S ETL-B209	2112.0291.02
TS Player and Recorder	R&S DVSG-K20	2113.0320.02

Recommended options

Designation	Type	Order number
SFN Alignment		
ATSC/8VSB SFN Frequency Offset	R&S ETL-K221	2112.0462.02
Illustrations		
Video and Audio Hardware 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
Miscellaneous		
DC Power Supply, 11 V to 18 V	R&S ETL-B230	2112.0256.02
Documentation of R&S ETL Calibration Values	R&S ETL-DCV	2082.0490.31

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