Measurements on FM Transmitters for Acceptance, Commissioning and Maintenance
Application Note

Product:

| R&S®ETL

Despite the advent of advanced digital transmission methods, analog broadcasting remains highly important. Until now, measurements on FM transmitters in connection with acceptance testing, commissioning and maintenance required using a variety of T&M instruments.

The R&S®ETL TV analyzer combines these instruments' capabilities in a single unit and can completely replace them. Now, for the first time, acceptance test measurements can be conducted on FM transmitters quickly and easily using just one compact test instrument. The R&S®ETL provides the functionalities of a power meter, spectrum analyzer, audio generator, FM measurement demodulator, stereo decoder, audio analyzer and more in just one box.

ROHDE&SCHWARZ

Measurements on FM Transmitters for Acceptance, Commissioning and Maintenance

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1 Overview

Frequency modulation (FM) remains very popular in analog broadcasting. Compared with amplitude modulation (AM), FM needs more bandwidth, but it is also more immune to interference and offers a better signal-to-noise ratio (modulation gain). FM also supports nonlinear (class C) amplifiers, which are more efficient.

Despite the advent of advanced digital transmission methods, analog broadcasting remains highly important. Until now, measurements on FM transmitters in connection with acceptance testing, commissioning and maintenance required using a variety of T&M instruments.

The R&S®ETL TV analyzer combines these instruments' capabilities in a single unit and can completely replace them. Now, for the first time, acceptance test measurements can be conducted on FM transmitters quickly and easily using just one compact test instrument. The R&S®ETL provides the functionalities of a power meter, spectrum analyzer, audio generator, FM measurement demodulator, stereo decoder, audio analyzer and more in just one box.

Fig. 1: **R&S®ETL.**

This application note covers the fundamental FM measurements performed during FM transmitter acceptance testing, commissioning and maintenance. These measurements are conducted using test signals. FM transmitter test standards are highly country- and customer-specific, so the settings and test limits contained in this application note are only intended as examples. The measurements described here are based on field reports and Rohde & Schwarz transmitter test department reports, as well as the IEC 244-13 test standard, and technical guidelines issued by the Institute for Broadcasting Technology (IRT) for public broadcasters in Germany, Austria and Switzerland.

Section 2 briefly describes the basics of FM broadcast technology. Section 3 explains the settings available on the R&S®ETL. Section 4 begins by covering the preparations for testing. That includes information on the necessary test equipment and setup, as well as steps to protect the T&M equipment against destructively high input power. Section 4 then goes on to describe basic configuration of the R&S®ETL for conducting measurements. Section 5 details individual types of measurements, including the requisite R&S®ETL configurations.

Appendix A explains the linkage between a transmitter's modulation input level and the resulting frequency deviation. Appendix B shows how to use the R&S®TxCheck software with the R&S®ETL to automate many of the measurements covered here in this document.

2 FM Basics

In frequency modulation (FM), the carrier frequency wave is varied in sync with the transmitted signal. The change in the carrier frequency caused by modulation is referred to as the frequency deviation. The greater the amplitude of the information signal, the greater the frequency deviation (see Fig. 2 and Fig. 3).

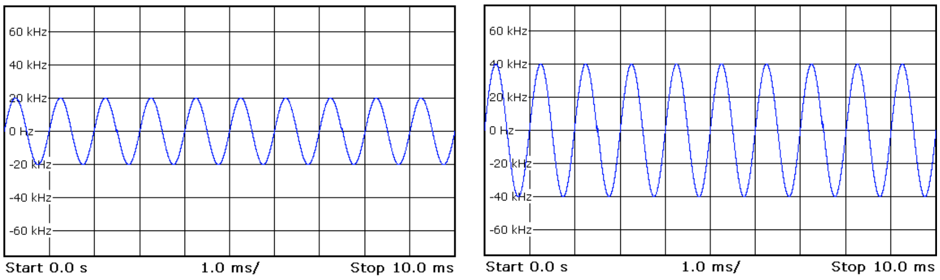


Fig. 2: Audio scope display showing a frequency-modulated 1 kHz audio signal – on the left with a 20 kHz frequency deviation (resulting from 0 dBu), and on the right with a 40 kHz frequency deviation (resulting from 6 dBu).

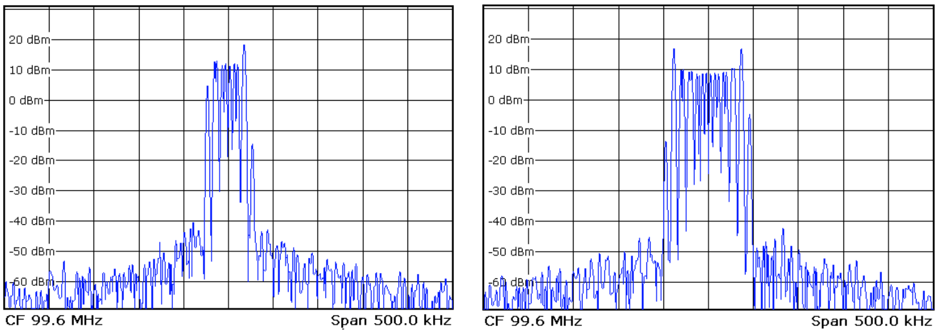


Fig. 3: RF spectrum of a frequency-modulated 1 kHz audio signal – on the left with a 20 kHz frequency deviation (resulting from 0 dBu), and on the right with a 40 kHz frequency deviation (resulting from 6 dBu).

2.1 The Multiplex (MPX) Signal

There are two types of audio signals: mono and stereo. Stereo signals are more common in broadcast radio. In a stereo transmission, the FM transmitter is used to transmit stereophonic signals, which consist of two independent audio channels.

The FM stereo system was designed to be backward compatible and allow broadcast signals to be received on mono equipment as well. The pilot tone multiplex system, defined in CCIR recommendation 450, section 2, was developed for this purpose. In this system, the modulation signal is generated by a special stereo coder. This can be a separate, upstream device, or it can be integrated in a transmitter. A transmitter without a stereo coder can be used as a mono transmitter.

A matrix circuit in the stereo coder generates a sum signal M (middle) and a difference signal S (side) from the left and right audio signals (each of which has a bandwidth of 15 kHz). The sum signal M equates to the mono signal transmitted by a mono transmitter. The difference signal S is amplitude-modulated on a subcarrier at 38 kHz. This subcarrier is suppressed to reduce the bandwidth required, and a pilot tone at 19 kHz is transmitted instead. The pilot tone enables a receiver (decoder) to identify that the broadcast signal is stereo; it also enables a stereo receiver to recover the suppressed subcarrier (at 38 kHz) and demodulate the difference signal.

The stereo coder's full output signal is called a multiplex (MPX) signal. This essentially consists of three parts:

- The sum signal M $\left(\frac{L+R}{2}\right)$, with a bandwidth of 40 Hz to 15 kHz
- The 19 kHz pilot tone
- The modulated difference signal S $\left(\frac{L-R}{2}\right)$, with a bandwidth of 23 kHz to 53 kHz

As VHF radio evolved, the following ancillary signals were incorporated to support additional services:

- Radio Data System (RDS): This carries static information (such as the station identifier and track titles) that appears on receiver displays. The information is transmitted digitally on a 57 kHz subcarrier
  - The precursor of RDS was ARI (*Autofahrer-Rundfunk-Information*, automobile radio information)
- Data Radio Channel (DARC): This is a system similar to RDS, and is used mainly in Japan and the USA
- Subsidiary Communication Authorization (SCA): This carries an additional, telephone-grade audio signal. The SCA ancillary signal's standard frequencies are 41 kHz (for mono transmitters only), 67 kHz and 92 kHz

These ancillary signals are added to the MPX signal (see Fig. 4).

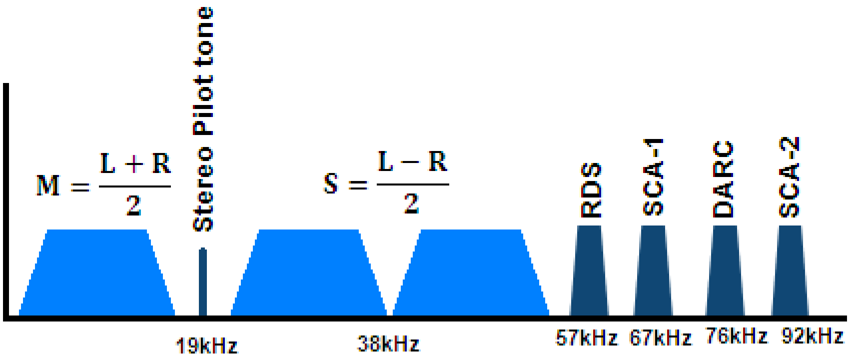


Fig. 4: Schematic diagram of an MPX signal spectrum.

2.1 Pre- and Deemphasis

Frequency modulation has a triangular noise spectrum. This means that the noise power density is not constant but increases with the audio-frequency bandwidth. To improve the signal-to-noise ratio at high frequencies, the stereo coder uses preemphasis. This is a process in which high frequencies are boosted prior to transmission. Preemphasis utilizes a time constant that differs from country to country: In Europe and Japan, it is generally 50 µs; in the USA, 75 µs. To return to a linear frequency response, the preemphasis must be reversed by the receiver in a process called deemphasis.

2.2 RF Bandwidth

The signal generated in the stereo coder is frequency-modulated in an exciter. Based on Carson's rule, the following applies approximately to the bandwidth of a frequency-modulated signal (see Fig. 5):

98 % of the spectral power within $B_{98\%} = 2(\Delta f_{Carrier} + f_{Signal_{max}})$

99 % of the spectral power within $B_{99\%} = 2(\Delta f_{Carrier} + 2 f_{Signal_{max}})$

where $\Delta f_{Carrier}$ = frequency deviation

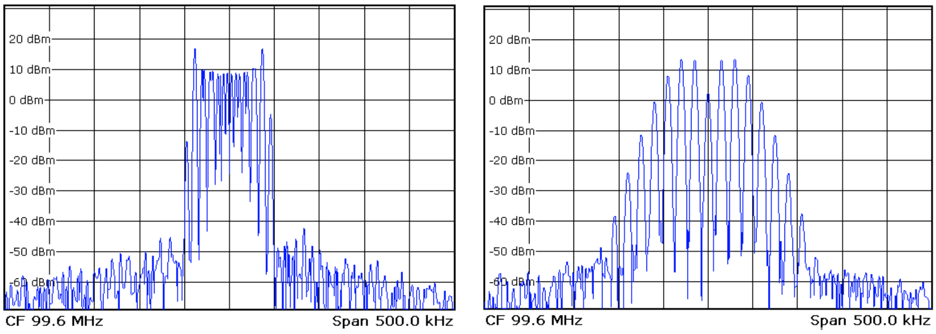


Fig. 5: RF spectrum of a frequency-modulated 1 kHz audio signal (left) and a frequency-modulated 15 kHz audio signal (right). Both signals have a frequency deviation of 40 kHz.

2.3 Stereo Decoder

In the decoder, the left channel (L) consists of the sum signal plus the difference signal; the right channel (R) consists of the difference of the sum signal and the difference signal:

$$M + S = \frac{L + R}{2} + \frac{L - R}{2} = L$$

$$M - S = \frac{L + R}{2} - \frac{L - R}{2} = R$$

2.4 Transmitter Inputs

Transmitters have an MPX input into which the MPX signal is fed. Transmitters with an integrated stereo coder have L and R inputs in addition to the MPX input.

Audio Engineering SocietyEuropean Broadcasting Union Most of today's advanced transmitters have an Audio Engineering Society/European Broadcasting Union (AES/EBU) input that accepts both stereo and mono digital audio signals. This input is specified in the AES3 standard. AES/EBU supports impedances of 110 ohms (on AES3 balanced cables) and 75 ohms (on unbalanced coaxial cable). The signal level for AES/EBU is given in decibels relative to full scale (dBFS) and is relative to the highest possible audio level.

3 R&S®ETL Settings for FM Measurements

The R&S®ETL combines several FM signal analyzers (see Fig. 6) with a stereo coder and an audio test signal generator in a single instrument. This means it offers a wide variety of possible settings. For the most part, though, only a few settings need to be made for any given measurement. This application note details the settings required for each type of measurement (see Section 5).

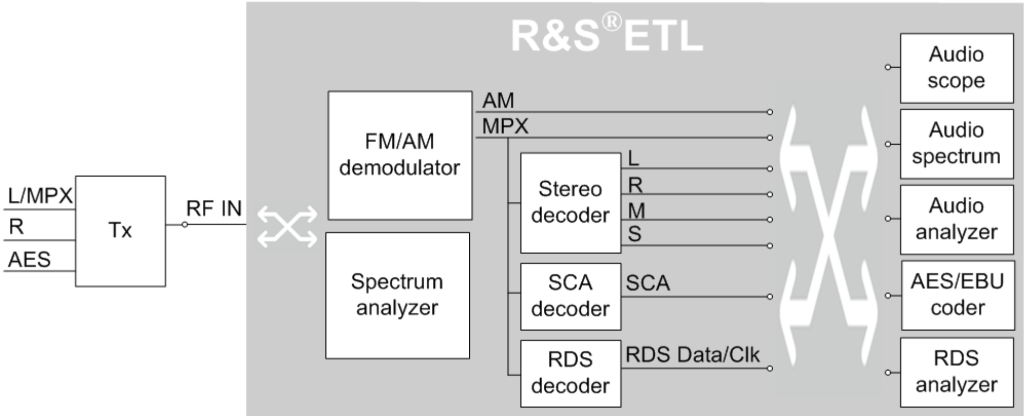


Fig. 6: Simplified overview of the analysis functions for acceptance-testing an FM transmitter.

This section provides an overview of the available settings, what they do, and how they interact. Having this background knowledge is not a prerequisite for performing the measurement, because information on all of the required settings is provided along with the measurement descriptions in Section 5. Here, in Section 3, users can read about what the settings actually mean.

The R&S®ETL provides the following configuration dialogs for FM measurements:

- Radio settings (3.1)
- Audio generator (3.2)
- Configuration dialogs for individual measurements:
  - Audio analysis measurements (3.3):
    - Frequency response
    - Crosstalk
    - Level
    - Signal-to-noise (S/N) ratio
    - Total harmonic distortion (THD)
    - Dual frequency distortion (DFD)
  - Modulation analysis measurements (3.4):
    - Audio scope
    - Audio spectrum
    - MPX power and peak deviation
    - MPX deviation distribution
    - Multipath detection
    - RDS

In configuration dialogs, it is important always to configure the settings from the top down, because some of the settings available are contingent upon others. For instance, the "Stereo Decoder" setting under "Radio Settings" is only available if "FM Stereo" has been selected under "Radio Standard".

3.1 General FM Settings – Radio Settings

The basic FM settings are available when the R&S®ETL is set to "Radio" mode under "TV/Radio Analyzer/Receiver" (MODE→TV/Radio Analyzer/ Receiver→Radio), and they can be configured under "Radio Settings" (see Fig. 7).

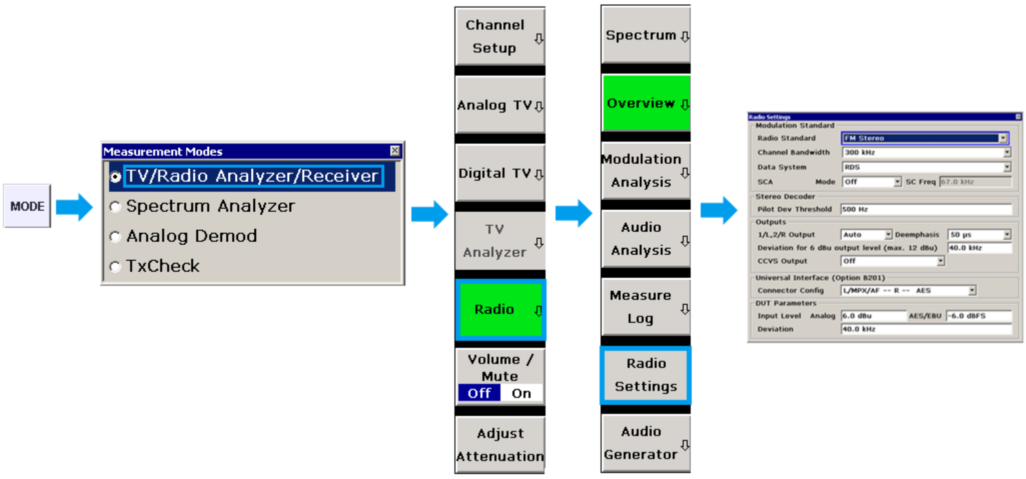


Fig. 7: Switching the R&S®ETL to "Radio" mode and opening the "Radio Settings" dialog.

The settings in the "Radio Settings" configuration dialog comprise the following five groups; these are described in the sections indicated below in parentheses (see Fig. 8).

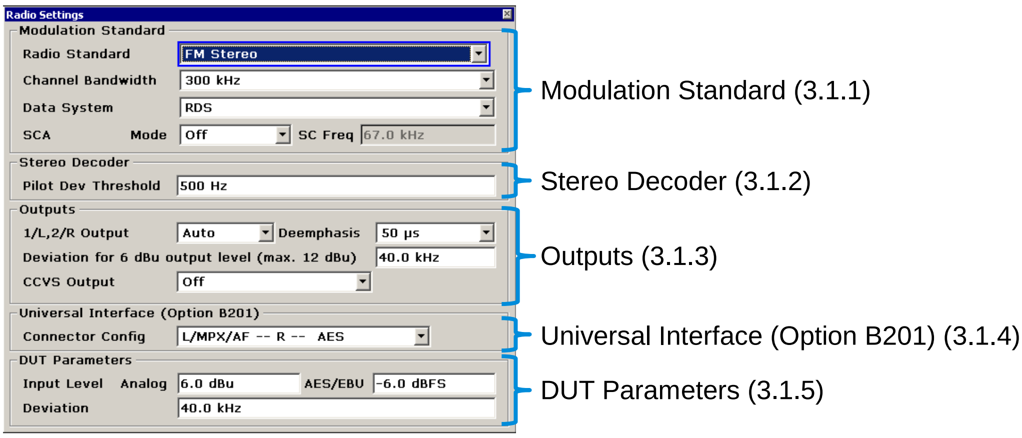


Fig. 8: The "Radio Settings" configuration dialog, accessed via MEAS→Radio Settings.

3.1.1 Modulation Standard

Radio Standard

The radio standard must be selected to match the transmitter's operating mode:

- FM Mono: This should be selected for mono-only transmitters because, according to some specifications (such as RaiWay) they may require an audio-frequency bandwidth of up to 17.5 kHz. In stereo, this bandwidth is technically unfeasible. Choosing "FM Mono" means that no stereo measurements will be available for selection in the R&S®ETL menu.
  "FM Stereo" should be selected as the radio standard for measurements on stereo transmitters in mono mode when an audio-frequency bandwidth of 15 kHz is sufficient, or for measurements on the sum signal M.
- FM Stereo: This setting causes the R&S®ETL to behave like a receiver with a stereo measurement decoder. The audio-frequency bandwidth is limited to 15 kHz.

Channel Bandwidth

A narrow channel selection (lower bandwidth) clips the sidebands. As bandwidths narrow, distortion increases. For this reason, to take precise measurements on transmitters, users should select the largest available bandwidth (1 MHz). However, when conducting measurements on a receive antenna with adjacent channels, it may be necessary to select narrower bandwidths in order to limit interference from adjacent channels as much as possible.

Data System

The "Data System" setting enables measurements to be performed on RDS signals (including the RBDS variant used in the USA) and on DARC signals. Choosing "None" under "Data System" means that these measurements will not be available or performed.

The only measurement available for DARC is frequency deviation ("DARC Deviation"). The R&S®ETL has a decoder for RDS and RBDS (MEAS→Modulation Analysis→RDS→Extended RDS Analysis). "RBDS mode" must be enabled for RBDS (see Fig. 9, top right). The "extended RDS analysis” option in the R&S®ETL makes it possible, among other things, to analyze transmitter names and alternative frequencies.

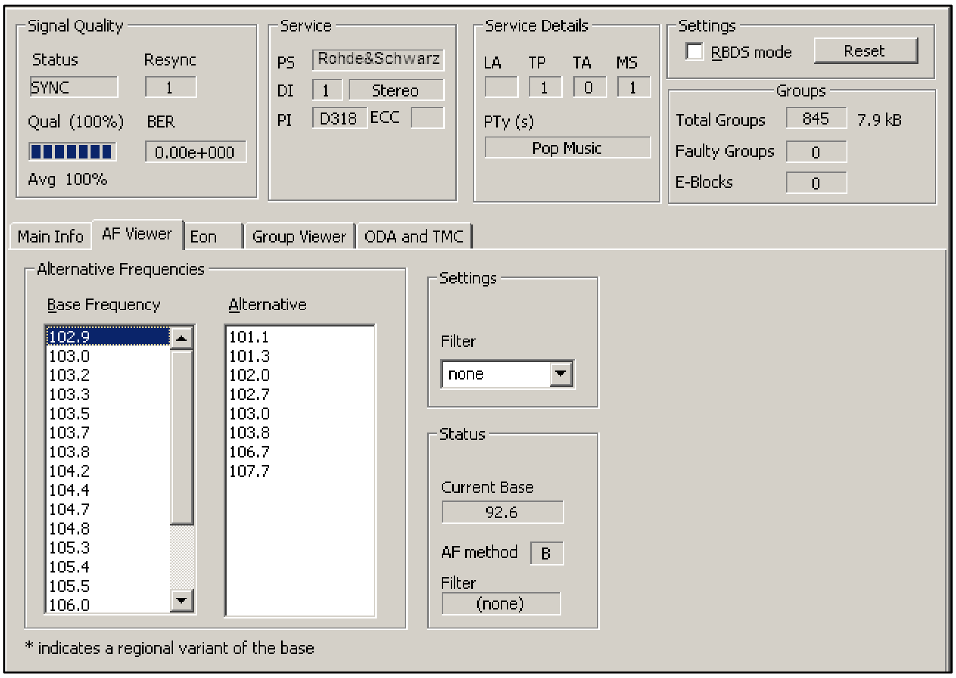


Fig. 9: RDS/RBDS decoder.

SCA Mode

The "SCA Mode" setting allows the SCA ancillary signal to be demodulated and measured. The setting distinguishes between "Narrow" (approx. 14 kHz bandwidth of the modulated subcarrier, which is used in the USA, for instance) and "Wide" (approx. 26 kHz bandwidth of the modulated subcarrier, which is used, in Italy, for example). If this is set to "Off", these measurements are not available or performed. If SCA is activated, the center frequency of the subcarrier to be demodulated must be entered under "SC Freq" (SC = subcarrier); this frequency defaults to 41 kHz (mono transmitters only) or 67 kHz. For stereo transmitters, 92 kHz is also common.

3.1.2 Stereo Decoder

Pilot Dev Threshold

"Pilot Dev Threshold" sets how high the minimum frequency deviation caused by the pilot signal must be in order for the signal to be recognized as stereo. This affects the appearance of the status bar on the lower right of the measurement screen: If the pilot deviation is smaller, the R&S®ETL displays the red warning "MONO". This setting also affects the automatic switching of the 1/L and 2/R output signals from stereo to mono (see 3.1.3).

The stereo decoder's actual synchronization with the pilot signal does not depend on this setting.

3.1.3 Outputs

Selected signals can be fed in analog or, in some instances, in digital form to an external audio analyzer for extended analysis. Two outputs are available for this purpose (see Fig. 10):

- CCVS (color composite video signal; the R&S®ETL also uses this to output analog TV signals – thus the name)
- Balanced outputs (1/L and 2/R)

Fig. 10: The R&S®ETL has two outputs for more extensive audio analysis.

The demodulated digital signal in AES/EBU format (available on the CCVS output) has better signal quality than the demodulated analog signals on the 1/L and 2/R outputs. This is why, if possible, the AES/EBU format should be used when an external audio analyzer is connected.

1/L, 2/R Output

Outputs 1/L and 2/R can be used for two purposes. First, outputs 1/L and 2/R can supply a generator signal to feed a transmitter. Second, a signal (a mono, decoded stereo, M&S or SCA signal) received on the RF input can be output for more detailed audio analysis (e.g. on an external audio analyzer). If "Auto" is selected under "1/L, 2/R Output", a mono or stereo signal is output, depending on the pilot signal threshold setting (see 3.1.2).

The selected signal also appears on the headphone output (AF Out) and in the AES/EBU signal; the latter can be selected on the CCVS output if required.

It is important to note that the 1/L and 2/R outputs are balanced but not floating. This means that it is not possible to produce an unbalanced signal by connecting an output to ground.

Deemphasis

The "Deemphasis" setting under "Outputs" affects the headphone output (AF Out), the 1/L and 2/R outputs and the AES signal. The deemphasis settings available for "Auto", "Mono", "Stereo" and "M&S" under "1/L, 2/R Output" are 50 µs, 75 µs or off. The deemphasis settings available for SCA under "1/L, 2/R Output" are 100 µs, 150 µs or off.

Deviation for 6 dBu output level

For technical reasons, the output levels on 1/L and 2/R are limited to 12 dBu. By changing the "Deviation for 6 dBu output level" setting, it is possible to adjust the output level range to suit specific requirements. If this is set to 40 kHz, signals with a frequency deviation of up to 80 kHz can be output without clipping. If set to 75 kHz, signals with a maximum deviation of 150 kHz can be output without clipping.
Note that the maximum possible signal-to-noise ratio on this output drops as the frequency deviation increases.

CCVS Output

The MPX signal, the demodulated signal in digital AES/EBU format, the pilot signal or the RDS/DARC or SCA subcarrier can be output on the CCVS output.

The demodulated signal in the digital AES/EBU format contains the signal selected under "1/L, 2/R Output" (mono, stereo, or M&S).

3.1.4 Universal Interface (Option B201)

Connector Config

The "Connector Config" setting allows the way the audio generator's signal outputs are assigned to be adjusted to the transmitter's signal inputs. This helps to avoid having to disconnect and reconnect cables.

There are two choices available for output signal assignment:

- "L/MPX/AF – R – AES"
  This is used if the transmitter under test has a combined input for L and MPX.
- "L – R – MPX/AF/AES"
  This can be selected if the transmitter has separate L, R and MPX inputs. Reconnection will be necessary in order to measure the AES/EBU modulation input.

If the way the signal outputs are assigned does not match the transmitter's signal inputs, reconnection will be necessary.

A third possible choice is available under "Connector Config"; this allows received and decoded RDS data and the RDS clock to be output:

- RDS Clk – RDS Dat – none:
  This setting is not required in connection with the measurements described here.

The same setting is available in the audio generator configuration dialog on the R&S®ETL (see 3.2.3).

3.1.5 DUT Parameters

The settings under "DUT Parameters" (DUT = device under test, in other words the FM transmitter being tested) enable the R&S®ETL to automatically compute the requisite signal level for a desired frequency deviation. Depending on the transmitter input used, the deviation and either the analog input level ("Input Level Analog") or the digital input level ("AES/EBU") must be entered in accordance with the transmitter settings.

3.2 Audio Generator Settings

The requisite audio generator settings are available if the R&S®ETL is set to "Radio" mode under "TV/Radio Analyzer/Receiver" (MODE→TV/Radio Analyzer/ Receiver→Radio). The audio generator settings can be configured under Audio Generator→Audio Generator Setup (see Fig. 11 and Fig. 12).

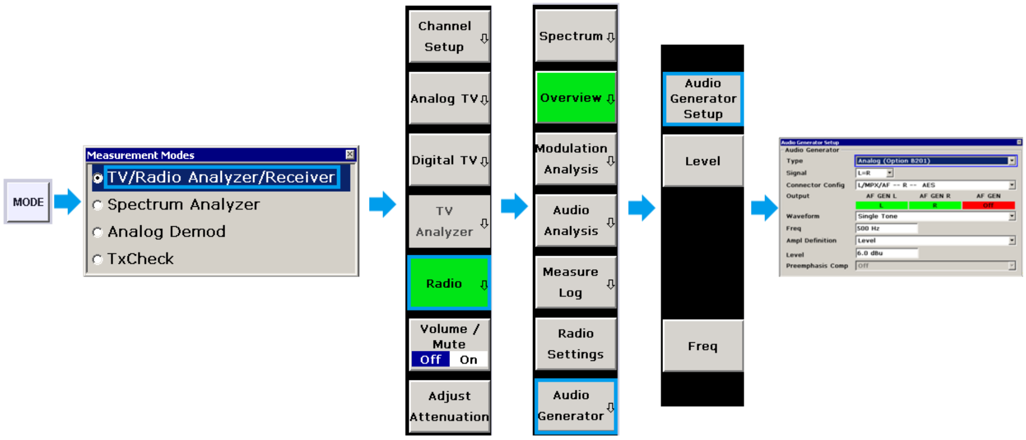


Fig. 11: Switching to "Radio" mode on the R&S®ETL and initiating the "Audio Generator Setup" configuration dialog.

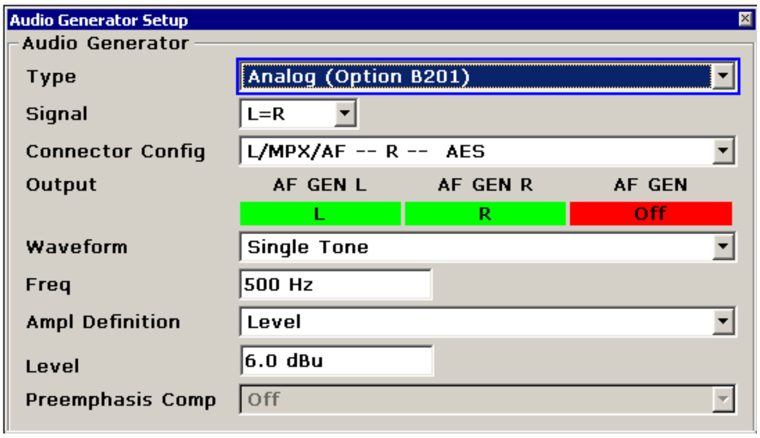


Fig. 12: The "Audio Generator Setup" configuration dialog. This is accessed via MEAS→Audio Generator→Audio Generator Setup.

The generator settings for audio analysis measurements can also be configured in the configuration dialog ("Setup") for each type of measurement (see 3.3). The settings are easier to make there because the configuration dialog only offers relevant and appropriate settings, which is why using this dialog is recommended. In the THD setup, for instance, no waveform setting is available because the measurement is only carried out with a single tone. If the audio generator is to be used for purposes other than audio analysis measurements, the settings must be made in "Audio Generator Setup".

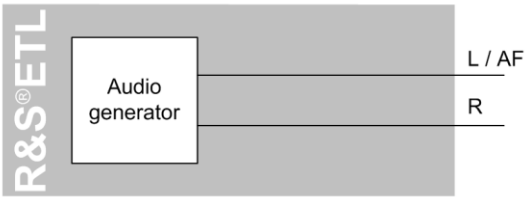
3.2.1 Type

The audio generator's "Type" setting determines the type of signal to be generated. The signal to be generated is available either on the R&S®ETL-B201 hardware option or on the 1/L and 2/R outputs (see Fig. 13), depending on the signal type.

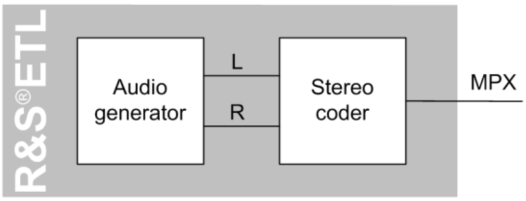
Fig. 13: Rear view of the R&S®ETL with the R&S®ETL-B201 hardware option and the 1/L, 2/R ports.

The following settings are available under "Type":

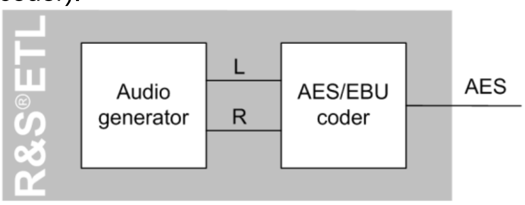
- Analog (Option B201):
  An uncoded analog stereo signal (L, R) to feed into an operational stereo coder, or a general audio signal (AF, audio frequency) up to 100 kHz to feed directly into the transmitter MPX input, bypassing the stereo coder.



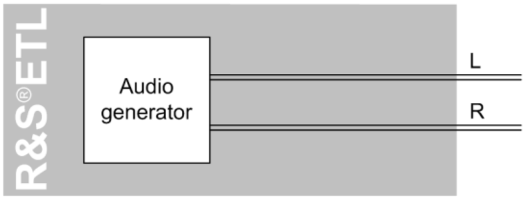
- MPX (Option 201):
  Analog MPX signal (M+S, pilot and, possibly, ancillary signals) to feed into the transmitter's MPX input.



- AES/EBU (Option B201):
  Uncoded digital stereo signal (e.g. to feed into a digital operational stereo coder).



- Analog (1/L, 2/R):
  Uncoded analog stereo signal that uses the 1/L and 2/R ports. Unlike the "Analog (Option B201)" type, the output signal is balanced; L=-R and L<>R signals are available, too (see 3.2.2). However, the signal-to-noise ratio and bandwidth (15 kHz) are lower and the frequency response greater. The "Analog (Option B201)" type should therefore be used if possible.



3.2.2 Signal

The composition of the signal generated can be selected here. The following signals are available:

- AF (= audio frequency): general audio signal up to 100 kHz
- L: left only, right off
- R: right only, left off
- L=R: left and right with same phase
- L=-R: left and right with opposed phase
- L<>R: left and right with different frequencies; the frequency and level can be selected separately

The options available depend on the setting under "Type" (see 3.2.1):

- Analog (Option B201): AF, L, R, L=R
- MPX (Option B201): L, R, L=R, L<>R, L=-R, SCA
- AES/EBU (Option B201): L, R, L=R, L=-R, L<>R
- Analog (1/L,2/R): L, R, L=R, L=-R, L<>R

3.2.3 Connector Config

As already noted in 3.1.4, this setting makes it possible to adapt the R&S®ETL-B201 hardware option's audio generator outputs to the transmitter's modulation inputs, and this setting can also be changed in the Radio Setting menu.

The graphic display in "Audio Generator Setup" (see Fig. 14) shows the signals currently configured on the R&S®ETL-B201 hardware option's output or on the 1/L and 2/R outputs. Green means that the signal is output; red means that no signal is output.

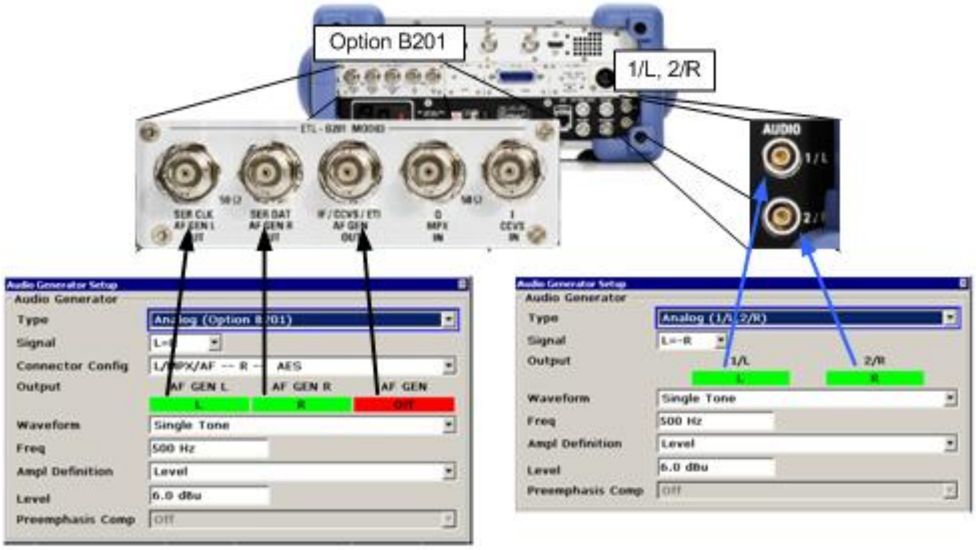


Fig. 14: Screenshots showing two possible signal configurations for the audio generator (bottom) and how they map to the generator outputs on the R&S®ETL (top).

3.2.4 Waveform

Depending on the type of measurement, a single-tone or dual-tone signal needs to be generated. The following settings are available:

- "Single Tone":
  A single sine-wave tone is generated at a chosen frequency for each channel. This is needed, for instance, for measuring frequency response (5.4) or total harmonic distortion (5.6.1).
- "Dual Tone, constant spacing" or "Dual Tone independent frequencies":
  Two sine-wave signals are generated on each channel. Both tones have the same amplitude. Due to the different requirements, the R&S®ETL offers two convenient input options to suit different test specifications:
  - Dual Tone, constant spacing: The frequency of the higher tone and the frequency spacing are specified – to measure the dual-frequency distortion, for example (5.6.2.1)
  - Dual Tone independent frequencies: Two independent frequencies are specified – to test input polarity, for example (5.8)

3.2.5 Ampl Definition and Level

The dimension (unit) for the generator amplitude is selected under "Ampl Definition":

- Level:
  The level in dBu (0 dBu = $\sqrt{600\ \Omega \cdot 1\,\mathrm{mW}} \approx 0{,}7746\ \mathrm{V}$).
- Peak Voltage:
  The peak voltage in V. The peak-to-peak voltage cannot be entered as such, but it can be specified easily here by applying a conversion factor of 2.
  With a dual-tone signal, the selected peak voltage is the total of the amplitude of both tones.
  The reason for entering the peak value here rather than the RMS value (more common in audio analysis) is that with FM the frequency deviation resulting from the generator signal is usually specified as the peak deviation.
- Desired DUT Deviation:
  The desired transmitter frequency deviation in kHz resulting from the generator level is entered directly here. This convenient function computes and inserts the requisite level based on the "DUT Parameters" entered under "Radio Settings" (see 3.1.5). For instance, if a THD measurement is conducted with a deviation of 100 kHz, entering the "Desired DUT Deviation" here saves having to calculate the requisite generator level (see appendix A).
  If preemphasis is enabled on the modulator, "Preemphasis Comp" (see 3.2.6) can compensate by reducing the level generated by the audio generator.

3.2.6 Preemphasis/Preemphasis Compensation

Preemphasis

The preemphasis function is only available for the generator type "MPX (Option B201)". It is part of the MPX generator contained in the stereo measurement decoder.

Preemphasis compensation

If "Ampl Definition" = "Desired DUT Deviation" has been selected, the "Preemphasis Compensation" setting is available for all other generator types ("Analog (Option B201)", "AES/EBU (Option B201)" and "Analog (1/L, 2/R)").
In accordance with the chosen time constant, the audio generator's level is reduced automatically in line with the frequency to provide a constant frequency deviation when transmitter preemphasis is activated. This makes measurements that require a constant frequency deviation (e.g. THD or crosstalk) easier to conduct.

3.3 Configuration Dialogs for Audio Analysis Measurements

The following audio analysis measurements are available:

- Frequency response
- Crosstalk
- Level
- Signal-to-noise (S/N) ratio
- Total harmonic distortion (THD)
- Dual frequency distortion (DFD)

The audio analysis measurements' configuration dialogs can be called up in the relevant measurement mode, and they are organized into three groups (see Fig. 15).

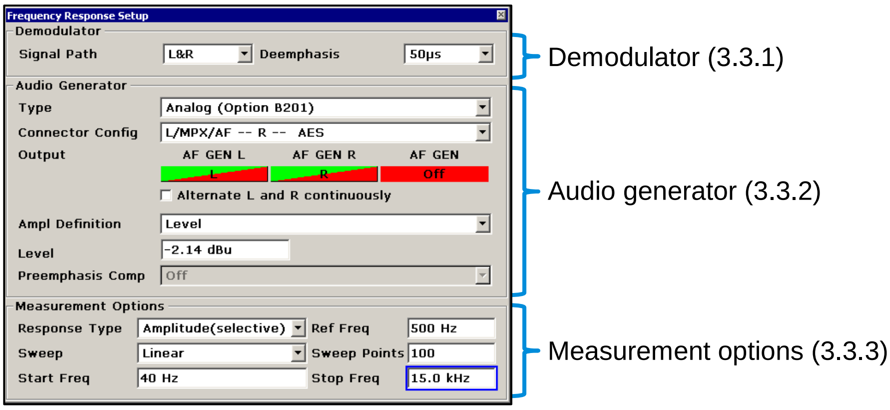


Fig. 15: "TV/Radio Analyzer/Receiver" operating mode, MEAS→Audio Analysis→Frequency Response→Frequency Response Setup.

The configurations available depend on the given measurement type and are explained here using an example based on a frequency response measurement.

3.3.1 Demodulator

The signal to be analyzed is selected under "Signal Path". In audio analyzer measurements, the choices available are limited to the signals that the generator can generate. A deemphasis setting of 50 µs, 75 µs or off can be selected for stereo-decoded signals (L, R, L&R, M&S, M, S).

3.3.2 Audio Generator

The choice of generator settings under "Audio Generator" is confined to generator settings relevant for the selected type of measurement (see 3.2). With measurements that call for automatic switching between the L path and the R path (in Amplitudenfrequenzgang, 5.4.1, for instance), the colored indicator is half green and half red (see Fig. 15). The outputs are switched automatically in automated measurements.

To avoid unnecessary wear on the relays in the R&S®ETL-B201 option, measurements are only carried out once in each position. (A measurement can be restarted with the RUN hardkey if required.) If the generator signal needs to alternate (e.g. for long-term measurements), "Alternate L and R continuously" can be enabled.

3.3.3 Measurement Options

The configurations available under "Measurement Options" depend on the given measurement type and are explained in context in this application note (see Section 5).

3.4 Configuration Dialogs for Modulation Analysis Measurements

The following measurements are available under "Modulation Analysis". They are mainly intended to be conducted during operation:

- Audio scope
- Audio spectrum
- MPX power and peak deviation
- MPX deviation distribution
- Multipath detection
- RDS

The settings in the modulation analysis measurements' configuration dialogs can be called up during the relevant measurements. The configurations available depend largely on the given measurement type.
This application note does not cover measurements conducted during operation, so the individual configuration options are not explained here.

4 Preparatory Steps

4.1 Required Equipment

Basic configuration

R&S®ETL TV analyzer with:

- options as needed (see Section 8)
- current firmware (available free of charge 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 measuring transmitter output level with a measurement uncertainty of < 0.1 dB

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

If the directional coupler is not part of the transmitter

Directional coupler

4.2 Test Setup

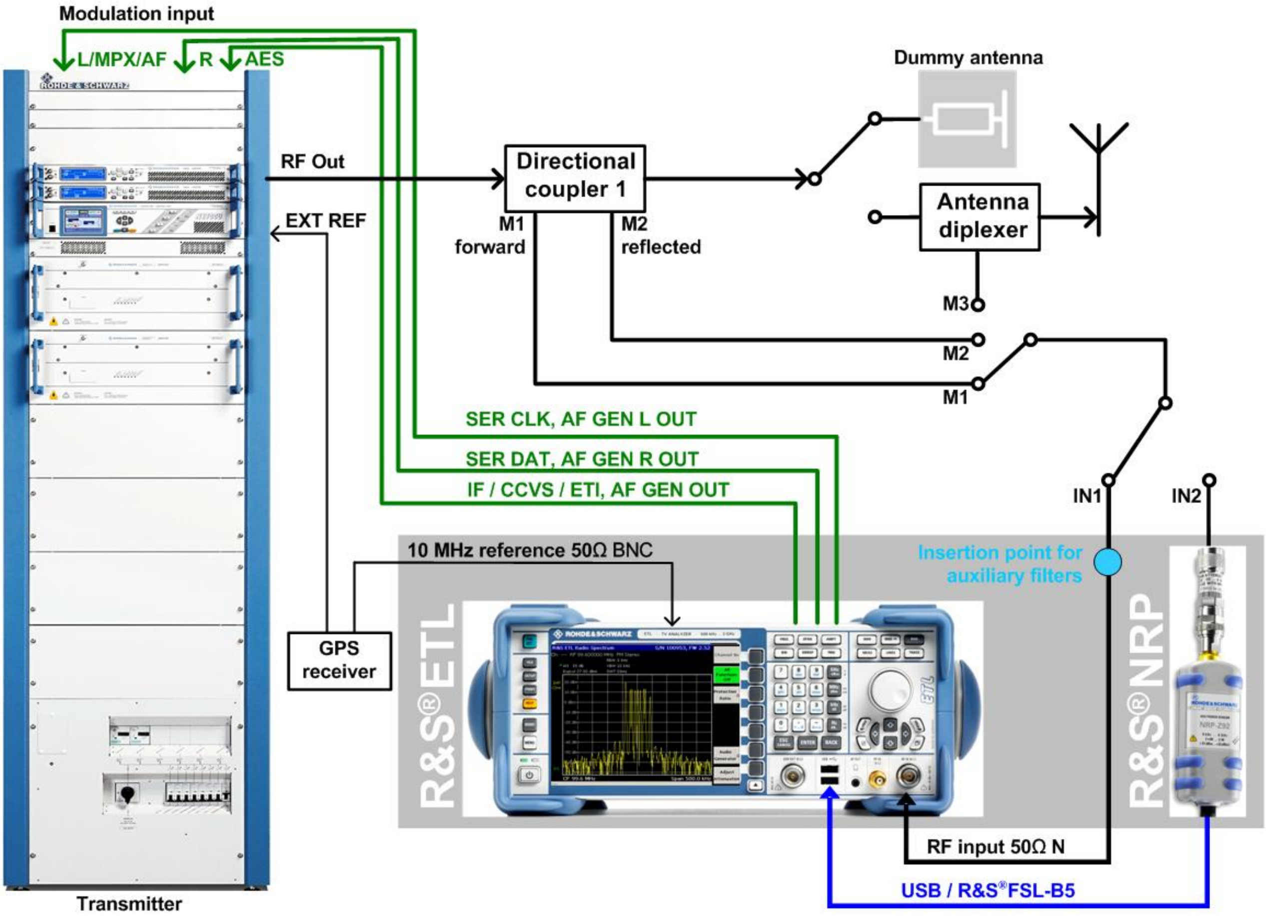


Fig. 16: Test setup.

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.

The RF input on the R&S®ETL (IN1) or the optional power sensor (IN2) is connected to the measurement interface of the transmitter output (M1 = forward, M2 = reflected).

For transmitter acceptance tests, the audio generator outputs located at the rear of the R&S®ETL are connected to the transmitter inputs (marked green, see 3.1.4).

The transmitter output is connected to a dummy antenna before the broadcast signal is applied to the antenna diplexer. As a result, the test port at the antenna diplexer (M3) is available as an additional measurement point.

4.3 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 specific measurements, such as the transmitter output level.

4.4 R&S®ETL Default Configuration for Measurements

The following conventions are used in these procedures:

- Terms in capital letters refer to key labels, e.g. "FREQ" for 

- Bulleted lists (e.g. ● Radio Standard) 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.

General settings
SETUP→Reference Ext: Use the external 10 MHz reference frequency[1]
MODE→TV/Radio Analyzer/Receiver→Radio
MEAS→Radio Settings *Modulation Standard* • Radio Standard: FM Stereo • Select Channel Bandwidth: 400 kHz • Data System: None • SCA Mode: Off *Stereo Decoder* • Pilot Dev Threshold: 500 Hz *Outputs:* Setting only required if the outputs 1/L and 2/R or CCVS are used for extended signal analysis (see 3.1.3) *Universal Interface (Option B201):* To be configured to match transmitter (see 3.1.4) *DUT Parameters:* To be configured to match the transmitter (see 3.1.5)
FREQ→Channel RF: Select based on the transmit frequency

Level adjustment
MENU→Adjust Attenuation[2]
AMPT→Preamp: Off
AMPT→More→Preselector: Off
AMPT→RF Atten Manual: Select the lowest possible setting without overloading[3]

[1] Only necessary if the frequency accuracy is to be measured with very high precision (> 10^{-5})
[2] For rough level adjustment.
[3] Overload warnings appear centered at the top of the display as "IFovl" or "Ovld".

5 Measurements

This section explains the measurements that are performed on the analog transmitter input. After that, Section 5.9 covers the differences associated with using the digital transmitter input (AES/EBU input).

5.1 Transmitter Output Level

When measuring the transmitter output level, it is important to ensure that the displayed power level refers exclusively to the power that has been decoupled by the directional coupler. The coupling attenuation can be entered using the R&S®ETL's "Ref Level Offset" function, which is then automatically calculated into the displayed value.

From the "Overview" mode, you can have the R&S®ETL measure the signal level directly via the RF input, at an accuracy of 1 dB. Using a separate power sensor makes it possible to achieve an accuracy of 0.1 dB.

When using the "Overview" menu, it is possible to select the unit of measurement and set the predefined limits from the table via MEAS→Overview→Edit Table (see Fig. 17). Measured values that are not within the set limits are displayed in red. To ensure that it is possible to quickly recognize values that are outside the limits – even on black-and-white printouts – such values are also marked with an asterisk (*).

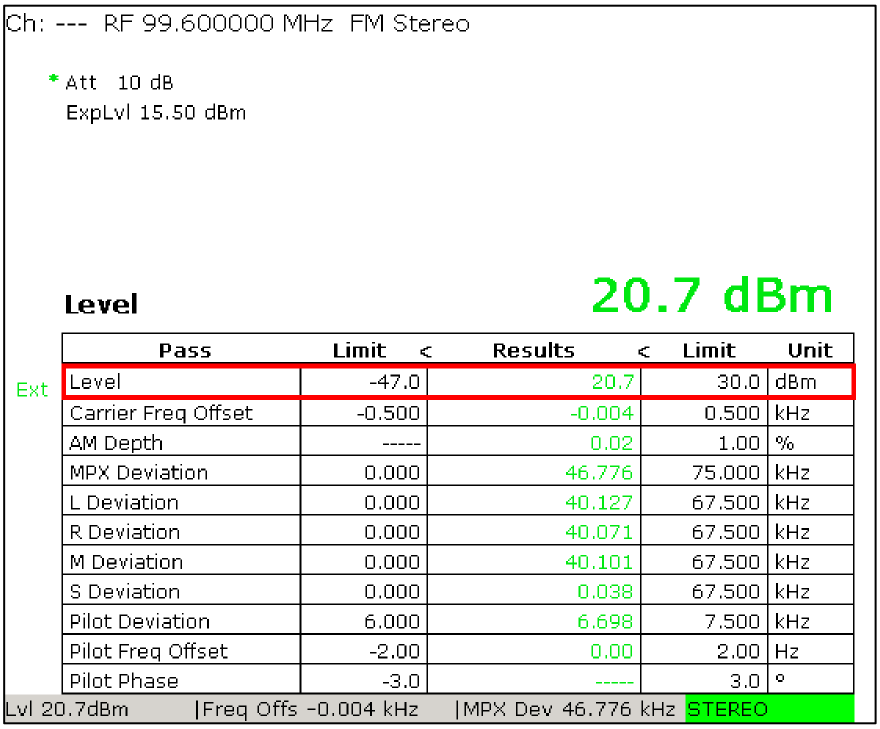
	Pass	Limit	<	Results	<	Limit	Unit
Ext	Level	-47.0		20.7		30.0	dBm
	Carrier Freq Offset	-0.500		-0.004		0.500	dBm
	AM Depth	-----	*	1.71		1.00	dBpW
	MPX Deviation	0.000		46.773		75.000	W
	L Deviation	0.000		40.137		67.500	dBmV
	R Deviation	0.000		40.078		67.500	dBµV
	M Deviation	0.000		40.109		67.500	V dBµA
	S Deviation	0.000		0.038		67.500	A
	Pilot Deviation	6.000		6.698		7.500	kHz

Fig. 17: "TV/Radio Analyzer/Receiver" mode in the MEAS→Overview→Edit Table menu: Selecting the unit of measurement for the level results.

This section describes how the transmitter output level is measured for a signal that is modulated with a maximum operating deviation (for example, 75 kHz). For the dimension (unit of measurement), the configuration proposed here employs "Desired DUT Deviation" for the generator amplitude (for the "Ampl Definition" setting). As an alternative, it is also possible to use the "Level" or the "Peak Voltage".

<table>
<tr><th colspan="2">Procedure: Transmitter output level</th></tr>
<tr><td colspan="2">⚠ Check to ensure that the max. input power is not exceeded (see Section 4.3).</td></tr>
<tr><td colspan="2">In each case, perform these steps at the test port:
• M1, for forward power
• M2, for reverse power</td></tr>
<tr><td colspan="2">Configure the general settings as described in Section 4.4.</td></tr>
<tr><td colspan="2">Set the transmitter input to "AF Stereo".
On the transmitter, turn on the preemphasis.</td></tr>
<tr><td colspan="2">MEAS→Overview→Audio Generator→Audio Generator Setup:
• Type: Analog (Option B201)
• Signal: L=R
• Connector Config: Set this parameter to match the transmitter (see 3.2.3)
• Waveform: Single Tone
• Freq: 500 Hz
• Ampl Definition: Desired DUT Deviation[1]
• Desired DUT Dev: For example, 75 kHz
• Preemphasis Comp: Set this parameter to match the transmitter's preemphasis setting</td></tr>
<tr><td colspan="2">Adjust the level as described in Section 4.4.</td></tr>
<tr><td>Method 1:
"TV/Radio Analyzer/Receiver"</td><td>Method 2:
Power sensor</td></tr>
<tr><td>AMPT→More→ExpectedLv Offset: Set to the full coupling attenuation at the test port for immediate compensation.</td><td>AMPT→More→Ref Level Offset: Set to the full coupling attenuation at the test port for immediate compensation.</td></tr>
<tr><td rowspan="2">Feed a signal into the RF input on the R&S®ETL (IN1)</td><td>Connect the power sensor (IN2), which is connected to the R&S®ETL via USB or sensor input, to the test port.</td></tr>
<tr><td>MODE→Spectrum Analyzer</td></tr>
<tr><td rowspan="2">MEAS→Overview</td><td>MENU→Power Meter→Frequency Coupling: Center</td></tr>
<tr><td>MENU→Power Meter→Power Meter→On</td></tr>
<tr><td>Read the level value (see Fig. 18).</td><td>Read the level value (see Fig. 19).</td></tr>
</table>

[1] For this it is necessary – as described in the section on the basic settings (Section 4.4) – for the transmitter's target operating parameters to be set correctly under “DUT Parameters“.



Pass	Limit <	Results	< Limit	Unit
Level	-47.0	20.7	30.0	dBm
Carrier Freq Offset	-0.500	-0.004	0.500	kHz
AM Depth	-----	0.02	1.00	%
MPX Deviation	0.000	46.776	75.000	kHz
L Deviation	0.000	40.127	67.500	kHz
R Deviation	0.000	40.071	67.500	kHz
M Deviation	0.000	40.101	67.500	kHz
S Deviation	0.000	0.038	67.500	kHz
Pilot Deviation	6.000	6.698	7.500	kHz
Pilot Freq Offset	-2.00	0.00	2.00	Hz
Pilot Phase	-3.0	-----	3.0	°

Fig. 18: "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).

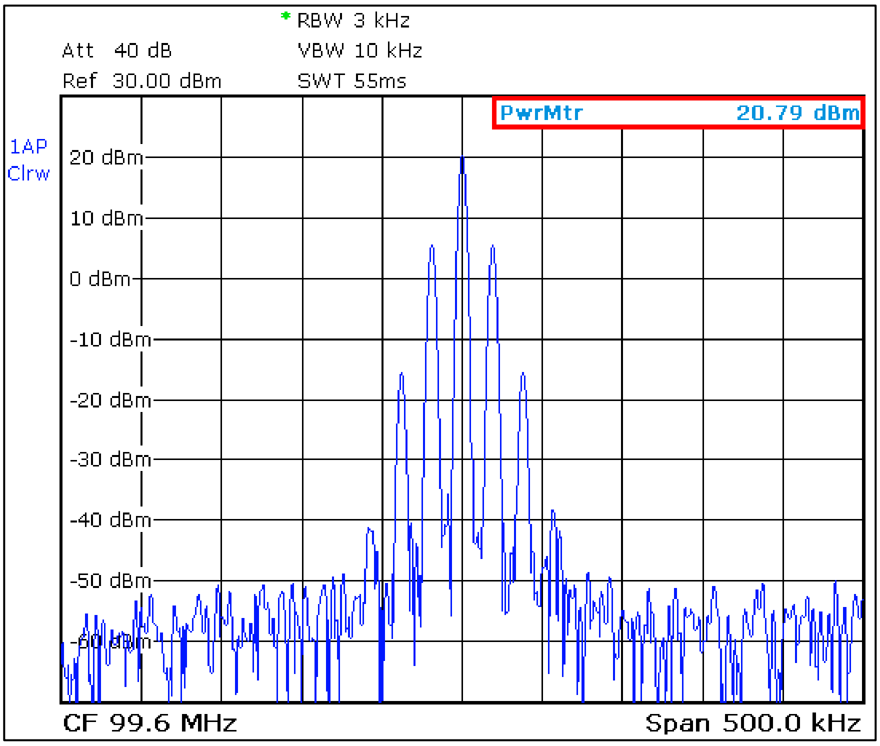


Fig. 19: Spectrum analyzer mode: FM spectrum with integrated reading from the power sensor displayed at the top right.

5.2 Frequency Accuracy

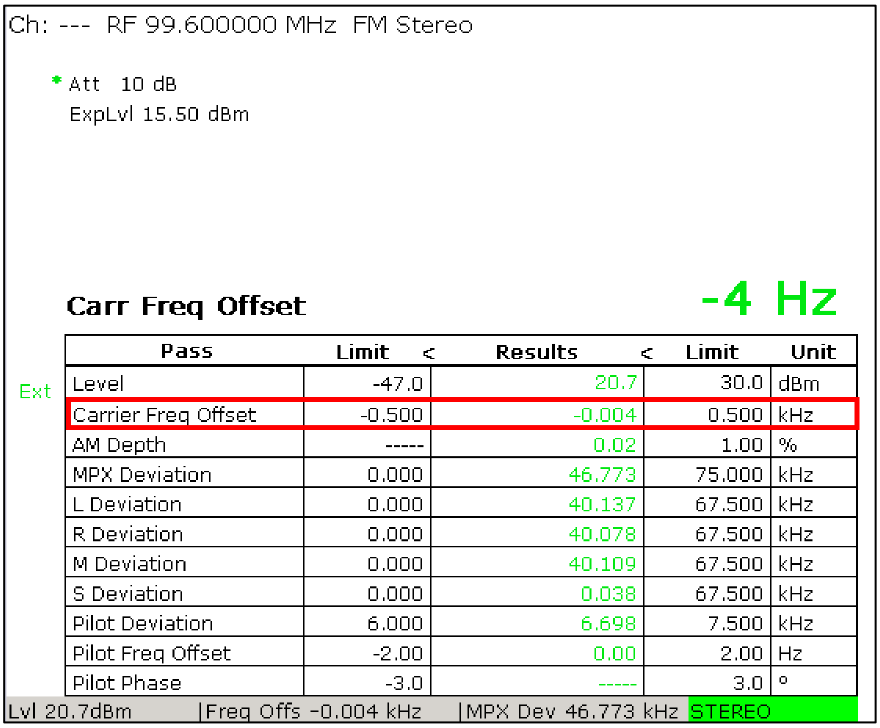
It is possible to measure the frequency accuracy with or without modulation. The R&S®ETL has been designed to also be able to measure the frequency accuracy with modulation.

The level of precision at which the frequency accuracy can be measured depends on how long it has been since the last time that the T&M instrument was calibrated. In general, it is possible to assume that an external reference is required in order to measure at an accuracy > 10^{-5} (see Basic Configuration 4.4).

<table>
<tr><th colspan="2">Procedure: Frequency accuracy</th></tr>
<tr><td colspan="2">⚠ Check to ensure that the max. input power is not exceeded (see 4.3).</td></tr>
<tr><td colspan="2">Connect the R&S®ETL (IN1) to test port M1.</td></tr>
<tr><td colspan="2">Configure the general settings as described in Section 4.4.</td></tr>
<tr><td>Method 1:
With modulation</td><td>Method 2:
Without modulation</td></tr>
<tr><td>Set the transmitter input to AF stereo.
On the transmitter, turn on preemphasis.</td><td>Set the transmitter to MPX.</td></tr>
<tr><td colspan="2">MEAS→Overview→Audio Generator→Audio Generator Setup:</td></tr>
<tr><td>• Type: Analog (Option B201)
• Signal: L=R
• Connector Config: Set to match the transmitter (see 3.2.3)
• Waveform: Single Tone
• Freq: 500 Hz
• Ampl Definition: Desired DUT Deviation[1]
• Desired DUT Dev: For example, 40 kHz
• Preemphasis Comp: Set to match the transmitter's preemphasis setting</td><td>• Signal: OFF

(None of the other settings influence the results.)</td></tr>
<tr><td colspan="2">Adjust the level as described in Section 4.4.</td></tr>
<tr><td colspan="2">MEAS→Overview</td></tr>
<tr><td colspan="2">Read the value for the carrier frequency offset (see Fig. 20).</td></tr>
</table>

[1] For this it is necessary – as described in the section on the basic settings (Section 4.4) – for the transmitter's target operating parameters to be set correctly under “DUT Parameters“.



Pass	Limit <	Results	< Limit	Unit
Level	-47.0	20.7	30.0	dBm
Carrier Freq Offset	-0.500	-0.004	0.500	kHz
AM Depth	-----	0.02	1.00	%
MPX Deviation	0.000	46.773	75.000	kHz
L Deviation	0.000	40.137	67.500	kHz
R Deviation	0.000	40.078	67.500	kHz
M Deviation	0.000	40.109	67.500	kHz
S Deviation	0.000	0.038	67.500	kHz
Pilot Deviation	6.000	6.698	7.500	kHz
Pilot Freq Offset	-2.00	0.00	2.00	Hz
Pilot Phase	-3.0	-----	3.0	°

Fig. 20: "TV/Radio Analyzer/Receiver" mode, MEAS→Overview menu: You can read the results for frequency accuracy ("Carrier Frequency Offset") in the second table row, in the status bar on the test screen or in the zoomed view (MEAS→Overview→Zoom).

5.3 Frequency Deviation Constant: Checking the Transmitter's Frequency Modulator Constant

When the transmitter's frequency modulator constant is set correctly, the corresponding nominal deviation (of the frequency) arises at a nominal level (usually 6 dBu). In the TR 5/3.5 guideline, the nominal deviation is also referred to as the standard testing deviation. In this measurement, the nominal deviation is the measurement variable to be tested.

Depending on the specific country and on the applicable specifications, the input level is expressed in dBu or in volts. As a "pseudo" unit of measurement, dBu is a logarithmic measure of voltage ($\sqrt{600\,\Omega \cdot 1\,mW} \approx 0.7746\,V_{RMS}$). The nominal deviation also varies depending on the country and on the applicable specifications. Germany, for instance, uses 40 kHz at 6 dBu, and Switzerland uses 50 kHz at 6 dBu for this. Together, the input level and the frequency deviation yield the modulator constant.

To enable you to make a quick check, the frequency deviation of the L, R, M, S and MPX signals are shown in the overview (see Fig. 20, lines 4 to 8). The values indicated there are measured using a peak detector.

For precise verification, it is possible to perform a measurement in the level mode (MEAS→Audio Analysis→Level). In that case, there are four detectors, each featuring different characteristics, available for measuring the frequency deviation:

- Selective: An FFT-based detector that selectively measures the largest spectral lines arising in the AF spectrum. Harmonics are not included in the measurement and, due to the narrowband characteristics, noise has very little influence on the measurement results. In addition, the system displays the frequency of the measured signal.
- PK: Peak detector. Used to measure the peak deviation of composite signals. Since the peak value is determined in an absolute measurement, noise has a relatively large influence on the measurement results. Consequently, the measured value tends to be somewhat too high. This detector is also used for the frequency deviation display in the R&S®ETL overview menu.
- QPK: Quasi-Peak Detector. As specified by ITU-R BS.468-4, this detector shows the RMS value for a sinusoidal signal, but not for other types of signals. It reacts to specific pulses and pulse groups in a predefined manner. Consequently, it is designed to deliver the best possible T&M representation of the effect that interference has on the human ear. In order to be able to indicate values from the various detectors in the same order of magnitude, the measured value is multiplied by the factor $\sqrt{2}$. The display shows $QPK \cdot \sqrt{2}$.
- RMS: Root mean square detector. Shows the average value independently of the shape of the curve. Noise has relatively little influence on the results, although this influence is significantly stronger than it is with the selective detector. As with the QPK value, this value is multiplied with the factor $\sqrt{2}$. The display shows $RMS \cdot \sqrt{2}$.

The measured values for the various detectors are displayed simultaneously (see Fig. 24 and Fig. 25).

For displaying the measured frequency deviation, the R&S®ETL offers four possibilities, which can be selected in the "Audio Level Setup" under "Mode" (see Fig. 21):

- Absolute: Absolute frequency deviation measured in Hz (for example, 40.525 kHz)
- Relative (dB): Variance of the frequency deviation in dB relative to the reference deviation entered under "Ref Deviation" (for example, 0.114 dB)

$$\text{Relative deviation (dB)} = 20 \cdot \log \frac{\text{Deviation}}{\text{Reference Deviation}}$$

- Relative (%): Frequency deviation expressed as a percentage of the value entered under "Ref Deviation" (for example, 101.317 %)

$$\text{Relative deviation (\%)} = 100 \cdot \frac{\text{Deviation}}{\text{Reference Deviation}}$$

- Relative Δ(%): Difference between the frequency deviation and the value entered under "Ref Deviation" (reference deviation) expressed as a percentage (for example, 1.317 %)

$$\text{Relative deviation } \Delta(\%) = 100 \cdot \frac{\text{Deviation} - \text{Reference Deviation}}{\text{Reference Deviation}}$$

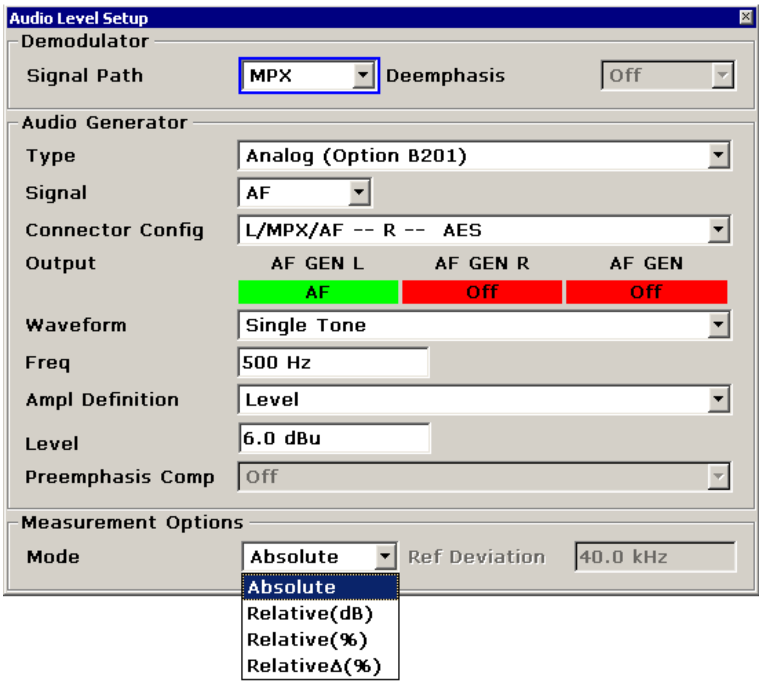


Fig. 21: Configuration dialog for "Audio Level Setup," which can be called up via MEAS→Audio Analysis→Level→Level Setup.

This section describes the settings for testing the modulator constant without or with the operating stereo encoder:

- Case 1: Without the operating stereo encoder
  Feeding of an audio signal (AF) into the transmitter's MPX input and analysis of the demodulated MPX signal (see Fig. 22). This verifies the transmitter's modulator constant.

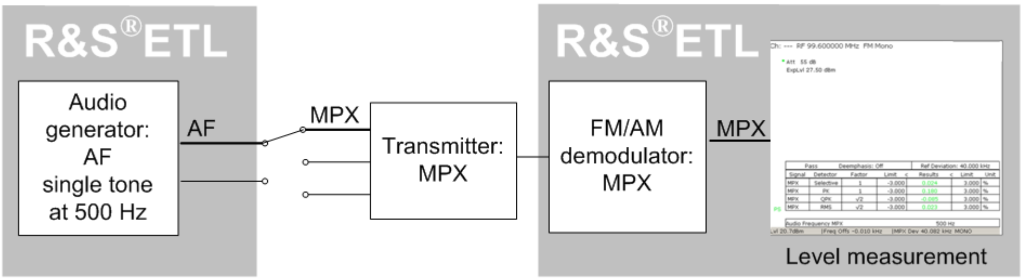


Fig. 22: Measurement configuration for verifying the transmitter's modulator constant.

- Case 2: With the operating stereo encoder
  Feeding of the L and R signals into the transmitter's operating stereo encoder and analysis of the decoded L and R signals (see Fig. 23). In addition, this makes it possible to check to see if the modulator constant is also correct for the operating stereo encoder being used, in other words, to ensure that the stereo encoder's gain is one.

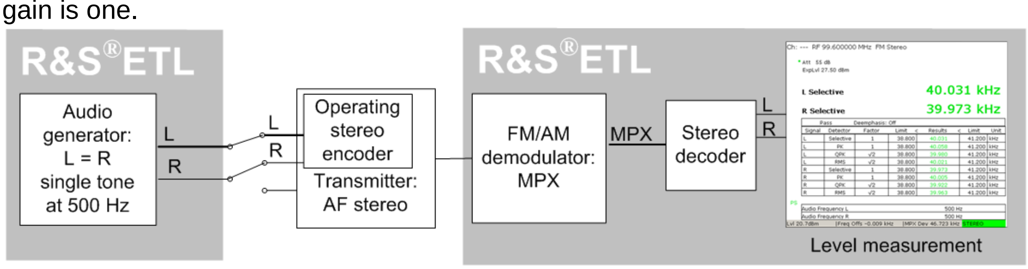
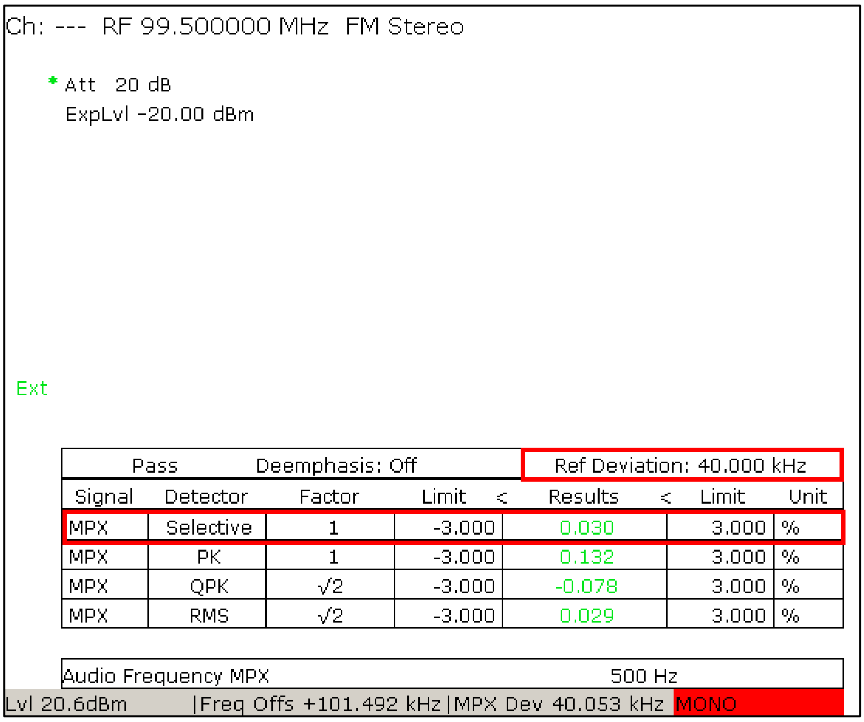


Fig. 23: Measurement configuration for verifying the transmitter's modulator constant when using the operating stereo encoder.

For the dimension (unit of measurement) of the generator amplitude ("Ampl Definition" setting), the configuration proposed here uses the "Desired DUT Deviation". As an alternative, it is possible to use the "Level" or the "Peak Voltage".

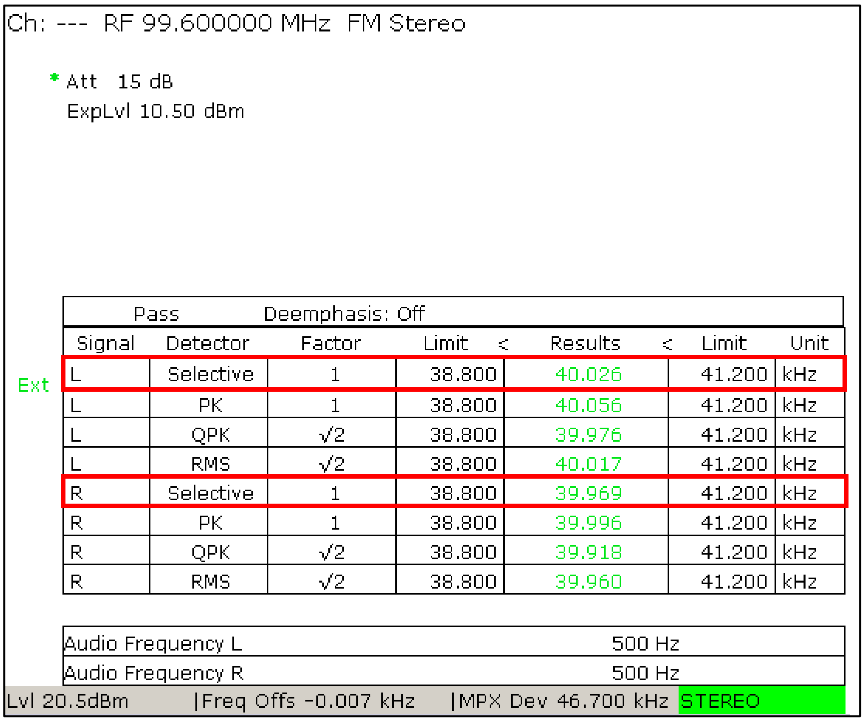
<table>
<tr><th colspan="2">Procedure: Verifying the transmitter's modulator constant</th></tr>
<tr><td colspan="2">⚠ Test to ensure that the max. input power is not exceeded (see Section 4.3).</td></tr>
<tr><td colspan="2">Connect the R&S®ETL (IN1) to test port M1.</td></tr>
<tr><td colspan="2">Configure the general settings as described in Section 4.4.</td></tr>
<tr><td>Case 1:
Without the stereo encoder</td><td>Case 2:
With the operating stereo encoder</td></tr>
<tr><td>Set the transmitter input to "MPX".</td><td>Set the transmitter input to "AF Stereo". On the transmitter, turn off the preemphasis.</td></tr>
<tr><td colspan="2">MEAS→Audio Analysis→Level→Level Setup:</td></tr>
<tr><td colspan="2">Demodulator:</td></tr>
<tr><td>• Signal Path: MPX</td><td>• Signal Path: L&R
• Deemphasis: Off</td></tr>
<tr><td colspan="2">Audio Generator:</td></tr>
<tr><td>• Type: Analog (Option B201)
• Signal: AF</td><td>• Type: Analog (Option B201)
• Signal: L=R</td></tr>
<tr><td colspan="2">• Connector Config: Set this value to match the transmitter (see 3.2.3)
• Waveform: Single Tone
• Freq: 500 Hz
• Ampl Definition: Desired DUT Deviation[1]
• Desired DUT Dev: For example, 40 kHz
• Preemphasis Comp: Off</td></tr>
<tr><td colspan="2">Measurement Options:
• Mode: Select the desired display mode (such as "Absolute", for instance).</td></tr>
<tr><td colspan="2">Adjust the level as described in Section 4.4.</td></tr>
<tr><td>Read the "MPX Selective" values (see Fig. 24). Use PRINT to generate a printout as needed.</td><td>Read the "L Selective" and "R Selective" values (see Fig. 25). Use PRINT to generate a printout as needed.</td></tr>
</table>

[1] For this it is necessary – as described in the section on the basic settings (Section 4.4) – for the transmitter's target operating parameters to be set correctly under “DUT Parameters“.



Pass	Deemphasis: Off					Ref Deviation: 40.000 kHz
Signal	Detector	Factor	Limit <	Results	< Limit	Unit
MPX	Selective	1	-3.000	0.030	3.000	%
MPX	PK	1	-3.000	0.132	3.000	%
MPX	QPK	√2	-3.000	-0.078	3.000	%
MPX	RMS	√2	-3.000	0.029	3.000	%

Fig. 24: "TV/Radio Analyzer/Receiver" mode, Audio Analysis→Level menu: Variance of the frequency deviation for the MPX signal compared to the entered standard test deviation, in percent: Level Setup: Relative Δ(%).[1]



Pass	Deemphasis: Off					
Signal	Detector	Factor	Limit <	Results	< Limit	Unit
L	Selective	1	38.800	40.026	41.200	kHz
L	PK	1	38.800	40.056	41.200	kHz
L	QPK	√2	38.800	39.976	41.200	kHz
L	RMS	√2	38.800	40.017	41.200	kHz
R	Selective	1	38.800	39.969	41.200	kHz
R	PK	1	38.800	39.996	41.200	kHz
R	QPK	√2	38.800	39.918	41.200	kHz
R	RMS	√2	38.800	39.960	41.200	kHz

Fig. 25: "TV/Radio Analyzer/Receiver" mode, MEAS→Audio Analysis→Level: Frequency deviation for the L&R signal: Level Setup: Absolute.

[1] There is no need to take action in response to the red "MONO" warning in the status bar, because that warning only indicates that no pilot has been found.

5.4 Frequency Response

With the R&S®ETL, it is possible to measure the amplitude-frequency response and the phase response up to 100 kHz as well as the balance (i.e., the difference between the amplitude-frequency responses in the right and left channels).

5.4.1 Amplitude-Frequency Response

The amplitude-frequency response is measured to ensure that the output signal remains constant across the frequency range being used. With the R&S®ETL, you can measure the amplitude-frequency response using two different detectors (RMS and Selective). The selective detector also makes it possible to simultaneously measure the phase and, due to its narrower bandwidth, it offers advantages for the dynamic range; nevertheless, it requires a slightly longer measurement period.

5.4.1.1 Audio Frequency Characteristic (up to 15 kHz, or 17.5 kHz for Mono Transmitters)

With the R&S®ETL, the preemphasis can be subtracted directly from the representation of the audio frequency response, or the preemphasis can be included in the representation. If the preemphasis is included in the representation, you can employ markers at certain reference values to check the audio frequency response (see Fig. 26), for example at a time constant of 50 µs at 15 kHz, an amplitude change of 13.66 dB (see appendix A.2 for calculation). The R&S®ETL can directly subtract the preemphasis and plot the variance from the ideal characteristic curve, and it can display the maximum positive and negative variance in a table (see Fig. 28). This makes it easier to read the results and ensures that the entire amplitude characteristic is checked, and not just individual reference points.

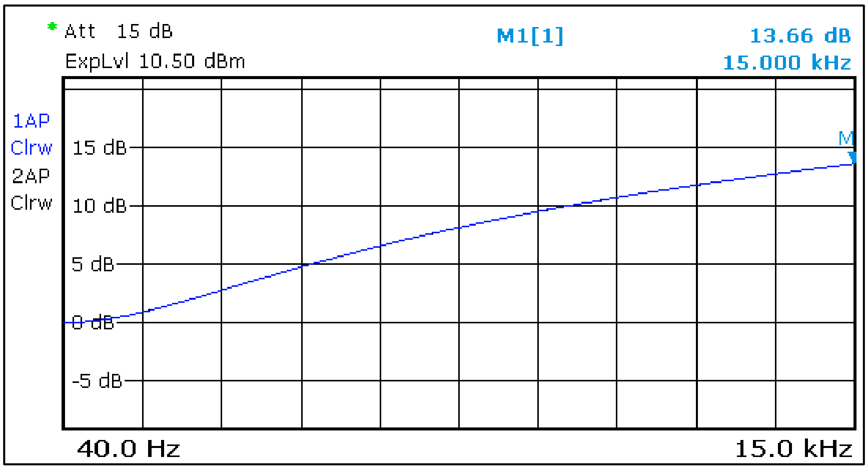


Fig. 26: "TV/Radio Analyzer/Receiver" mode, MEAS→Audio Analysis→Frequency Response: Typical amplitude characteristic for an FM signal with the transmitter's preemphasis turned on and without deemphasis on the receiver (measured as described below for Method 1 with "Deemphasis" set to "OFF").

The audio amplitude-frequency response up to 15 kHz can be measured separately one after the other for input signal L and input signal R. Alternatively, the R&S®ETL can switch automatically between the channels. For this, "L&R" is selected under "Signal Path". The results are displayed in a diagram with two traces.

IEC 244-13 specifies that the exciter's preemphasis is to be turned on and that the input level is to maintained at a constant level during the measurement. The input level is to be selected so that the frequency deviation up to 15 kHz does not exceed the peak deviation.

In conjunction with a transmitter that has a nominal deviation of 40 kHz at an input level of 6 dBu, in order not to exceed a peak deviation of 75 kHz, it is possible to calculate a maximum audio input level of: $20\log\left(\frac{75}{40}\right)+6=11.5\ dBu$. When preemphasis with a time constant of 50 µs is turned on, this value must be reduced by: $20\log\frac{1}{\sqrt{1+(2\pi*15\ kHz*50\ \mu s)^2}}=13.6\ dBu$ for the audio frequency 15 kHz. That results in a max. audio input level of –2.1 dBu.

For the max. audio input level for other transmitter configurations and peak deviations, and for the corresponding calculation, refer to Appendix A.

Besides the measurement with a constant level, the following configuration table also contains the settings for a measurement with a constant frequency deviation. In the following section, 500 Hz is used as the reference frequency. In practice, 40 Hz is also used frequently for this.

<table>
<tr><th colspan="2">Procedure: Audio frequency characteristic</th></tr>
<tr><td colspan="2">⚠ Check to ensure that the max. input power is not exceeded (see Section 4.3)</td></tr>
<tr><td colspan="2">Connect the R&S®ETL (IN1) to test port M1.</td></tr>
<tr><td colspan="2">Configure the general settings as described in Section 4.4.</td></tr>
<tr><td colspan="2">Set the transmitter input to "AF Stereo".
On the transmitter, turn on preemphasis.</td></tr>
<tr><td>Method 1:
With a constant level
(in line with IEC 244-13)</td><td>Method 2:
With a constant frequency deviation</td></tr>
<tr><td colspan="2">MEAS→Audio Analysis→Frequency Response→Frequency Response Setup (see Fig. 27)</td></tr>
<tr><td colspan="2">Demodulator:
• Signal Path: L&R</td></tr>
<tr><td>• Deemphasis: Set to match the transmitter's preemphasis setting</td><td>• Deemphasis: Off</td></tr>
<tr><td colspan="2">Audio Generator:
• Type: Analog (Option B201)
• Connector Config: Set to match the transmitter's configuration (see 3.2.3)
• Output: Alternate L and R continuously: deactivate (see 3.3.2)</td></tr>
<tr><td>• Ampl Definition: Level
• Level: For example, –2.1 dBu (see Appendix A)</td><td>• Ampl Definition: Desired DUT Deviation[1]
• Desired DUT Dev: For example, 75 kHz
• Preemphasis Comp: Set to match the transmitter's preemphasis setting</td></tr>
<tr><td colspan="2">Measurement Options:
• Response Type: Amplitude (selective)
• Ref Freq: For example, 500 Hz
• Sweep: Linear
• Sweep Points: 100[2]
• Start Freq: 40 Hz
• Stop Freq: 15 kHz</td></tr>
<tr><td colspan="2">Adjust the level as described in Section 4.4.</td></tr>
<tr><td colspan="2">Start the measurement by selecting RUN.</td></tr>
<tr><td colspan="2">Set MEAS→Audio Analysis→Frequency Response→Diagram Range→Freq Response Range so that the entire frequency response is clearly visible.</td></tr>
<tr><td colspan="2">Read the variance for the audio frequency response in the table of results, (see Fig. 28). Use PRINT to generate a printout of the measurement screen as needed.</td></tr>
</table>

[1] For this it is necessary – as described in the section on the basic settings (Section 4.4) – for the transmitter's target operating parameters to be set correctly under “DUT Parameters“.

[2] Increasing the number of sweep points results in a higher resolution but requires a longer measurement period.

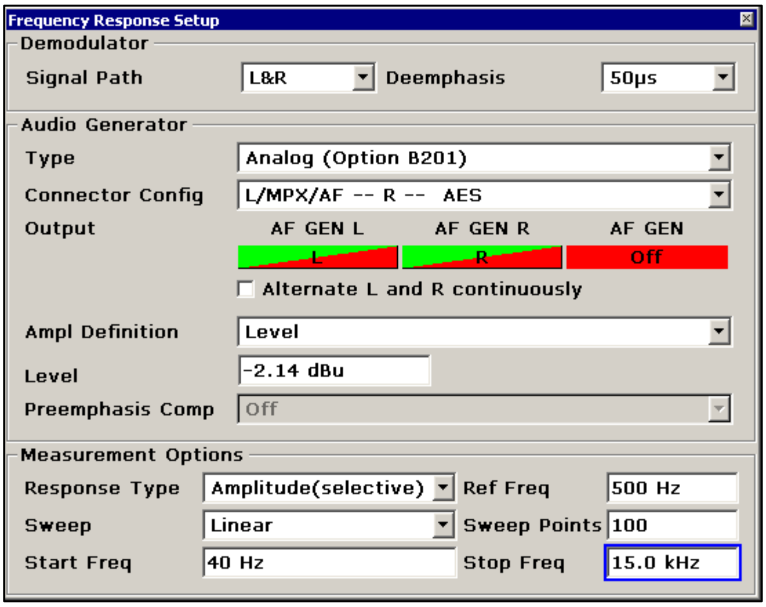


Fig. 27: "TV/Radio Analyzer/Receiver" mode, MEAS→Audio Analysis→Frequency Response→Frequency Response Setup: Configuration for measurement of the audio amplitude-frequency response in line with Method 1.

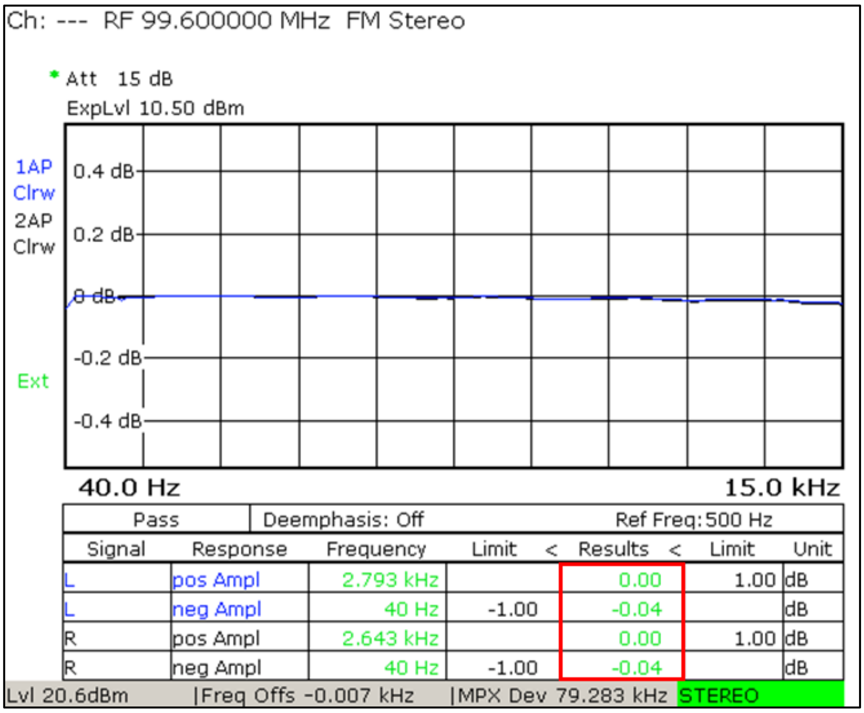


Fig. 28: "TV/Radio Analyzer/Receiver" mode, MEAS→Audio Analysis→Frequency Response: Measured audio frequency response in line with Method 2; maximum positive / negative variance from the ideal amplitude-frequency response in the table.

5.4.1.2 Baseband Frequency Characteristic (up to 100 kHz).

The baseband frequency characteristic, which is also referred to as the MPX amplitude-frequency response, is measured up to 100 kHz. IEC 244-13 specifies that the exciter's preemphasis is to be turned off and that the input level is to maintained at a constant level during the measurement.

The R&S®ETL enables you to either enter the constant audio level (“Ampl Definition“ = “Level“) or enter the corresponding frequency deviation (”Ampl Definition“ = ”Desired DUT Deviation“).

<table>
<tr><th colspan="2">Procedure: Baseband frequency characteristic</th></tr>
<tr><td colspan="2">⚠ Check to ensure that the max. input power is not exceeded (see Section 4.3).</td></tr>
<tr><td colspan="2">Connect the R&S®ETL (IN1) to test port M1.</td></tr>
<tr><td colspan="2">Configure the general settings as described in Section 4.4.</td></tr>
<tr><td colspan="2">Set the transmitter input to MPX.</td></tr>
<tr><td colspan="2">MEAS→Audio Analysis→Frequency Response→Frequency Response Setup (see Fig.29):
Demodulator:
• Signal Path: MPX
Audio Generator:
• Type: Analog (Option B201)
• Connector Config: Configure to match the transmitter (see 3.2.3)</td></tr>
<tr><td>• Ampl Definition: Level
• Level: For example, 6 dBu</td><td>• Ampl Definition: Desired DUT Deviation[1]
• Desired DUT Dev: For example, 40 kHz
• Preemphasis Comp: Off</td></tr>
<tr><td colspan="2">Measurement Options:
• Response Type: Amplitude (selective)
• Ref Freq: 500 Hz
• Sweep: Linear
• Sweep Points 100[2]
• Start Freq: 10 Hz
• Stop Freq: 100 kHz</td></tr>
<tr><td colspan="2">Adjust the level as described in Section 4.4.</td></tr>
<tr><td colspan="2">Start the measurement by selecting RUN.</td></tr>
<tr><td colspan="2">Set MEAS→Audio Analysis→Frequency Response→Diagram Range→Freq Response Range so that the entire frequency response is clearly visible.</td></tr>
<tr><td colspan="2">Read the values for the variances in the results for the baseband frequency response in the table of results (see Fig. 30). Use PRINT to generate a printout of the measurement screen as needed.</td></tr>
</table>

[1] For this it is necessary – as described in the section on the basic settings (Section 4.4) – for the transmitter's target operating parameters to be set correctly under “DUT Parameters“.
[2] Increasing the number of sweep points results in a higher resolution but requires a longer measurement period.

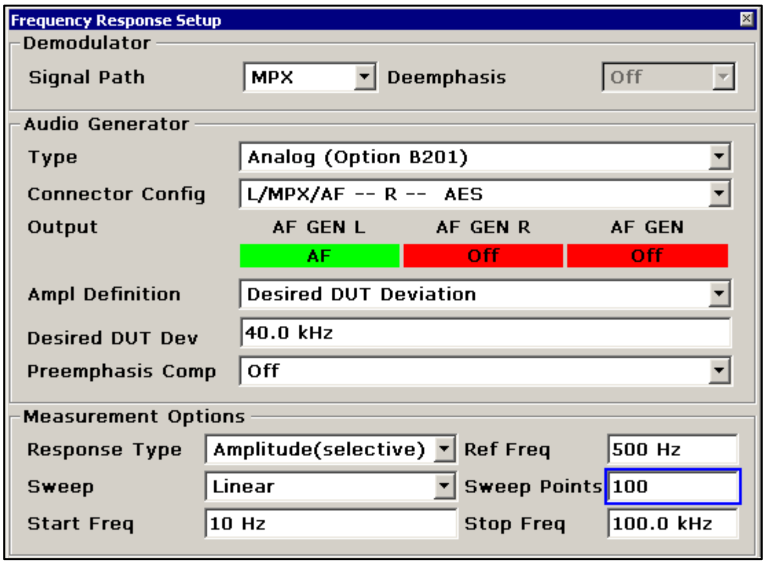


Fig.29: "TV/Radio Analyzer/Receiver" mode, MEAS→Audio Analysis→Frequency Response→Frequency Response Setup: Configuration for measurement of the amplitude frequency response up to 100 kHz.

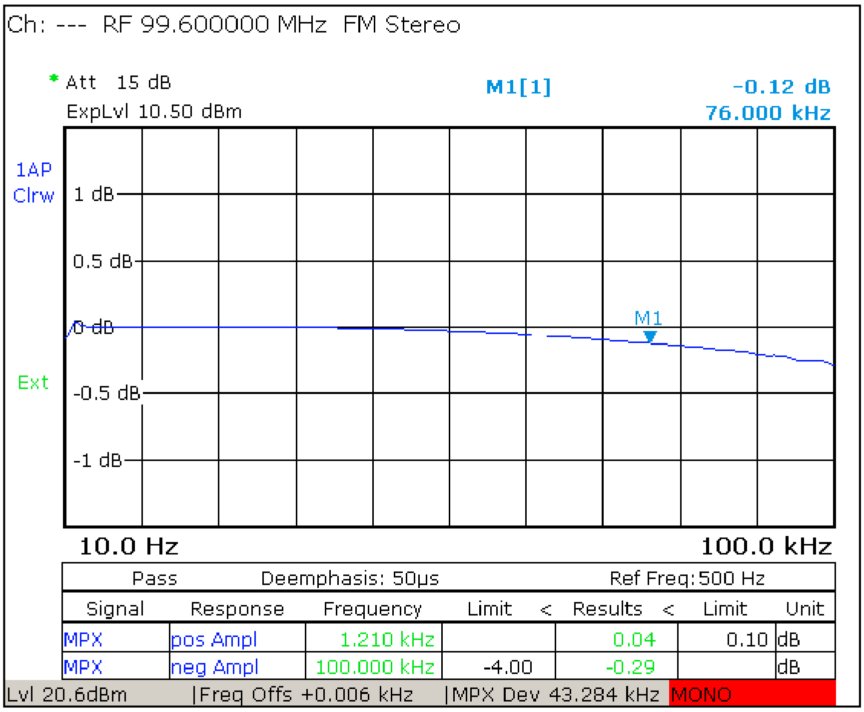


Fig. 30: "TV/Radio Analyzer/Receiver" mode, MEAS→Audio Analysis→Frequency Response: Measured frequency response with MPX input signal; maximum positive / negative variance from the ideal amplitude-frequency response in the table.[1]

[1] There is no need to take action in response to the red "MONO" warning in the status bar, because that warning only indicates that no pilot has been found.

5.4.2 Phase Response

Besides measuring the amplitude-frequency response, the R&S®ETL makes it possible to measure the phase frequency response as required, for example, by the technical guidelines "Stereo Encoders for the Pilot-tone System" (TR No. 5/3.2) and "VHF/FM Radio Broadcasting Transmitters" (TR No. 5/3.1). These specifications require measurement of the phase response in the baseband (see 5.4.2.2).

The phase response of the transmitter's transfer function influences crosstalk in the stereo channels. In the past, measuring the frequency phase response required a great deal of effort. For that reason, the decision was frequently made to merely measure the effects (the crosstalk) instead. Nevertheless, the R&S®ETL makes it easy to measure the phase response directly, which then makes it possible to analyze what is causing the crosstalk.

The technical guidelines cited above stipulate that the phase tolerance is to be measured using a reference frequency of 500 Hz (or 57 kHz for the additional RDS signal). Nonetheless, at a reference frequency of 500 Hz, the highpass filter at the transmitter input causes a residual phase shift, even when the cutoff frequency is very low. That, in turn, leads to a downward tendency in the measured curve (see Fig. 31, left), which makes it appear that the limits are not being maintained when the frequencies are high. In such cases, Rohde & Schwarz recommends measuring the phase response with a higher reference frequency (such as 5 kHz), which leads to a horizontal curve progression (see Fig. 31, right).

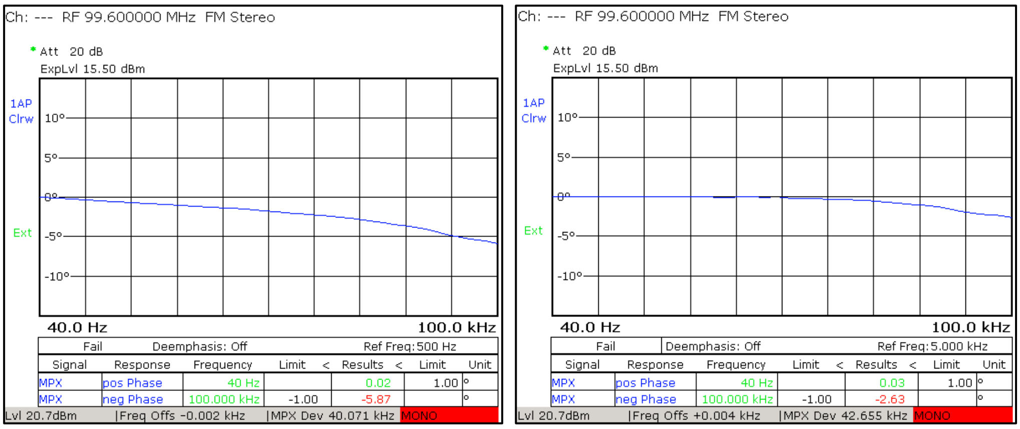


Fig. 31: "TV/Radio Analyzer/Receiver" mode, MEAS→Audio Analysis→Frequency Response: Measured phase response up to 100 kHz with a reference frequency of 500 Hz (left) or 5 kHz (right).

It is also possible, for instance, to measure the phase in the L and R signals (which is equivalent to the audio phase response; see 5.4.2.1). The specifications "VHF/FM Radio Broadcasting Transmitters" (TR No. 5/3.1) and "Stereo Encoders for the Pilot-tone System" (TR No. 5/3.2) do not required that.

5.4.2.1 Audio Phase Response

<table>
<tr><th colspan="2">Procedure: Audio phase response</th></tr>
<tr><td colspan="2">Check to ensure that the max. input power is not exceeded (see Section 4.3).</td></tr>
<tr><td colspan="2">Connect the R&S®ETL (IN1) to test port M1.</td></tr>
<tr><td colspan="2">Configure the general settings as described in Section 4.4.</td></tr>
<tr><td colspan="2">Set the transmitter input to AF stereo.
On the transmitter, turn on preemphasis.</td></tr>
<tr><td>Method 1:
With a constant level</td><td>Method 2:
With a constant frequency deviation</td></tr>
<tr><td colspan="2">MEAS→Audio Analysis→Frequency Response→Frequency Response Setup:</td></tr>
<tr><td colspan="2">Demodulator:
• Signal Path: L&R</td></tr>
<tr><td>• Deemphasis: Set to match the transmitter's preemphasis setting</td><td>• Deemphasis: Off</td></tr>
<tr><td colspan="2">Audio Generator:
• Type: Analog (Option B201)
• Connector Config: Set to match the transmitter (see 3.2.3)
• Output: Alternate L and R continuously: deactivate (see 3.3.2)</td></tr>
<tr><td>• Ampl Definition: Level
• Level: For example, −2.1 dBu (see Appendix A)</td><td>• Ampl Definition: Desired DUT Deviation[1]
• Desired DUT Dev: For example, 40 kHz
• Preemphasis Comp: Set to match the transmitter's preemphasis setting</td></tr>
<tr><td colspan="2">Measurement Options:
• Response Type: Phase
• Ref Freq: For example, 5 kHz
• Sweep: Linear
• Sweep Points 100[2]
• Start Freq: 40 Hz
• Stop Freq: 15 kHz</td></tr>
<tr><td colspan="2">Adjust the level as described in Section 4.4.</td></tr>
<tr><td colspan="2">Start the measurement by selecting RUN.</td></tr>
<tr><td colspan="2">Set MEAS→Audio Analysis→Frequency Response→Diagram Range→Phase Range so that the entire phase response is clearly visible.</td></tr>
<tr><td colspan="2">In the results table, read the values for any nonconformance in the phase response (see Fig. 32). Use PRINT to generate a printout of the measurement screen as needed.</td></tr>
</table>

[1] For this it is necessary – as described in the section on the basic settings (Section 4.4) – for the transmitter's target operating parameters to be set correctly under "DUT Parameters".

[2] Increasing the number of sweep points results in a higher resolution but requires a longer measurement period.

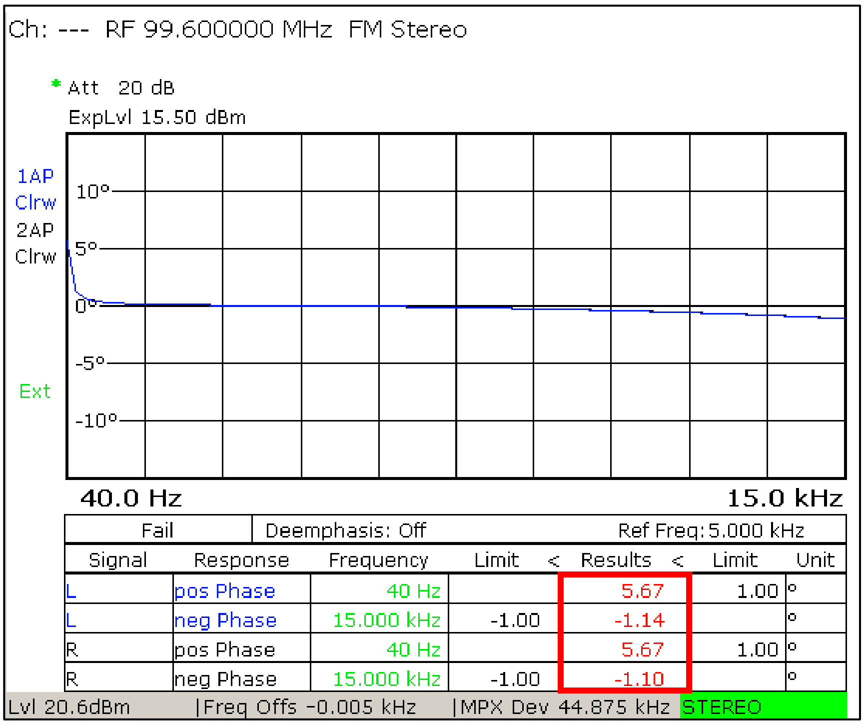


Fig. 32: "TV/Radio Analyzer/Receiver" mode, MEAS→Audio Analysis→Frequency Response: Measured phase response of L&R signal with a reference frequency of 5 kHz; maximum positive / negative variance from the ideal phase response in the table.

5.4.2.2 Baseband Phase Response

Procedure: Baseband phase response	
⚠ Check to ensure that the max. input power is not exceeded (see Section 4.3).	
Connect the R&S®ETL (IN1) to test port M1.	
Configure the general settings as described in Section 4.4.	
Set the transmitter input to MPX.	
MEAS→Audio Analysis→Frequency Response→Frequency Response Setup:	
Demodulator: • Signal Path: MPX	
Audio Generator: • Type: Analog (Option B201) • Connector Config: Set to match the transmitter (see 3.2.3)	
• Ampl Definition: Level • Level: For example, 6 dBu (see Appendix A)	• Ampl Definition: Desired DUT Deviation[1] • Desired DUT Dev: For example, 40 kHz • Preemphasis Comp: Off
Measurement Options: • Response Type: Phase • Ref Freq: For example, 5 kHz • Sweep: Linear • Sweep Points 100[2] • Start Freq: 10 Hz • Stop Freq: 100 kHz	
Adjust the level as described in Section 4.4.	
Start the measurement by selecting RUN.	
Set MEAS→Audio Analysis→Frequency Response→Diagram Range→Phase Range so that the entire phase response is clearly visible.	
In the results table, read the values for any nonconformance in the phase response (see Fig. 33). Use PRINT to generate a printout of the measurement screen as needed.	

[1] For this it is necessary – as described in the section on the basic settings (Section 4.4) – for the transmitter's target operating parameters to be set correctly under “DUT Parameters“.

[2] Increasing the number of sweep points results in a higher resolution but requires a longer measurement period.

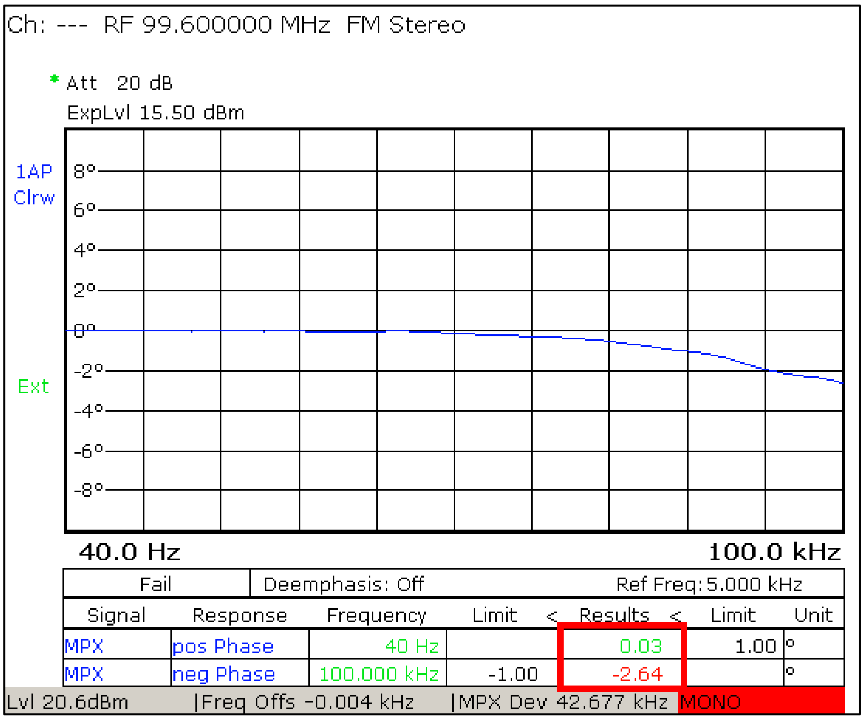


Fig. 33: "TV/Radio Analyzer/Receiver" mode, MEAS→Audio Analysis→Frequency Response: Measured phase response of the MPX signal up to 100 kHz the 5 kHz reference frequency; maximum positive / negative variance from the ideal phase response in the table. [1]

[1] There is no need to take action in response to the red "MONO" warning in the status bar, because that warning only indicates that no pilot has been found.

5.4.3 Balance

The difference in the amplitude-frequency responses for the right and left channels is referred to as balance. The individual frequency responses are measured with the RMS detector.

<table>
<tr><th colspan="2">Procedure: Balance</th></tr>
<tr><td colspan="2">⚠ Check to ensure that the max. input power is not exceeded (see Section 4.3).</td></tr>
<tr><td colspan="2">Connect the R&S®ETL (IN1) to test port M1.</td></tr>
<tr><td colspan="2">Configure the general settings as described in Section 4.4.</td></tr>
<tr><td colspan="2">Set the transmitter input to AF stereo.
On the transmitter, turn on preemphasis.</td></tr>
<tr><td>Method 1:
With a constant level</td><td>Method 2:
With a constant frequency deviation</td></tr>
<tr><td colspan="2">MEAS→Audio Analysis→Frequency Response→Frequency Response Setup, (see Fig. 34)</td></tr>
<tr><td colspan="2">Demodulator:
• Signal Path: L&R</td></tr>
<tr><td>• Deemphasis: Set to match the transmitter's preemphasis</td><td>• Deemphasis: Off</td></tr>
<tr><td colspan="2">Audio Generator:
• Type: Analog (Option B201)
• Connector Config: Set to match the transmitter (see 3.2.3)
• Output: Alternate L and R continuously: deactivate (see 3.3.2)</td></tr>
<tr><td>• Ampl Definition: Level
• Level: For example, −2.1 dBu (see Appendix A)</td><td>• Ampl Definition: Desired DUT Deviation[1]
• Desired DUT Dev: For example, 40 kHz
• Preemphasis Comp: Set to match the transmitter.</td></tr>
<tr><td colspan="2">Measurement Options:
• Response Type: Balance (rms)
• Sweep: Linear
• Sweep Points 100[2]
• Start Freq: 40 Hz
• Stop Freq: 15 kHz</td></tr>
<tr><td colspan="2">Adjust the level as described in Section 4.4.</td></tr>
</table>

[1] For this it is necessary – as described in the section on the basic settings (Section 4.4) – for the transmitter's target operating parameters to be set correctly under “DUT Parameters“.

[2] Increasing the number of sweep points results in a higher resolution but requires a longer measurement period.

Start the measurement by selecting RUN.
Set MEAS→Audio Analysis→Frequency Response→Diagram Range→Freq Response Range so that the entire frequency response is clearly visible.
In the results table, read the values for any nonconformance in the balance (see Fig. 35). Use PRINT to generate a printout of the measurement screen as needed.

When audio generator type "MPX (Option B201)" or "Analog (1,L 2,R)" is used, it is possible to measure the balance M&S.

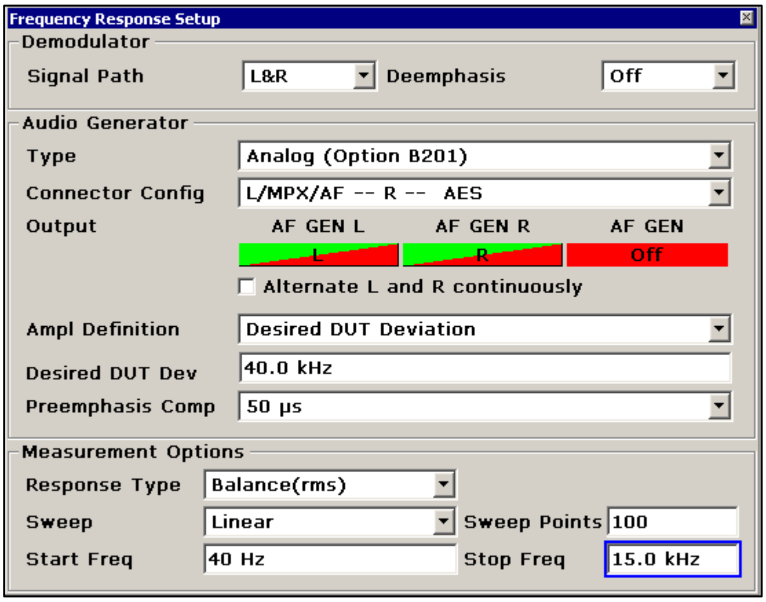


Fig. 34: "TV/Radio Analyzer/Receiver" mode, MEAS→Audio Analysis→Frequency Response→Frequency Response Setup: Configuration for measuring the balance.

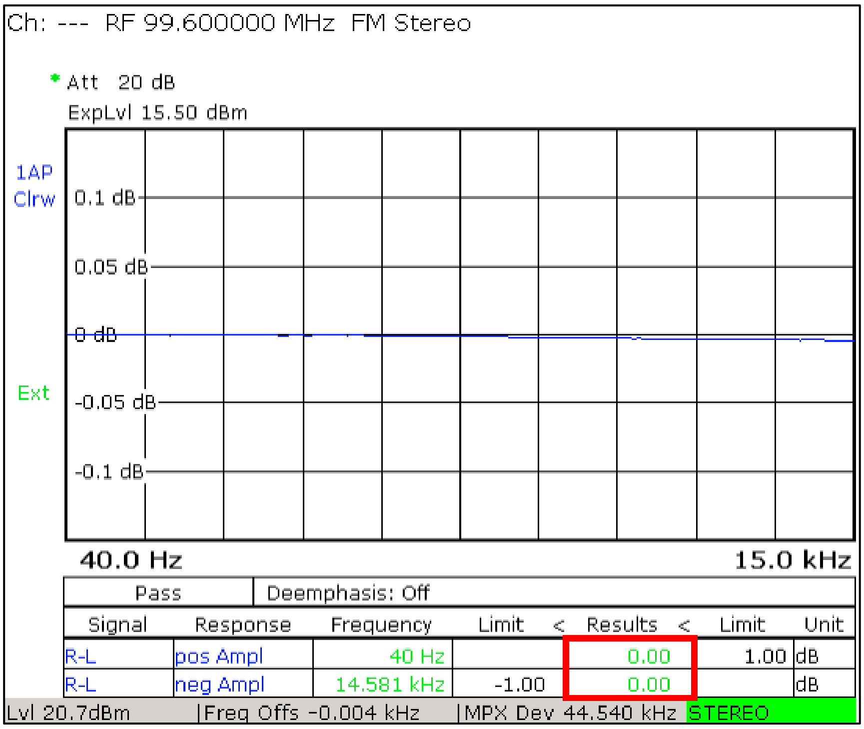


Fig. 35: "TV/Radio Analyzer/Receiver" mode, MEAS→Audio Analysis→Frequency Response: Measured balance; maximum positive / negative variance in the table.

5.5 Stereo Crosstalk

The undesired transmission of the L and R signals from each of those two channels into the other is known as stereo crosstalk. To perform the measurement, the first step is to feed in an L input signal and measure the frequency deviation in the R signal. After that, an R signal is fed in, and the frequency deviation is measured in the L signal.

To measure the stereo crosstalk, the R&S®ETL makes – in line with IEC 244-13 – three possibilities available, which can be selected for the "Crosstalk Setup" under the "Crosstalk Type" (see Fig. 36):

- Linear:
  With linear crosstalk, a ratio is formed out of the RMS value for the modulation signal at the output of the modulated channel and the RMS value for the fundamental at the output of the unmodulated channel. This ratio is then indicated in dB.
  If, for example, the amplitude of the R signal in the M and S signals does not match (as the result of linear distortion), the R signal's component is no longer completely canceled out through formation of L=M+S. In such cases, linear crosstalk has produced the components contained in the L signal that remain because of the inequality of the R signal.
- Nonlinear:
  In the case of nonlinear crosstalk, the system measures harmonics from sum signal M in the difference signal S (total harmonic distortion) and intermodulation from the difference signal S in the sum signal M (difference frequency distortion), which determines the non-linear distortions. In addition, because of the measurement principle, noise is also measured.
- Linear and nonlinear combined:
  When the sum is derived from both linear and nonlinear crosstalk, this is also referred to as crosstalk attenuation or stereophonic channel separation.

In line with IEC 244-13, it makes sense to measure the combined linear and nonlinear crosstalk or to measure these two components separately as linear crosstalk and nonlinear crosstalk.

For measuring the crosstalk on the SCA channel, the R&S®ETL offers the possibility of using an imaginary channel as a reference (Ref Dev).

IEC 244-13 specifies that stereo crosstalk be measured with preemphasis turned on and with a constant frequency deviation. With conventional measuring equipment, accomplishing that can require a great deal of effort, because it is necessary to recalculate and enter the audio level for each frequency. The R&S®ETL performs that task for you. To configure the device for that, it is necessary to select the "Desired DUT Deviation" and activate "Preemphasis Comp" (see Method 1).

Due to the significant effort required for performing a measurement using a constant frequency deviation, until now, test technicians have often performed the measurements using a constant level instead. Method 2 shows the configuration for doing that.

<table>
<tr><th colspan="2">Procedure: Stereo crosstalk</th></tr>
<tr><td colspan="2">⚠ Check to ensure that the max. input power is not exceeded (see Section 4.3).</td></tr>
<tr><td colspan="2">Connect the R&S®ETL (IN1) to test port M1.</td></tr>
<tr><td colspan="2">Configure the general settings as described in Section 4.4.</td></tr>
<tr><td colspan="2">Set the transmitter input to AF stereo.
On the transmitter, turn on preemphasis.</td></tr>
<tr><td>Method 1:
With a constant frequency deviation
(in line with IEC 244-13)</td><td>Method 2:
With a constant level</td></tr>
<tr><td colspan="2">MEAS→Audio Analysis→Crosstalk→Crosstalk Setup (see Fig. 36):</td></tr>
<tr><td colspan="2">Demodulator:
• Signal Path: L&R</td></tr>
<tr><td>• Deemphasis: Off</td><td>• Deemphasis: Set to match the transmitter's preemphasis setting</td></tr>
<tr><td colspan="2">Audio Generator:
• Type: Analog (Option B201)
• Connector Config: Set to match the transmitter (see 3.2.3)
• Output: Alternate L and R continuously: deactivate (see 3.3.2)</td></tr>
<tr><td>• Ampl Definition: Desired DUT Deviation[1]
• Desired DUT Dev: For example, 75 kHz
• Preemphasis Comp: Set to match the transmitter</td><td>• Ampl Definition: Level
• Level: For example, –2.1 dBu (see Appendix A)</td></tr>
<tr><td colspan="2">Measurement Options:
• Crosstalk Type: Linear and Nonlinear combined
• Reference: R&L
• Sweep: Linear
• Sweep Points 100[2]
• Start Freq: 10 Hz
• Stop Freq: 15 kHz</td></tr>
<tr><td colspan="2">Adjust the level as described in Section 4.4.</td></tr>
<tr><td colspan="2">Start the measurement by selecting RUN.</td></tr>
<tr><td colspan="2">If necessary, set the MEAS→Audio Analysis→Crosstalk→Diagram Range→Crosstalk Range and Ref Position so that the trace is clearly visible.</td></tr>
<tr><td colspan="2">In the results table, read the values for stereo crosstalk (see Fig. 37). Use PRINT to generate a printout of the measurement screen as needed.</td></tr>
</table>

If you intend to measure the crosstalk from the M channel and S channel, it is necessary to use ports 1/L and 2/R; furthermore, in the "Audio Generator Setup" under "Type", you must select "Analog (1/L, 2/R)". After that, the "Crosstalk Setup" under "Signal Path" offers the options M, S or M&S.

[1] For this it is necessary – as described in the section on the basic settings (Section 4.4) – for the transmitter's target operating parameters to be set correctly under “DUT Parameters“.
[2] Increasing the number of sweep points results in a higher resolution but requires a longer measurement period.

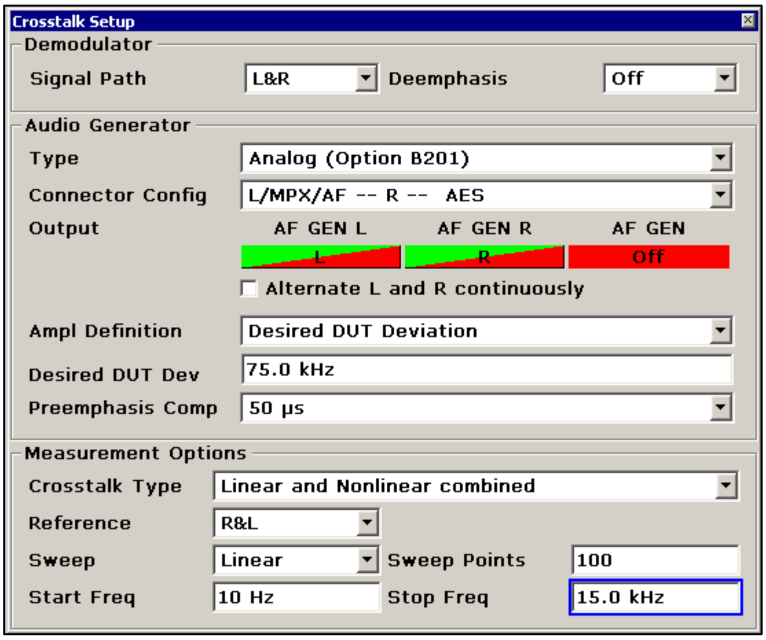


Fig. 36: "TV/Radio Analyzer/Receiver" mode, MEAS→Audio Analysis→Crosstalk→Crosstalk Setup: Configuration of the measurement for stereo crosstalk according to Method 1.

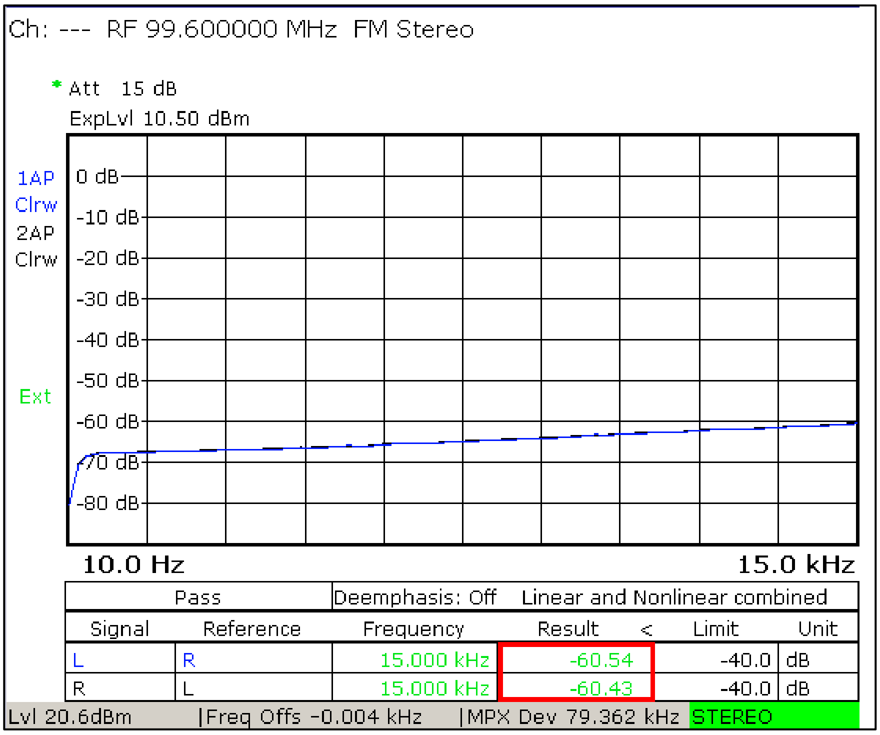


Fig. 37: "TV/Radio Analyzer/Receiver" mode, MEAS→Audio Analysis→Crosstalk: Measured stereo crosstalk; max. value in the table.

5.6 Nonlinear Distortion

5.6.1 Total Harmonic Distortion (THD)

Total harmonic distortion is a measure of nonlinearity distortion. It indicates the extent to which the overall signal is made up of undesired harmonics and is specified as a percentage or in dB. According to IEC 244-13, for this, the RMS values for all harmonics (d_2, d_3, ...) are set in relation to the sum of the RMS value for the fundamental and the RMS values for all harmonics:

$$THD_{Definition\ 1} = \sqrt{\frac{V_{RMS\_d2}{}^2 + V_{RMS\_d3}{}^2 + \cdots + V_{RMS\_dn}{}^2}{V_{RMS\_f1}{}^2 + V_{RMS\_d2}{}^2 + U_{RMS\_d3}{}^2 + \ldots + V_{RMS\_dn}{}^2}}$$

$$= \sqrt{\frac{\sum (V_{RMS\_Harmonic})^2}{V_{RMS\_f1}{}^2 + \sum (V_{RMS\_Harmonic})^2}}$$

Besides that definition, there is another definition, according to which the RMS values for all harmonics (d_2, d_3, ...) are set in relation to the RMS value for the fundamental:

$$THD_{Definition\ 2} = \sqrt{\frac{V_{RMS\_d2}{}^2 + V_{RMS\_d3}{}^2 + \cdots + V_{RMS\_dn}{}^2}{V_{RMS\_f1}{}^2}}$$

As is the case with most analyzers, the implementation realized in the R&S®ETL corresponds to Definition 1. In the case of the distortion that arises in practice, both definitions lead to the same results.

The voltages for the harmonics – and thus their influence on the overall harmonic distortion – decrease as the order increases.

For the measurement of the overall harmonic distortion, the R&S®ETL offers two measured values, which are displayed on the results screen:

- THD: For the sum of the harmonics, the first eight harmonics (d_2-d_9) are measured selectively and added together.
- THD+N (Total Harmonic Distortion + Noise): For the sum of the harmonics, the individual harmonics are not measured selectively; instead, the overall RMS after the suppressed fundamental up to the cut-off frequency (15 kHz) is used as the sum for the harmonics. This captures all harmonics up to the cut-off frequency. Nevertheless, this measurement also captures all other forms of interference, such as noise and intermodulation (much as is the case with nonlinear stereo crosstalk; see 5.5).

5.6.1.1 THD – Audio

IEC 244-13 specifies that the harmonic distortion is to be measured with preemphasis turned on. The input frequency is to be varied between 40 Hz and 7.5 kHz. The frequency deviation is to be kept constant for the different input frequencies. The R&S®ETL performs the complex level calculations that are required for this because of the fact that preemphasis is turned on. Using "Desired DUT Deviation" and "Preemphasis Comp" makes it possible to enter the desired frequency deviation directly.

Procedure: THD – Audio
⚠ Check to ensure that the max. input power is not exceeded (see Section 4.3).
Connect the R&S®ETL (IN1) to test port M1.
Configure the general settings as described in Section 4.4.
Set the transmitter input to AF stereo. On the transmitter, turn on preemphasis.
MEAS→Audio Analysis→THD→THD Setup: *Demodulator:* • Signal Path: L&R • Deemphasis: Off *Audio Generator:* • Type: Analog (Option B201) • Connector Config: Set to match the transmitter (see 3.2.3) • Output: Alternate L and R continuously: deactivate (see 3.2.3) • Freq: For example, set to 40 Hz, 500 Hz, 5 kHz and 7.5 kHz one after the other • Ampl Definition: Desired DUT Deviation[1] • Desired DUT Dev: For example, 40 kHz • Preemphasis Comp: Set to match the transmitter's preemphasis setting *Measurement Options:* • Unit: dB or %[2]
Adjust the level as described in Section 4.4.
Start the measurement by selecting RUN.
MEAS→Audio Analysis→THD→Diagram Range→Auto Range
In the results table, read the THD values (see Fig. 38). Use PRINT to generate a printout of the measurement screen as needed.

[1] For this it is necessary – as described in the section on the basic settings (Section 4.4) – for the transmitter's target operating parameters to be set correctly under ”DUT Parameters“.

[2] Depending on how you want to display the results.

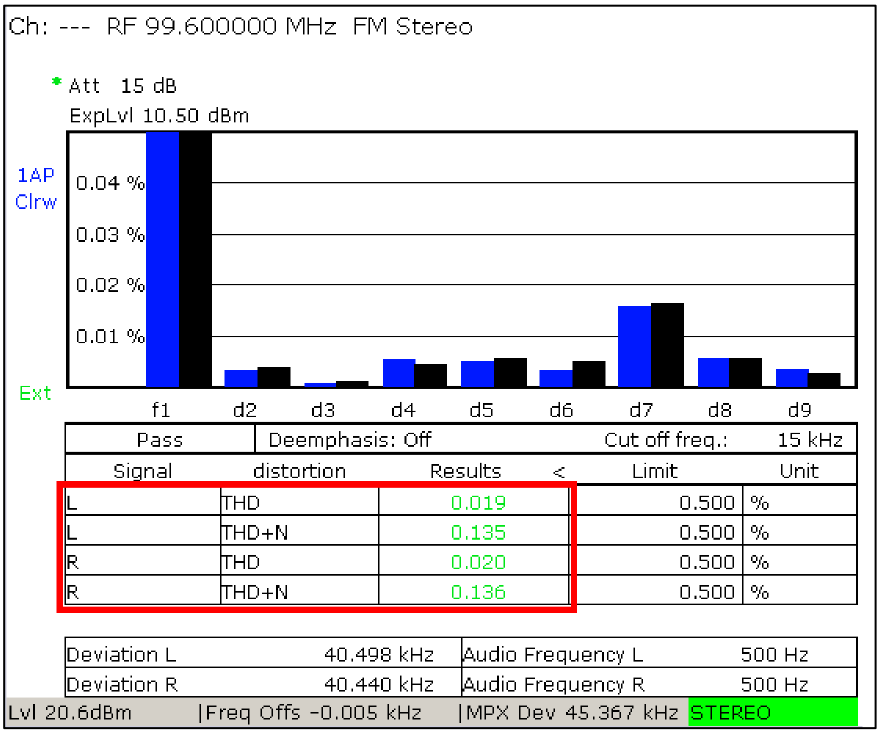


Fig. 38: "TV/Radio Analyzer/Receiver" mode, MEAS→Audio Analysis→THD: Measuring the total harmonic distortion at 500 Hz.

5.6.1.2 THD – Baseband

When performed in line with the technical guideline "VHF/FM Radio Broadcasting Transmitters" (TR No. 5/3.1), the measurement is taken without a stereo encoder or decoder.

Procedure: THD – baseband
⚠ Check to ensure that the max. input power is not exceeded (see Section 4.3).
Connect the R&S®ETL (IN1) to test port M1.
Configure the general settings as described in Section 4.4.
Set the transmitter input to MPX.
MEAS→Audio Analysis→THD→THD Setup: *Demodulator:* • Signal Path: MPX *Audio Generator:* • Type: Analog (Option B201) • Connector Config: Set to match the transmitter (see 3.2.3) • Freq: Set to the selected frequency • Ampl Definition: Desired DUT Deviation[1]	• Ampl Definition: Level • Desired DUT Dev: For example, 75 kHz	• Level: For example, −2.1 dBu (see Appendix A) • Preemphasis Comp: Set to match the transmitter *Measurement Options:* • Unit: dB or %[2]
Adjust the level as described in Section 4.4.
Start the measurement by selecting RUN.
MEAS→Audio Analysis→THD→Diagram Range→Auto Range
In the results table, read the THD value. Use PRINT to generate a printout of the measurement screen as needed.

[1] For this it is necessary – as described in the section on the basic settings (Section 4.4) – for the transmitter's target operating parameters to be set correctly under “DUT Parameters“.
[2] Depending on how you want to display the results.

5.6.2 Dual Frequency Distortion (DFD)

Dual frequency distortion is a measure of undesired second and third-order nonlinear distortion. It is expressed as percentage or as a ratio in dB. This measurement is based on the technique of using two signals – f_1 and f_2 – of the same amplitude with a frequency spacing of 1 kHz. This leads to quadratic distortion (of the second order) representing the difference frequency distortion ($f_2 - f_1$ = 1 kHz) and the sum frequency distortion ($f_1 + f_2$). In addition to second-order products (depending on the measurement specification: $d_2 = f_1 - f_2$ or $d_2 = f_1 - f_2$ & $f_1 + f_2$) , the third-order intermodulation products ($d_3 = 2f_2 - f_1$ & $2f_1 - f_2$) are also important here:

$$d_2(F_2 - F_1) = 20 \cdot \log\left(\frac{V_{RMS}(F_2 - F_1)}{V_{RMS}(F_1) + V_{RMS}(F_2)}\right)$$

$$d_2(F_2 - F_1 \,\&\, F_2 + F_1) = 20 \cdot log\left(\frac{V_{RMS}(F_2 - F_1) + V_{RMS}(F_2 + F_1)}{V_{RMS}(F_1) + V_{RMS}(F_2)}\right)$$

$$d_3(2F_2 - F_1 \,\&\, 2F_1 - F_1) = 20 \cdot log\left(\frac{V_{RMS}(2F_2 - F_1) + V_{RMS}(2F_1 - F_2)}{V_{RMS}(F_1) + V_{RMS}(F_2)}\right)$$

5.6.2.1 Audio Intermodulation

IEC 244-13 specifies that the exciter's preemphasis is to be turned on, that the input frequency is to be varied, and that the signals' input level is to be selected so that the signal components generate the same deviation. Entering the individual signal levels for the two-tone signal on the R&S®ETL is not necessary. The signal levels are automatically set so that, together, they result in the desired frequency deviation or level that was entered and so that each signal component generates the same frequency deviation.

Unlike IEC 244-13 (Method 1 in the section below) the technical guideline "Stereo Encoders for the Pilot-tone System" (TR No. 5/3.2) requires that the measurement be performed with preemphasis or deemphasis (Method 2 in the section below).

It must be ensured that, during measurement of audio intermodulation (signal path: L&R) the upper cut-off frequency is 15 kHz. Intermodulation influences that arise above this cut-off frequency are not reflected in the results. The measured intermodulation products (in dB) refer to the measured frequency deviation of $\frac{f_1 + f_2}{2}$.

<table>
<tr><th colspan="2">Procedure: Audio intermodulation</th></tr>
<tr><td colspan="2">⚠ Check to ensure that the max. input power is not exceeded (see 4.3).</td></tr>
<tr><td colspan="2">Connect the R&S®ETL (IN1) to test port M1.</td></tr>
<tr><td colspan="2">Configure the general settings as described in Section 4.4.</td></tr>
<tr><td>Method 1:
Preemphasis turned on
(in line with IEC 244-13)</td><td>Method 2:
Preemphasis turned of
(in line with TR 5/3.2)</td></tr>
<tr><td colspan="2">Set the transmitter input to AF stereo.</td></tr>
<tr><td>On the transmitter, turn on preemphasis.</td><td>On the transmitter, turn off preemphasis.</td></tr>
<tr><td colspan="2">MEAS→Audio Analysis→DFD→DFD Setup:

Demodulator:
• Signal Path: L&R
• Deemphasis: Off

Audio Generator:
• Type: Analog (Option B201)
• Connector Config: Set to match the transmitter (see 3.2.3)
• Waveform: Dual Tone, constant spacing
• Upper Freq: For example, 6 kHz
• Freq Spacing 1 kHz
• Ampl Definition: Desired DUT Deviation[1]
• Desired DUT Dev: For example, 40 kHz</td></tr>
<tr><td>• Preemphasis Comp: Set to match the transmitter's preemphasis</td><td>• Preemphasis Comp: Off</td></tr>
<tr><td colspan="2">Measurement Options:
• Unit: dB or %</td></tr>
<tr><td colspan="2">Adjust the level as described in Section 4.4.</td></tr>
<tr><td colspan="2">Start the measurement by selecting RUN.</td></tr>
<tr><td colspan="2">In the table of results, read the values for the intermodulation products (d_2 and d_3; see Fig. 39). Use PRINT to generate a printout of the measurement screen as needed.</td></tr>
</table>

[1] For this it is necessary – as described in the section on the basic settings (Section 4.4) – for the transmitter's target operating parameters to be set correctly under “DUT Parameters“.

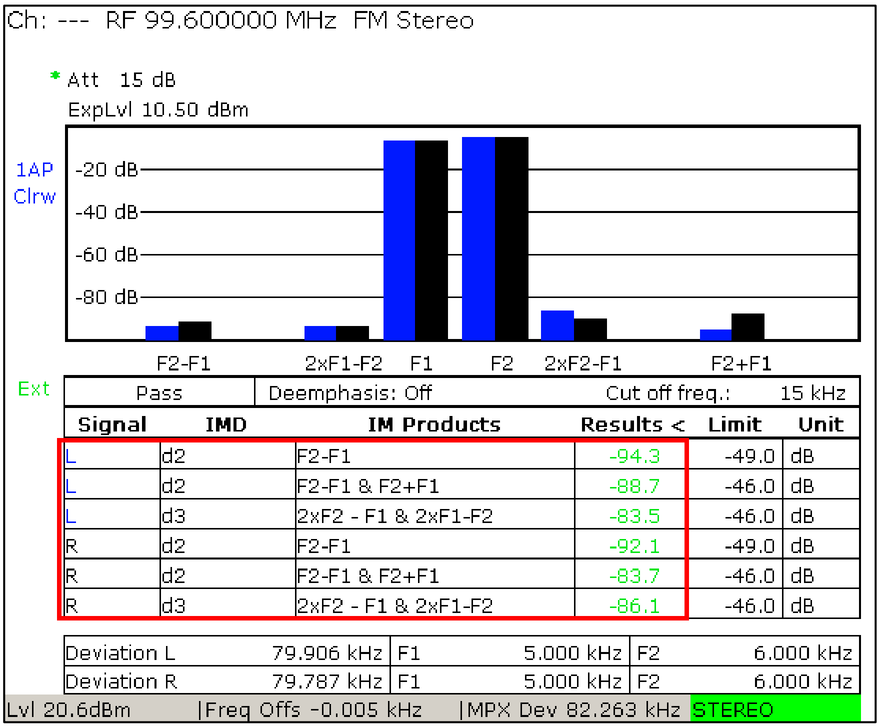


Fig. 39: "TV/Radio Analyzer/Receiver" mode, MEAS→Audio Analysis→DFD: Measurement of dual-frequency distortion (DFD) with the upper frequency (f_2) 6 kHz.

5.6.2.2 Intermodulation in the Baseband (up to 100 kHz)

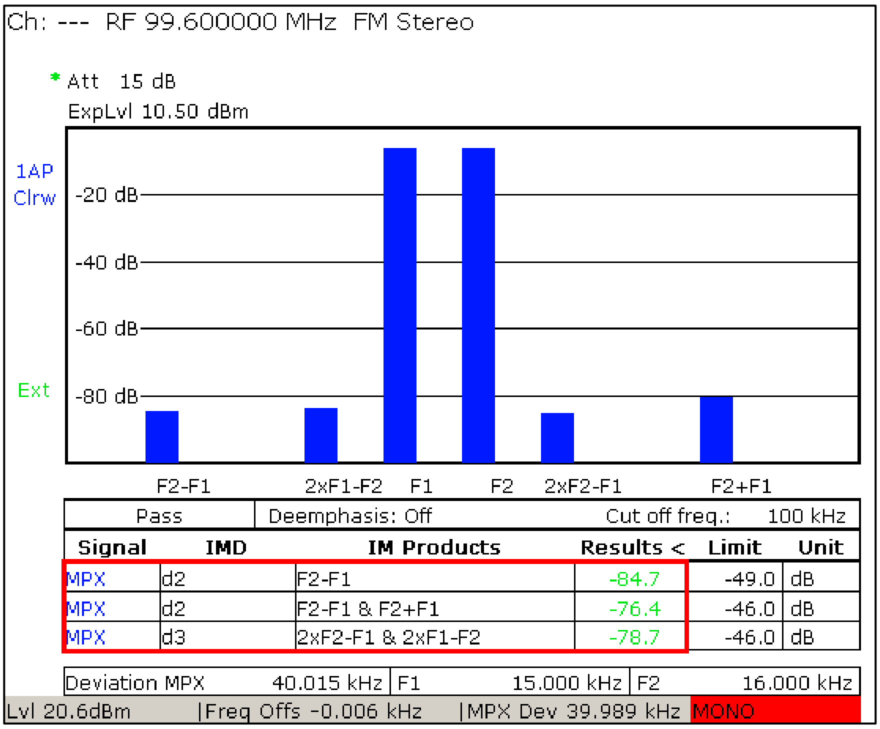
IEC 244-13 specifies that the exciter's preemphasis is to be turned off, that the input frequencies are to be varied, and that the signals' input levels are to be selected so that the signal components have the same amplitude. It is not necessary to enter the individual signal levels for the two-tone signal on the R&S®ETL. The signal levels are automatically set so that, together, they result in the desired frequency deviation or level that was entered and so that each signal component generates the same frequency deviation. The frequency deviation for the different input frequencies is to be kept constant. The R&S®ETL enables you to either enter the audio level or enter the corresponding frequency deviation. Both configurations lead to the same result.

The technical guideline "VHF/FM Radio Broadcasting Transmitters" (TR No. 5/3.1) specifies that the measurement is to be taken in the frequency range from 15 kHz to 76 kHz.

It must be ensured that, during measurement of intermodulation in the baseband ("Signal Path: MPX") the upper cut-off frequency is 100 kHz. Intermodulation products that arise above this cut-off frequency are not reflected in the results. The measured intermodulation products (in dB) refer to the measured frequency deviation of $\frac{f_1+f_2}{2}$.

Procedure: Intermodulation in the baseband
⚠ Check to ensure that the max. input power is not exceeded (see Section 4.3).
Connect the R&S®ETL (IN1) to test port M1.
Configure the general settings as described in Section 4.4.
Set the transmitter input to MPX.
MEAS→Audio Analysis→DFD→DFD Setup: *Demodulator:* • Signal Path: MPX • Deemphasis: Off *Audio Generator:* • Type: Analog (Option B201) • Connector Config: Set to match the transmitter (see 3.2.3) • Waveform: Dual Tone, constant spacing • Upper Freq: For example, 16 kHz, 26 kHz, 41 kHz, 51 kHz, 76 kHz • Freq Spacing 1 kHz • Ampl Definition: Level • Level: For example, 6 dBu — or — • Ampl Definition: Desired DUT Deviation[1] • Desired DUT Dev: For example, 40 kHz • Preemphasis Comp: Off *Measurement Options:* • Unit: dB or %
Adjust the level as described in Section 4.4.
Start the measurement by selecting RUN.
In the table of results, read the values for the intermodulation products (d_2 and d_3; see Fig. 40). Use PRINT to generate a printout of the measurement screen as needed.

[1] For this it is necessary – as described in the section on the basic settings (Section 4.4) – for the transmitter's target operating parameters to be set correctly under “DUT Parameters“.



Signal	IMD	IM Products	Results <	Limit	Unit
MPX	d2	F2-F1	-84.7	-49.0	dB
MPX	d2	F2-F1 & F2+F1	-76.4	-46.0	dB
MPX	d3	2xF2-F1 & 2xF1-F2	-78.7	-46.0	dB

Fig. 40: "TV/Radio Analyzer/Receiver" mode, MEAS→Audio Analysis→DFD: Measurement of dual-frequency distortion (DFD) with the upper frequency (f_2) of 16 kHz.[1]

[1] There is no need to take action in response to the red "MONO" warning in the status bar, because that warning only indicates that no pilot has been found.

5.6.2.3 Intermodulation at 57 kHz

In the technical guidelines "VHF/FM Radio Broadcast Transmitters" (TR No. 5/3.1) and "VHF/FM Rebroadcast Receivers" (TR No. 5/3.5), the measurement of the intermodulation is performed using these input frequency pairs: 6.2 kHz and 31.6 kHz as well as 9.3 kHz and 47.7 kHz. Here, the intermodulation products at 57 kHz are to be analyzed:

$f_1 = 6.2$ kHz, $f_2 = 31.6$ kHz: $d_3 = 2{\cdot}f_2 - f_1 = 57$ kHz

$f_1 = 9.3$ kHz, $f_2 = 47.7$ kHz: $d_2 = f_1 + f_2 = 57$ kHz

In each case, the guidelines require a frequency deviation of ±22.5 kHz or ±10 kHz, respectively. Since the overall frequency deviation is entered on the R&S®ETL, the value entered here must be 45 kHz or 20 kHz. TR 5/3.1 stipulates that the intermodulation products be referenced to a calculated frequency deviation of 40 kHz. Since the reference to a calculated frequency deviation is a special case, the intermodulation products are not measured using the R&S®ETL's DFD function (which references the intermodulation products to the measured frequency deviation); instead, they are measured in the audio spectrum.

Procedure: Intermodulation at 57 kHz
⚠ Check to ensure that the max. input power is not exceeded (see Section 4.3).
Connect the R&S®ETL (IN1) to test port M1.
Configure the general settings as described in Section 4.4.
Set the transmitter input to MPX.
MEAS→Modulation Analysis→Audio Spectrum→Audio Spectrum Setup: • Signal Path: MPX
MEAS→Modulation Analysis→Audio Spectrum→Audio Generator→ Audio Generator Setup • Type: Analog (Option B201) • Signal: AF • Connector Config: Set to match the transmitter (see 3.2.3) • Waveform: Dual Tone, independent frequencies • Freq 1: 6.2 kHz or 9.3 kHz Freq 2: 31.6 kHz or 47.7 kHz • Ampl Definition: Desired DUT Deviation[1] • Desired DUT Dev: For example, 20 kHz or 45 kHz • Preemphasis Comp: Off
Adjust the level as described in Section 4.4.
MKR→Marker 1: 57 kHz
TRACE→Trace Mode: Average
MEAS→Modulation Analysis→Audio Spectrum→Diagram Range→Ref Deviation: 40 kHz
Read the measured marker value (see Fig. 41). Use PRINT to generate a printout of the measurement screen as needed.

[1] For this it is necessary – as described in the section on the basic settings (Section 4.4) – for the transmitter's target operating parameters to be set correctly under “DUT Parameters“.

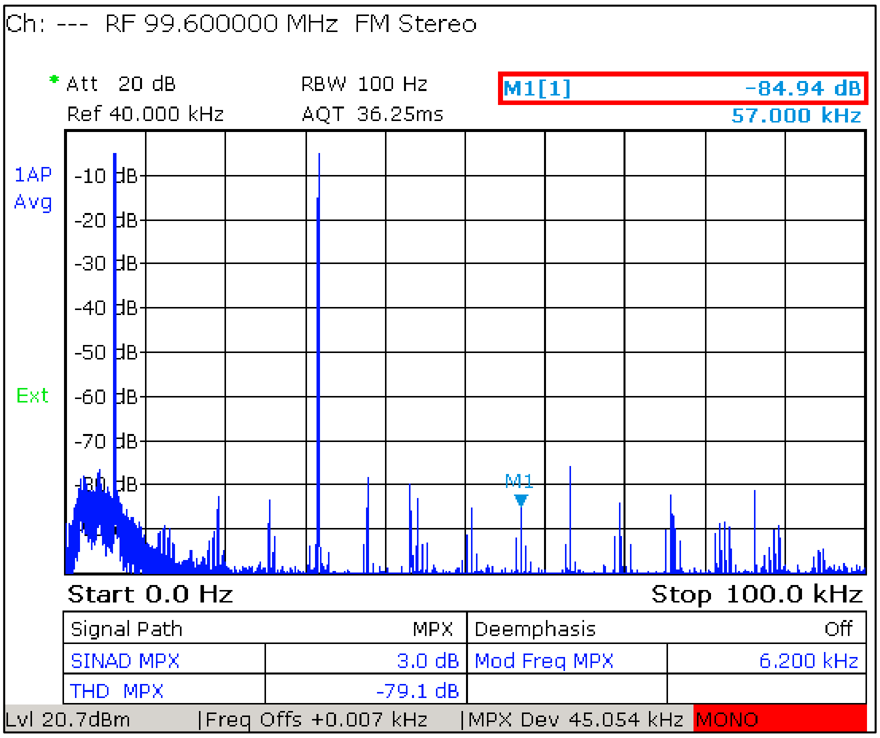


Fig. 41: "TV/Radio Analyzer/Receiver" mode, MEAS→Modulation Analysis→Audio Spectrum: Measurement of intermodulation products at 57 kHz using the marker function (top right).[1]

[1] There is no need to take action in response to the red "MONO" warning in the status bar, because that warning only indicates that no pilot has been found.

5.7 Spurious Modulation (Signal-to-Noise Ratio, S/N)

For the signal-to-noise ratio, a differentiation is made between the spurious frequency modulation and spurious amplitude modulation. The higher the S/N value is, the higher the signal quality. The signal-to-noise ratio is defined as the ratio of the audio signal (wanted signal) to noise, and it is expressed in dB:

$$\frac{S}{N} = 20\ log\frac{V_{Signal}}{V_{Noise}}$$

5.7.1 Spurious Frequency Modulation

5.7.1.1 Unweighted and Weighted Noise Voltage

IEC 244-13 specifies that the unweighted and the weighted noise voltage be measured using a QPK detector. In the weighted measurement of the noise voltage, the ITU-R BS.468-4-compliant filter is also used. This filter accounts for the effects that noise has on the human ear and provides the best possible representation of these requirements from a T&M perspective.
Besides the QPK detector, which also takes the effects on the human ear into account, the R&S®ETL also makes it possible to perform the measurement with an RMS detector. The test specifications stipulate which detector is to be used for measurement.

The test specification stipulates which frequency deviation is to be used to generate the signal when measuring the signal-to-noise ratio. That means that the signal amplitude (V_{Signal}) is predefined and does not have to be measured separately; measurement of the incidental deviation (V_{Noise}) is sufficient. Measuring the signal amplitude would cause the results to be overdetermined.

With the R&S®ETL, V_{Signal} is calculated using the data entered in the "DUT Parameters" (see 3.1.5) and the reference deviation (frequency deviation from the test specification). When entering the "Deviation" under "DUT Parameters", it is important to ensure that the peak deviation is always entered on the R&S®ETL. Prior verification of the transmitter's modulator constant (see 5.3) ensures that a measurement of V_{Signal} leads to the same value as to the one that was determined through calculations.

If the FM noise voltage is measured with the R&S®ETL for channels L and R in combination ("Signal Path: L&R"), the user must select whether the measurement will be weighted or unweighted ("Weighting Filter ITU-R BS.468-4"). If the channels are measured sequentially ("Signal Path: L " or "Signal Path: R") both values are always shown.

The section below provides an example of the settings for measuring the left channel.

Procedure: Unweighted and weighted noise voltage
⚠ Check to ensure that the max. input power is not exceeded (see Section 4.3).
Connect the R&S®ETL (IN1) to test port M1.
Configure the general settings as described in Section 4.4.
Set the transmitter input to AF stereo. On the transmitter, turn on preemphasis .
MEAS→Audio Analysis→ S/N→S/N Setup (see Fig. 42). *Demodulator:* • Signal Path: L • Deemphasis: Set to match the transmitter's preemphasis setting *Audio Generator:* • Signal: Off • No configuration of the signal (such as "Waveform", "Ampl Definition") is necessary, because the signal is not measured *Measurement Options:* • Ref Deviation: Frequency deviation of the reference audio signal, for example: 40 kHz
MEAS→Audio Analysis→S/N: Read the measured values (see Fig. 43).

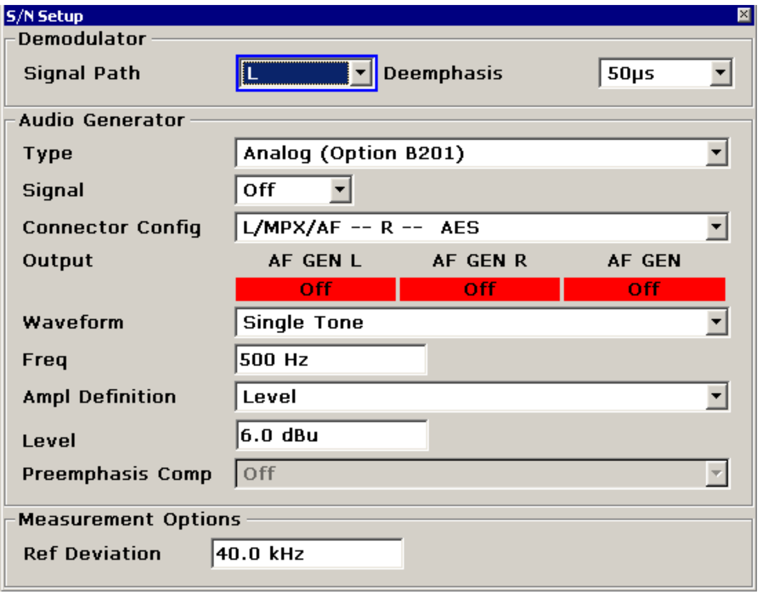


Fig. 42: "TV/Radio Analyzer/Receiver" mode, MEAS→Audio Analysis→S/N→S/N Setup: Configuration for measuring the spurious frequency modulation.

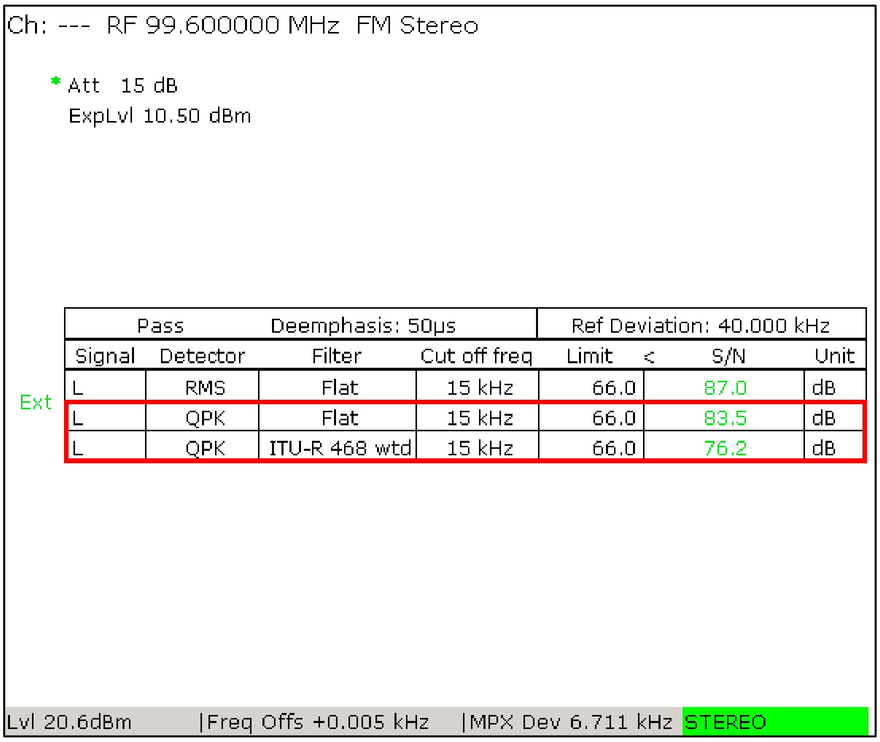


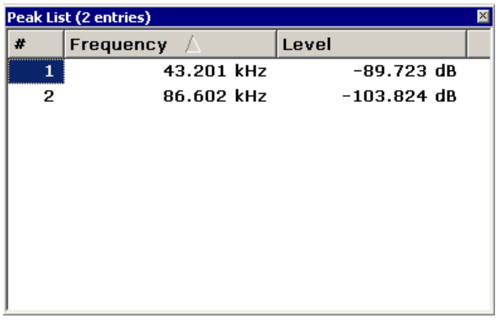
Fig. 43: "TV/Radio Analyzer/Receiver" mode, MEAS→Audio Analysis→S/N: Unweighted and weighted signal-to-noise ratio for the L channel in the 2nd/3rd line.

5.7.1.2 Periodic Noise Voltage

Periodic noise includes all discrete, unwanted interference frequencies within the audio frequency band. It is the ratio, expressed in dB, between an unwanted component and a reference level or reference deviation.

Besides offering capabilities for using markers to perform manual investigations within the spectrum, the R&S®ETL also supports the automatic generation of a list of all peaks. Here, it is also possible to configure the device for certain additional conditions (such as frequency above 150 Hz or Peak > –80 dB). The user can sort the list according to frequency or level.

Procedure: Periodic noise
⚠ Check to ensure that the max. input power is not exceeded (see Section 4.3).
Connect the R&S®ETL (IN1) to test port M1.
Configure the general settings as described in Section 4.4.
Set the transmitter input to MPX.
MEAS→Modulation Analysis→Audio Spectrum→Audio Spectrum Setup: • Signal Path: MPX
MEAS→Modulation Analysis→Audio Spectrum→Audio Generator→Audio Generator Setup: • Signal: Off • No configuration of the signal (such as "Waveform", "Ampl Definition") is necessary, because the signal is not measured
MEAS→Modulation Analysis→Audio Spectrum→Audio BW: 20 Hz
MEAS→Modulation Analysis→Audio Spectrum→Diagram Range→Ref Deviation: For example, 40 kHz
Set MEAS→Modulation Analysis→Audio Spectrum→Diagram Range→Ref Position: so that the signal is clearly visible (for instance, 130 %).
TRACE→Trace Mode→Average
MKR→More→Marker Peak List
MKR→More→Marker Peak List→Left Limit: For example, 150 Hz
MKR→More→Marker Peak List→Threshold: For example, 80 Hz
MKR→More→Marker Peak List
Read the measured peak value (see Fig. 44). Use PRINT to generate a printout of the measurement screen (see Fig. 45.) as needed.



Peak List (2 entries)

#	Frequency	Level
1	43.201 kHz	-89.723 dB
2	86.602 kHz	-103.824 dB

Fig. 44: "TV/Radio Analyzer/Receiver" mode, MEAS→Modulation Analysis→Audio Spectrum: List of the periodic noise voltages (Peak List: MKR→More→Marker Peak List) greater than −105 dB (right).

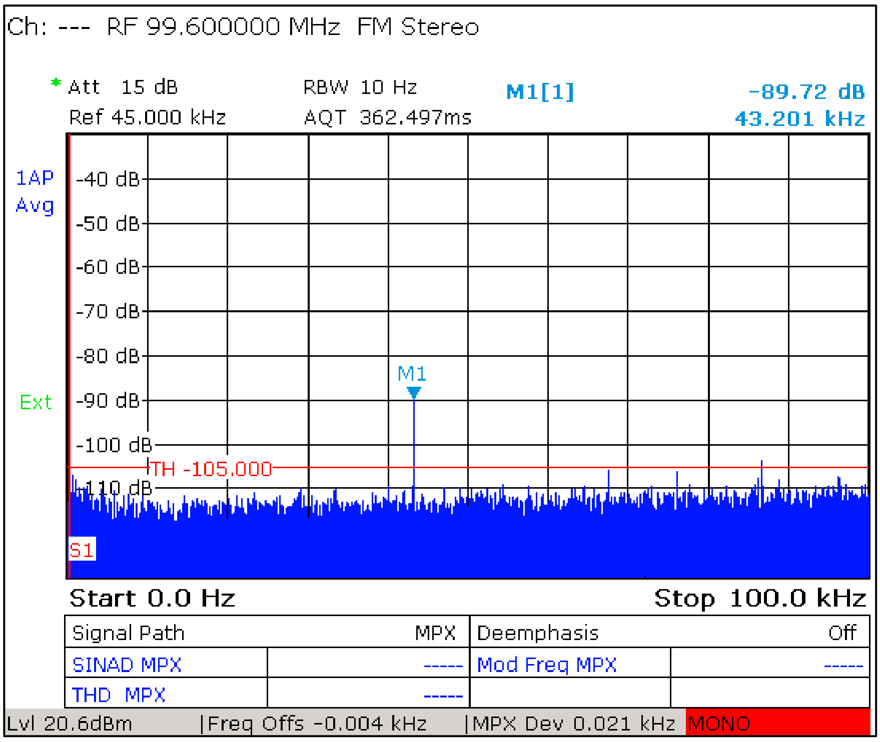


Fig. 45: "TV/Radio Analyzer/Receiver" mode, MEAS→Modulation Analysis→Audio Spectrum: Periodic noise voltage in the spectrum with a limit greater than –105 dB.[1]

[1] There is no need to take action in response to the red "MONO" warning in the status bar, because that warning only indicates that no pilot has been found.

5.7.2 Spurious Amplitude Modulation

The configuration for measuring the spurious amplitude modulation depends on the specific test specification. IEC 244-13 specifies that the measurement be performed with a PK detector and without a band limitation. Measurements performed in line with ETSI EN 302 018-1 are also made with a PK detector, but with the band limited to 20 kHz. Measurements performed in line with TR 5/3.1 are taken with and without a ITU-R 468 wtd-compliant weighting filter with a QPK detector and with the band limited to 20 kHz. The R&S®ETL supports all four of these configurations.

The spurious amplitude modulation measurement ist taken without FM modulation. Here, a modulation depth ("Mod Depth") of 100 % is assumed as the reference.

5.7.2.1 Spurious Amplitude Modulation without Input Signal

For the spurious amplitude modulation, the peak voltage at the output of a linear envelope detector is measured without a modulation signal. The result is expressed as a percentage of the envelope detector output's direct current component.

Procedure: Spurious amplitude modulation without input signal
⚠ Check to ensure that the max. input power is not exceeded (see Section 4.3).
Connect the R&S®ETL (IN1) to test port M1.
Configure the general settings as described in Section 4.4.
Set the transmitter input to MPX.
MEAS→Audio Analysis→ S/N→S/N Setup: *Demodulator:* • Signal Path: AM • Deemphasis: Off *Audio Generator:* • Signal: Off • No configuration of the signal (such as "Waveform" or "Ampl Definition") is necessary, since the signal is turned off *Measurement Options:* • Ref Mod Depth: Permanently set to 100 %.
MEAS→Audio Analysis→S/N: Read the measured values (see Fig. 46).

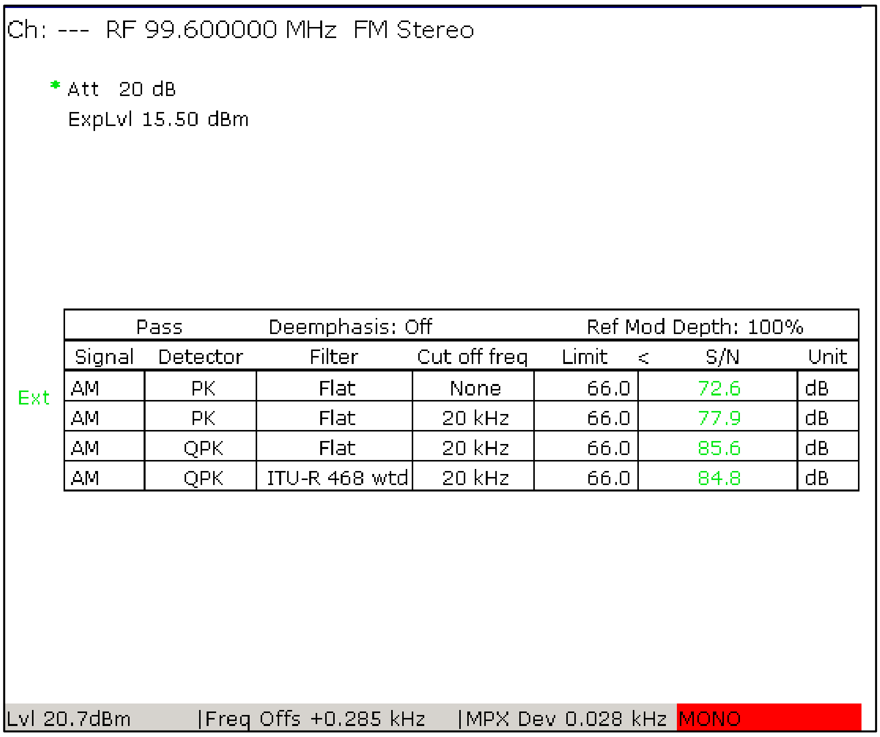


Fig. 46: "TV/Radio Analyzer/Receiver" mode, MEAS→Audio Analysis→S/N: Spurious amplitude modulation as required by IEC 244-13 in line 1, by ETSI EN 302 018-1 in line 2 and by TR 5/3.1 (with and without filter) in line 3/4.[1]

[1] There is no need to take action in response to the red "MONO" warning in the status bar, because that warning only indicates that no pilot has been found.

5.7.2.2 Synchronous Amplitude Modulation

The synchronous amplitude modulation is measured with FM modulation. It is a measure for the FM-AM conversion using, for example, the RF frequency response in the transmitter.

<table>
<tr><th colspan="2">Procedure: Synchronous amplitude modulation</th></tr>
<tr><td colspan="2">⚠ Check to ensure that the max. input power is not exceeded (see Section 4.3).</td></tr>
<tr><td colspan="2">Connect the R&S®ETL (IN1) to test port M1.</td></tr>
<tr><td colspan="2">Configure the general settings as described in Section 4.4.</td></tr>
<tr><td colspan="2">Set the transmitter input to MPX.</td></tr>
<tr><td colspan="2">MEAS→Audio Analysis→ S/N→S/N Setup:

Demodulator:
• Signal Path: AM
• Deemphasis: Off

Audio Generator:
• Type: Analog (Option B201)
• Signal: AF
• Connector Config: Set to match the transmitter (see 3.2.3)
• Freq: For example, 500 Hz</td></tr>
<tr><td>• Ampl Definition: Desired DUT Deviation[1]
• Desired DUT Dev: For example, 40 kHz
• Preemphasis Comp: Off</td><td>• Ampl Definition: Level
• Level: For example, 6 dBu (see Appendix A)</td></tr>
<tr><td colspan="2">Measurement Options:
• Ref Mod Depth: Permanently set to 100 %.</td></tr>
<tr><td colspan="2">MEAS→Audio Analysis→S/N: Read the measured values.</td></tr>
</table>

[1] For this it is necessary – as described in the section on the basic settings (Section 4.4) – for the transmitter's target operating parameters to be set correctly under ”DUT Parameters“.

5.7.3 Noise Power Density at 57 kHz

The technical guideline "VHF/FM Radio Broadcasting Transmitters" (TR No. 5/3.1) demands that the noise power density measured at the output of a measurement modulator that has been realized in line with TR 5/3.4 and is terminated with 600 Ω is not greater than –100 $\frac{\mathrm{dBm}}{\mathrm{Hz}}$ at 57 kHz. This measurement ensures that the signal-to-noise ratio in the RDS channel is sufficient.

Due to the load impedance of 600 Ω, the noise power results in a voltage. Depending on that voltage and on the modulation constant, a certain deviation arises. Thus, the measured quantity that actually exists in physical form at the transmitter output is not the noise power density, but rather the "noise deviation density." TR 5/3.1, therefore, describes an indirect measurement of the "noise deviation density" as the noise power density at the output of a special test configuration (a demodulator constant of 6 dBu for 40 kHz deviation, load impedance of 600 Ohm). Since this test configuration has not been standardized internationally, the measurement results achieved in this way are not valid everywhere.

For this reason, the R&S®ETL employs a different approach. Without any detours, the "noise deviation density" is set in direct relation to a reference deviation (the audio spectrum analyzer's reference deviation). This result offers the advantage of general validity and is independent of a specific test setup.

The difference between these two methods lies in the dimension of the output quantity. As defined by TR 5/3.1, the noise power density describes the quotient of the noise power and bandwidth, referenced to 1 mW ($\mathrm{dB}(\frac{1}{1\,\mathrm{mW}\cdot 1\,\mathrm{Hz}})$, reduced to $\frac{\mathrm{dBm}}{\mathrm{Hz}}$). The "noise deviation density" for the R&S®ETL, on the other hand, describes the quotient of the RMS noise deviation and the square of the bandwidth[1], set in relation to the reference deviation ($\mathrm{dB}\left(\frac{1}{\mathrm{Referenzhub}\cdot\sqrt{1\,\mathrm{Hz}}}\right)$, reduced to $\frac{\mathrm{dB}}{\sqrt{\mathrm{Hz}}}$). These two quantities can be converted back and forth:

$$10\log\left(\frac{Noise\ power}{Bandwidth}\cdot\frac{1}{1\ mW}\right) =$$
$$20\log\left(\frac{RMS\ noise\ deviation}{\sqrt{Bandwidth}}\cdot\frac{1}{Reference\ deviation}\right) + 20\log\left(\frac{Demodulator\ constant\cdot Reference\ deviation}{\sqrt{Load\ impedance}}\right)$$

Where $Demodulator\ constant = \frac{Demodulator\ output\ voltage}{Nominal\ deviation}$

In practice, it is possible to avoid the conversion by simply setting the appropriate reference deviation on the R&S®ETL. The displayed deviation density in $\frac{dB}{\sqrt{Hz}}$ (referenced to the reference deviation) corresponds to the noise power density in $\frac{dBm}{Hz}$, when the reference deviation is selected so that 0 dBm would arise on the required resistor. Therefore, at a reference deviation of 40 kHz – which causes 6 dBu to be present at a 600 Ohm resistor (as required by TR 5/3.1) – it would be necessary to enter 20 kHz (which corresponds to 0 dBm at 600 Ohm) as the reference deviation.

---

[1] For the square of the bandwidth, the physically correct unit $\sqrt{\boldsymbol{Hz}}$ can be derived by converting the power density to the "voltage density":

$\widetilde{\boldsymbol{V}}\ \left[\frac{V}{\sqrt{Hz}}\right] = \sqrt{\widetilde{\boldsymbol{P}}\ \left[\frac{W}{Hz}\right]\cdot \boldsymbol{R}[\Omega]}$ or with SI units: $\widetilde{\boldsymbol{V}}\ \left[\frac{kg\cdot m^2}{A\cdot s^3\cdot\sqrt{s^{-1}}}\right] = \sqrt{\widetilde{\boldsymbol{P}}\ \left[\frac{kg\cdot m^2}{s^3\cdot s^{-1}}\right]\cdot \boldsymbol{R}\left[\frac{kg\cdot m^2}{A^2\cdot s^3}\right]}$

The numerical value of the displayed "noise deviation density" then corresponds to the noise power density as defined by TR 5/3.1.

Procedure: Noise power density at 57 kHz
⚠ Check to ensure that the max. input power is not exceeded (see Section 4.3).
Connect the R&S®ETL (IN1) to test port M1.
Configure the general settings as described in Section 4.4.
Set the transmitter input to MPX.
MEAS→Modulation Analysis→Audio Spectrum→Audio Generator→ Audio Generator Setup: *Audio Generator:* • Signal: OFF • No configuration of the signal (such as "Waveform" or "Ampl Definition") is necessary, because the signal is turned off
MEAS→Modulation Analysis→Audio Spectrum→Audio Spectrum Setup: • Signal Path: MPX
MEAS→Modulation Analysis→Audio Spectrum→Diagram Range→Ref Deviation: For example, 20 kHz
MEAS→Modulation Analysis→Audio Spectrum→MKR→More→Noise Meas: On
MKR→Marker 1: 57 kHz
TRACE→Trace Mode→Average
MEAS→Audio Analysis→S/N: Read the measured values (see Fig. 46).
Read the marker value (see Fig. 47). Use PRINT to generate a printout of the measurement screen as needed.

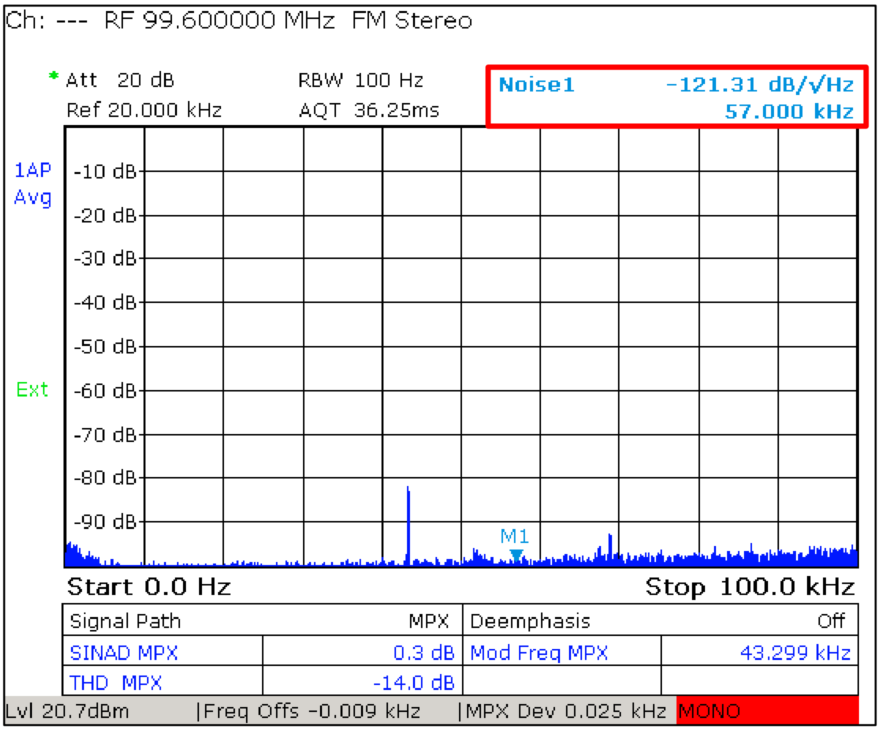


Fig. 47: "TV/Radio Analyzer/Receiver" mode, MEAS→Modulation Analysis→Audio Spectrum: Noise power density at 57 kHz.[1]

[1] There is no need to take action in response to the red "MONO" warning in the status bar, because that warning only indicates that no pilot has been found.

5.8 Polarity of the Input

This measurement is used to check to see if driving the system with a positive instantaneous value for the input signal causes a frequency increase in the output frequency. It is easy to check this with the R&S®ETL by feeding in two audio tones, whereby the following must be valid: $f_2 = 2{\cdot}f_1$. Since the phases of these signals are generated in sync, a superposition occurs in which the absolute value of the positive peak values is greater than the absolute value of the negative peak values (see Fig. 48).

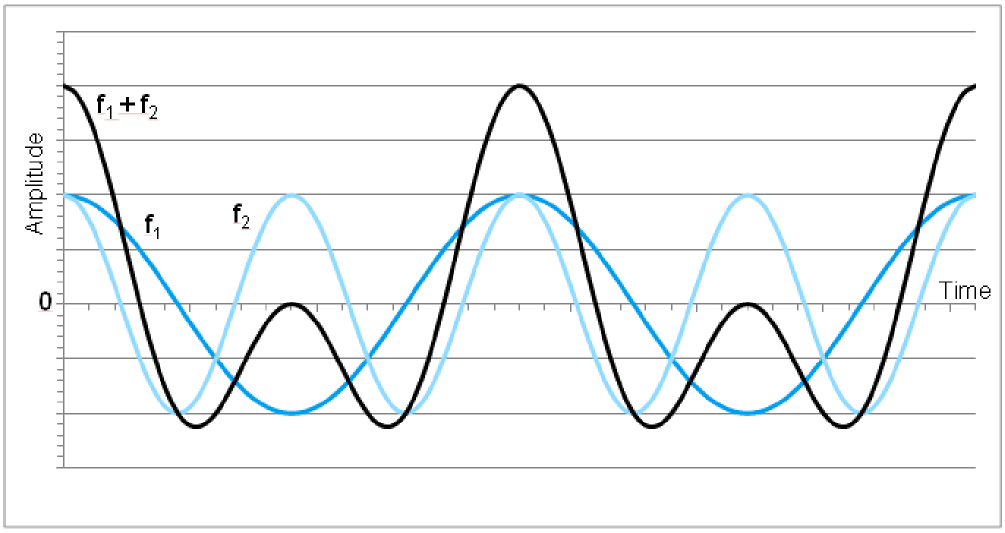


Fig. 48: Superposition of the signals generated with a synchronous phase leads to a signal for which the absolute value of the positive peak is larger than that of the negative peak.

The section below specifies the settings for testing the left channel. The right channel can be verified in the same way. When the polarity is only reversed for only one of the channels, the M and S signals are switched, and mono receivers will remain "mute." L and R must be tested separately; otherwise, it would not be possible to establish the fact that the polarity has been reversed for both inputs.

<table>
<tr><th colspan="2">Procedure: Polarity of the input</th></tr>
<tr><td colspan="2">⚠Check to ensure that the max. input power is not exceeded (see Section 4.3).</td></tr>
<tr><td colspan="2">Connect the R&S®ETL (IN1) to test port M1.</td></tr>
<tr><td colspan="2">Configure the general settings as described in Section 4.4.</td></tr>
<tr><td colspan="2">Set the transmitter input to AF stereo.
On the transmitter, turn off preemphasis.</td></tr>
<tr><td colspan="2">MEAS→Modulation Analysis→Audio Scope→Audio Generator→
Audio Generator Setup (see Fig. 49):</td></tr>
<tr><td colspan="2">Audio Generator:
• Type: Analog (Option B201)
• Signal: L
• Connector Config: Set to match the transmitter (see 3.2.3)
• Waveform: Dual Tone, independent frequencies
• Freq 1: For example, 500 Hz
• Freq 2: For example, 1 kHz</td></tr>
<tr><td>• Ampl Definition: Level
• Level: For example, 6 dBu (see Appendix A)</td><td>• Ampl Definition: Desired DUT Deviation[1]
• Desired DUT Dev: For example, 40 kHz
• Preemphasis Comp: Off</td></tr>
<tr><td colspan="2">MEAS→Modulation Analysis→Audio Scope→Audio Scope Setup:
• Signal Path: L</td></tr>
<tr><td colspan="2">Adjust the level as described in Section 4.4.</td></tr>
<tr><td colspan="2">MEAS→Modulation Analysis→Audio Scope→Diagram Range→Trigger Level: Set this parameter to a value that results in a steady image; for example, 30 Hz.</td></tr>
<tr><td colspan="2">Check to see if the absolute values of the positive peak value is greater than the absolute value of the negative peak values (see Fig. 50); if it is greater, the polarity is not reversed.</td></tr>
</table>

[1] For this it is necessary – as described in the section on the basic settings (Section 4.4) – for the transmitter's target operating parameters to be set correctly under “DUT Parameters”.

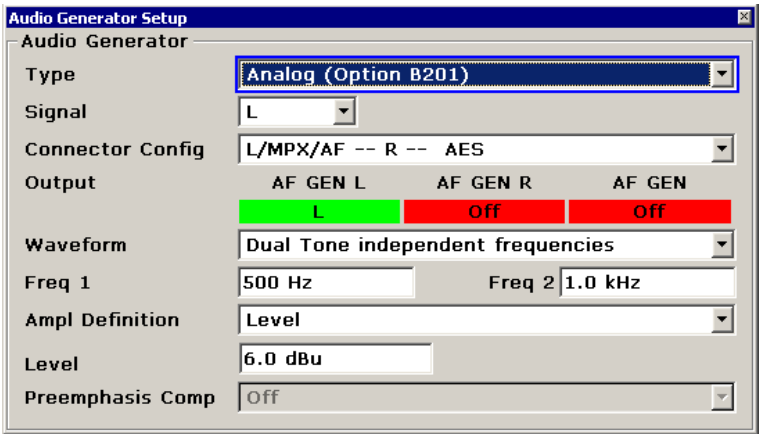


Fig. 49: "TV/Radio Analyzer/Receiver" mode, MEAS→Modulation Analysis→Audio Scope→Audio Generator→Audio Generator Setup: Configuration for checking the polarity.

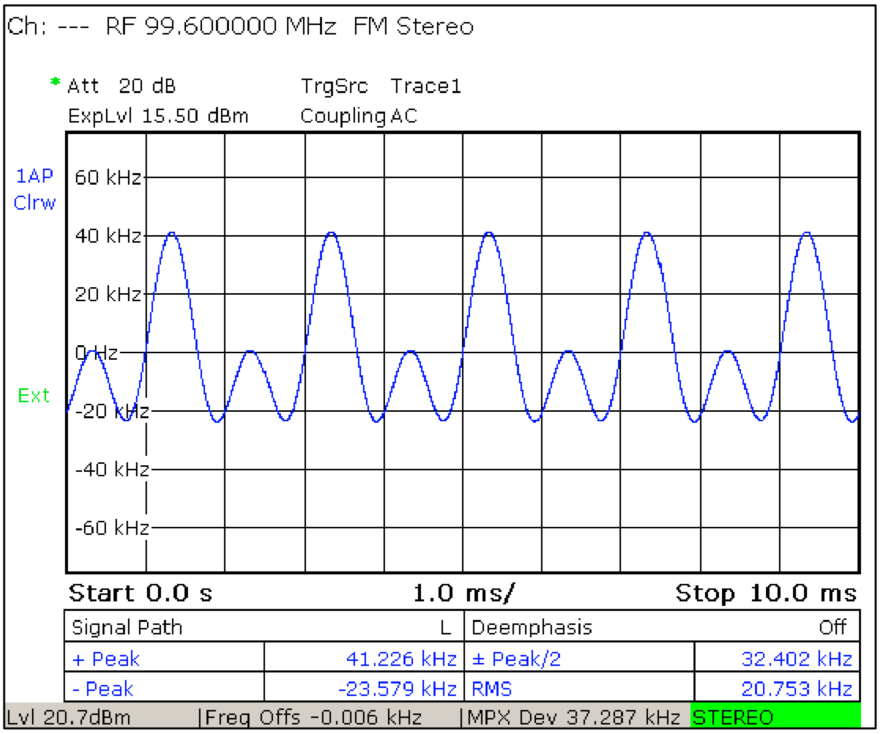


Fig. 50: "TV/Radio Analyzer/Receiver" mode, MEAS→Modulation Analysis→Audio Scope: When a dual tone is being fed in with $f_2 = 2·f_1$, the absolute value of the positive peak value (+Peak) is greater than the absolute value of the negative peak value (–Peak), if a positive instantaneous value for the input signal causes a frequency increase.

5.9 Digital Input Signal (AES/EBU)

Most transmitters also make an AES/EBU input available that can be used to feed digital audio signals (stereo or mono) into the transmitter. To test the AES/EBU input, it is possible to repeat the measurements that were made for the L&R inputs – such as the measurements for the amplitude-frequency response (5.4.1.1) and stereo crosstalk (5.5), for instance. The question of which measurements should be performed again needs to be decided on an individual basis depending on the specific circumstances. This section will not repeat the details for configuring the individual measurements. Instead, it will only described the differences and special considerations.

To perform the measurements, the transmitter input is set to "AES Stereo", and the R&S®ETL's AES encoder is used. To use the R&S®ETL's AES encoder, the user selects the "AES/EBU (Option B201)" as the "Audio Generator Type". To match the transmitter's AES input, the "Impedance" is set to 75 Ω or 110 Ω (see Fig. 51). The signal level for AES/EBU is expressed in dBFS. As an alternative, it is possible to enter the desired frequency deviation by selecting "Desired DUT Deviation" under "Type". To test the AES/EBU input, these adapted settings can be used to repeat all of the measurements that have been described up until this point.

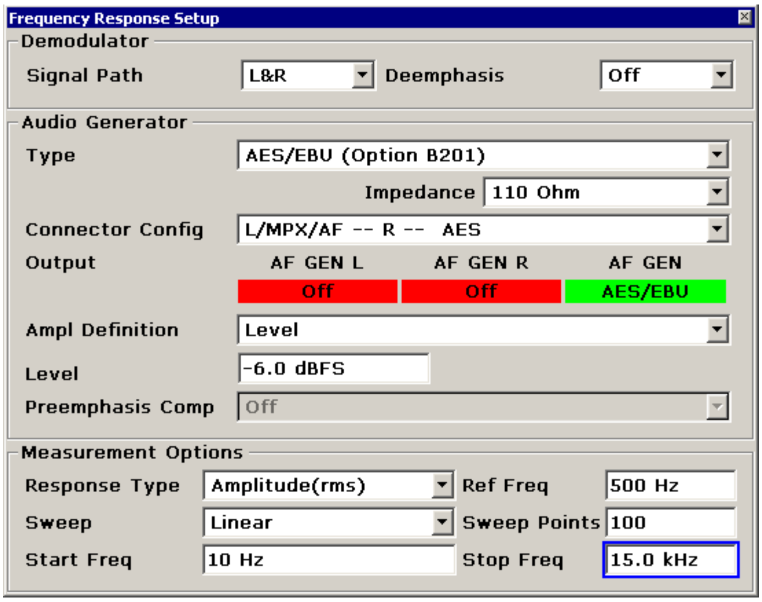


Fig. 51: "TV/Radio Analyzer/Receiver" mode, MEAS→Audio Analysis→Frequency Response→Frequency Response Setup: Configuration for measuring the audio amplitude-frequency response for the transmitter's AES/EBU input.

During the phase measurement, observations could reveal that the characteristic is marked by triangular outliers (see Fig. 52). This is due to the fact that the instantaneous variance in the regeneration of the timing frequency for some AES encoders is too great; as a result, the phase "runs off" during the measurement and has to be corrected frequently.

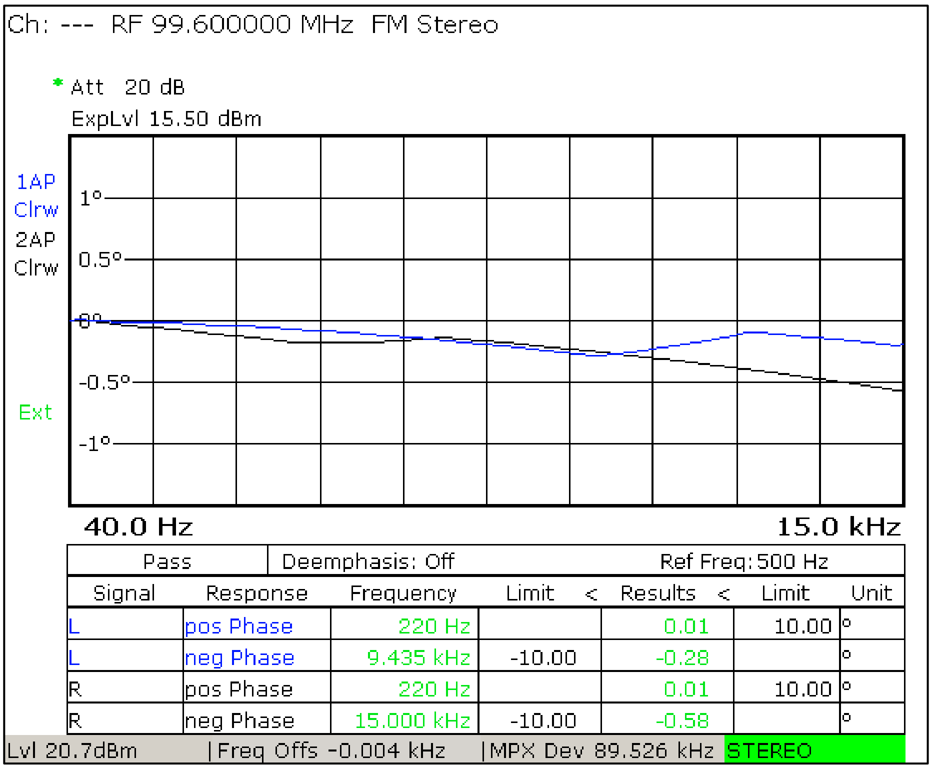


Fig. 52: "TV/Radio Analyzer/Receiver" mode, MEAS→Audio Analysis→Frequency Response: Audio phase frequency for the transmitter's AES/EBU input.

6 Abbreviations

AES/EBU	Audio Engineering Society/European Broadcasting Union
AF	Audio frequency
AM	Amplitude modulation
ARI	Autofahrer-Rundfunk-Information (German wireless information service for car drivers)
CCIR	Comité Consultatif International des Radiocommunications
DARC	Data Radio Channel
FFT	Fast Fourier transform
FM	Frequency modulation
IRT	Institut für Rundfunktechnik
IEC	International Electrotechnical Commission
PK	Peak
QPK	Quasi-Peak
RDS	Radio Data System
RMS	Root mean square
SCA	Subsidary Communication Authorization
TR	Technical guidelines for Germany's public broadcasters (*Technische Richtlinien der öffentlich-rechtlichen Rundfunkanstalten in der Bundesrepublik Deutschland*)

7 Auxiliary 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.

8 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[1]	R&S®NRP-Z91	1168.8004.02
Required options		
FM (radio) Firmware	R&S®ETL-K110	2112.0410.02
FM (radio) Audio Analyzer/Generator	R&S®ETL-K111	2112.0427.02
DTV, ATV, FM Universal Interface	R&S®ETL-B201 (MOD3)	2112.0304.03
RF Preselector	R&S®ETL-B203	2112.0327.03
One of the following two FM frontends:		
• High SNR FM frontend	R&S®ETL-B110	2112.0233.02
• FPGA External Board, High SNR FM	R&S®ETL-B310	2112.0340.02
Power Sensor Support with NRP[1]	R&S®FSL-K9	1301.9530.02
One of the following three power sensor interfaces[1]		
• 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

[1] Only for measuring the transmitter output level when an accuracy better than 1 dB is required.

A Input Level and Frequency Deviation

A.1 Overview in Tables

The following tables show the audio level that must be entered in order to generate a desired frequency deviation at 15 kHz. The transmitter configurations used here (nominal level of 6 dBu and nominal deviation of 40 kHz or 50 kHz) cover the most commonly used FM transmitter configurations. If other configurations are required, they can be calculated easily using the corresponding formulas (see A.2).

Nominal deviation of 40 kHz, nominal level of 6 dBu						
Desired deviation [kHz] at 15 kHz	Audio level without preemphasis		Audio level Preemphasis 50 µs		Audio level Preemphasis 75 µs	
	[dBu]	[V]	[dBu]	[V]	[dBu]	[V]
20	0	0.77	–13.6	0.16	–17	0.11
25	1.9	0.97	–11.7	0.20	–15.1	0.14
40	6	1.55	–7.6	0.32	–11	0.22
50	7.9	1.93	–5.7	0.40	–9.1	0.27
75	11.5	2.90	–2.1	0.60	–5.5	0.41
100	14	3.86	0.4	0.80	–3	0.54

Nominal deviation of 50 kHz, nominal level of 6 dBu						
Desired deviation [kHz] at 15 kHz	Audio level without preemphasis		Audio level Preemphasis 50 µs		Audio level Preemphasis 75 µs	
	[dBu]	[V]	[dBu]	[V]	[dBu]	[V]
20	–2	0.62	–15.6	0.13	–19	0.09
25	0	0.77	–13.6	0.16	–17	0.11
40	4.1	1.24	–9.5	0.26	–12.9	0.17
50	6	1.55	–7.6	0.32	–11	0.22
75	9.5	2.32	–4.1	0.48	–7.5	0.32
100	12	3.09	–1.6	0.64	–5	0.43

A.2 Mathematical Correlation Between the Input Level and the Frequency Response

Depending on the country and on the applicable specifications, the input level is either expressed in dBu or in volts. As a "pseudo" unit of measurement, dBu is a logarithmic measure of voltage ($0dBu = \sqrt{600\,\Omega \cdot 1\,mW} \approx 0.7746\,V_{RMS}$). The conversion from volts to dBu and back is calculated as follows:

$$Level\,[V] = \sqrt{600 \cdot 10^{\frac{Level\,[dBu]}{10}} \cdot 10^{-3}} \qquad Level\,[dBu] = 10 \cdot \log(\frac{Level^2[V]}{600 * 10^{-3}})$$

Setting the transmitter's modulator constant results in the corresponding nominal deviation for a given nominal level. The nominal deviation also varies in different countries and specifications. For the calculation to determine which input level has to be set in the audio generator for a desired deviation, the following relationship applies:

$$Level\,[V] = \frac{Desired\ deviation}{Nominal\ deviation} \cdot Nominal\ level\,[V]$$

$$Level\,[dBu] = 20\log\left(\frac{Desired\ deviation}{Nominal\ deviation}\right) + Nominal\ level\,[dBu]$$

For the preemphasis, 50 µs is usually used as the time constant in Europe and Japan, and 75 µs is used in the US. When preemphasis is turned on in the transmitter, a frequency-dependent increase arises in the audio level. When entering the value on the audio generator, it is necessary to compensate for this with a corresponding reduction.

$$Factor\ for\ the\ increase = \sqrt{1 + (2\pi \cdot Audio\ frequency\ \cdot Time\ constant)^2}$$

$$Increase\,[dBu] = 20\,log\frac{1}{\sqrt{1 + (2\pi \cdot Audio\ frequency \cdot Time\ constant)^2}}$$

Increase in the audio level for a time constant of 50 µs:

Audio frequency	40 Hz	100 Hz	500 Hz	1 kHz	5 kHz	6 kHz	7.5 kHz	10 kHz	15 kHz
Factor for the increase	1.00	1.00	1.01	1.05	1.86	2.13	2.56	3.30	4.82
Increase in dB	0	0	0.1	0.4	5.4	6.5	8.1	10.3	13.6

Increase in the audio level for a time constant of 75 µs:

Audio frequency	40 Hz	100 Hz	500 Hz	1 kHz	5 kHz	6 kHz	7.5 kHz	10 kHz	15 kHz
Factor for the increase	1.00	1.00	1.03	1.11	2.56	3.00	3.67	4.82	7.14
Increase in dB	0	0	0.2	0.8	8.1	9.5	11.3	13.6	17

A.3 Example for Calculating the Required Audio Level

For a transmitter with a nominal deviation of 50 kHz at an input level of 6 dBu (corresponds to about 1.54 volts), a deviation of 100 kHz is to be achieved. This yields an audio input level of:

$$20\,log\left(\frac{100}{50}\right) + 6 = 12\,dBu \qquad \frac{100}{50} \cdot 1.54 = 3.09\,V$$

By making the corresponding selections in "Audio Generator Setup" under "Ampl Definition" (see 3.2.5) on the R&S®ETL, it is possible to enter the desired peak deviation ("Desired DUT Deviation"), the audio generator level in dBu ("Level") or the audio generator level in volts ("Peak Voltage"). Consequently, no conversion is required when "Ampl Definition" is selected.

If a preemphasis of 50 µs is used with this transmitter, the audio level that is entered must be reduced by a corresponding amount. If the deviation of 100 kHz at a 15 kHz audio frequency is to be achieved, the audio level must be reduced as follows:

$$20\log\frac{1}{\sqrt{1 + (2\pi * 15\,kHz * 50\,\mu s)^2}} = 13.6\,dBu$$

$$\sqrt{1 + (2\pi \cdot 15\,kHz\ \cdot 50\,\mu s)^2} = 4.82$$

The audio level to be entered is:

$$12\,dBu - 13.6\,dBu = \ 1.6\,dBu \qquad \frac{3.09\,V}{4.82} = 0.64\,\mathrm{V}$$

B Automated Measurements with 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. With the aid of R&S®TxCheck, you can automate the following measurements:

- Transmitter Output Level (5.1)
- Frequency Accuracy (5.2)
- Audio Frequency Characteristic (up to 15 kHz, or 17.5 kHz for Mono Transmitters) (5.4.1.1)
- Baseband Frequency Characteristic (up to 100 kHz). (5.4.1.2)
- Audio Phase Response (5.4.2.1)
- Baseband Phase Response (5.4.2.2)
- Stereo Crosstalk (5.5)
- Total Harmonic Distortion (THD) (5.6.1)
- Audio Intermodulation (5.6.2.1)
- Intermodulation in the Baseband (up to 100 kHz) (5.6.2.2)
- Digital Input Signal (AES/EBU) (5.9)

This Application Note includes the file "7BM105.ETLtxi". When this file is opened in R&S®TxCheck, the software can perform all of the measurements on the transmitter's L&R input and MPX input that can be automated:

Performing Automated Measurements Using R&S®TxCheck
Copy the file 7BM105.ETLtxi to the R&S®ETL.
⚠ Check to ensure that the max. input power is not exceeded (see 4.3).
Connect the R&S®ETL (IN1) to test port M1.
MODE→TxCheck
In the R&S®TxCheck application, go to File/Open Profile (*.ini) and select the previously copied profile "7BM105.ETLtxi".
By selecting the “Settings” tab, adjust parameters such as the frequency and transmitter parameters (see Fig. 53).
Set the basic configuration using the "Write Settings to ETL" button.
If necessary, select the "Measurements" tab to adapt the configuration of the individual measurements (such as the "Desired DUT Deviation" and the "Preemphasis Compensation") as well as the limits for the individual measurement parameters (see Fig. 54).
Go to "Measurement/Start Measurement" to start the measurement.
After the measurements are complete, go to "File/Save" to save the results.

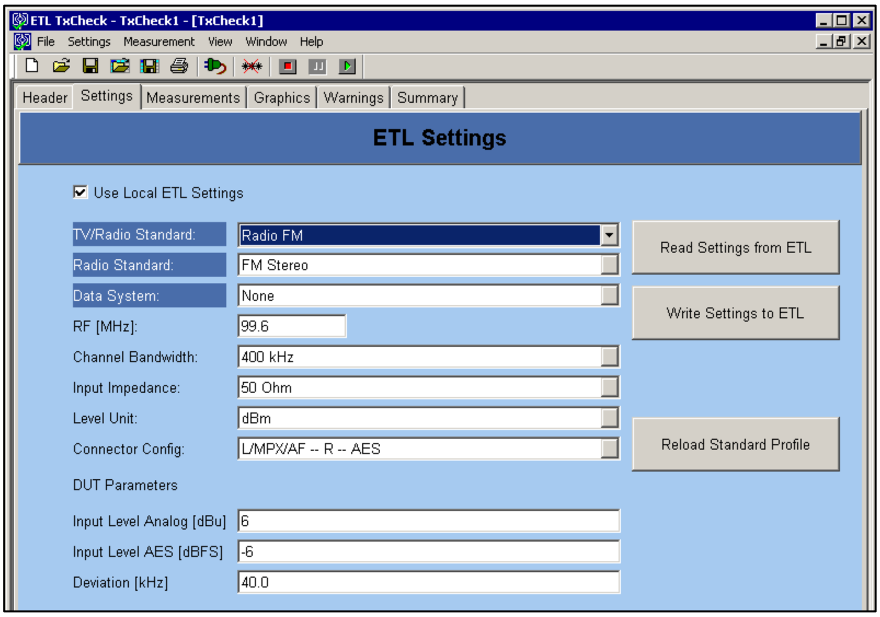


Fig. 53: R&S®TxCheck User Interface, "Settings" tab.

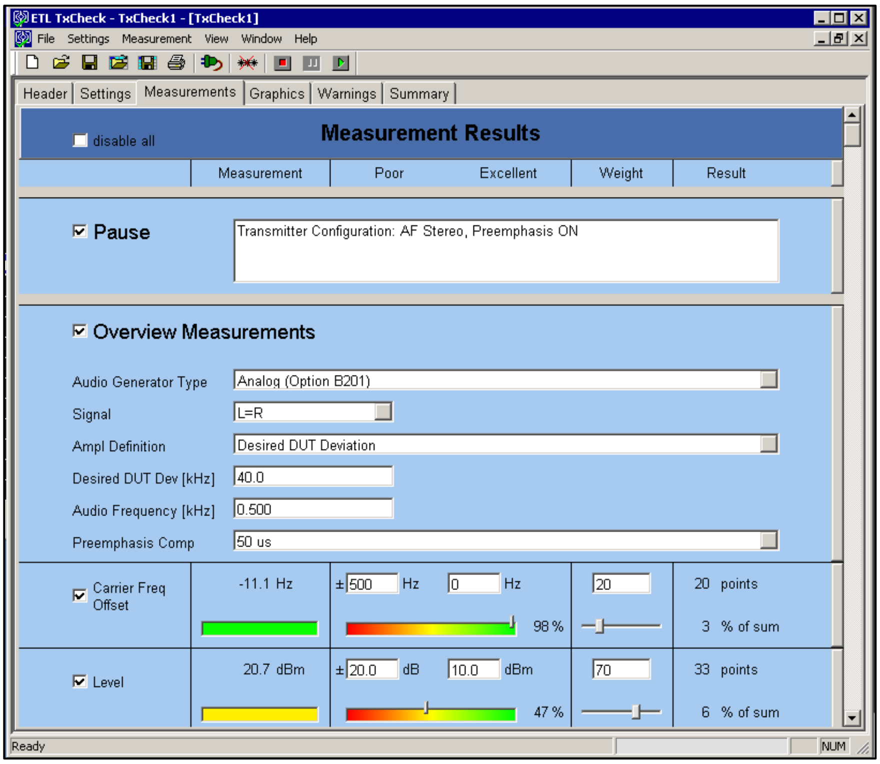


Fig. 54: R&S®TxCheck User Interface, "Measurements" tab.

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 that 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. (see Fig. 55).

|x Overview Measurements

Audio Generator Type	Analog (Option B201)
Signal	L=R
Ampl Definition	Desired DUT Deviation
Desired DUT Dev [kH	40.0
Audio Frequency [kH	0.500
Preemphasis Comp	50 us

Ix Carrier Freq Offset	-5.1 Hz	± 500 Hz	0 Hz	20	99 %	20 points	0 % of sum
Ix Level	20.7 dBm	± 20.0 dB	10.0 dBm	70	47 %	33 points	0 % of sum

|x Frequency Response Measurements

Signal Path	L	Deemphasis	Off
Audio Generator Type	Analog (Option B201)		
Ampl Definition	Desired DUT Deviation		
Desired DUT Dev [kH	40.0		
Preemphasis Comp	50 us		
Response Type	Amplitude(selective)	Ref Freq [kHz]	0.500
Sweep	Linear	Sweep Points	100
Start Freq [kHz]	0.040	Stop Freq [kHz]	15.000

|x Frequency Response Graphics

Freq Resp Range [dE	2
Ref Position [%]	50

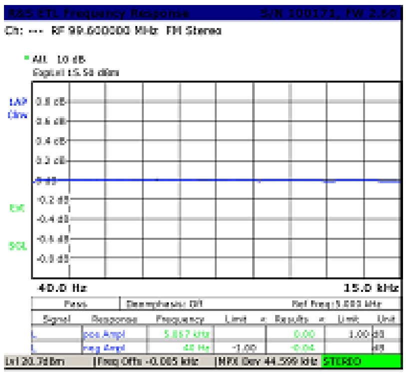


Fig. 55: R&S®TxCheck: Excerpt from the report.

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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