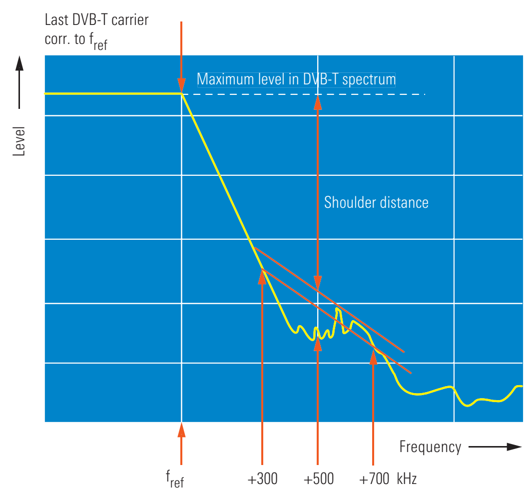
Continued from No. 170

Measurements on MPEG2 and DVB-T signals (4)

Part 3 of this refresher topic dealt with masks for out-of-band components and the measurement of the shoulder distance. In this contribution, the emphasis is on the determination of the crest factor and power measurements on medium-power DVB-T transmitters.



To refresh your memory: in part 3 of this topic, measurement of the shoulder distance to ETR 290 was discussed

Crest factor of DVB-T signal

Definition

The crest factor K_{CREST} is the quotient of the peak voltage value V_p and the root-mean-square voltage value V_{rms} expressed as a logarithmic ratio:

$$K_{CREST} = 20 \cdot \log(V_p / V_{rms})\ \text{dB}$$

The crest factor directly indicates the drive level up to which an amplifier used in a DVB-T transmitter is in the linear range and the point at which signal limiting becomes active.

For measurements with a spectrum analyzer featuring CCDF (complementary cumulative distribution function) capability, it should be taken into account that an instrument of this type measures the peak envelope power (PEP) rather than the absolute voltage peaks that occur in the amplifier. The measured value, therefore, has to be corrected by a factor of $\sqrt{2}$ or 3.01 dB. The test tip on page 52 describes in detail the different weighting applied to the signal. In this topic, only the crest factor derived from the absolute voltage peaks will be discussed.

Crest factor and level limiting in DVB-T transmitters

In the theoretical case that all carriers of the COFDM signal, which is very similar to white noise, attain their maximum amplitudes with identical phase at the same time, all carrier amplitudes add up to give the maximum possible peak amplitude $V_{p\ max}$. In the 8k mode this peak amplitude yields a crest factor of

$$K_{CREST\ max.} = 20 \cdot \log\sqrt{6817} = 38.3\ \text{dB}$$

and in the 2k mode

$$K_{CREST\ max.} = 20 \cdot \log\sqrt{1705} = 32.3\ \text{dB}.$$

These maximum values will, however, not occur in practice. So, a realistic maximum value of $K_{CREST} \geq 15.7$ dB is assumed for both modes for an amplitude probability distribution of $1 \cdot 10^{-7}$. This corresponds to a V_p/V_{rms} ratio of approx. 6.1 (FIG 25). For the transmitter power this means that a peak power of 37.2 times the mean power would have to be provided as a safety margin. Using such a margin, virtually all signal components could be transmitted, with favourable effect on the BER. This is not acceptable in terms of efficiency however. Investigations have shown that with a crest factor of approx. 13 dB there will be no appreciable impairment of the BER.

A safety margin of 20 times the mean transmitter power, however, is economically impractical either. For this reason, the crest factor is limited to approx. 10 dB to 11 dB in all DVB-T transmitters. A spectrum analyzer with CCDF function will indicate for such limitation a crest factor of about 7 dB, which is a typical and internationally valid value. This crest factor, however, means an appreciable degradation of the BER. A BER (before the Viterbi decoder) of $1 \cdot 10^{-5}$ to $1 \cdot 10^{-6}$ is obtained at the transmit antenna, with channel filtering for boosting shoulder distance taken into account.

See also test tip on page 52: "CCDF determination – a comparison of two measurement methods".

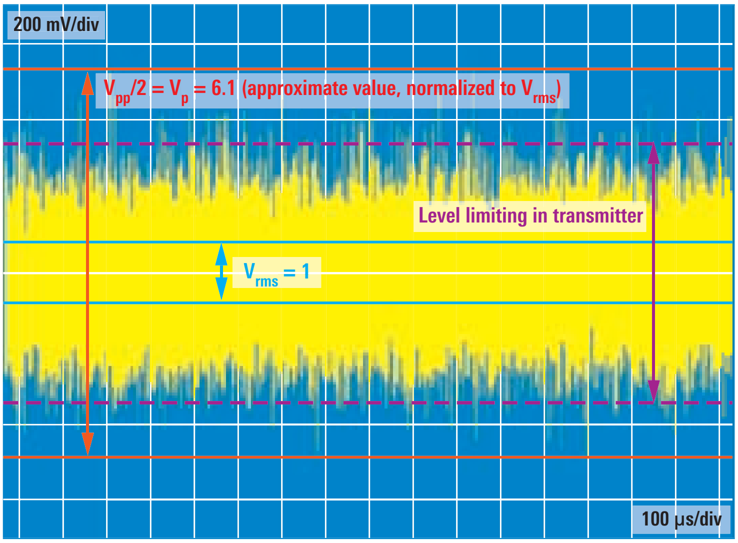


FIG 25
Time-domain signal in DVB-T

The new solid-state amplifier generations from Rohde & Schwarz employ highly linear LDMOS transistors. This means that demands on digital precorrectors are less stringent than with predecessors using bipolar or MOS technology. Limitation of the crest factor to approx. 10 dB to 11 dB safely prevents voltage peaks and so reliably protects the transistors. Determining the crest factor at the transmitter output is, therefore, indispensable as it is crucial for power transistor lifetime.

Crest factor measurement

This measurement is performed with the DVB-T Test Receiver EFA, model 40 or 43. The EFA calculates the crest factor based on the amplitude probability distribution (CCDF). The display indicates the current crest factor during the measurement ($10.24 \cdot 10^6$ samples), the maximum crest factor since the beginning of the measurement, and the margin active for the test configuration (FIG 26).

Power measurements on DVB-T transmitters

Mean power measurements

In the case of analog transmitters, signal power is determined by measuring the peak power of the sync pulse floor of the modulated CCVS signal. The sync pulse floor is always the reference in analog TV because this signal component must be transmitted without compression or distortion.

In DVB this is different: the "Sync 1 Inversion and Randomization" block of the DVB modulator (see EN 300 421, EN 300 429 or EN 300 744) ensures constant mean power of the transmitter output signal. In DVB, therefore, it is not the peak power that is measured, based on the crest factor, but the mean output power. Three methods are available:

1. Mean power measurement with Power Meter NRVS and thermal power sensor (FIG 27)

Thermal power sensors supply the most accurate results if there is only one TV channel in the overall spectrum, which is nearly always the case at the DVB-T transmitter. Plus, they can easily be calibrated by performing a highly accurate DC voltage measurement, provided the sensor is capable of DC measurement.

2. Mean power measurement with Spectrum Analyzer FSEx or FSP

A frequency cursor is placed on the lower and another one on the upper frequency of the DVB channel. The spectrum analyzer calculates the power for the band between the cursors (FIG 28). The method provides sufficient accuracy as in DVB-T normally no signals are put on the air in the adjacent channels.

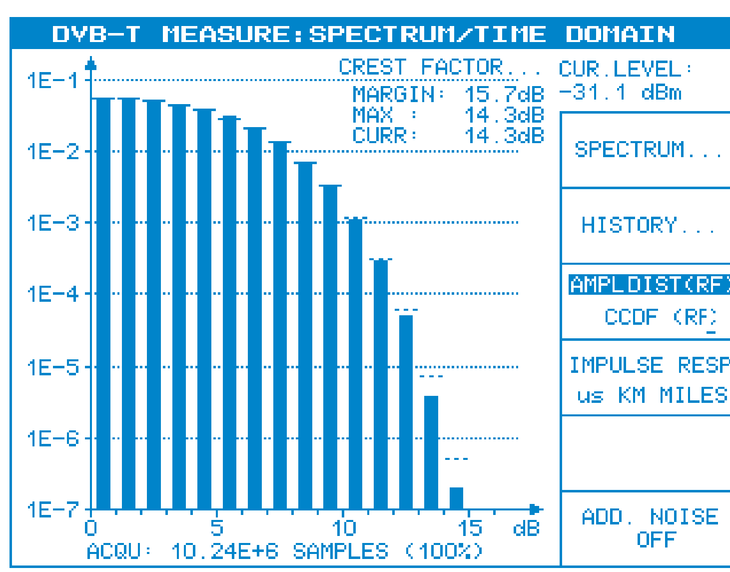


FIG 26
Crest factor measurement with DVB-T Test Receiver EFA

Photo 43 225/3

FIG 27
Power Meter NRVS (data sheet PD 0756.3182)

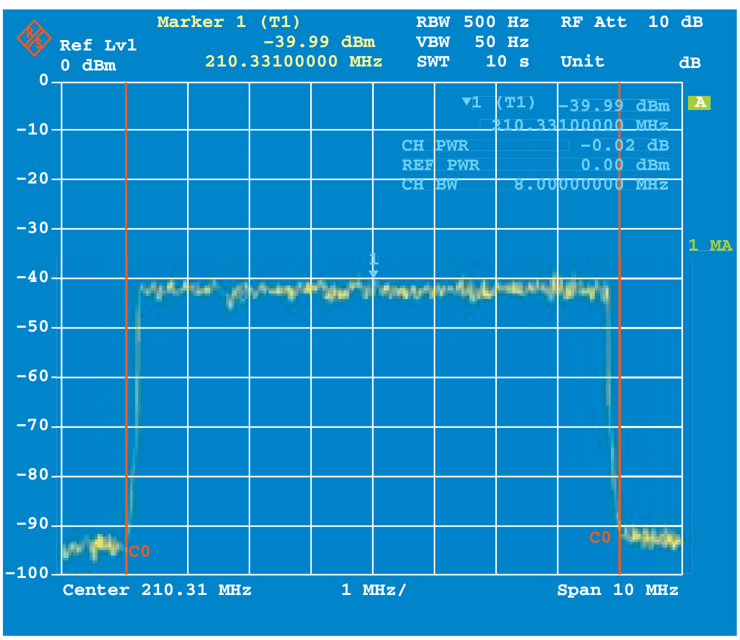


FIG 28
Measurement of mean transmitter power with a spectrum analyzer

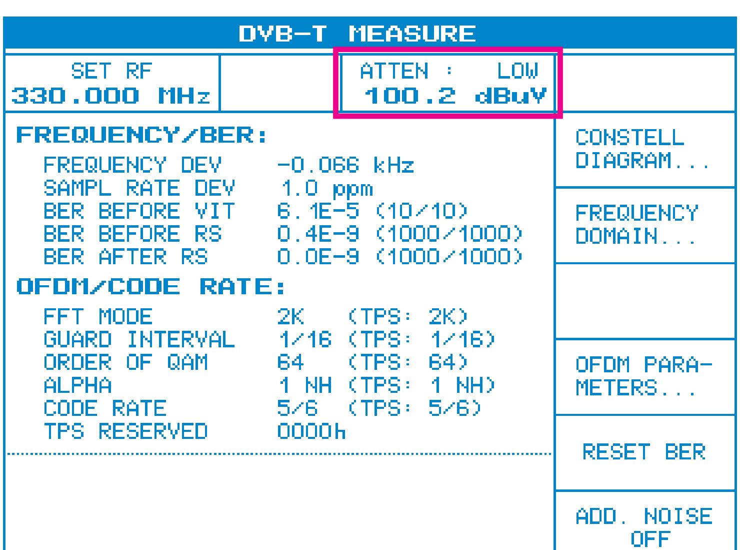


FIG 29
Display of DVB-T Test Receiver EFA. Marked red: mean transmitter power

3. Mean power measurement with DVB-T Test Receiver EFA

The test receiver displays all important signal parameters in a status line. For example, the righthand upper status field indicates the mean power in various switchable units (FIG 29). Investigations on channel spectra revealing pronounced frequency response have shown the high measurement accuracy of the test receiver. A comparison of levels obtained with the EFA on the one hand and the NRVS with thermal power sensor on the other hand yielded a maximum difference of 1 dB – comparison measurements being performed with various EFA models at different channel frequencies and on different, non-flat spectra. Thanks to the EFA's built-in SAW filters of 6 MHz, 7 MHz and 8 MHz IF bandwidth, highly accurate results are obtained even if the adjacent channels are occupied.

Example of above comparison test series

An echo with 250 ns delay and 2 dB attenuation relative to the original signal is generated by means of the TV Test Transmitter SFQ with the fading simulator option. The echo plus the signal sent via the direct path produce the fading spectrum shown in FIG 30 with pronounced dips in the frequency response characteristic. The maximum difference between the results obtained with the NRVS and the EFA occurred at –33.79 dBm for the NRVS and –33.0 dBm for the EFA. The results of the above level measurements are stated in detail in [11].

Output power in the event of amplifier failure

In the state-of-the-art transmitters from Rohde & Schwarz [12], the Exciter SV 700 feeds the DVB-T signal to the power splitter that drives the power amplifiers. These are designed as twin amplifiers. The amplifier output stages, likewise designed as twin stages, are LDMOS power transistors (FIG 31). Depending on the required transmitter power, a number of amplifiers operate in parallel. Two amplifiers are combined via a coupler in each case. The coupler output signal is bandpass-filtered to increase the shoulder distance and taken to the transmit antenna. Depending on the degree of suppression of the stopband of the bandpass filter, an extra filter may be required to suppress local oscillator harmonics.

If one of the twin amplifiers fails, half of the power of the other twin is terminated by an absorber which is cooled to prevent overheating. The residual output power of a transmitter after an amplifier failure is calculated as follows:

$$P_{out} = P_{nominal} \cdot \left(\frac{m-n}{m}\right)^2$$

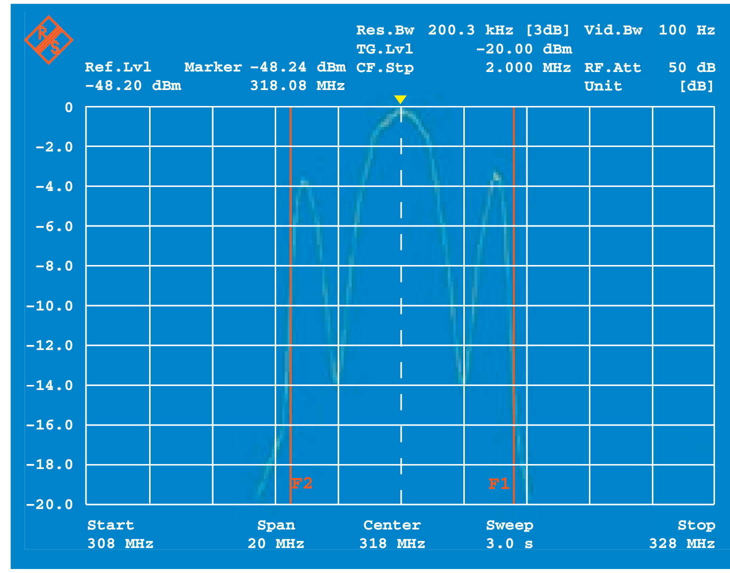
where P_{out} is the real output power, $P_{nominal}$ the nominal output power, m the number of amplifiers fitted, and n the number of defective amplifiers.

Example: In a 2.5 kW DVB-T transmitter with a total of six amplifiers, one amplifier has failed. The transmitter continues operation with reduced power as follows:

$P_{out} = P_{nominal} \cdot 0.694$
(with m = 6 and n = 1).

The transmitter characteristic remains the same, it is merely shifted – parallel to the previous characteristic – towards the lower power value. All other quality parameters remain unchanged. This also applies if individual power transistors of an amplifier fail. The advantage is that neither the amplifiers nor the power transistors are overloaded, i.e. the MTBF (mean time between failures) of the operational elements is not affected.

FIG 30
Fading spectrum



Amplifier replacement

Long-term measurements

FIG 32 illustrates the setup for a long-term measurement with the DVB-T Test Receiver EFA. A defective amplifier can easily be identified in remote monitoring from the transmitter power histogram

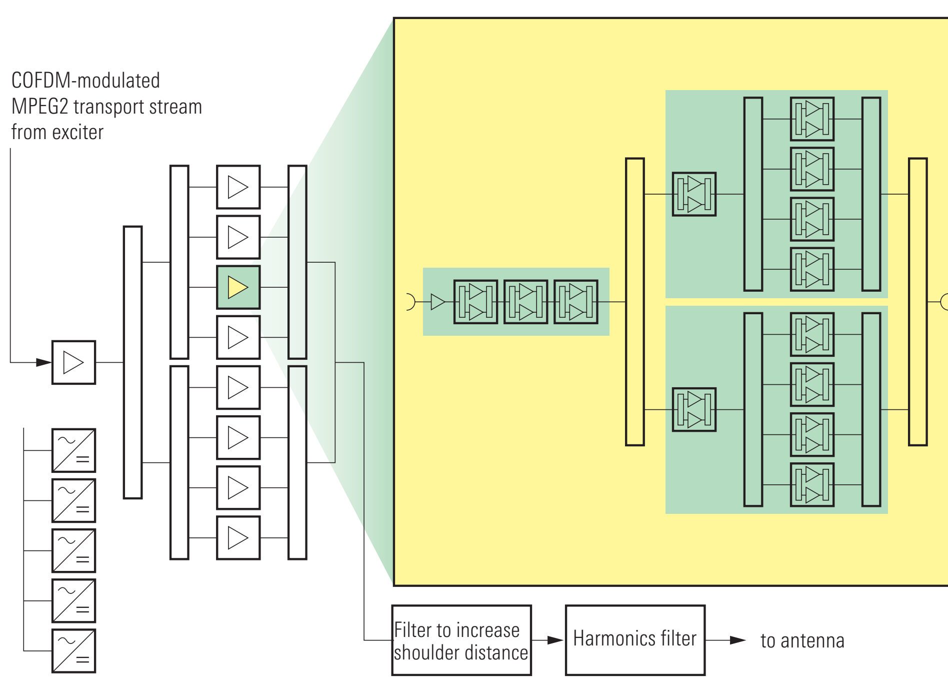


FIG 31 Basic design of state-of-the-art solid-state transmitters from Rohde & Schwarz

displayed on the test receiver (FIG 33). If the transmitter power is reduced by a constant 1.59 dB, e.g. with DVB-T Transmitter NV 7250, this means that one of the six amplifiers has failed. At higher transmitter powers the difference is smaller but still clearly identifiable from the histogram. The power drop in each case can be calculated with the above equation.

What to do if an amplifier fails?

First, remove the defective amplifier plug-in from the transmitter rack and insert a replacement. The Rohde & Schwarz transmitters allow replacement also during operation. Next, match the level and phase of the replacement amplifier to that of its twin amplifier. To do this, use a Spectrum Analyzer FSEx or FSP or a Test Receiver EFA as employed in DVB-T transmitter monitoring. The procedure is very simple: with optimally matched phase, the transmitter will output maximum power. Therefore, adjust the phase until maximum transmitter output power is attained.

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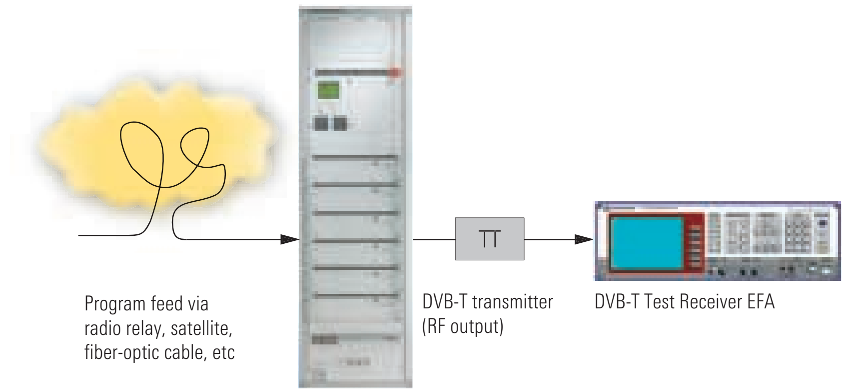

FIG 32 **Long-term measurement of transmitter power**

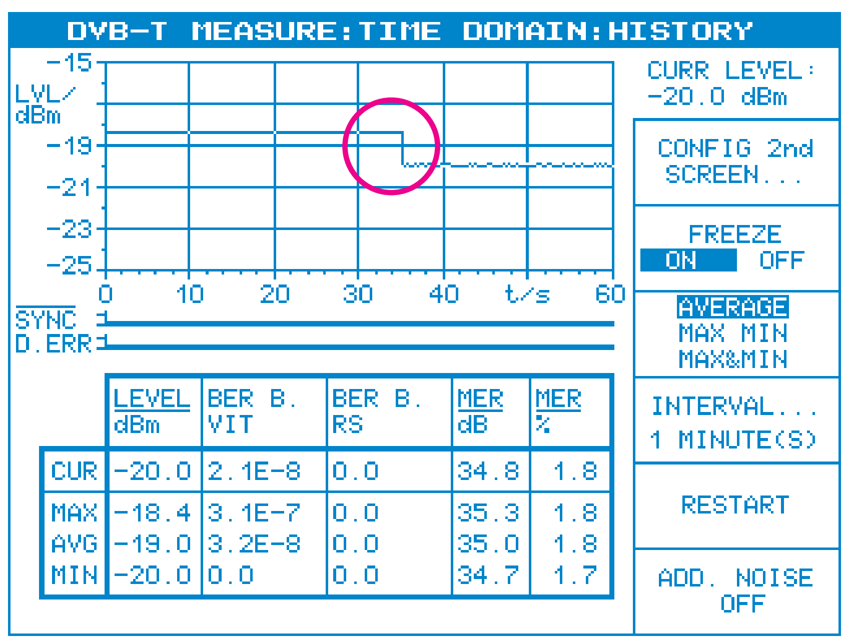

FIG 33 **Power histogram generated by DVB-T Test Receiver EFA. Marked red: power drop after failure of one of the six amplifiers is clearly identifiable.**

REFERENCES
[11] Application Note 7BM12 (for free-of-charge download from Rohde & Schwarz web site)
[12] UHF Transmitter Family NV/NH 7000 – Liquid-cooled TV transmitters for terrestrial digital TV. News from Rohde & Schwarz (1999) No. 165, pp 11–13