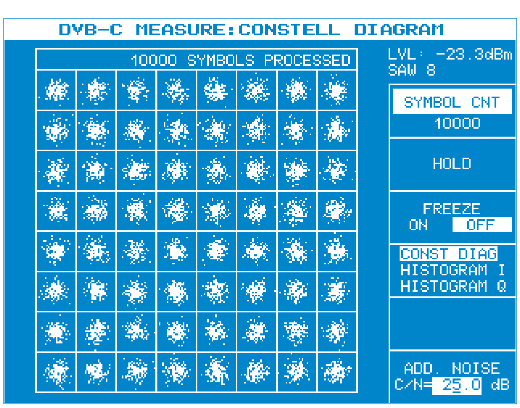
The right way to measure:

SNR and MER of digitally modulated signals with additive noise

This test tip describes for different digital TV transmission standards the correlation between the superimposed noise in the channel (carrier-to-noise ratio, or C/N) and the maximum measurable signal-to-noise ratio (SNR) in the test receiver. Furthermore, it portrays software that automatically determines the bit error ratio (BER) as a function of C/N.

FIG 1
Deviation of the measured values from the ideal position due to noise (C/N = 25 dB) – here shown for 64 QAM, measured with the TV Test Receiver R&S EFA.



Calculating the SNR

The transmission of digitally modulated signals can be accompanied by manifold types of interference that has to be analyzed and quantified – for example, with the high-end TV Test Receiver R&S EFA from Rohde & Schwarz. Sometimes special cases such as the influence of additive white Gaussian noise are also of interest to users. The noise fed to the transmission channel (described by the ratio of the carrier power C to the noise power N in the transmission channel) results in a deviation of the measured values from the ideal position in the constellation diagram (FIG 1). In extreme cases this can cause bit errors. Unlike C/N, the SNR is determined on the basis of the I/Q data and is thus a baseband quantity. By mathematically eliminating other causes of interference such as phase noise, carrier suppression, etc (reduction method), appropriate test algorithms make it possible to determine the noise components on the basis of the constellation data. The ratio between the rms value of the payload data and the reduced effective error is referred to as SNR and usually given in dB. The modulation error ratio (MER) is obtained by establishing the relationship between the rms value of the payload data and the effective error without reduction. The MER value in dB is thus always lower (worse) than the SNR value. Another common measurand is the error vector magnitude (EVM): It is determined by the ratio of the cumulative error to the peak value of the payload data, and is specified in %.

Correlation between C/N and SNR

The ratio of the carrier to the noise in the channel (C/N) is determined from the noise power density N_0 of the channel and the noise bandwidth B. With single-carrier signals, the symbol rate (with VSB methods, half the symbol rate) is usually used as the noise bandwidth; in the case of OFDM signals, the bandwidth of the transmission channel (e.g. 8 MHz) is normally used. By applying the reduction method, the noise components remain unchanged. The noise in the transmission channel (C/N) thus has an immediate effect on the SNR. However, the following special features have to be taken into account:

Single-carrier modulation without pilot (QAM, e.g. DVB-C / -S, J.83/B)

Filtering the receive signal in the root raised cosine filter (Nyquist filter) at the receiver end gives the useful signal a different shape than the noise. This also changes the ratio of both components to each other (FIG 2).

Modulation with pilot (e.g. DVB-T)

If a pilot (subcarrier) exists, it is included in the total power but is not part of the useful signal components. This also leads to a change of the attainable SNR with the specified C/N and should be taken into account when making calculations (FIG 2).

Single-carrier modulation with pilot (e.g. ATSC)

Both effects are to be taken into account.

Modulation and TV standard	Noise bandwidth B_N	SNR_{max} / dB = C/N / dB + k
QAM (DVB-C, r = 0.15)	B_N = symbol rate (R&S EFA mod. 60/63)	k = −0.1660 dB
QAM (DVB-C, r = 0.15)	B_N = channel bandwidth (R&S EFA mod. 20/23)	k = −0.1660 dB + 10 × log (chan. bandw. / symbol rate)
QAM (J.83/B, r = 0.12)	B_N = symbol rate (R&S EFA mod. 70/73)	k = −0.1323 dB
QAM (J.83/B, r = 0.18)	B_N = symbol rate (R&S EFA mod. 70/73)	k = −0.2000 dB
OFDM (DVB-T, with pilot)	B_N = channel bandwidth = 8 or 7 or 6 MHz (R&S EFA mod. 40/43)	k = −0.1169 dB
8VSB (ATSC, with pilot, r = 0.115)	B_N = symbol rate/2 (R&S EFA mod. 50/53)	k = −0.4387 dB

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QAM (DVB-C, r = 0.15)	B_N = symbol rate	k = −0.1660 dB
QAM (J.83/B, r = 0.18)	B_N = symbol rate	k = −0.2000 dB
QPSK (DVB-S, r = 0.35)	B_N = symbol rate	k = −0.3977 dB
OFDM (DVB-T, with pilot)	B_N = useful bandwidth	k = −0.3345 dB
8VSB (ATSC, with pilot, r = 0.115)	B_N = symbol rate/2	k = − 0.4387 dB

FIG 2 Left: maximum measurable SNR (baseband noise) as a function of C/N (noise in transmission channel) taking into account the modulation parameters. Noise source is the TV Test Receiver R&S EFA. With a specific C/N, the actually obtainable SNR/MER cannot exceed the specified maximum values, which thus represent the theoretical upper limit. In practice, quantization effects, receiver noise and rounding effects in signal processing always result in SNR and MER values that are below the specified limits.
Right: Like the table on the left, but here the noise source is the TV Test Transmitter R&S SFQ.

The BER graphs described in the relevant technical literature usually use the SNR as a parameter, not the C/N.

Software for displaying BER as a function of C/N

For fully automatic measurement of the bit error ratio (BER) as a function of the channel noise (C/N), Rohde & Schwarz has developed software that makes it easy to control the TV Test Receiver R&S EFA from a PC. The software outputs the BER values at different points (before or after error correction) and graphically displays them (FIG 3). The noise generator in the R&S EFA is used to set the C/N value. All conversions between C/N and SNR described in the table in FIG 2 are performed automatically by the software and displayed in the form of a double scale (C/N and SNR or S/N) if desired. The measurement time is automatically adapted as a function of the measured BER. The software, which is called **EFA Noise-Diagram**, can be downloaded from the Rohde & Schwarz website free of charge.

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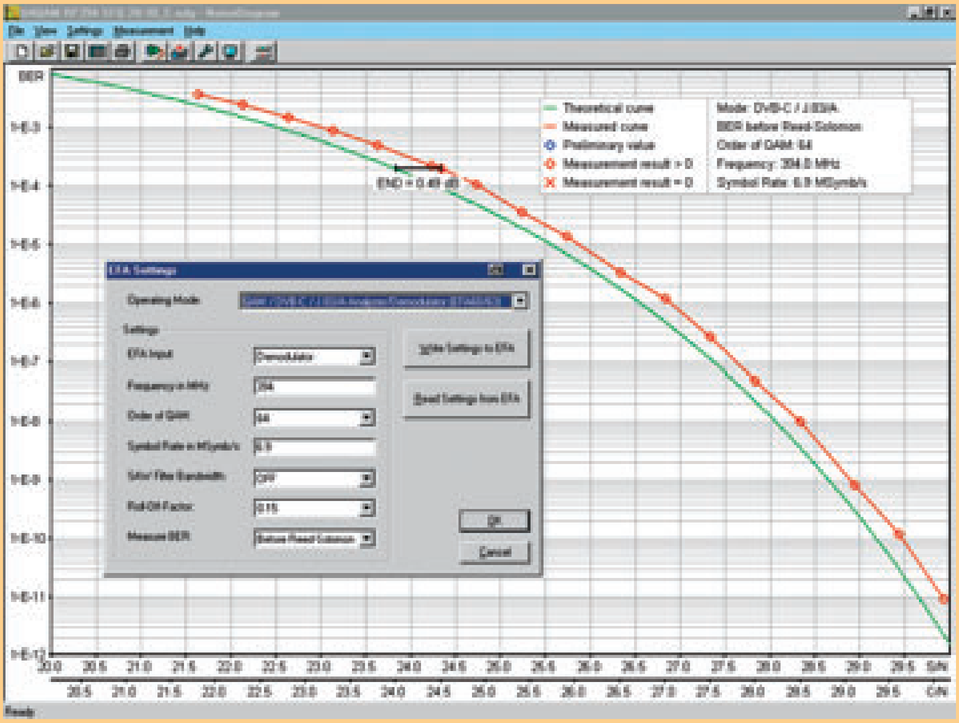

FIG 3 Measurement of the bit error ratio BER as a function of the channel C/N, with conversion to the obtainable SNR values (second scale, S/N; see also the left-hand table in FIG 2). The noise is generated by the noise generator in the TV Test Receiver R&S EFA. The display is for DVB-C. Green: the theoretically obtainable curve; red: the curve actually measured. The END (equivalent noise degradation) is determined automatically from the measured values.