3.6.3 Error Sources in DVB-S

Digital TV has a clearly defined range in which it operates correctly. Transition between the operational range and total failure of a DVB-S system is very distinct. DVB-S uses outer and inner forward error correction (Reed-Solomon and Viterbi), which makes this transition even more pronounced than in DVB-C, while it renders the system much more error-tolerant. The sources of the errors determining the BER values before and after Viterbi, which serve as indicators for system operability, are known. A distinction is made between errors originating from the DVB modulator/transmitter and errors occurring during transmission.

The following errors occur in the modulator/ transmitter:

- different amplitudes of the I and Q components,
- phase between I and Q axis deviating from 90 °,
- phase jitter generated in the modulator,
- insufficient carrier suppression in DVB modulation,
- amplitude and phase frequency response distorting the I and Q pulses being shaped during signal filtering, and
- noise generated in the modulator and superimposed on the QPSK signals.

Amplitude and phase frequency response are aggravated during transmission by:

- nonlinearities of the satellite's transponder cause distortions of the DVB-S signal,
- intermodulation with adjacent channels degrading signal quality,
- interference and noise superimposed on the useful signal, and
- reflections distorting amplitude and phase frequency response.

Whereas the errors produced outside the modulator can be simulated by means of auxiliary equipment, the distortion introduced by the modulator itself can only be generated with a professional test transmitter. Here, TV Test Transmitter SFQ comes into its own as a stress transmitter. Tests reveal that a single parameter will not cause failure of the DVB-S system, even if degraded to the point of maximum error. As an example, the table below lists the limit values for modulator parameters that may occur simultaneously without errors resulting after the outer and inner FEC.

Parameter	Deviation from ideal value set on test transmitter
I/Q IMBALANCE	25 %
I/Q QUADRATURE ERROR	10 °
PHASE JITTER	(cannot be set with SFQ alone, see also Application Note 7BM30)
CARRIER SUPPRESSION	50 %

Table 3.7 Tolerable modulator errors in DVB-S with code rate 3/4

The BER before RS FEC resulting for the above values and the code rate 3/4 remains below the measurement limit of $0.0*10^{-9}$. In addition to these grave errors, noise may be superimposed on the useful signal. The additional carrier-to-noise (C/N) ratio is still 6.5 dB for a BER < $2.0*10^{-4}$.
When switchover is made to the code rate 1/2, the C/N ratio increases to 3.8 dB, including all modulator errors listed in Table 3.7 (see also Table 3.8 "Maximum SNR for the different code rates").

This demonstrates the high reliability of DVB-S transmission systems. Test and measurement requirements in STB production, DVB-S transmission, etc are, for this reason, not very stringent. The measurements to be performed will be described later.

TV Test Transmitter SFL-S, which was specially designed for production, offers the same range of settings as the SFQ and therefore also allows acceptance tests at the end of the production line.

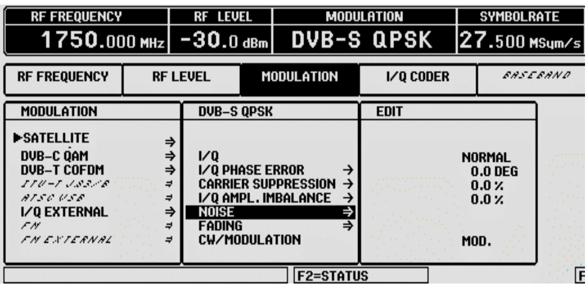


Fig. 3.19 SFQ menu for QPSK parameter setting

3.6.4 Bit Error Ratio (BER)

A defined BER can be generated by means of a noise generator with selectable bandwidth and level. The theoretical BER as a function of the signal-to-noise (S/N) ratio is described by calculated graphs for the five code rates in the QPSK mode.

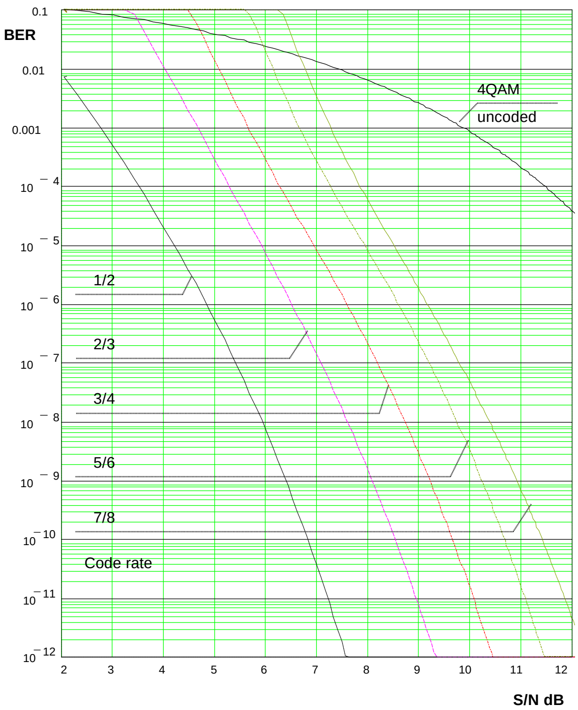


Fig. 3.20 Theoretical BER(S/N) for the five code rates in QPSK mode

Note: The theoretical curves shown in Fig. 3.20 present the BER as a function of the S/N ratio. The following relationship exists between S/N and C/N for DVB-S with a roll-off factor of r = 35 %:
$S/N = C/N + k_{roll\text{-}off} = C/N - 0.398$ dB

TV Test Transmitter SFQ as well as the members of the SFL Test Transmitter family have integrated, optional noise generators (e.g. SFL-N for SFL).
The curves being very steep in the range BER $\leq 2*10^{-4}$, which is the reference value in all measurements connected with BER, the noise level can be determined very accurately.

This is done either using the method described in Application Note 7BM03 *(see Annex 4C to Part 4 (DVB-T) of the "Digital TV Rigs and Recipes")*, or by a direct measurement with TV Test Receiver EFA.
7BM03 also explains C/N to S/N conversion.

When one compares error susceptibility of DVB-C and DVB-S, it will be noticed immediately that the decision fields of the two DTV systems are very different in size. The "area" of a decision field in DVB-C with 64QAM is smaller by a factor of 16 than that of a DVB-S decision field. This factor alone means an extra margin of error tolerance of $10*\log(16) = 12$ dB. Inner FEC (Viterbi) additionally improves the BER by two more decades. These two factors together guarantee, for example, quasi-error-free (QEF) reception for the lowest code rate of ½, even if an S/N ratio as low as 3.7 dB is obtained in the receiver after $\sqrt{\cos}$ filtering. This is valid even on the assumption of an equivalent noise degradation (END) of 0.4 dB. The improvement in quality over analog reception is evident.

Table 3.7 lists the minimum SNR values (SNR = signal-to-noise ratio) for the five code rates $P = \frac{1}{2}, \frac{2}{3}, \frac{3}{4}, \frac{5}{6}$ and $\frac{7}{8}$ for a BER $\leq 2*10^{-4}$ before Reed-Solomon forward error correction:

Code rate P	Max. SNR (dB)
1/2	3.3
2/3	5.1
3/4	6.1
5/6	7.1
7/8	7.7

Table 3.8 Minimum SNR for the different code rates

3.6.5 BER Measurement with SFQ

If TV Test Transmitter SFQ is fitted with options SFQ-B10 (DVB-T Coder) and SFQ-B17 (BER Measurement), the BER can be determined additionally with SFQ alone.

An SFQ-generated data stream (PRBS BEFORE CONVolutional coder) or the valid NULL PRBS PACKET MPEG2 transport stream is DVB-S-modulated and applied to the device under test (DUT).

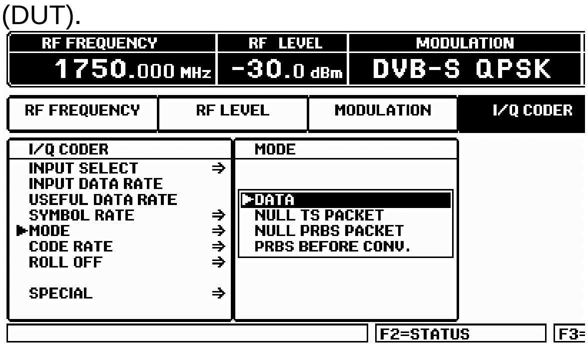


Fig. 3.21 BER measurement with SFQ-generated data

The TS packets are demodulated and output by the DUT, for example via the common interface (CI), and then re-applied to SFQ for BER measurement.

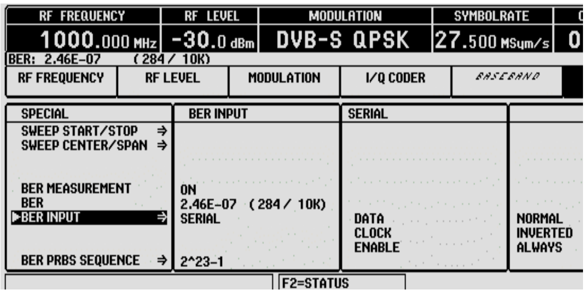


Fig. 3.22 BER measurement

In the following, this measurement will be explained by means of an example. The END (equivalent noise degradation) parameter of the front end of a DVB-S set-top box is to be determined.

Settings on SFQ

MODULATION	**NOISE ON** **C/N is being varied**
CODER	**REED SOLOMON OFF** **MODE NULL PRBS PACKET** **PRBS 2^{23} - 1**
SPECIAL	**BER MEASUREMENT ON** **BER INPUT PARALLEL** **MODE NULL PRBS PACKET** **BER PRBS SEQUENCE 2^{23} - 1**

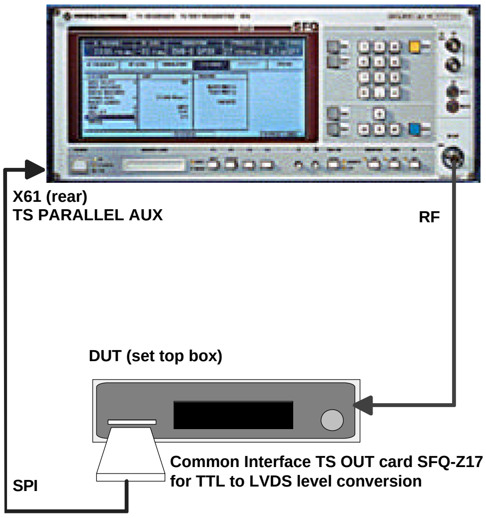


Fig. 3.23 Test setup and settings for BER/END measurement

TV Test Transmitter SFQ modulates the null PRBS packets (null packets with payload consisting of PRBS bytes). Channel coding is complete except that the Reed-Solomon encoder is switched off.

As a result, the Reed-Solomon decoder in the DUT detects more than eight apparently errored bytes, because the 16 error protection bytes are missing. The Reed-Solomon decoder sets the TEI (transport error indicator) error flag and allows the transport stream to pass unchanged. The BER before the Reed-Solomon decoder can thus easily be measured.

On a set-top box, the transport stream is brought out as a TTL signal at the common interface. An adapter card converts the TTL signal to an LVDS signal. This signal is taken to SFQ (TS PARALLEL AUX input) for BER measurement. The SFQ BER Measurement option (SFQ-B17) removes the four-byte header from the transport packets (SFQ is set to NULL PRBS PACKET mode, see left). The remaining 184 bytes of useful data contain the original PRBS of $2^{23} - 1$, which is evaluated to obtain the BER.

To determine the END, the C/N ratio of the SFQ output signal is varied to a BER of $1 * 10^{-4}$. Using the method described in Application Note 7BM03, the C/N value is precisely determined and then converted to the S/N value by subtracting the roll-off factor. The difference between the measured S/N and the theoretical S/N shown in Fig. 3.20 "Theoretical BER(S/N) for the five code rates in QPSK mode" for DVB-S (or the corresponding diagram for DVB-C) at a BER of $1 * 10^{-4}$ is the wanted END in dB. It should not exceed 0.8 dB.

3.6.6 Crest Factor of DVB-S Signal

The structure of a DVB-S signal is determined by the four states it may assume in a QPSK constellation diagram. After settling, DVB-S signals have identical amplitude while the phases change by ±90 ° or ±180 °. Correspondingly, different level steps with different overshoots occur. Amplitude levels of $2 * d$ or $2 * d * \sqrt{2}$ are used (see Fig. 3.8 "QPSK constellation diagram"). The height of the overshoots depends on the roll-off factor. To detect limiting effects, the crest factor is measured. This factor is defined as the quotient of the peak voltage value and the root-mean-square (rms) voltage value. Spectrum Analyzer FSP measures the crest factor using the complementary cumulative distribution function (CCDF). If the factor so determined attains a value of K_{CREST} > 7 dB at a probability of $1 * 10^{-7}$, it can be assumed that there are no limiting effects in the DVB-S system under test.

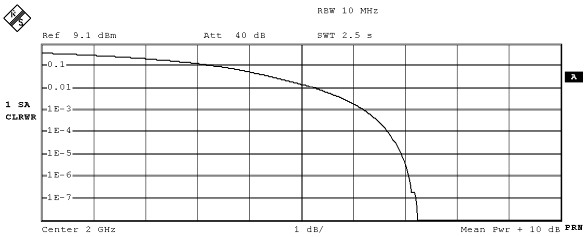


Fig. 3.24 Crest factor of a DVB-S signal

Any limitations of the DVB-S signal would mean that information is missing, with the consequence of increasing BER. Correct level adjustment, therefore, helps to avoid an unnecessary reduction of the system's safety margin.

3.6.7 DVB-S Spectrum and Shoulder Distance

For MPEG2 transport streams transmitted via satellite, the receive conditions must be monitored to guarantee constant, adequate coverage of the service area in question. Thanks to the robustness of the DVB-S system, all that is to be done is measuring the amplitude frequency response and shoulder distance using a well-aligned consumer satellite antenna. Although fading effects play a minor role in DVB-S reception, the effects of reflections with a constant phase, which produce a non-flat spectrum, should at least be examined. Such a spectrum is simulated by TV Test Transmitter SFQ.

Fig. 3.25 shows the optimal amplitude frequency response for a symbol rate of 27.5 Msymb/s, which corresponds to a signal bandwidth of 27.5 MHz. The effect of $\sqrt{\cos}$ roll-off filtering with roll-off factor r = 0.35 is easy to recognize.
Fig. 3.26 illustrates the effect of an echo with constant phase. The notch in amplitude frequency response produced by the echo is clearly discernible.

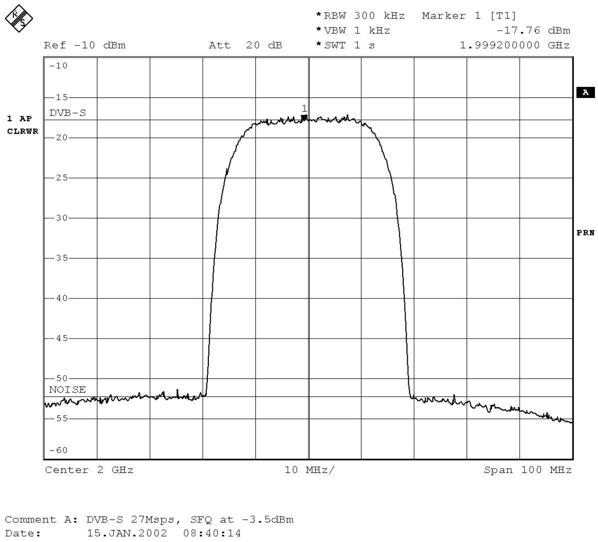


Fig. 3.25 Optimal amplitude frequency response for DVB-S

The shoulder distance in Fig. 3.25 is 47 dB. From Fig. 3.20 "Theoretical BER(S/N) for the five code rates in QPSK mode" it can be seen that a C/N (converted to S/N) of 47 dB will in any case yield a BER better than that of QEF reception.

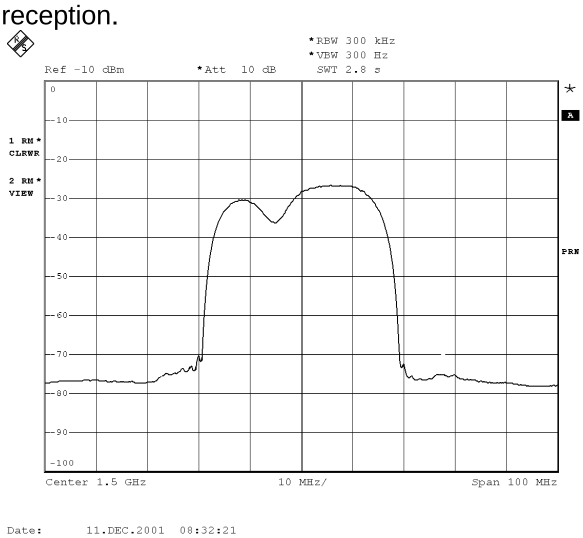


Fig. 3.26 Amplitude frequency response in DVB-S with 20 ns/6.5 dB echo

Echoes like those shown in Fig. 3.26 are quite likely to occur in the event of mismatch in the cabling system of a building or misalignment of the satellite antenna. It is therefore advisable to examine the reasons if a DVB-S set-top box produces a fading profile like the one shown above, although this profile should not cause a deterioration of the BER.

3.6.8 How to Generate a Defined Echo

By means of a defined mismatch, an echo is generated and superimposed on the RF output signal of TV Test Transmitter SFQ. The mismatch is introduced by a 50 Ω coaxial cable terminated with a short-circuit impedance and inserted in the RF feeder line to the set-top box via a T section. The notch in amplitude frequency response occurs at a defined frequency which depends on the length of the inserted cable. An echo delay of 2∗5 ns (forward and reflected) is assumed for each meter of length. In the above example, the notch comes at 1495 MHz, which corresponds to a delay of 20.067 ns.
The above spectrum was generated by means of a 2 m 50 Ω coaxial cable terminated with a short-circuit impedance, causing a delay of $t = 2 \times 2 \times 5 = 20$ ns. The frequency at which the first notch occurs is equal to $f_1 = 1/t = 50$ MHz. The notch is repeated at $f_n = n \times f_1$ (with n = 1, 2, 3,...).
For n = 30, for example, the notch should occur at $f_{30} = 1500$ MHz. The measured spacing from the center frequency is in this case only 5 MHz or 0.33 % (see fig 3.26). The depth of the notch depends on the quality of the cable.

Note: The optional Fading Simulator SFQ-B11 has a useful bandwidth of 14 MHz, which is too narrow for generating fading effects in DVB-S. Common DVB-S bandwidths are clearly larger than 20 MHz.

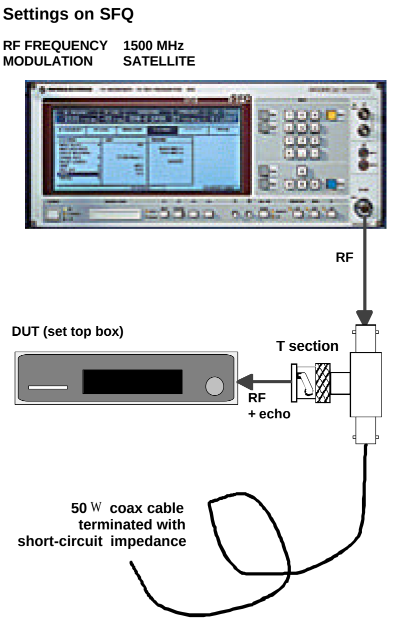
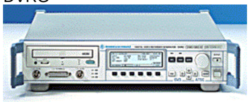
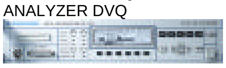
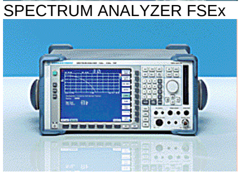
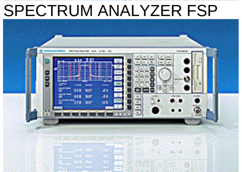


Fig. 3.27 Test setup for echo generation

3.7 Overview of DVB-S Measurements

Instrument, Test Point	Test Parameter
On satellite uplink **TS source for production**	
MPEG2 MEASUREMENT GENERATOR DVG 	Test signal generator for reproducible MPEG2 measurements, various test sequences
DTV RECORDER GENERATOR DVRG 	Test signal generator for reproducible MPEG2 measurements, various test sequences; recording of user-defined transport streams, recording of error events
TS output stream at common interface of STB	
MPEG2 MEASUREMENT DECODER DVMD 	Realtime MPEG2 transport stream protocol analysis
MPEG2 REALTIME MONITOR DVRM 	Realtime MPEG2 transport stream protocol monitoring
DIGITAL VIDEO QUALITY ANALYZER DVQ 	Measurement of signal quality after MPEG2 coding and decoding
At test transmitter/ **satellite uplink** **Reception via satellite antenna** **Analyzers for production**  SPECTRUM ANALYZER FSEx  SPECTRUM ANALYZER FSP  SPECTRUM ANALYZER FSU	DVB-S spectrum Shoulder distance Roll-off factor Crest factor Output power

Instrument, Test Point	Test Parameter
At test transmitter/ **satellite uplink**  **Power Meter NRVS with Thermal Power Sensor NRV-Z51**	High-precision thermal measurement of output power
Simulation of **DVB-S transmission**  TV TEST TRANSMITTER SFQ Option NOISE GENERATOR	C/N setting for END/BER measurement Simulation of defined receive conditions Simulation of modulator defects
DVB-S test transmitter **for production**  TV TEST TRANSMITTER SFL-S	Test transmitter for production Simulation of modulator defects for testing and adjustment of set-top boxes in production