Products: R&S® SFU broadcast test system

Tolerance to Noise Tests for DTV Receivers With R&S®SFU-K41, -K42 and -K43
Part 1: Impulsive Noise

Application Note

Testing the tolerance to phase and impulsive noise is an integral part of quality tests for *DVB-T/H* and *ATSC (8VSB)* receivers, and several national and international standards specify guidelines and minimum requirements in this context. This Application Note introduces the *R&S® SFU-K42* impulsive noise option, the *R&S® SFU-K41* phase noise option, as well as the *R&S® SFU-K43* multinoise use option and describes how these can be used for testing the tolerance to phase and impulsive noise on commercial receivers.

Subject to change – C K Tan / H.Gielen 01.2007 – 7BM64_1E

Contents

1 Overview

TV viewers familiar with existing analog *PAL*,*SECAM* and *NTSC* systems were, and often still are, in the belief that the new digital TV standards such as *DVB* and *ATSC* are entirely immune to interference. However, anybody with a deeper understanding of this subject knows that the reality is more complex. In several regions of the world, digital TV is a fact of life, and some readers who have access to the terrestrial variants of these standards – such as TV on public transportation, just to name one – may know all too well what we're talking about and are already familiar with new terms like *blocking* and *frozen* pictures.

It is more correct to say that the effect of noise and interference on digital TV is different rather than saying that there's a total absence of susceptibility to interference. The effect of noise on analog TV is characterized by a depreciation of picture quality that's somewhat proportional to the level of interference. One of the most representative indications of this is the appearance of what is commonly known as *snow.* The amount of snow that is visible on the screen increases with every dB in signal-to-noise ratio deterioration.

The impact of noise on digital TV, on the other hand, is characterized by the "falling off the cliff" effect. Perform the simple experiment of removing the antenna plug from your (analog) TV antenna input and you quickly learn that loss of picture synchronization, or what is known in layman terms as *rolling*, only takes place after the signal-to-noise ratio has fallen far below a level deemed fit for acceptable viewing. This is especially true in the absence of impulsive noise. Since the synchronization mechanism in analog TVs could be classified as "digital", the above experiment gives us a pretty good idea of what the effect of interference on their digital counterparts might be.

Tolerance to noise and interference tests for digital TV receivers are included in several related standards and guidelines and are meanwhile common practice in R&D and QA departments. The *R&S® SFU broadcast test system* with the *R&S® SFU-K41, -K42* and *-K43* noise and interference generator options are indispensable tools for performing such measurements.

2 Interference and Noise

2.1 The Origin and Nature of Noise

Digital TV receivers may experience interference of different origin and nature. This includes:

- Interference from adjacent and neighboring analog *PAL/SECAM* or *NTSC* TV channels: Since digital and analog TV channels share the same frequency bands, both may experience interference from each other's presence
- Interference from adjacent and neighboring digital *DVB* or *ATSC* TV channels
- Signal path fading: Digital TV signals transmitted over the air are affected by atmospheric conditions that may periodically reduce the signal strength
- Reflection: Digital TV signals can experience reflection on infrastructure and other objects, causing reception of the same signal multiple times at different signal strengths and at different points in time. This is commonly known as multipath fading
- Interference from atmospheric and thermal noise
- Man-made or natural impulsive interference such as lightning, ignition sparks or impulsive noise from switching devices
- Interference from noise generated by oscillator instability and jitter known as phase noise

The first four types of interference are either man-made wanted signals or interference originating from man-made wanted signals and can't be immediately classified as noise. Tests that define how a receiver performs under such interference are usually grouped under *multi-path fading and adjacent channel interference tests* and are beyond the scope of this document. The last three types of interference, however, can be classified as noise, and the way a receiver performs under the influence of such signals are usually grouped under the following three tests:

- Receiver sensitivity and signal/noise (S/N) performance
- Receiver tolerance to impulsive interference
- Receiver tolerance to phase noise

S/N tests are part of virtually any receiver performance test standard and are usually well understood. Less common and therefore less understood are *impulsive interference* and *phase noise* tests. This Application Note consists of two parts:

- Part 1*: Impulsive Noise* (this document)
- Part 2*: Phase Noise*

and covers these subjects in detail.

2.2 Impulsive Noise

2.2.1 Deriving a Parametric Model

Impulsive noise can be described as one or more repetitive or non-repetitive pulses with a random intensity, duration and occurrence. There are numerous sources of impulsive noise around us, including common household items such as small and large appliances, heating systems and ignition devices. Impulsive interference can penetrate the receiver via wiring, the enclosure as well as the antenna or CATV input connector. Measures to counteract the first two modes of interference belong to the field of EMI suppression and can be dealt with relatively easily with proper shielding practices. Reducing the influence of impulsive noise received via the RF channel (antenna or CATV connector) is another matter altogether and must be handled by error correction mechanisms inside the receiver.

The fact that impulsive noise is very chaotic and random in nature makes deduction of mathematical and statistical relationships a challenging if not impossible task. Nevertheless, if performance in this context is to be tested, quantifiable waveforms must be defined. In view of a future launch of digital TV services, a group within the UK-based *DTG group* conducted an extensive research program in 2001 with the aim of determining parametric data of impulsive noise. The results of these findings were later adopted by other test standards.

Mathematically a train of i interference impulses can be represented as

$$n(t) = \sum_i A_i \cdot P \cdot w_i \cdot (t - \tau_i)$$

where:

- A_i = the amplitude of impulse i
- w_i = the duration of impulse i
- τ_i = the time of occurrence of impulse i

The above model is fully defined only if the statistical distributions of all the parameters in the equation are known. For this purpose, impulsive noise data from the following devices was collected empirically during the study:

- Three different types of central heating devices
- Ignition system for cookers
- Dishwashers
- Light switches being turned off
- Fluorescent and incandescent lights being turned on
- Three different sources of traffic interference

The obtained empirical data was cast into a representative repetitive pulse train with the following parameters:

- The minimum and maximum pulse spacing T_{ps}
- The number of pulses per burst n
- The minimum and maximum duration of the burst T_b
- The effective duration of the burst T_{eff}

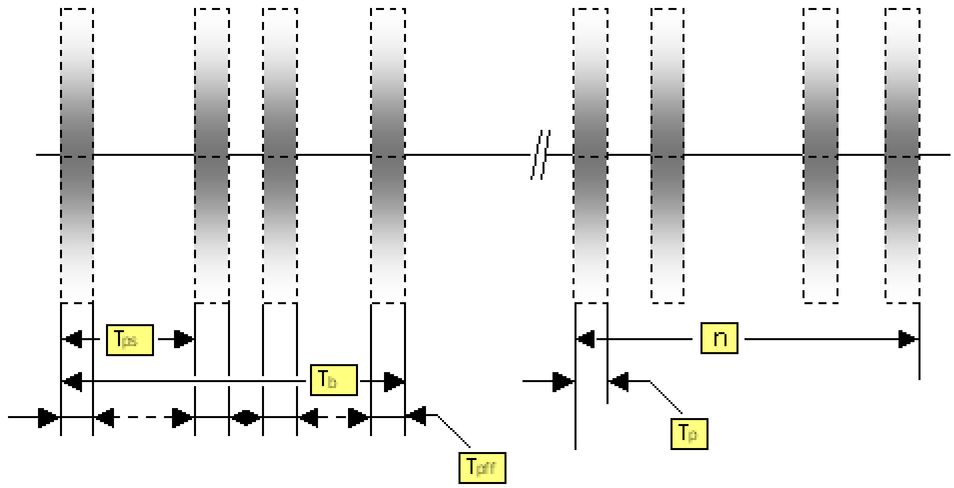


Fig. 1 Parametric timing model for impulsive noise derived by DTG study

The test results showed that the interference could be categorized within the following boundaries:

- $n = 1-20$
- $T_{ps} = 1-35\mu s$
- $T_b = 1.75-175.25\mu s$
- $T_{eff} = 0.25-5\mu s$

To further simplify the parametric data, the following assumptions were made:

- The impulsive interference is assumed to be AWGN.
- The repetition of successive interference bursts is set at $10m\sec$. This length is considered to be sufficient for the receiver to recover from a previous burst.
- The impulse must be shorter than the duration of a symbol; otherwise it will interfere with the subsequent symbol and can be seen as AWGN instead. In fact, test results show that for bursts shorter than an OFDM symbol but longer than 500ns, the C/I performance is roughly within a $2dB$ window of AWGN performance. For pulses shorter than 500ns, receiver behavior

deviates from what one observes under AGWN. For this purpose, the duration was set at 250ns.

Together with the collected data, this defined the parametric models used in impulsive noise tests for the *DVB-T* receiver noise tolerance test. The test consists of six waveform patterns with different numbers of 250ns pulses that are randomly spaced and repeated every 10ms. The suggested observation period is one minute, and the failure criterion is that there can be no more than one uncorrectable error every minute. An alternative and often used subjective criterion in case a reading of faulty received bits or BER figure can't be obtained is the occurrence of visible errors such as the appearance of *blocking* or *still* pictures.

2.2.2 Understanding the Impact of Impulsive Noise

In chapter 4.2.2, we subject a commercially available *DVB-T* receiver to impulsive and AWGN noise simultaneously and observe its behavior. We will see that the point of failure for the C/I (impulsive noise) vs. C/N (AWGN) ratio shows an asymptotical relationship like the one shown in the following diagram.

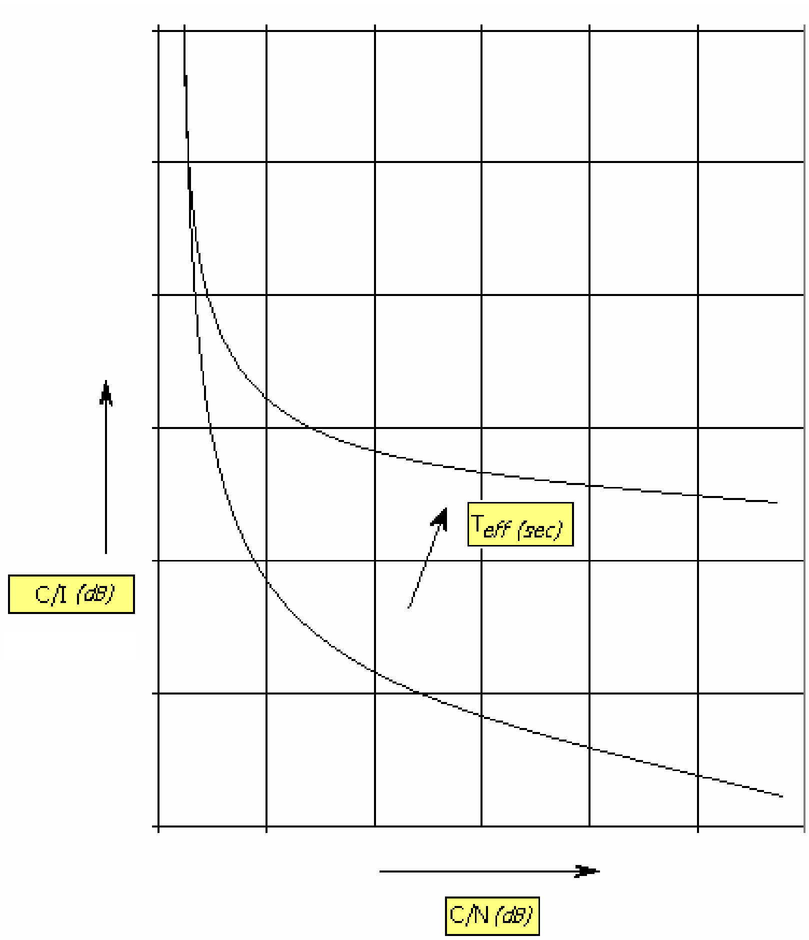


Fig. 2 C/I vs. C/N @ receiver failure point

When we reduce the impulsive noise level, the C/N ratio at the point of failure approaches the value associated with the failure point of only AWGN noise. At the other end of the curve, i.e. when impulsive noise is added, the behavior becomes dominated by it and the limit value tends toward a fixed C/I value corresponding to the breakdown point in an AWGN-free environment. This is consistent with the findings in the DTG study.

The curve shifts upward with increasing effective burst duration T_{eff}. The pulses are generated by gating a Gaussian noise source of power P. Hence the noise energy in a burst is the product of P and the total duration of the combined number of gating impulses T_e within the burst train.

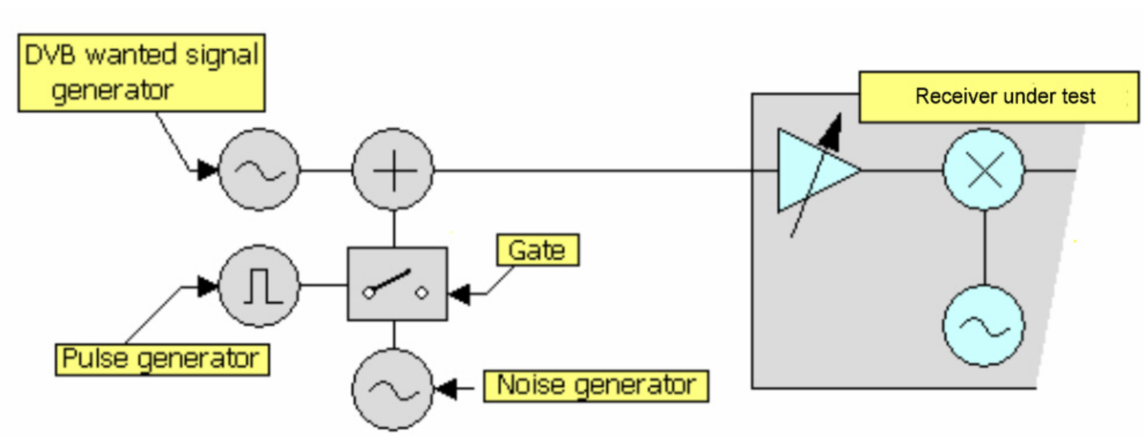


Fig. 3 Creating a AWGN signal

Since the total signal energy is the product of the carrier power, C, and the active symbol duration, T_u, the ratio of wanted signal energy to interference energy is

$$\frac{(C \times T_u)}{(P \times T_e)}$$

The theoretical failure point corresponds to this quantity equaling the minimum carrier-to-noise requirement, $(C/N)_{ref}$ for the system. In other words, the tolerance of the receiver to the interference signal should exceed its tolerance to ungated Gaussian noise by a factor of T_u/T_e. This so-called *tolerance factor* is generally expressed in dB. Note that it is independent of modulation mode, receiver implementation margin and degradation criterion, but that the FFT size affects it via the T_u duration, yielding $6dB$ higher figures for $8K$ than for $2K$.

3 Related Test Standards

3.1 Overview

Although a developer or manufacturer of digital TV receivers may perform tolerance to noise tests in its labs and production facilities to iron out design problems or monitor product quality, introduction of digital TV receivers in certain markets is subject to impulsive noise tolerance tests.

Unlike the phenomenon we see in mobile communications and wireless networking where receiver performance specifications are usually issued by the body that governs the actual standard, TV receiver performance is in most cases still a national affair and heavily influenced by existing *EMI/EMS* standards, the adopted digital TV standard, coexistence with local analog TV and other participants in the radio spectrum. Local regulations and political situations play a part as well.

Table 1 Digital TV receiver noise performance test standards and recommendations at a glance

Geo-area	Test standard	Digital TV standard	Applicable to	Impulsive noise sensitivity	C/N figure performance	Phase noise tolerance
International	*IEC / EN 62216-1*	DVB-T	Terrestrial receivers	No specifications	Chapter 12.7.2	No specifications
Pan-European	*EICTA / TAC / MBRAI E-Book*	DVB-T	Terrestrial receivers	Chapter 8.11	Chapter 8.6	No specifications
United Kingdom	*DTG D-Book*	DVB-T	Terrestrial receivers	Chapter 11.14.3	Chapter 11.13	No specifications
Italy	*DGT Vi D-Book*	DVB-T	Terrestrial receivers	No specifications	*Refer to* *EICTA / TAC / MBRA E-Book* Chapter 8.6	No specifications
Scandinavia	*NorDig Unified*	DVB-T,C,S	Terrestrial, cable and satellite receivers	No specifications	Section 3.4.8	No specifications
Australia	*AS4933.1*	DVB-T	Terrestrial, cable and satellite receivers	No specifications	Refer to IEC/EN 62216-1 Chapter 12.7.2	No specifications
Taiwan	*BSMI*	DVB-T		Section 4.7	Section 4.4	No specifications

United States, Canada *Korea*	*FCC/ ATSC Doc A/74*	ATSC (8- VSB)	Terrestrial receivers	Section 4.4.4	No specifications	Chapter 4.3
Japan	*ARIB/ STD-B21*	ISDB-T	Terrestrial and satellite receivers	No specifications	Appendix.13	No specifications

The most obvious example is Europe, which has uniformly adopted the *DVB-T* standard governed by the *Digital Video Broadcasting* organization and the *European Telecommunications Standards Institute ETSI®*, while sales of TV receivers are often still subject to national standards. This doesn't make it any easier for the test and measurement engineer. The table on the previous page gives an overview of existing noise-related tests in different digital TV standards. Virtually any standard enforces receiver signal-to-noise performance to be tested; most standards require tolerance to impulsive noise, while phase noise sensitivity is still an exception.

3.2 Impulsive Noise and DTG/D Book, EICTA/ TAC/MBRAI and BSMI

These standards specify that a *DVB-T/H* receiver should be subjected to several Gaussian noise burst patterns with characteristics based on the findings of the DTG group. The fixed duration of a single pulse is 250ns and is chosen in such a way that it is shorter than the symbol period T_s, and thus only affects a single symbol. The repetition rate is set at 10ms, which is sufficiently large for them to behave as isolated events. The bit errors in the receiver resulting from burst n will have been flushed by the error correction system by the time the second burst is received. The number of bursts in a train is defined by:

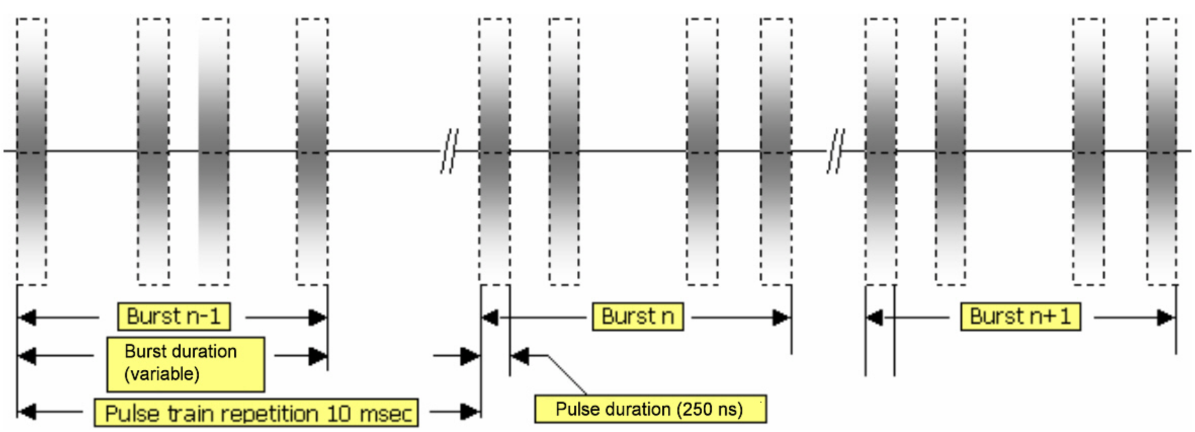


Fig. 4 Impulse interference patterns defined in EICTA/TAC/MBRAI

The level and number of impulses within a given burst depend on the chosen test pattern, while the impulse spacing within a given burst is random but within the boundaries of a minimum/maximum spacing limit. The above-mentioned standards define six different patterns to which the receiver under test must be subjected without any signs of malfunctioning in order to qualify for compliance.

Table 2 Different impulsive noise test patterns

Test pattern No.	Number of pulses per burst	Minimum/maximum impulse spacing (µs)		Burst duration (µs)	Tolerance factor for 2K DVB-T (dB)	Tolerance factor for 8K DVB-T (dB)
1	1	N/A	N/A	0.25	29.5	32.5
2	2	1.5	45.0	45.25	26.5	32.5
3	4	15.0	35.0	105.25	23.5	29.5
4	12	10.0	15.0	165.25	18.7	24.7
5	20	1.0	2.0	38.25	16.5	22.5
6	40	0.5	1.0	39.25	13.5	19.5

The *R&S®* SFU-*K42* and *-K43* noise options inside the *R&S® SFU broadcast test system* have all the required functionality to generate interference patterns matching the above table. The following image reflects the setting for test pattern 4.

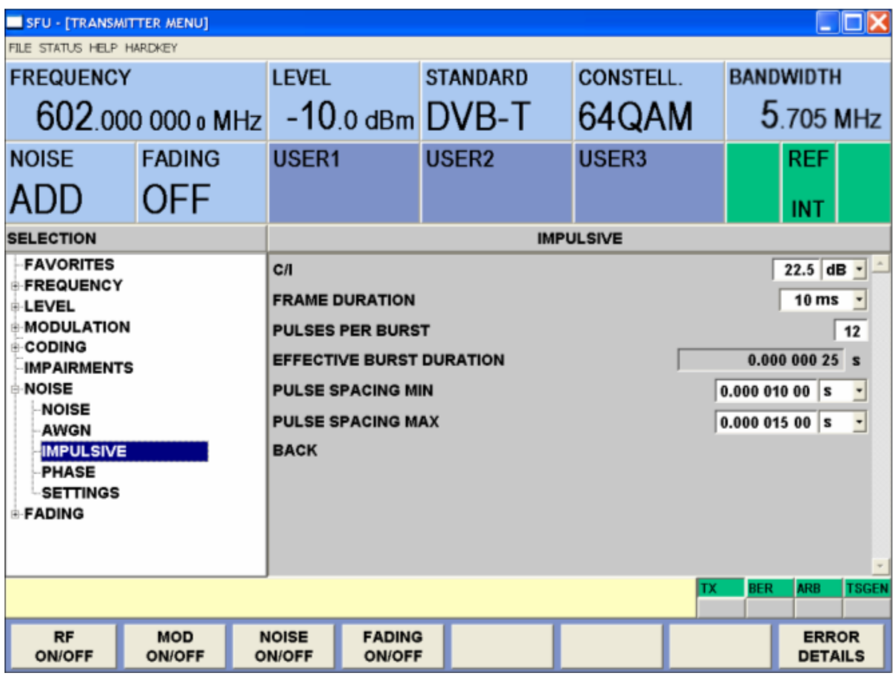


Fig. 5 Impulsive noise settings for DVB-T tests

3.3 Impulsive Noise and FCC/ATSC Doc A/74

ATSC receivers are subject to the requirements defined in the *FCC/ATSC Doc A/74* document. In terms of immunity to noise, this document only specifies that the receiver should tolerate a gated AWGN noise with a minimum duration of 165µs repeated every 100ms without visible errors. The generator noise burst should have an average power of at least $-5dB$ (average power of ungated noise instead of the average power over the burst period) relative to the average power of the wanted signal, measured in $6MHz$. This is shown in the figure below.

Test pattern No.	Number of pulses per burst	Spacing (ms)	Burst duration (µs)	Tolerance factor (dB)
1	1	100.0	165.0	-5.0

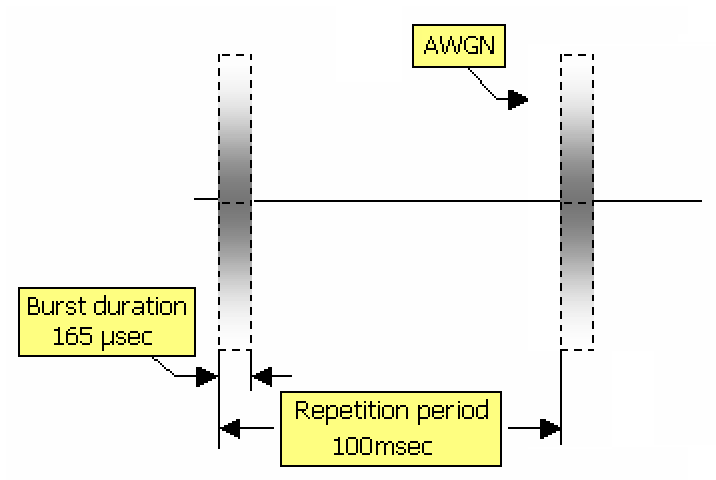


Fig. 6 Gated noise burst specification for ATSC tests

The impulsive noise source in the *R&S® SFU* must be set as follows to generate a compliant signal.

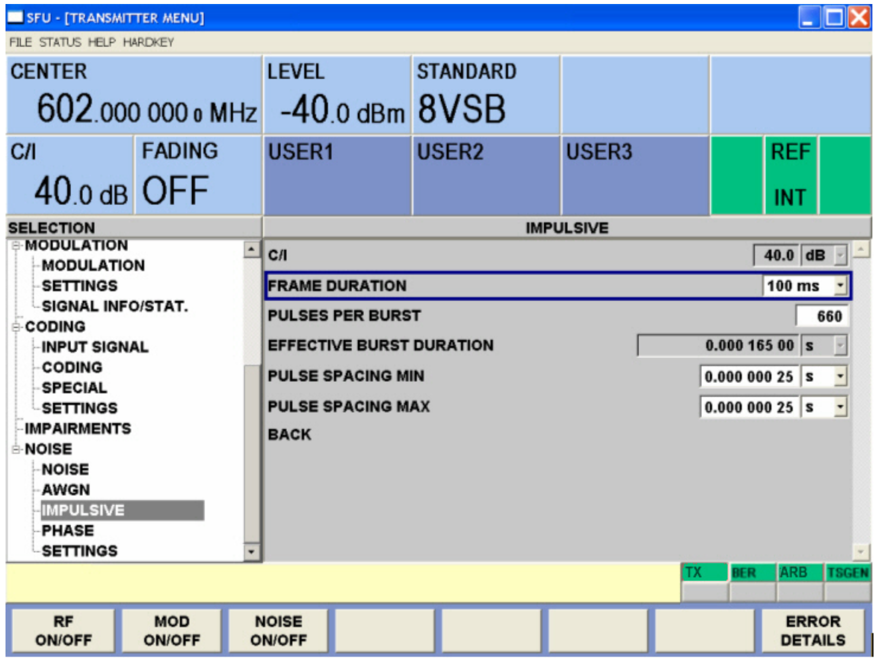


Fig. 7 Impulsive noise settings for ATSC tests

4 Immunity Tests

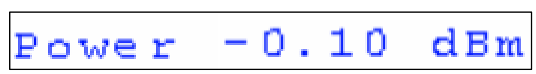
4.1 Verification of the Interference Signal

4.1.1 Impulsive Noise Level

The level and timing of the *R&S® SFU's* interference source are calibrated within the specifications of the instrument. Nevertheless, it doesn't do any harm to verify the actual values prior to the actual test.

Measuring the power of a gated noise impulse with a spectrum analyzer or other instrument can be a challenge, especially in view of the very short duration of 250ns required for certain test patterns. Such short burst cycles set high standards on the gate and triggering mechanisms of the instrument. Fortunately an alternative method exists – namely, measuring the power of the ungated noise signal via regular channel power measurements together with a pulse duration measurement via an oscilloscope.

Although most spectrum analyzers incorporate a function to measure the S/N ratio by the press of a button, some lower-end models do not include such a function. In that case, use two consecutive channel power measurements instead. A channel power measurement reading on a spectrum analyzer always reflects the total output power irrespective of the components of the actual signal. These components may include the following:



- Wanted and unwanted modulation components
- Carrier or remainder thereof
- Noise

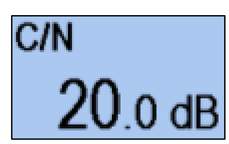
In mathematical terms:

$$P_i = 10\log\int_{fl}^{fh} \mathrm{P(f)}\,df$$

where:

- P_i : Total power shown on the display
- f_h : Lower frequency limit
- f_h : Upper frequency limit

By applying the following procedure, we can tell with confidence how much noise is present inside the signal at a specific C/N setting.

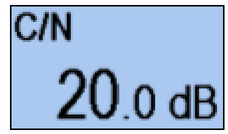


- Measure the channel power of the wanted DTV signal P_{signal}.
- Measure the noise power of ungated noise over the same bandwidth at a location outside the wanted signal's band P_{noise}.
- Calculate the ratio and verify if this corresponds to the C/N setting.

- Measure the gate timing.

Since the measurement procedure determines the noise power, we need to determine the relationship between P_{noise} and the C/N setting on the instrument. The noise in our case is AWGN and therefore power distribution is uniform over the entire frequency spectrum. In practice there is a limit for the noise generator, which is $90\ MHz$ for the *R&S® SFU.* However, this is well beyond the limits for our application. To calculate the noise power P_{noise}:

$$P_{total} = P_{signal} + P_{noise} \quad \text{(in W)}$$

Since P_{signal} and P_{noise} only differ by a factor C/N 

or A in linear terms, we can write:

$$P_{total} = \frac{P_{noise}}{A} + P_{noise} \Rightarrow P_{noise} = \frac{P_{total}}{\frac{1}{A}+1} = \frac{A \cdot P_{total}}{1+A} \quad \text{with } A = 10^{-\frac{C/N}{10}}$$

If we solve this expression for P_{noise}, we obtain:

$$P_{noise} = 10 \cdot \log\left[\frac{10^{\left(\frac{P_{total}-C/N}{10}\right)}}{1+10^{\left(\frac{-C/N}{10}\right)}}\right] \quad \text{(in dB)}$$

Example: For a Level setting of $-45.0\,dBm$ and C/N setting of $20\,dB$, the noise power has to be $-65.0\,dBm$.

The measurement procedure on the next page describes how to measure the power level of the noise signal. Connect the *R&S® FSL, R&S® FSQ, R&S® FSU or R&S® FSP spectrum analyzer* to the *R&S® SFU broadcast test system* as follows:

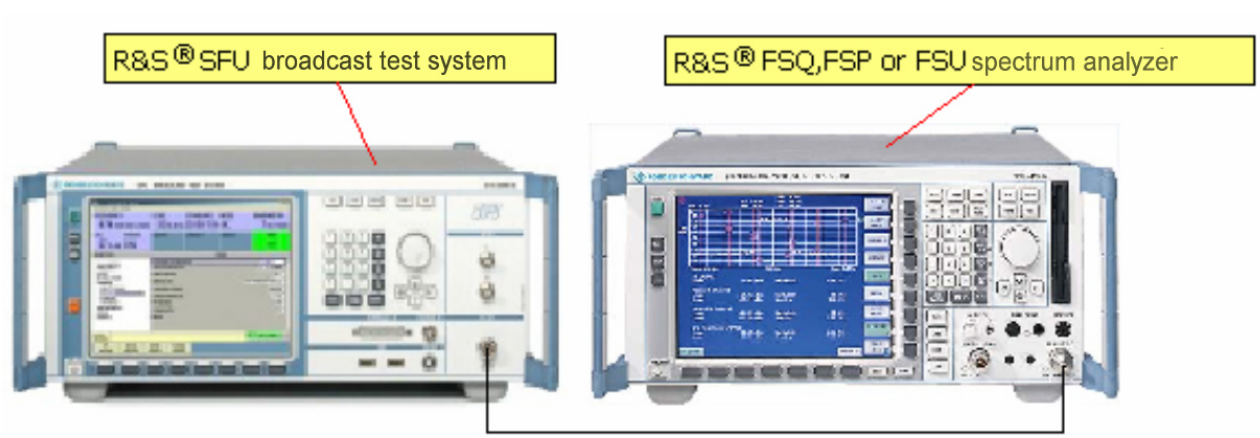


Fig. 8 Setup for channel power measurement

On the *R&S® SFU broadcast test system*:

- Press the Appl key and select TX in the menu to open the MMI of the generator.
- Press the green Preset button.
- Select the Frequency menu in the Selection window and adjust the Frequency to $602 MHz$. This corresponds to UHF channel 37. Change the Frequency setting on the instrument and the center frequency on the spectrum analyzer accordingly if you would like to perform the test on a different TV channel.
- Set the Level setting in the Level menu to $0.0 dBm$.
- Depending on the type of receiver, set the Transmission Standard to DVB-T/H or 8VSB if you will perform tests on an ATSC receiver.

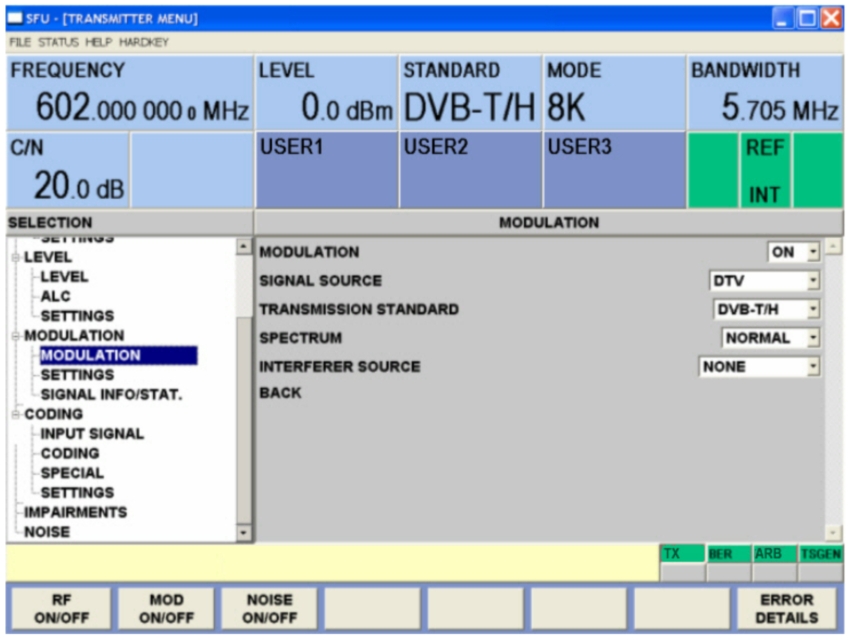


Fig. 9 Modulation standard

- Set the Source field in the Coding/Input Signal window to TS-Player.
- Set the Noise mode to Add.
- Switch AWGN or IMPN (PPB400.000) on.
- Set the Bandwidth coupling in the Noise/Settings menu to On.
- Leave the remaining settings at their respective defaults.
- Press the Appl key and select TSGEN in the menu to open the transport stream generator.

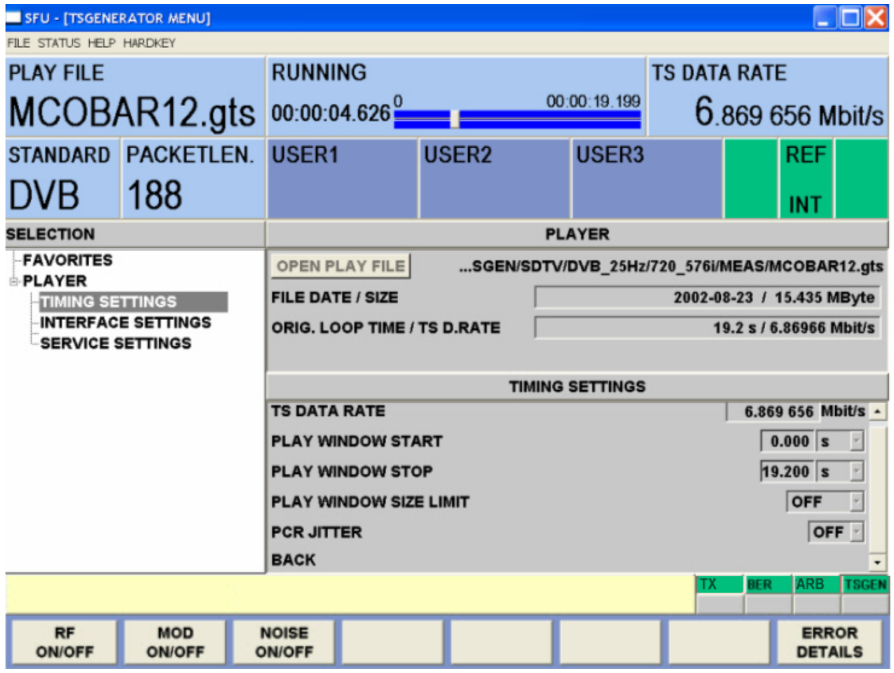


Fig. 10 TS Player window

- Click the Open File icon with the mouse or rotary knob to open the file dialog. Select one of the test videos in the SDTV folder. Choose a still pattern that allows you to determine signs of interference easily like one of the MCOBAR*.GTS patterns. Don't choose video clips that contain checkered patterns like GROUPER.GTS, since the initial signs of interference resemble unnaturally looking square patterns, which are hard to spot on a patterned backgrounds like the checkered skin of the grouper fish.
- Press the Play softkey. The Running indicator must be visible together with a moving tracking bar.

On the *R&S® FSL, R&S® FSP, R&S® FSU* or *R&S® FSQ spectrum analyzer:*

- Press the Preset button.
- Set the Center Frequency to the same value as the Frequency setting on the *R&S® SFU* ($602\,MHz$). The instrument must now display the carrier in the center of the screen. Press the Span button and set the span to $10\,MHz$.
- Press the Trace button and subsequently the Detector softkey. Set the detector to RMS.
- Press the BW button and subsequently the RES BW Manual button. Set the resolution bandwidth to $10\,kHz$. Press the Video BW Manual button and set the resolution bandwidth to $1\,kHz$.
- Press the Meas button and subsequently the Chan Pwr ACP softkey to put the instrument in channel power measurement mode.
- Press the CP/ACP Config button to configure the channel settings. No of Adj Chan must be set to 0. Enter $5.705\,MHz$ in the Channel Bandwidth setting (depending on *DVB-T* channel BW; for *ATSC (8-VSB)*, use $5.381\,\mathrm{MHz}$ as Channel Bandwidth setting).

- If everything goes well, the display of the spectrum analyzer should look like the diagram below. The Power indicator in the lower part of the screen now displays the channel power of the digital TV and must indicate a value close to 0.0 dBm (*R&S® SFU* Level setting).

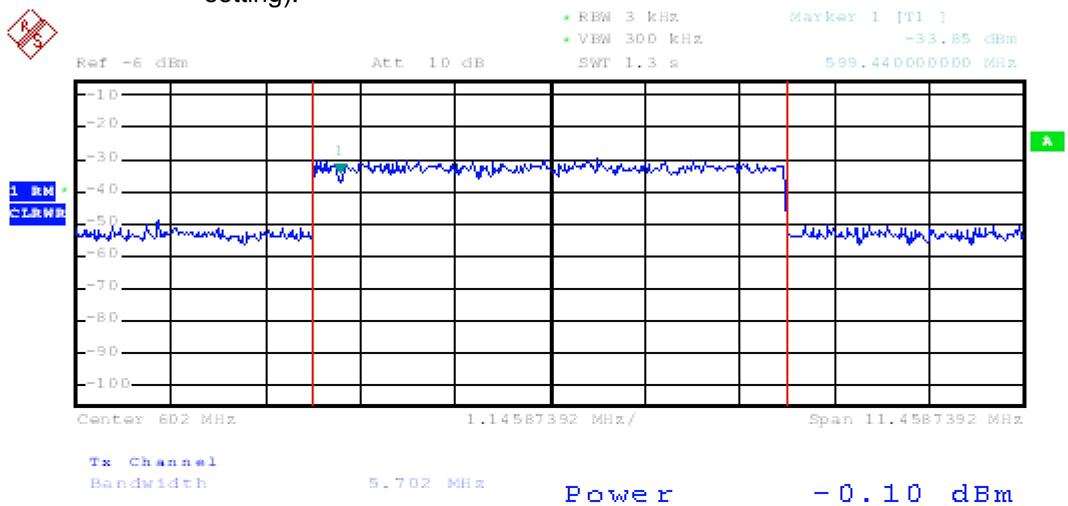


Fig. 11 ATSC or DVB signal channel power measurement.

- Press the Freq key and change the center frequency with the rotary knob until the two red marker lines are completely off the channel. The display should now look like the diagram in Fig. 12.

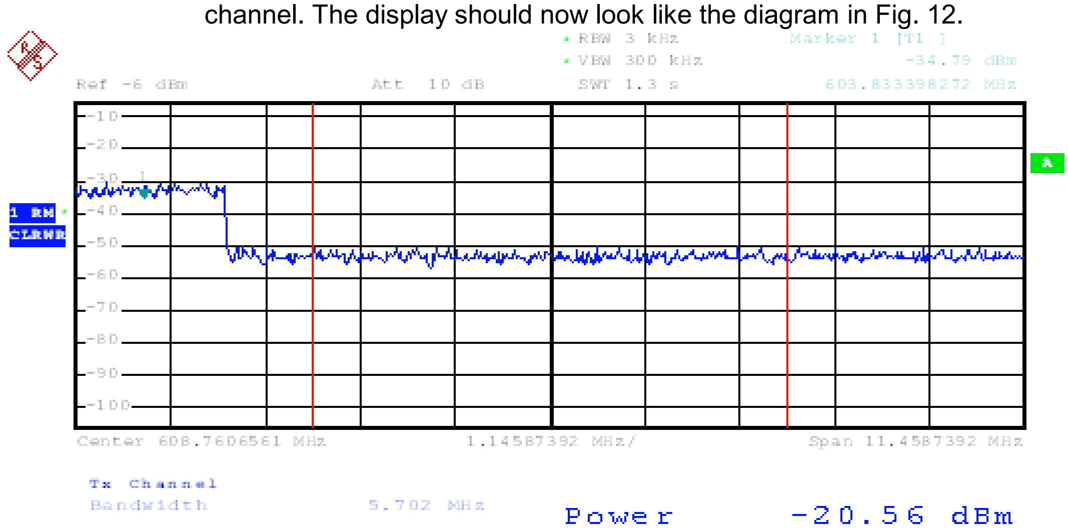


Fig. 12 Noise power measurement over same bandwidth as DVB or ATSC channel

- The Power indication in the lower part of the screen should show a reading of around -20.0 dBm , i.e. the noise power measured over the selected bandwidth. A matching reading is an indication of a correctly calibrated C/N setting on the *R&S® SFU*, namely 20.0 dB .

4.1.2 Noise Impulse Timing

4.1.2.1 Burst Spacing

The burst spacing T_s can be verified with the aid of an oscilloscope or spectrum analyzer.

On the *R&S® SFU broadcast test system:*

- Maintain the settings from the previous paragraph
- Set the Impulsive Noise field in the Noise/Noise window to On and switch other noise types off
- Set the Noise field to Noise Only
- Set the noise parameters in accordance with pattern 1 in table 2 or 3

On the *R&S® FSQ, R&S® FSU, R&S® FSP, R&S® FSL spectrum analyzer*

- Press the Preset button
- Press the Center softkey and enter 602 MHz. The instrument probably shows the leakage of the 602 MHz carrier plus the sporadic appearance of the impulsive noise spikes.

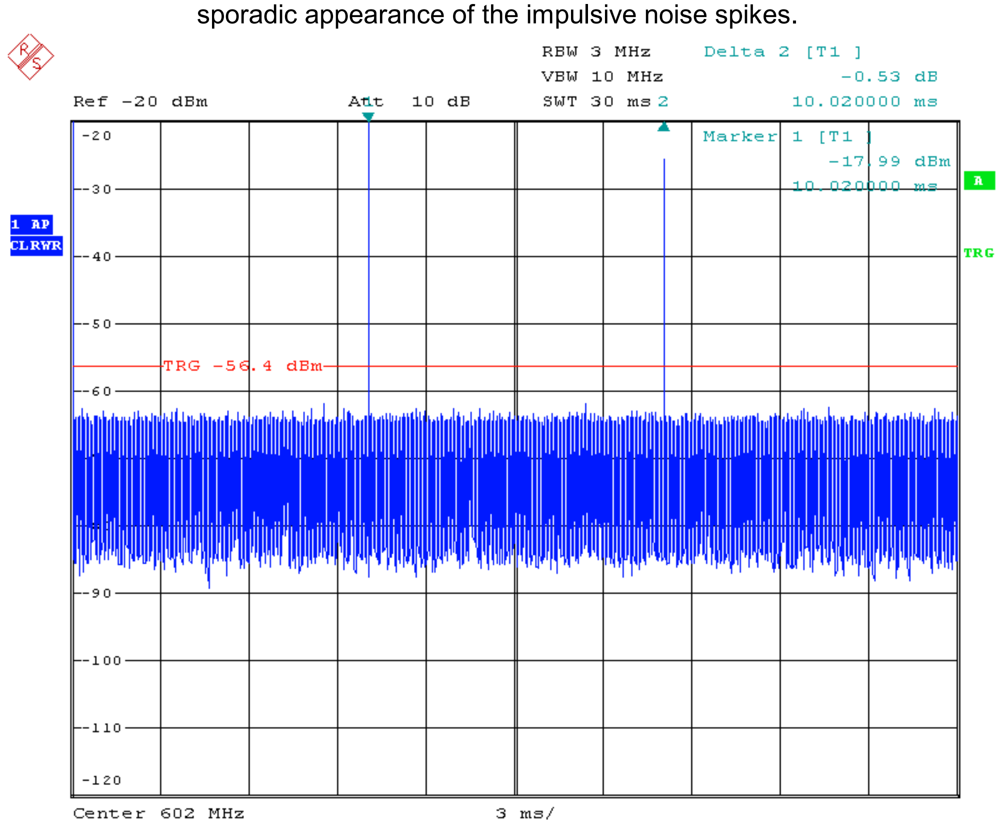
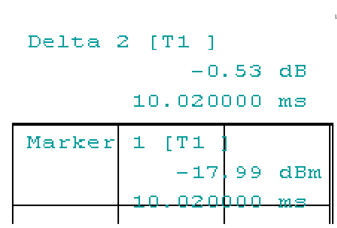


Fig. 13 Burst spacing measurement with spectrum analyzer

- Press the Sweep button and set the sweep time to 30ms. (300ms). We expect the spacing of 10ms (100ms) between two successive bursts so there should be two to three spikes visible on the screen.
- Press the Trigger button and set the trigger mode to Video. Adjust the trigger level until the pulses are still. This should resemble the image in Fig. 13.
- To measure the spacing between both pulses use the Δ marker function. Press the Mrk key. A marker appears on top of one of impulses. Press the Marker 2 softkey. A second marker appears on the screen.
- Press the Mrk→ key and subsequently the Peak key. The upper area of the display must now show the time difference between two impulses:

  -10ms for *EICTA/DBook…. (DVB)* compliant test signals. -100ms for *FCC (ATSC)* compliant test signals.



4.1.2.2 Pulse Duration

Because the spectrum analyzer only measures power at a given frequency, the phase of a given frequency component relative to others is lost and therefore the measured frequency spectrum is not sufficient for reconstructing a time domain representation of the signal. In other words, spectrum analyzers are not well suited for single-shot signals or signals with low duty cycles, since the average signal power is very low. To perform correct measurements on the impulse itself, we need to use an oscilloscope, if possible with a bandwidth $\geq 200\ \mathrm{MHz}$. Connect the *R&S® SFU* to the instrument as shown on the next page.

On the oscilloscope:

- Set the time base to 50 – 100ns per division.
- Set the vertical sensitivity so that it corresponds to the level setting of the *R&S® SFU.* To get an idea of the magnitude of the voltage, calculate the voltage from the power level P_{noise}.

$$U_{RMS} \approx 0.2\sqrt{10^{\left(\frac{P_{noise(dBm)}}{10}\right)}}$$

where:

- $P_{noise(dBm)}$: the noise power in dBm.
- U_{rms}: the ungated RMS voltage of the noise signal.

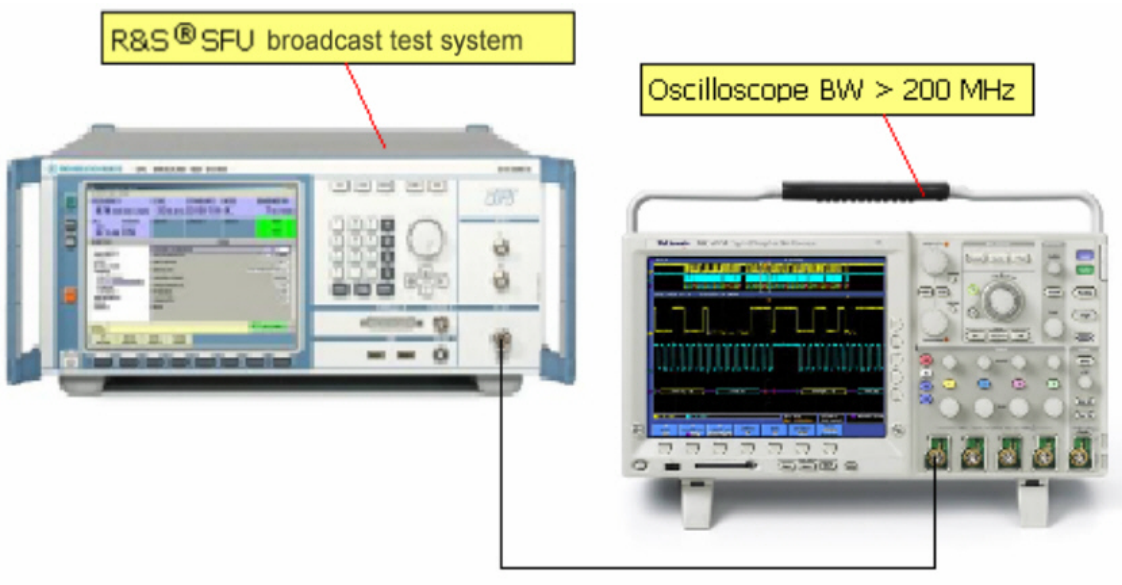


Fig. 14 Test setup for impulse duration measurement

Remember that many oscilloscopes have a $1M\Omega$ input impedance, meaning that the noise source is unloaded. This results in a voltage that is twice as high as a 50Ω load. The following image is a screenshot of the correctly calibrated noise impulse, i.e. $250ns$.

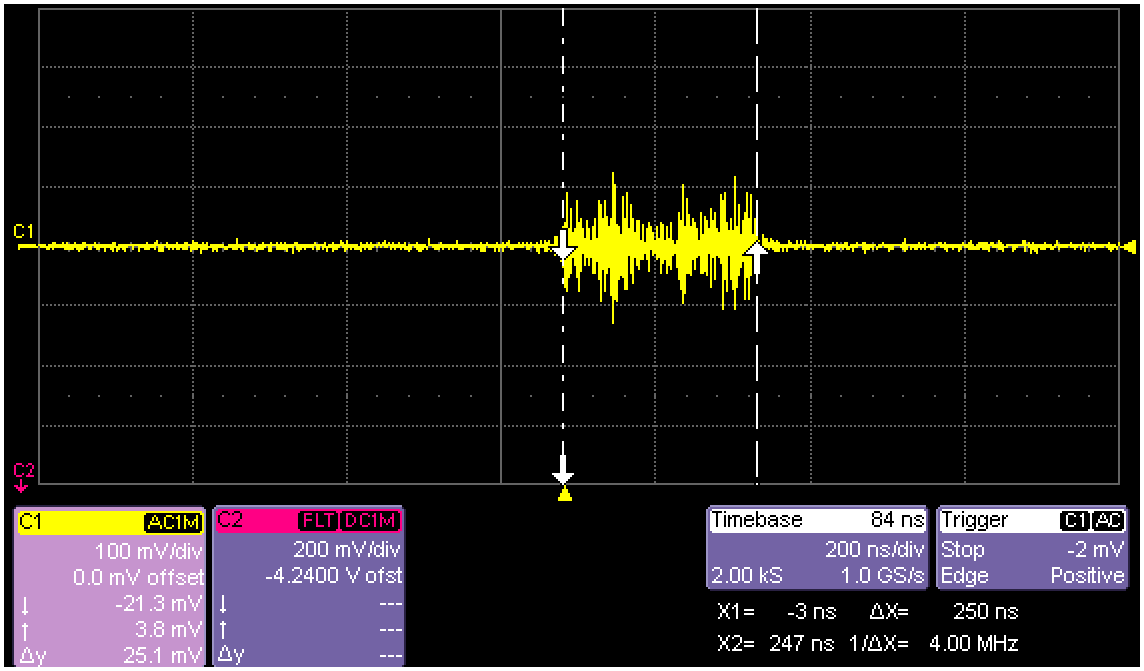


Fig. 15 Screenshot of noise impulse duration and shape

4.2 Different Test Scenarios

4.2.1 Receiver Immunity to Impulsive Noise in the Absence of AWGN

4.2.1.1 Test Preparation

As we learned in chapter 3, the *EICTA, DTG, FCC*, etc, immunity to impulsive noise tests require only subjection to impulsive noise without any additional AWGN and/or phase noise. This means that you can perform this test scenario without the *R&S® SFU-K43* option. Connect the *R&S® SFU's* RF-Out connector to the antenna input of the receiver under test via a coaxial 50Ω cable. Except for some professional models, the antenna inputs of digital TV receivers for the consumer market are 75Ω F-type connectors.

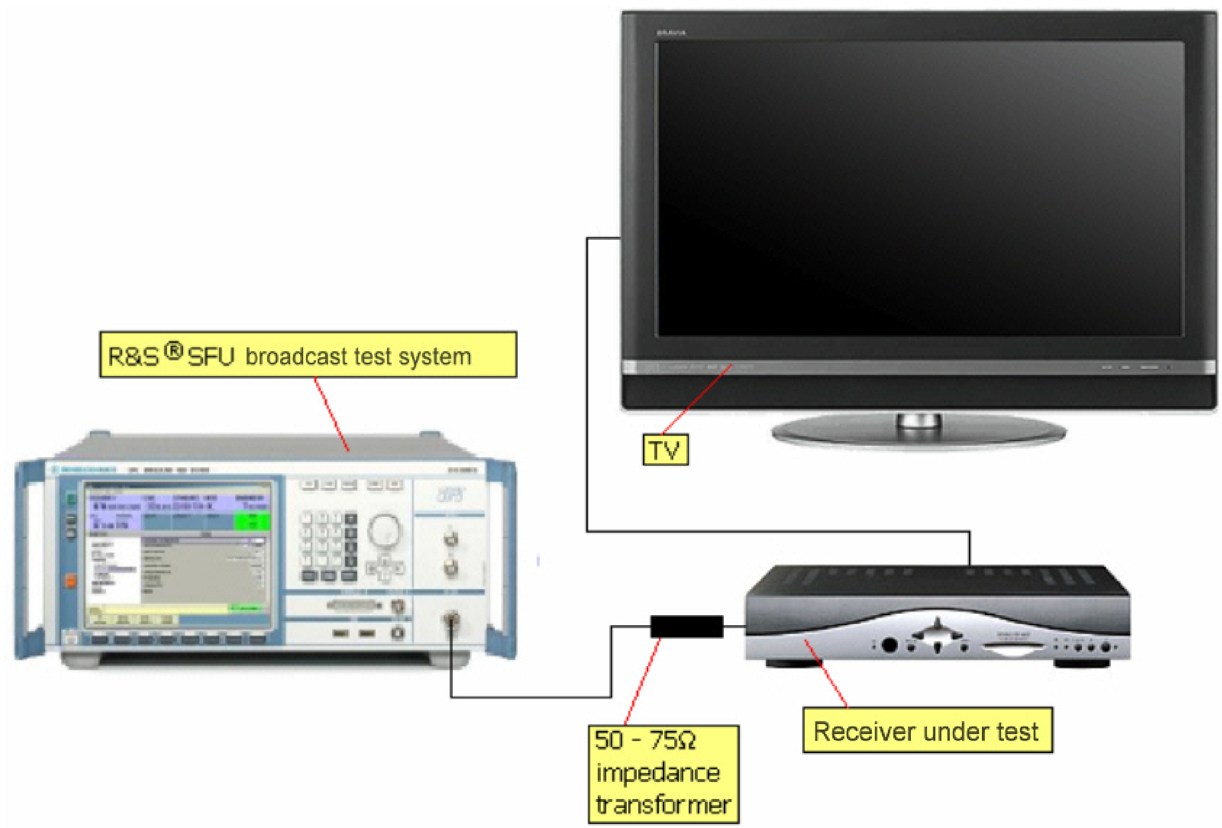


Fig. 16 Test setup

To avoid considerable measurement errors, you need to make use of a matching pad (impedance transformer) in your test setup to match the different impedances. A suitable matching pad for this purpose is the *R&S® RAM 358.5414.02.* You also require a converter to adapt the N-type connector of the matching pad to an F-type connector. The matching pad, connectors and cable assemblies impose signal losses due to mismatching and energy dissipation. Approximate values are:

- Matching pad: $A_{pad} = \pm 4.0dB$ approximately
- Cable: The signal loss depends on the used cable grade. For the *Hubert & Suhner S-Series®* grade cable used in our test, this is: $A_{cable(f)} \approx 0.2\sqrt{f} + 0.045f(dB)$ or for a $50cm$ cable $@602MHz$ this mounts up to approx. $0.1dB$
- Connectors: One may assume a total loss (four connectors) of about $A_{conn} = \pm 0.8dB$

The total of $A_{total\ @\ 602MHz} = 4.0 + 0.1 + 0.8 = 4.9dB$ must be taken into consideration when setting and measuring levels. To obtain more accurate path loss figures a calibration may be performed with the aid of a generator and a 75Ω RF power meter to determine the losses of the entire cable assembly.

Connect the TV to the Y/Rg/Gg outputs of the receiver under test.

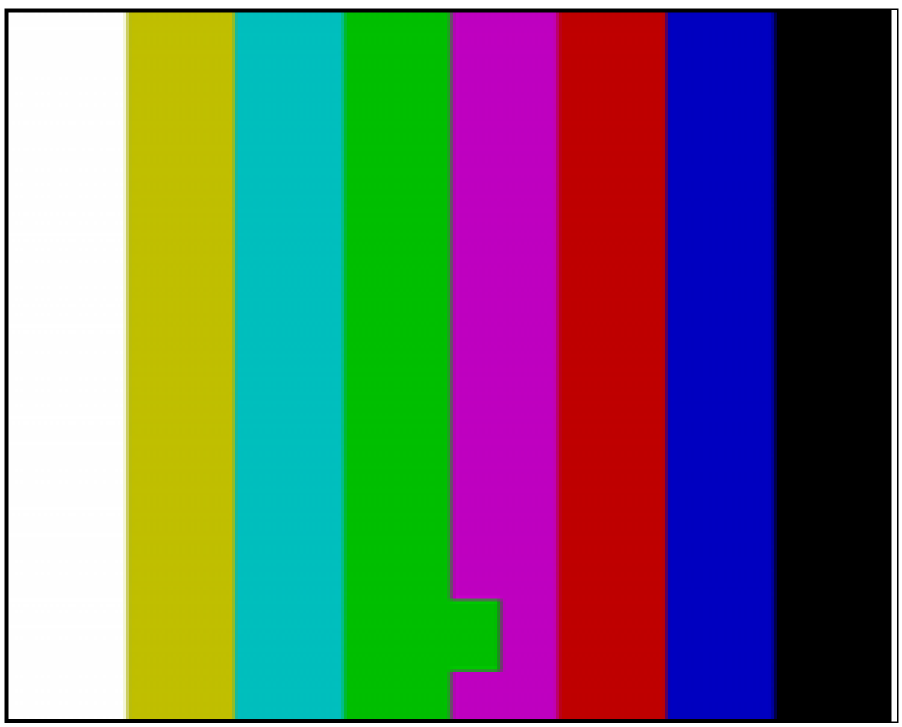


Fig. 17 A color bar test pattern with moving edge makes early signs of receiver failure easy to spot

If you switch the *R&S® SFU* on and use the settings given in the previous chapter, the TV must display the *MCOBAR* test pattern shown in Fig. 17. The moving edge is an important aid for visual detection of receiver failure. Unlike analog TV, in digital TV one cannot determine the difference between still pictures and pictures that are frozen due to interference. .

Enable the following noise source(s) in the Noise/Noise window:

- Noise: Add
- AWG: Off
- Impulsive Noise: On
- Phase Noise: Off

If your instrument doesn't have an *R&S® SFU-K43*, the user interface of earlier versions of the *R&S® SFU-K42* may differ slightly from the example depicted here.

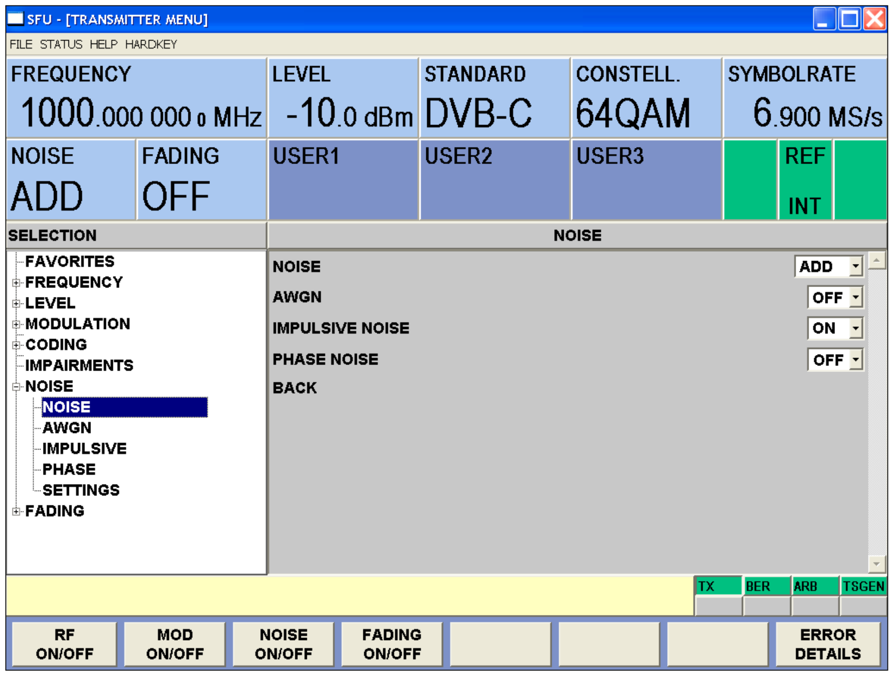


Fig. 18 Impulsive noise only

Set the characteristics of the noise impulses. For example, to subject the receiver to pattern 3 in the *EICTA/MBRAI* or related test standard, use the following settings in the Noise/Impulsive window:

- C/I: 60.0 dB (maximum value)
- Frame duration: 10 ms
- Pulses per burst: 4
- Pulse spacing min: 15 µs
- Pulse spacing max: 35 µs
- Pulse duration: 105.25 µs

For *FCC* tolerance to noise tests on *ATSC* receivers, use:

- C/I: 60.0 dB (maximum value)
- Frame duration: 100 ms
- Pulses per burst: 660
- Pulse spacing min: 250 ns
- Pulse spacing max: 250 ns (minimum)

Set the Bandwidth coupling in the Noise/Settings menu to On as well.

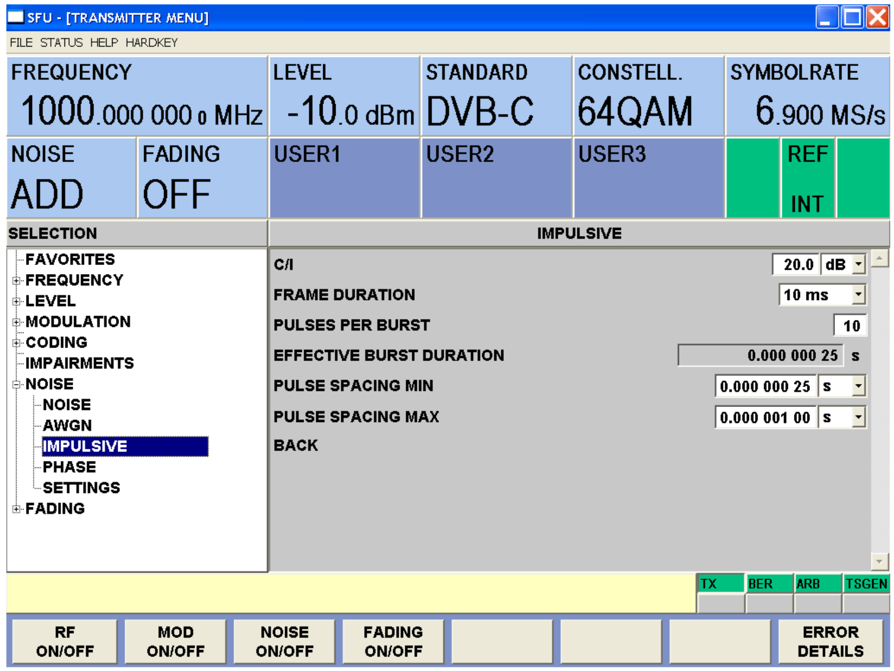


Fig. 19 Impulse timing settings

4.2.1.2 Test Execution

As for the remaining parameters, use the same settings as the ones mentioned in the previous chapter. Set the Modulation and Coding for compatibility with your receiver.

- Set the Level at a value representative for realistic reception conditions, i.e. values between $-80.0.....-50.0dBm$. Correct this value upwards by the $4.9dB$ RF path loss from the cable assembly. The following snippet is the sensitivity figure of a commercially available *DVB-T* receiver.

Min. Input level :	< 92 dBm (for QPSK - CR 2/3 at BER = 2 10^{-4})

Refer to the specifications of your *receiver under test* for details.

- Set the C/I value $@60dB$. When you observe the TV image, there should not yet be any sign of failure..
- Decrease the C/I value in a stepwise fashion until the video is visibly affected. Use large steps until you notice a failure and repeat with smaller steps in the proximity of the failure point to determine a more exact value.
- Record the C/N value.

An early indication of a breakdown is an increased bit error ratio (BER) reading in the decoder stage of the receiver. When the BER increases dramatically, visible failure isn't far off. The table below shows the relationship between the BER and the C/I reading taken before the Viterbi decoder. BER measurements are only possible if the MPEG transport stream from the decoder is accessible. If this is the case, you could use the *R&S® SFU-K60* BER measurement option to determine the point of failure.

C/I (dB)	BER before Viterbi decoder
60	0.0
50	0.0
40	0.0
30	1.7e-7
28	7.7e-6
26	1.6e-4
24	1.5e -3
22	7.0e -3
20	2.1e-2
19	3.1e-2
18	4.4e-2 (breakdown)

Table 3 BER vs. *C/I reading taken before Viterbi decoder*

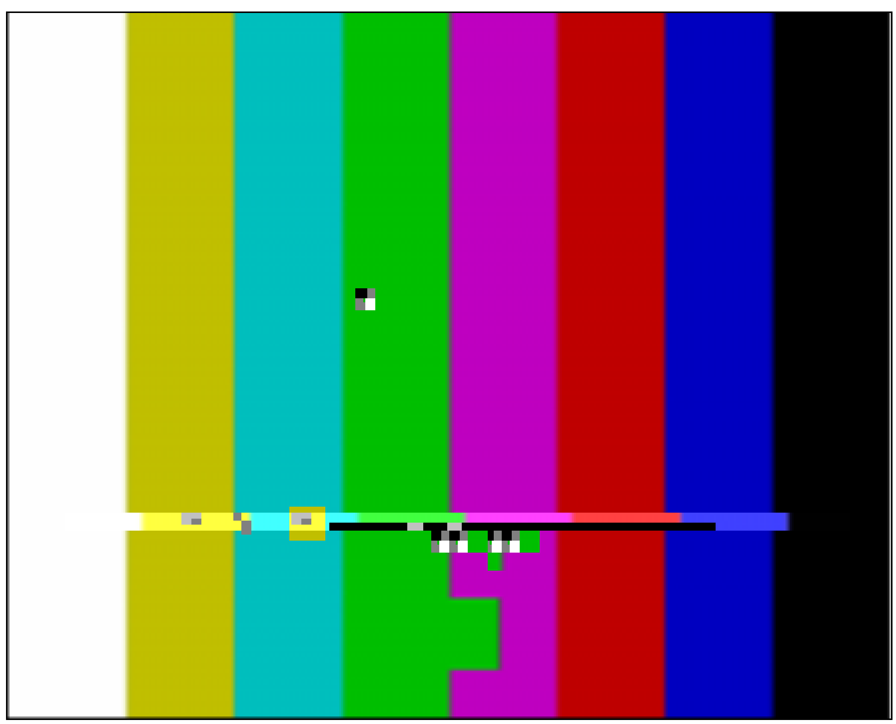


Fig. 20 Receiver breakdown. The interference level passed the threshold at which error correction is no longer possible.

4.2.2 Receiver Performance Under the Influence of Multinoise

4.2.2.1 Preparation

The test scenario in this paragraph demonstrates the amount of flexibility the *R&S® SFU-K43* offers in combination with the *R&S® SFU-K40, -K41,* and *-K42* options for noise susceptibility tests on digital TV receivers. We subject a commercial *DVB-T* receiver to two different kinds of noise (impulsive noise and AWGN) at the same time and determine the receiver's breakdown point for different noise level combinations. This puts the *receiver under test* in a situation that approaches real-life conditions, at least if we ignore multipath fading. Measurements take place at two realistic wanted signal levels of $-50.0dBm$ and $-70.0dBm$. The obtained results are plotted in a two-dimensional graph C/N (AWGN) vs. C/I (Impulsive interference) at the point of breakdown, giving us an immediate graphical impression of receiver performance. Such tests could prove useful in the development stage. The test setup is depicted below.

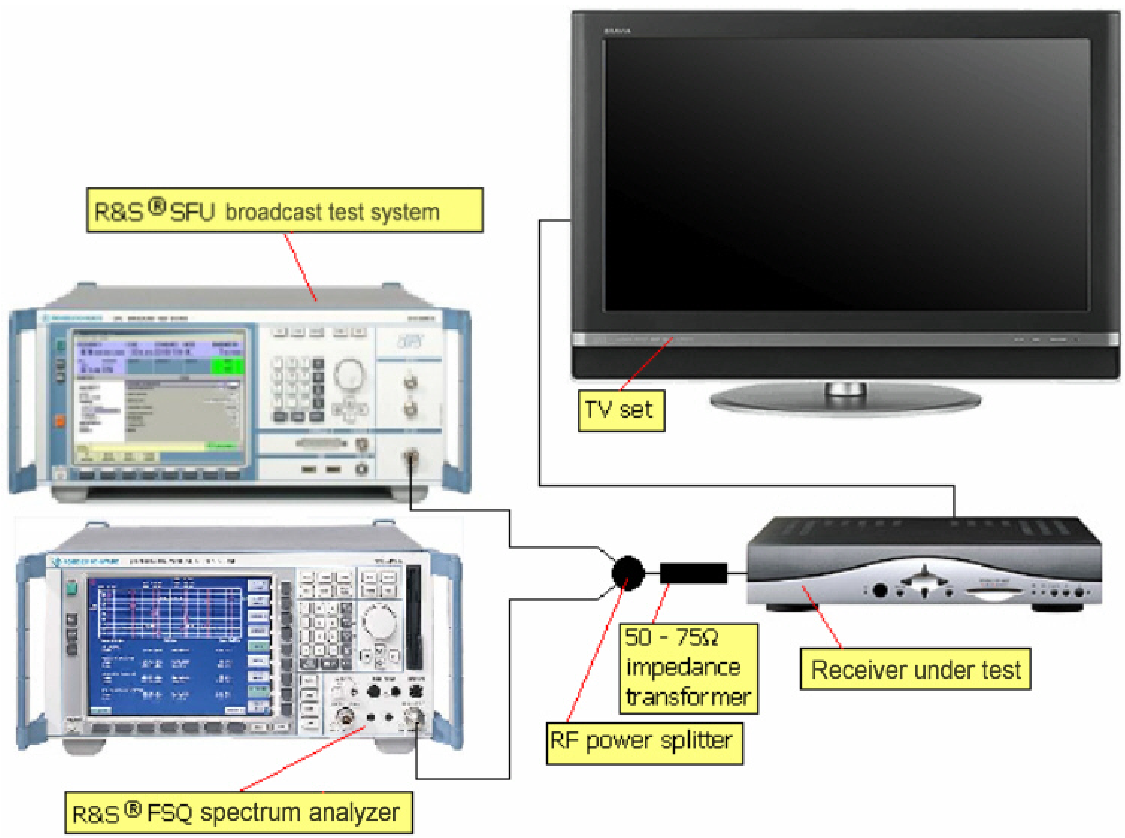


Fig. 21 Test setup for receiver tolerance to multiple noise tests

The equivalent circuit of the above setup may be represented by:

- A wanted *DVB-T* signal C with variable level (via A).
- A Gaussian noise source I_{awgn} with variable attenuator A which allows control over the C/N ratio.
- An impulsive noise source I_{imp} with variable timing and variable attenuator to change the C/I ratio.
- The introduction of a variable amount of phase noise I_{ph}.

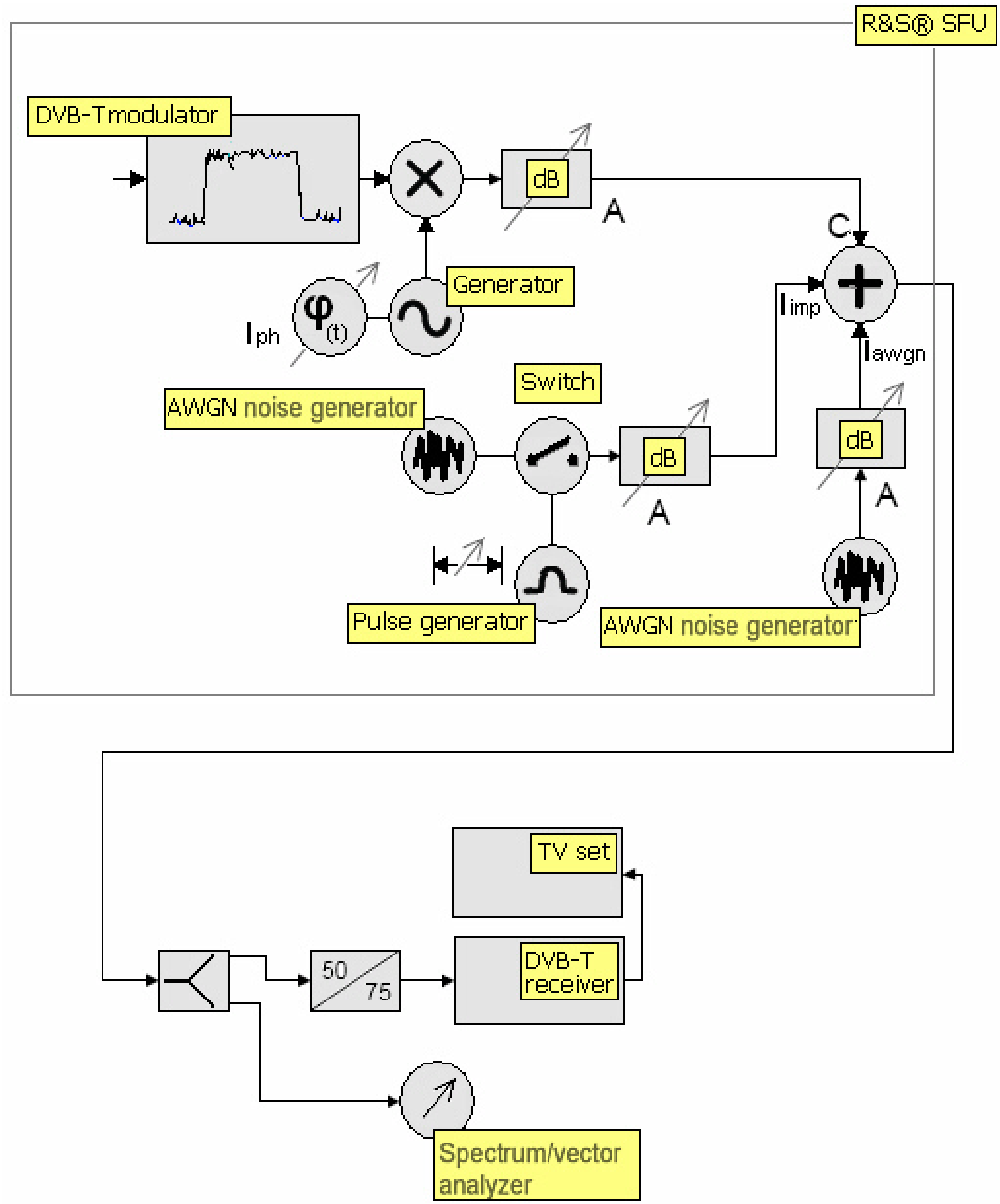


Fig. 22 Equivalent circuit of setup

We connect the *DVB-T receiver under test* to a TV set, allowing us to determine receiver breakdown. This method is rather subjective and part 2 of this Application Note (Phase Noise) shows us how to make use of an *R&S®DVQ video quality analyzer* to determine the point of breakdown in a more objective manner. The BER method used in the previous paragraph may also be used to determine the point of breakdown. You may optionally include a spectrum analyzer or vector network analyzer to monitor the power levels and/or constellation.

The test is executed three times with the following wanted signals:

Test scenario	Wanted signal Level *(dBm)*	FFT size	Constellation	Guard interval	EICTA impulsive interference pattern	Code rate
1	-50.0	*2K*	*64QAM*	1/32	No. 3	3/4
2	-50.0	*2k*	*64QAM*	1/4	No. 3	1/2
3	-70.0	*8K*	*16QAM*	1/4	No. 3	1/2

Table 4 Test signals

- Switch both the AWGN and Impulsive noise sources on in the Noise/Noise menu:
  - Noise: Add
  - AWGN: On
  - Impulsive Noise: On
  - Phase Noise: Off

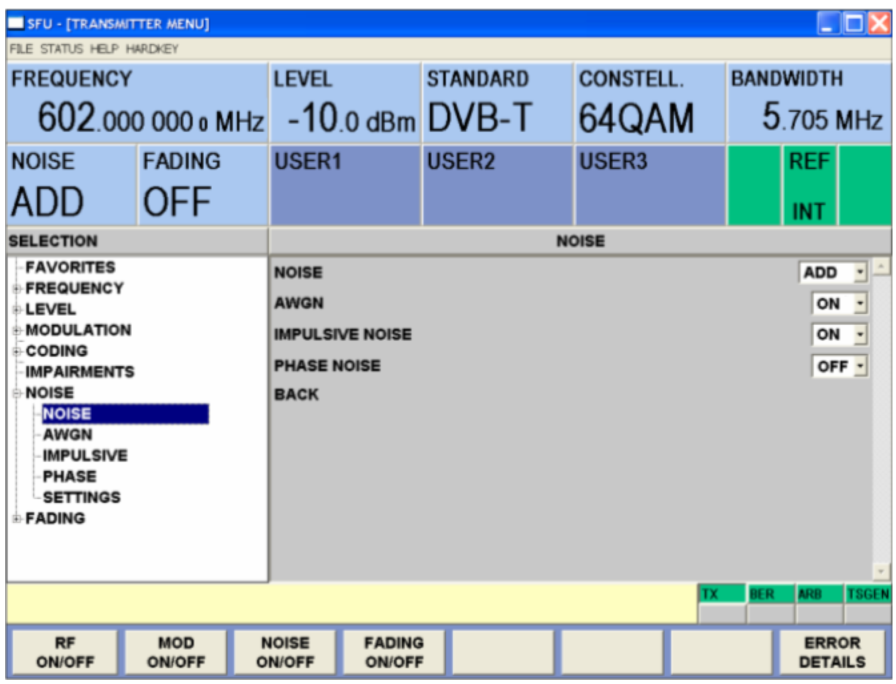


Fig. 23 DVB-T signal with AWGN and impulsive noise

- Switch the Bandwidth Coupling in the Noise/Settings window on if it is off.
- Start the test with the first C/N setting in table 5 i.e. $50.0dB$.

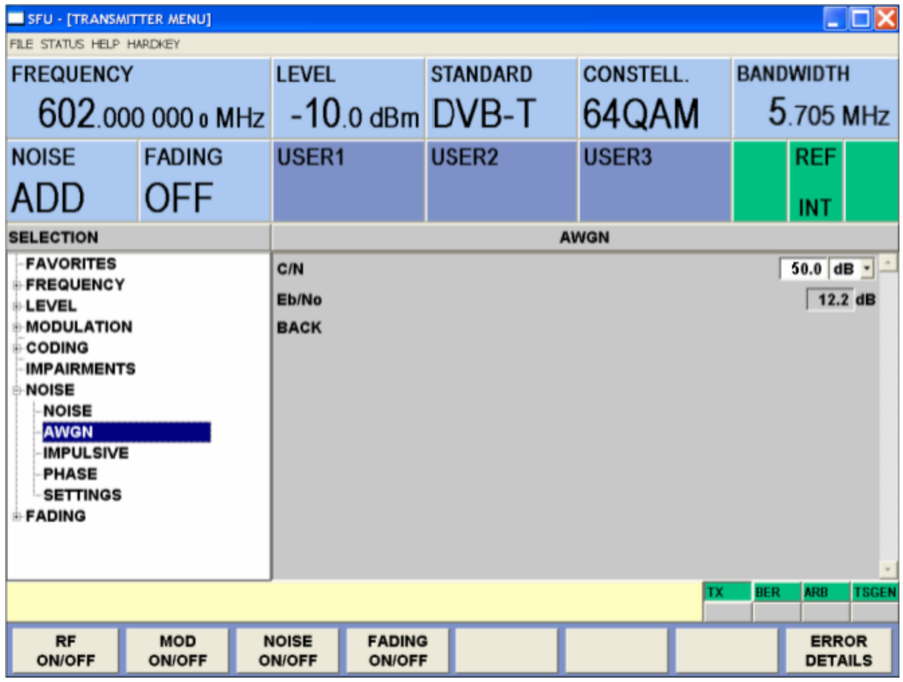


Fig. 24 *AWGN noise level setting*

- Set the parameters in Noise/Impulsive window in accordance with *EICTA* pattern 3.

Test pattern No.	Number of pulses / burst	Minimum / maximum impulse spacing (µs)		Burst duration (µs)
3	*4*	15.0	35.0	105.25

Table 5 Burst pattern settings

- C/I: 50.0 dB
- Frame duration: 10 ms
- Pulses per burst: 4
- Pulse spacing min: 15.0 µs
- Pulse spacing max: 35.0 µs

- Set the Modulation and Coding parameters in accordance with test scenario 1 in table 4.
- Set the output Level to $-50dBm$. Again, take the losses of the RF path into account. That is, the actual Level setting must be approx. $-50.0+4.6=-45.4dBm$.

4.2.2.2 Test Execution

- Increase the C/I setting in $5dB$ steps until the TV image shows signs of reception breakdown, and record the value of the setting. Maintain a $30\sec$ observation period and reduce the level increments to $1dB$ steps in the proximity of the failure point to obtain a more a accurate value.

- Repeat the previous steps with the remaining C/N values in table 5, and repeat the entire test with the other two modulation settings.

4.2.2.3 Test Results

The figures in the following table show our *receiver under test*'s failure point at a given (C/N, C/I) setting for each of the test scenarios in table 4. As several earlier studies, including the one conducted by the DTG group, already established, , figures show the superior performance of the *8K-16QAM* mode in a noisy environment. Since noise performance vs. Doppler performance is a trade-off, this is obviously a factor to be taken into consideration for network planning. The results are depicted graphically in Fig. 5.

C/N (dB)	C/I (dB) @ point of breakdown		
	Test scenario 1	Test scenario 2	Test scenario 3
+50.0	-5.00	-13.50	Above -30.00
+40.0	-4.90	……..	……..
+30.0	-4.00	…….	……..
+28.0	-2.30	…….	……..
+26.0	-2.20	…….	……..
+24.0	-2.1	…….	……..
+23.0	-2.00	-13.00	……..
+22.0	-2.00	-12.50	……..
+21.0	-2.00	-12.00	……..
+20.0	-2.00	-11.00	……..
+19.0	Fails > 24.00	-10.00	……..
+18.0		-9.00	……..
+17.0		-4.00	……..
+16.0		-2.10	……..
+15.0		-2.00	……..
+14.0		-2.00	……..
+13.0		Fails > 15.00	……..
+12.0			……..
+11.0			……..
+10.0			Above -30.00

Table 6 Receiver breakdown point C/N vs. C/I

For lower C/N values, the curve approaches the AWGN level for which the receiver fails in the absence of any impulsive noise in an asymptotical manner as expected.

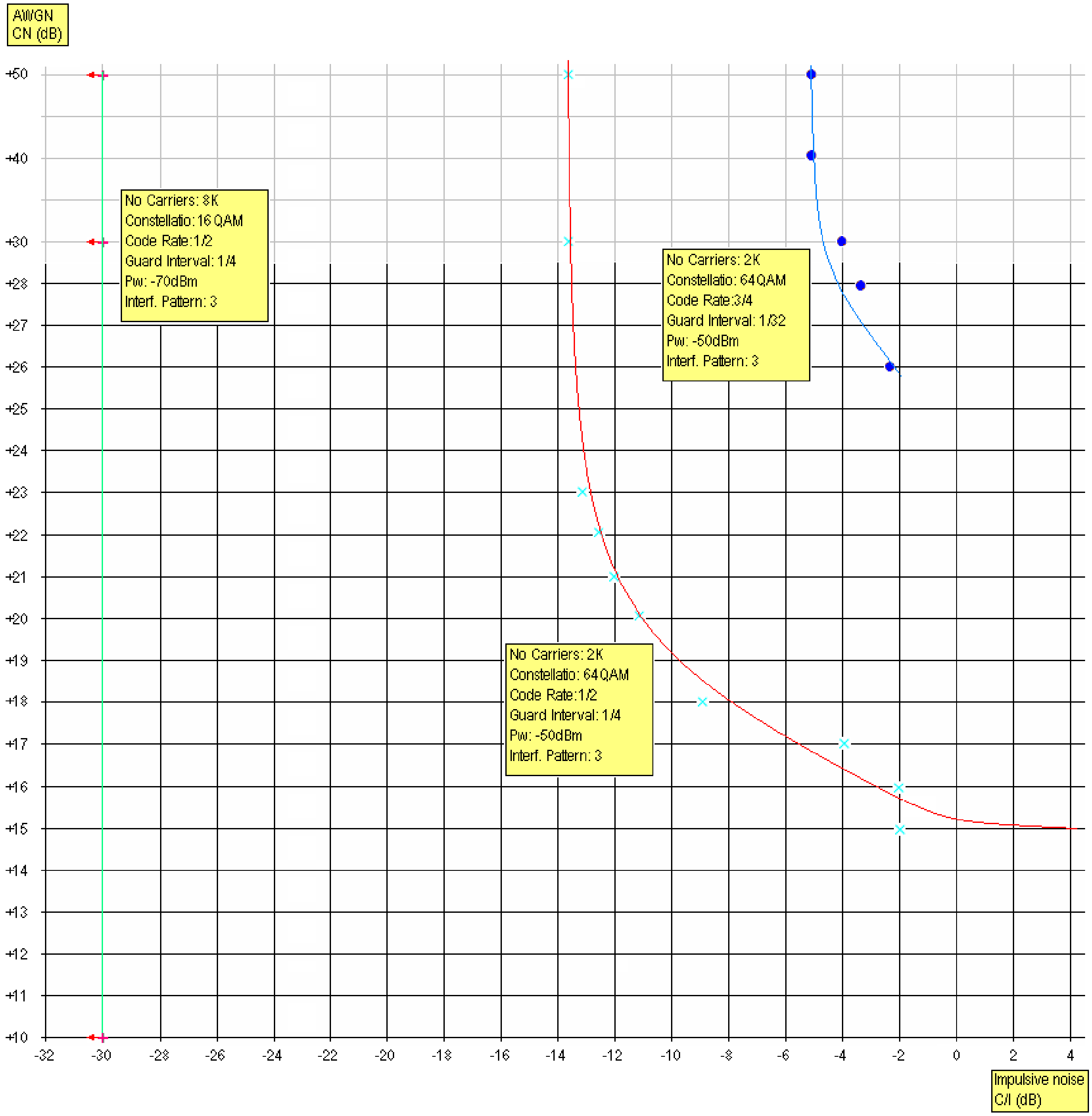


Fig. 25 *Receiver's failure point at a given (C/N, C/I) pair for three different test scenarios*

5 Summary

The *R&S® SFU-K40, -K41* and *-K42* options can generate noise with various characteristics and therefore offer the R&D and broadcasting engineer a great deal of flexibility when analyzing receiver performance under the influence of noise. The *R&S® SFU-K43* opens the door to even more possibilities with its ability to subject the *receiver under test* to different kinds of noise simultaneously. To limit the size of this Application Note, we restricted ourselves to impulsive noise. If you are interested in tests related to phase noise, please refer to part 2.

6 References

Phase noise:

[1] The effects of phase noise in OFDM, EBU technical review 1998, Jonathan Stott.

[2] Understanding the effects of phase noise on orthogonal frequency division multiplexing. IEEE transactions broadcasting volume 47 No2, June 2001, Ana Garcia Armada.

Impulsive noise:

[3] Modeling impulsive interference in DVB-T, EBU technical review 2004, José Lago-Fernández & John Salter.

[4] A tutorial on impulsive noise in COFDM systems, DTG Monograph No.5 DTG group 2001, P.Lewis.

Standards, guidelines and recommendations:

[5] Mobile & portable DVB-T radio access interface specification EICTA/TAC/MBRAI-02-016 Version 0.9.1.

[6] ATSC recommended practice receiver performance guidelines DOC A/74.

[7] Tests of ATSC 8-VSB reception performance of consumer digital television receivers. OET Report, FCC/OET TR 05-1017, Stephen R. Martin.

[8] Digital Video Broadcasting (DVB) Measurement guidelines for DVB systems. Technical Report ETSI TR 101 290 V1.2.1.

User manuals:

[9] R&S® SFU Broadcast Test System operating manual, 2110.2522. 12-05.00, Rohde & Schwarz.

[10] R&S® FSQ Signal Analyzer operating manual, 1155.5047.12-05, Rohde & Schwarz.

[11] Tektronix® TDS680B 2-channel digital real time oscilloscope user's manual, Tektronix.

Related Application noes:

[12] 7BM61_0E: Creating Test Scenarios in Accordance with IEC 62002 (MBRAI) Using the R&S SFU, Rohde & Schwarz

[13] 7BM51_0E: Measuring Bit Error Rate using the R&S SFU-K60 Option, Rohde & Schwarz

7 Additional Information

Our Application Notes are regularly revised and updated. Check for any changes at http://www.rohde-schwarz.com.

Please send any comments or suggestions about this Application Note to Broadcasting-TM-Applications@rohde-schwarz.com.

8 Ordering Information

Type	Designation	Order no.
R&S SFU	Broadcast Test System	2110.2500.02
R&S SFU-B1	Coder Extension 1	2110.7424.02
R&S SFU-B10	Coder Extension 10	2110.7747.02
R&S SFU-B11	ETI Input/Output	2110.7553.03
R&S SFU-B2	Coder Extension 2	2110.8089.02
R&S SFU-B3	Memory Extension 1	2110.7447.02
R&S SFU-B30	Fading Simulator	2110.7530.02
R&S SFU-B31	Fading Simulator Extension to 40 Paths	2110.7547.02
R&S SFU-B4	Memory Extension 2	2110.7453.02
R&S SFU-B5	User I/O	2110.7460.02
R&S SFU-B6	Additional Hard Disk	2110.7501.02.03
R&S SFU-B90	High Power and Overvoltage Protection	2110.8008.02
R&S SFU-K1	DVB-T/H Coder	2110.7301.02
R&S SFU-K10	MediaFLO Coder	2110.7524.02
R&S SFU-K108	AMC Coder	only on request
R&S SFU-K11	T-DMB/DAB Coder	2110.7518.02
R&S SFU-K120	DMB-TH Coder	2110.7760.02
R&S SFU-K190	ATV Standard B/G Coder	2110.8050.02
R&S SFU-K191	ATV Standard D/K Coder	2110.8037.02
R&S SFU-K192	ATV Standard I	2110.8043.02
R&S SFU-K193	ATV Standard M/N Coder	2110.8066.02
R&S SFU-K194	ATV Standard L Coder	2110.8072.02
R&S SFU-K199	Multi ATV Predefined	2110.8089.02
R&S SFU-K2	DVB-C Coder	2110.7324.02
R&S SFU-K20	TS Generator	2110.7476.02
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R&S SFU-K22	TRP Player	2110.7499.02
R&S SFU-K221	T-DMB/DAB Streams	2110.4348.02
R&S SFU-K23	Video Generator	2110.7799.02
R&S SFU-K3	DVB-S/DSNG Coder	2110.7330.02
R&S SFU-K30	Enhanced Fading	2110.7560.02
R&S SFU-K32	DAB Gaussian Fading	2110.7630.02
R&S SFU-K35	ARB Generator	2110.7601.02
R&S SFU-K351	T-DMB/DAB Waveforms	2110.4277.02
R&S SFU-K352	DVB-H Waveforms	2110.4425.02
R&S SFU-K353	DRM Waveforms	2110.4554.02
R&S SFU-K354	DTV Interferers	2110.4690.02
R&S SFU-K4	ATSC/8VSB Coder	2110.7353.02
R&S SFU-K42	Impulsive Noise	2110.7676.02
R&S SFU-K43	Multinoise Use	2110.7682.02
R&S SFU-K5	J.83/B Coder	2110.7360.02
R&S SFU-K6	ISDB-T Coder	2110.7376.02
R&S SFU-K60	BER Measurements	2110.7782.02
R&S SFU-K7	DMB-T Coder	2110.7382.02
R&S SFU-K8	DVB-S2 Coder	2110.7399.02
R&S SFU-K80	Extended I/Q	2110.7953.02
R&S SFU-K81	Realtime Disabled	2110.7960.02
R&S SFU-K82	Realtime Enabled	2110.7976.02
R&S SFU-K9	DIRECTV	2110.7401.02
R&S SFU-U43	Upgrade Kit for R&S SFU-K43	2110.7699.02
R&S DV-DVBH	DVB-H Stream Library	2085.8704.02
R&S DV-H264	H.264 Stream Library	2085.7650.02
R&S DV-HDTV	HDTV Sequences	2085.7650.02
R&S DV-ISDBT	ISDB-T Stream Library	2085.9146.02
R&S DV-TCM	Test Card M Streams	2085.7708.02

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