Products: R&S® SFU Broadcast Test System, R&S® SFE Broadcast Tester, R&S® AFQ100 I/Q Modulation Generator

Doc.A/74 ATSC receiver performance tests made easy with the R&S®SFU Broadcast Test System and the R&S®SFE Broadcast Tester

Application Note

The Federal Communications Commission (FCC) ruled that no later than February 17, 2009 all analogue NTSC broadcasting must come to an end. It is therefore not surprising that the demand for ATSC receivers is high at the time this application note was published. ATSC TV sets and set-top are subject to the ATSC recommended practice Doc.A/74 *"Receiver Performance Guidelines"* before they can be sold freely in the markets that adopted the standard. Although the number of tests defined in Doc.A/74 is less extensive then the ones for their DVB-T counterparts (EN62002, MBRAI) some clarification is nevertheless due.

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Subject to change – H.Gielen 01.2008 – 7BM71_1E

Contents

1 Introduction

Reliable reception is a requirement for any terrestrial broadcasting system, and therefore also for the *Advanced Television System Committee* (ATSC) system used in North America and Korea. The *ATSC* recommended practice *Doc.A/74 "receiver performance guidelines"* defines six principal tests with the aim to ensure adequate ATSC receiver performance under unfavourable conditions. These six principal tests are:

- *Minimum and maximum receiver sensitivity*
- *Receiver multi-signal overload*
- *Tolerance to transmitter carrier phase noise*
- *Tolerance to impulsive noise bursts*
- *Tolerance to other ATV and DTV signals*
- *Behaviour under multi-path fading conditions*

Anyone familiar with the *IEC62002, Nordig Unified* and *DTG D-Book* counterparts for DVB-T receivers will notice that the number of tests is considerably less. One of the reasons is the absence of multiple modulation schemes in ATSC. Indeed ATSC only employs one single 8VSB modulation mode, contrary to the numerous OFDM carrier/constellation modes of DVB-T. In addition the impulsive noise pattern to which the receiver is subjected in the "tolerance to impulsive noise bursts" test is limited to one.

Owing to the fact that ATSC uses a residual carrier, some tests defined in *Doc.A/74* are unique. This includes "tolerance to transmitter carrier phase noise" and certain "multi-path fading conditions" to determine the receiver's performance in the proximity of airports where considerably Doppler frequency shifts take place through signals that bounce off on the large and highly reflective surface of fast moving aircraft.

The *R&S®SFU* incorporates all the functionality to execute most *Doc.A/74* tests directly without any additional test equipment. For "tolerance to overload with multiple ATV/DTV signal" and "behaviour under multi-path fading conditions" some additional equipment respectively set-up effort is required. In this application note we clarify the configuration and execution of the defined tests with an *R&S®SFU.*

2 Test equipment

Most tests defined in *ATSC Doc.A/74* can be performed with only one single *R&S®SFU* fitted with the relevant options and a medium range spectrum analyzer like the *R&S®FSL* or *FSP*. The table below shows the options and additional instruments required to perform a specific test.

Table 1 Overview required test equipment / options for the main R&S SFU

	Device options											
Tests	R&S® SFU-B90 (High output power)	TS generator (R&S®SFU-K20) or TRP Player (R&S®SFU-K22)	ATSC/8VSB coder (R&S®SFU-K4)	Phase noise (R&S®SFU-K41)	Impulsive Noise (R&S®SFU-K42)	Fading simulator, 20 paths (R&S®SFU-B30)	Interferer management (R&S®SFU-K37)	Arbitrary generator (R&S®SFU-K35)	Memory extension (R&S®SFU-B3)	ATV predefined (R&S®SFU-K199)	DTV Interferer (R&S® SFU-K354)	**Additional Generators**
Receiver sensitivity		X	X									
Multi-signal overload		X	X				X	X				X
Phase noise		X	X	X								
Impulsive noise		X	X		X							
Co-channel interference NTSC	X	X	X				X		X	X		
Co-channel interference ATSC	X	X	X				X	X	X		X	
Adjacent channel rejection NTSC	X	X	X				X		X	X		
Adjacent channel rejection ATSC	X	X	X				X	X	X		X	
Taboo channel rejection NTSC		X	X				X		X	X		X[1)]
Taboo channel rejection ATSC		X	X				X	X	X		X	X[1)]
Single static echoes amplitude / equalizer profile		X	X			X						
Single dynamic echoes		X	X			X						
Multiple Dynamic echoes		X	X			X						
Dynamic multi-path in presence of Doppler frequency shift and airplane flutter		X	X			X						

1) Due to the maximal IQ output bandwidth of 80 MHz from the R&S SFU, scenarios N+14 and N+15 require an additional test transmitter.

In order to generate multiple signal overload as well as taboo channels outside the IQ output bandwidth of the R&S SFU, two broadcast tester R&S SFE can be used additionally. The minimum configuration for those interferer signals could look as follows:

Table 2 Overview required test options for the additional R&S SFEs

Tests	ATSC/8VSB coder (R&S®SFE-K4)	ATV M/N coder (R&S®SFE-K193)
Receiver sensitivity		
Multi-signal overload	X	X
Phase noise		
Impulsive noise		
Co-channel interference NTSC		
Co-channel interference ATSC		
Adjacent channel rejection NTSC		
Adjacent channel rejection ATSC		
Taboo channel rejection NTSC	X	X
Taboo channel rejection ATSC	X	X
Single static echoes amplitude / equalizer profile		
Single dynamic echoes		
Multiple Dynamic echoes		
Dynamic multi-path in presence of Doppler frequency shift and airplane flutter		

3 Tests procedures

3.1 Minimum and maximum receiver sensitivity

3.1.1 General

Doc.A/74 states that an ATSC receiver must successfully operate in a noiseless channel with signal levels between -83 dBm and -8 dBm at the antenna input.

3.1.2 Test setup

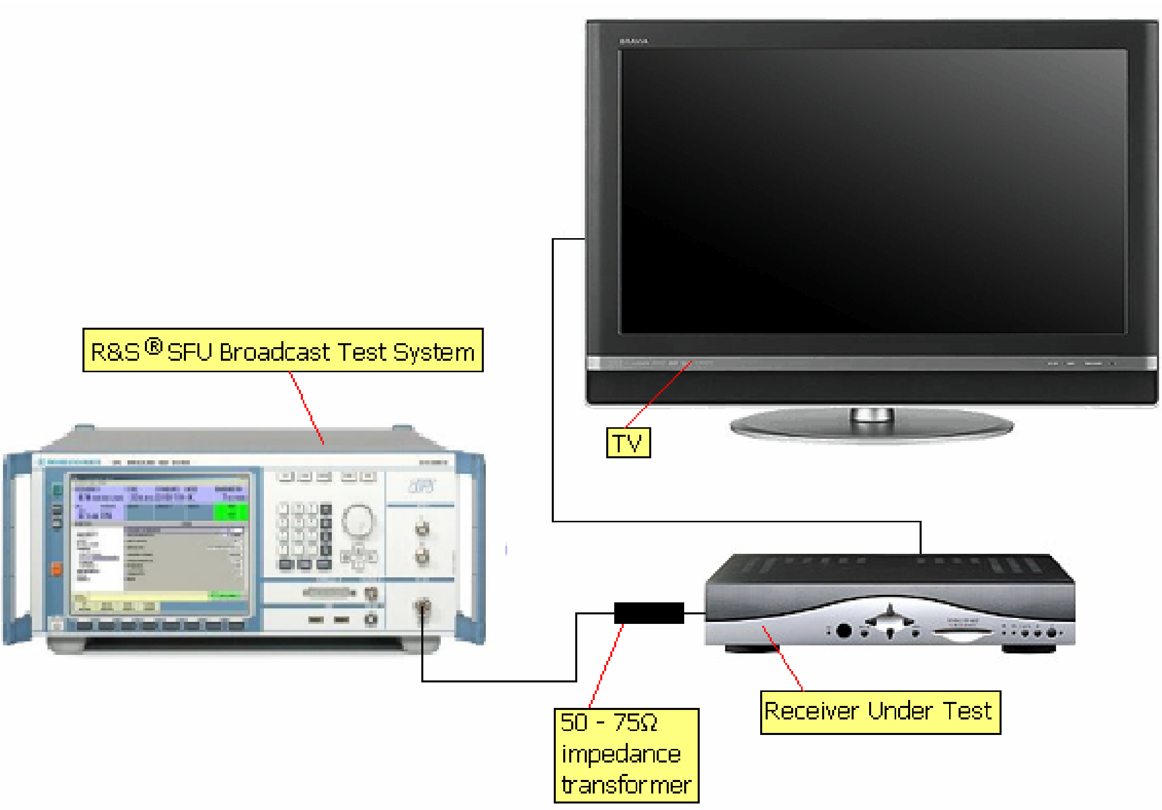
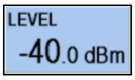


Figure 1 "Receiver sensitivity" test set-up

Connect the *R&S®SFU's* RF-Out connector to the antenna input of the receiver under test via a shielded 50 Ω cable. Except for some professional models the antenna input of digital TV receivers for the consumer market is 75 Ω. Use an *R&S® RAM 358.5414.02* matching pad to convert the impedance.

3.1.3 Test procedure

- Press the Preset button, set-up an ATSC service on the *R&S® SFU* and tune the receiver under test at the service.
- Minimum sensitivity: Decrease the Level setting 

until you reach the point-of-failure (POF). This value must be lower than -83 dBm. Please also take the insertion loss of the 50 – 75 Ohm matching pad into consideration.
- Maximum sensitivity: Increase the Level setting again to -50 dBm. Increase the Level further until you reach the POF. This level must be larger than -8 dBm.

The output power of the *R&S® SFU-B90* is limited to +19 dBm. It is possible that the maximum sensitivity of certain receiver models is above this value.

3.2 Multi-signal overload

3.2.1 General

Doc.A/74 specifies that the receiver has a certain tolerance (-8 dBm total power) to multiple high level TV signals. Other than saying "more than one" the document does not enforce the number and type (ATSC/NTSC) of these TV signals. In fact it suggests deriving the signal by amplifying the local VHF/UHF spectrum received via an aerial. This is not always obvious in a laboratory setting.

The *R&S®SFU-K193/199* option allows you to generate one additional NTSC adjacent channel. To generate additional ATSC/NTSC signals use the set-up of figure 2. Additional interferer can also be generated by using other signal generators, such as R&S SFQ, R&S SFL or R&S SFM.

Table 3 Possible generator combination for multi-signal overload test

Test transmitter 1 (main)	Test transmitter 2 (aux)	Test transmitter 3 (aux)	Number and type of adjacent TV signals				
			1 ATSC/ 1 NTSC	2 NTSC	2 ATSC	1 ATSC/ 2 NTSC	2 ATSC/ 1 NTSC
R&S®SFU	*R&S®SFE*	*R&S®SFE*	Yes	Yes	Yes	Yes	Yes

3.2.2 Test setup

- Use the set-up of figure 3.

3.2.3 Possible Test procedure

- Press the Preset button, set-up an ATSC service on the *R&S® SFU* and tune the receiver under test at the service.

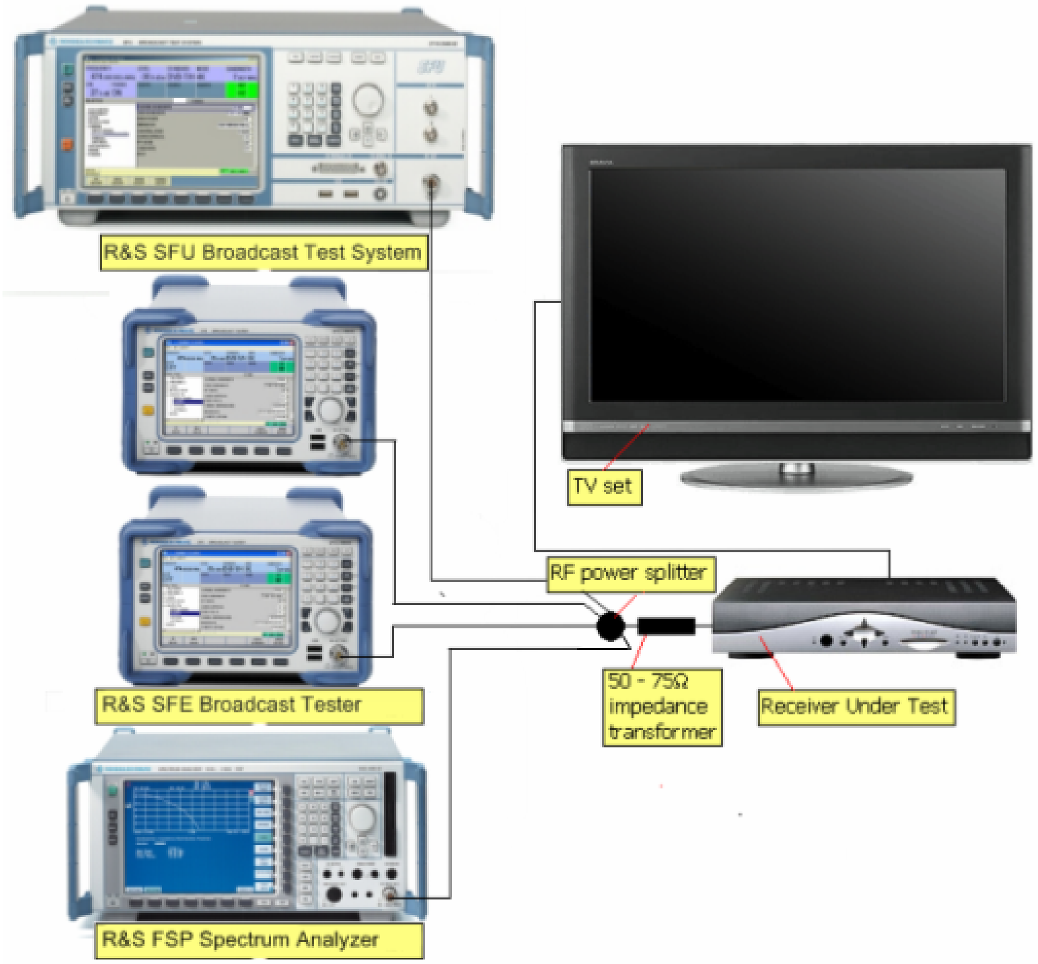


Figure 2 Multi-signal overload with two additional test transmitter (R&S® SFE)

- Set the Interferer to ATV predefined. Select Standard M/N and adjust the Frequency Offset to -5.06 MHz. Set the C/I setting at 0.0 dB.
- Generate e.g. two ATSC signals with the *R&S® SFE*. Set the Level setting of instruments at -20 dBm and the Frequency in 6.0 MHz steps above the chosen wanted channel on the *R&S® SFU.*
- Increase the Level setting of the *R&S® SFU* or *R&S® SFEs* or both until you reach the POF.

- Perform a channel power measurement with a spectrum analyzer or calculate the total power of all signals at the POF. This value must exceed -8 dBm.

3.3 Phase noise performance

3.3.1 General

To reduce the energy an ATSC signal is transmitted in vestigial sideband (8VSB). The disadvantage of this method however is that the carrier must be re-generated within the receiver before any demodulation can take place. A common method is locking a local oscillator to whatever is left of the carrier via a phase lock loop. The method is unfortunately very sensitive to phase noise and it is therefore no wonder that *Doc.A/74* includes a test to check this particular function in the receiver.

In order to pass qualification the receiver must tolerate a level of phase noise that equals or exceeds -80 dBc/Hz at 20 kHz away from the carrier. *Doc.A/74* does not specify any phase noise profile (spectrum) meaning that the *R&S® SFU-K41* default profile can be used.

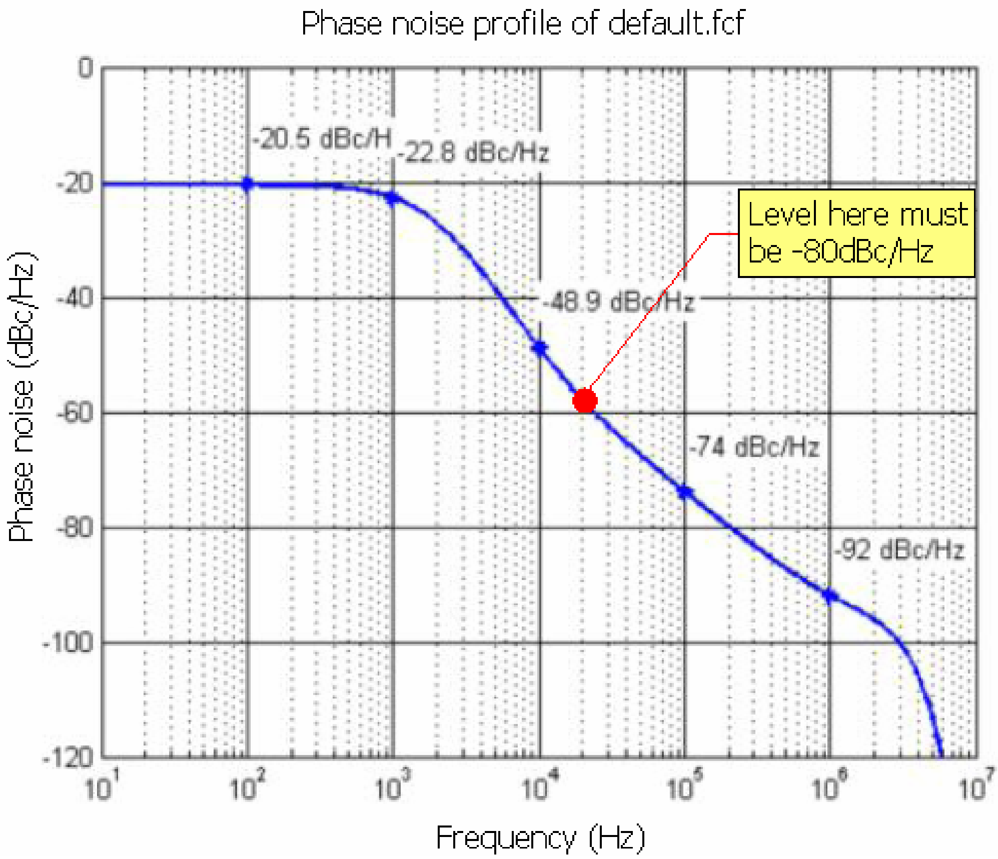


Figure 3 Default phase noise profile of the R&S® SFU-K41

Unfortunately the *R&S® SFU-K41* specifies phase noise levels only at 10 kHz respectively 100 kHz off the carrier leaving the user clueless about the level at 20 kHz.

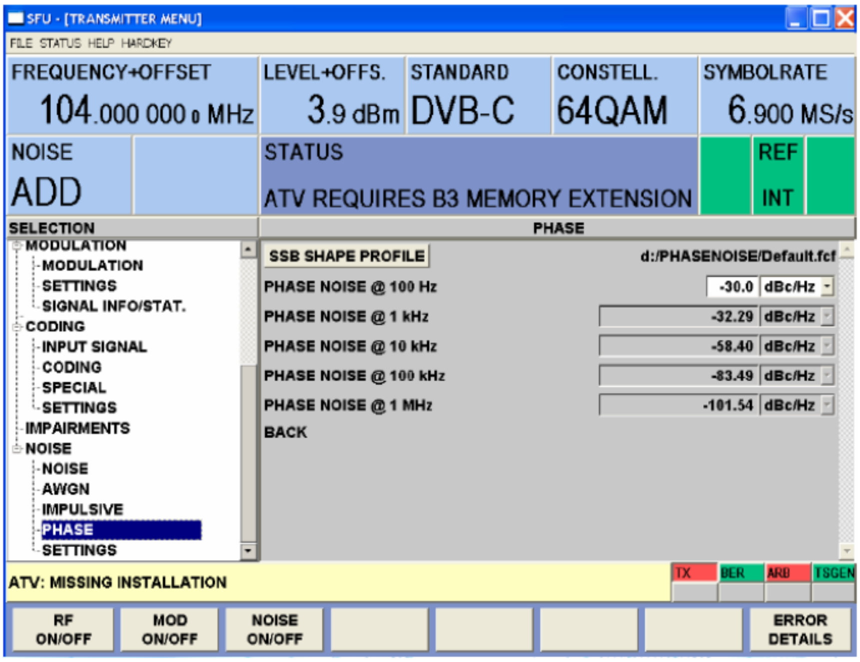


Figure 4 Settings on the R&S® SFU-K41 Phase Noise option

Use one of the two methods to verify the noise level at 20 kHz.

- Method 1: Set the *R&S® SFU-K41* to Noise only. In this mode the instrument generates an unmodulated carrier which is subjected to phase noise.

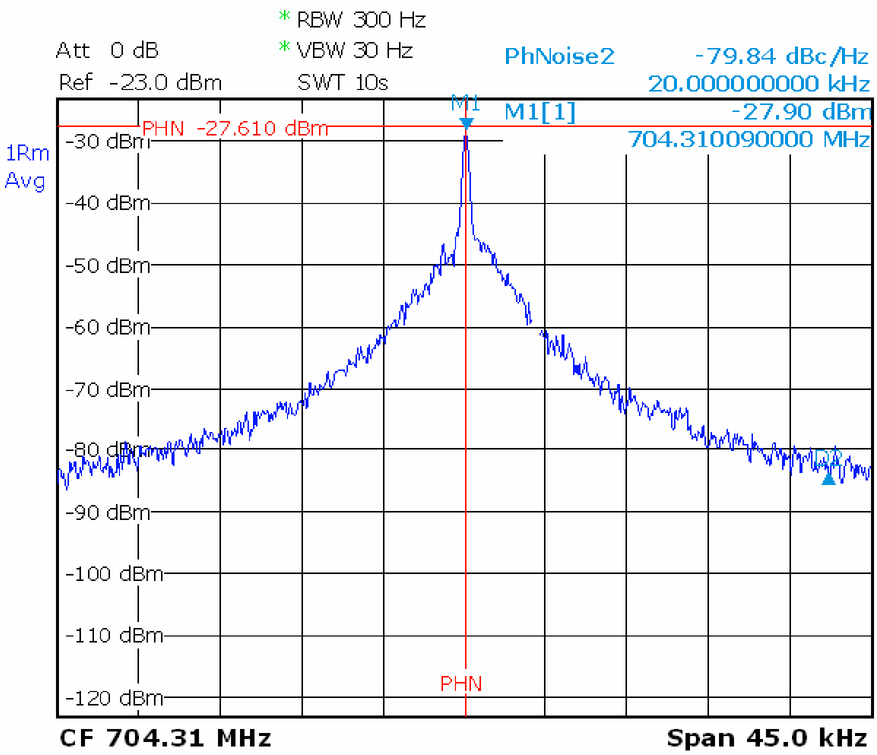


Figure 5 Phase noise level measurement at 20 kHz off the carrier

Measure the noise level at 20 kHz off the carrier with the spectrum analyzer's phase noise measurement function. Use the Detector, Span, Averaging, and RBW settings of figure 6.

- Method 2: A phase noise profiling tool is available via application note *7BM63 "Phase Noise Profile Creator for the R&S® SFU"*.
  1) Use the tool to define a profile with the following coordinates: -45 dBc/Hz at 1 kHz, -80.0 dBc/Hz at 20 kHz.
  2) Copy the file generated by the tool via a memory stick on the instrument and load the profile (SSB Shape profile button) into the *R&S® SFU-K41.*
  3) Set Phase noise @100Hz at -45 dBc/Hz. The phase noise level at 20 kHz is now fixed at -80.0 dBc/Hz.

3.3.2 Test setup

- Maintain the basic test set-up of figure 1.

3.3.3 Test procedure

- Press the Preset button, set-up an ATSC service on the *R&S® SFU* and tune the receiver under test at the service.
- Set Noise to Noise only.
- Set Phase noise to on.
- Adjust the phase noise level at 20 kHz to -80 dBc/Hz as described in the previous paragraph.
- Set Noise to Add.
- Increase the Phase Noise @ 100Hz reading until you reach the POF.
- Set Noise to Noise only
- Measure the phase noise level at 20 kHz once more.
- Record this value. The value should exceed -80 dBc/Hz.

3.4 Burst noise performance

3.4.1 General

Doc.A/74 specifies that the receiver must tolerate a noise signal that is impulsive in nature with a signal-to-interference ratio of -5 dB or less. This impulsive white noise burst must have a duration of 165µs and repeat itself at a rate of 10 Hz. Such signal is depicted in figure 7.

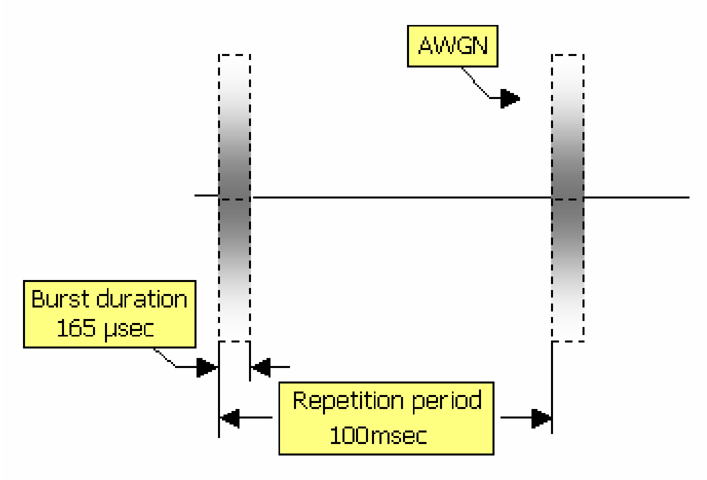


Figure 6 Impulsive noise burst as specified in Doc A/74

Such signal can be generated with the *R&S®SFU-K42* impulsive noise option. Since the *R&S®SFU-K42* works with a basic impulse duration of 250ns use the following settings in the impulsive noise menu:

- Pulses per burst : 660 (660 x 0.25 µs = 165 µs).
- Frame duration : 100 ms.

One may verify the timing accuracy of the impulse noise bursts with an oscilloscope of adequate bandwidth (≥ 300 MHz). A procedure is given in application note 7BM64_0E *"Tolerance to noise tests for DTV receivers with the SFU-K41-42-43 Part I Impulsive Noise".*

3.4.2 Test setup

- Maintain the basic test set-up of figure 1.

3.4.3 Test procedure

- Press the Preset button, set-up an ATSC service on the *R&S® SFU* and tune the receiver under test at the service.
- Switch the impulsive noise on. Set the C/I at 15 dB.
- Eventually verify the timing and level of the impulsive noise as described in application note 7BM50_0E.
- Decrease the C/I setting in the impulsive noise menu until the receiver reaches the POF.
- Record the C/I setting and verify if this exceeds -5 dB.

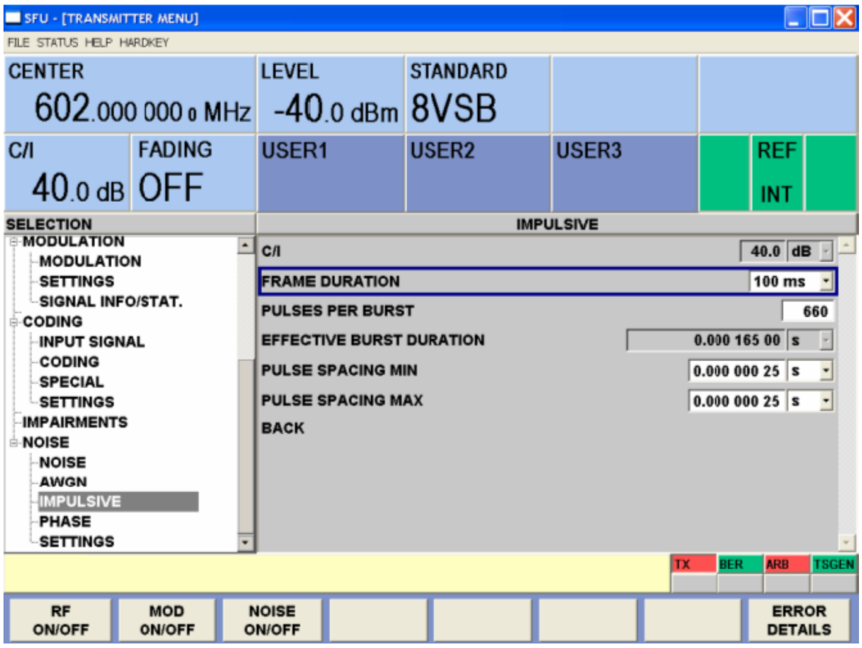


Figure 7 R&S®SFU-K42 Settings for ATSC burst noise performance test

3.5 Tolerance to other ATV and DTV signals

3.5.1 Co-channel rejection

3.5.1.1 General

This test determines the sensitivity of the receiver to a weaker interfering ATSC or NTSC signal transmitted by another transmitter on the same frequency in a different geographical location. *Doc.A/74* recommends that the receiver tolerates ATSC and NTSC co-channel interferers with levels equal or exceeding the ones specified in the following table. The test must be executed at 2 different wanted signal levels.

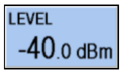
Table 4 Minimum wanted signal/interferer (S/I) limits for NTSC and ATSC co-channels.

Wanted signal level dBm	**NTSC co-channel minimum S/I ratio** dB	**ATSC co-channel minimum S/I ratio** dB
-68.0	+2.5	+15.5
-53.0	+2.5	+15.5

3.5.1.2 Test setup

- Maintain the basic test set-up of figure 1.

3.5.1.3 Test procedure NTSC interferer

- Press the Preset button, set-up an ATSC service on the *R&S® SFU* and tune the receiver under test at the service.
- Set the Level setting of the *R&S®SFU* at -68 dBm. 

- Set the Interferer to ATV predefined. Select the M/N predefined standard and keep the Interferer Frequency Offset at 940 kHz.
- Set the Interferer Attenuation setting at 20 dB.
- Decrease the Interferer Attenuation until the receiver reaches its POF.
- Record this value. This value must not be higher than +2.5 dB.
- Repeat the test with a Level setting of -53.0 dBm.

Table 5 Minimum S/I limits for NTSC co-channel.

Wanted signal level dBm	**Minimum S/I ratio** dB
-68.0	+2.5
-53.0	+2.5

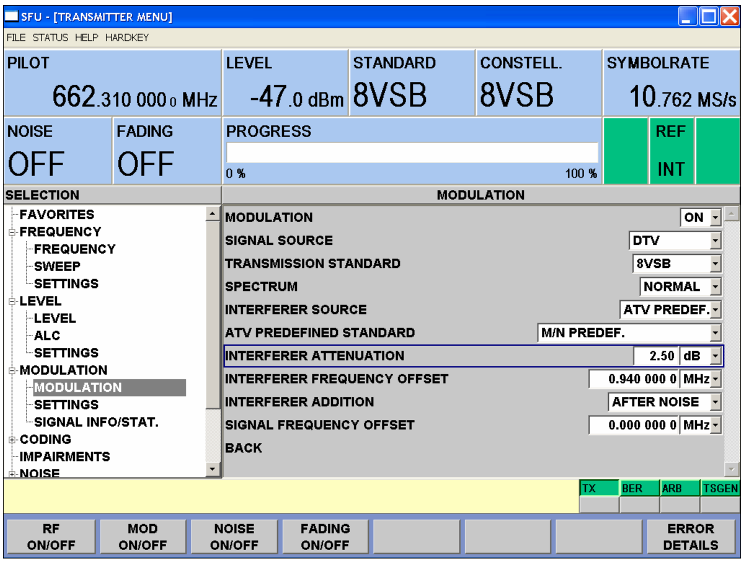
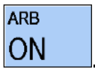
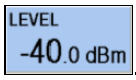


Figure 8 Interferer settings for co-channel test

The reason ne may verify the timing accuracy of the impulse noise bursts with an oscilloscope of adequate bandwidth (≥ 300 MHz). A procedure is given in application note

3.5.1.4 Test procedure ATSC interferer

- Press the Preset button, set-up an ATSC service on the *R&S® SFU* and tune the receiver under test at the service.
- Load the ATSC waveform from the *R&S®SFU-K354* library in the *R&S®SFU-K35* Arbitrary waveform generator (Load waveform in Arb menu). Start the arbitrary waveform generator 

.
- Set the Level setting of the *R&S® SFU* at -68 dBm 

.
- Set the Interferer to ARB. Start the arbitrary waveform generator and keep the Interferer Frequency Offset at 0.0 MHz. Set the Interferer Attenuation setting at 20 dB.
- Decrease the Interferer Attenuation setting until the receiver reaches the POF.
- Record this value. This value must not be higher than +15.5 dB.
- Repeat the test with a Level setting of -53 dBm.

Table 6 Minimum S/I limits for ATSC co-channel

Wanted signal level dBm	**Minimum S/I ratio** dB
-68.0	+15.5
-53.0	+15.5

3.5.2 Adjacent channel rejection

3.5.2.1 General

This test determines the sensitivity (selectivity) of the receiver to strong ATSC or NTSC signals transmitted in the upper and lower adjacent frequency channel. *Doc.A/74* recommends that the receiver tolerates ATSC and NTSC adjacent channel interferers with levels equal or exceeding the ones specified in the following table. The test must be executed at 3 different wanted signal levels.

Table 7 Minimum S/I limits for NTSC and ATSC adjacent channels.

Wanted signal level dBm	**NTSC adjacent channel minimum S/I ratio** dB	**ATSC adjacent channel minimum S/I ratio** dB
-68.0	-40	-33
-53.0	-35	-33
-28.0	-26	-20

3.5.2.2 Test setup

- Maintain the set-up of figure 1.

3.5.2.3 Test procedure NTSC interferer

- Follow the same test procedure as defined in 3.5.2 however this time with an Interferer Frequency Offset of 12.94 MHz for the upper adjacent channel, respectively -13.05 MHz for the lower adjacent channel.
- Set the Signal Frequency Offset at 6 MHz respectively -8.0 MHz.
- Adjust the Pilot Frequency with -6.0, respectively 8.0 MHz to compensate for the non-zero Signal Frequency Offset.

In principle one can perform this test with an Interferer Frequency Offset of 6.94 MHz respectively -5.06 MHz and leave the Signal Frequency Offset at zero. However due to the high interferer level, the wanted signal operates at the lower end of the instrument range. This leads to a comparatively higher residue carrier inside the wanted signal resulting in distorted test results. The residue carrier can be shifted out of the wanted signal band by introducing a Signal Frequency Offset.

Table 8 Interferer frequency offset, signal frequency offset, and pilot frequency offset settings

	Interferer frequency offset MHz	**Signal frequency offset** MHz	**Pilot frequency (Main frequency setting in frequency menu)** MHz
Upper adjacent channel	12.94	6.0	Wanted channel frequency - 6.0
Lower Adjecent Channel	-13.06	-8.0	Wanted channel frequency + 8.0

- Repeat the test with the Level settings and minimum S/I tolerances defined in the following table.

Table 9 Minimum S/I limits for NTSC adjacent channel

Wanted signal level dBm	**Minimum S/I level** dB
-68.0	-40
-53.0	-35
-28.0	-26

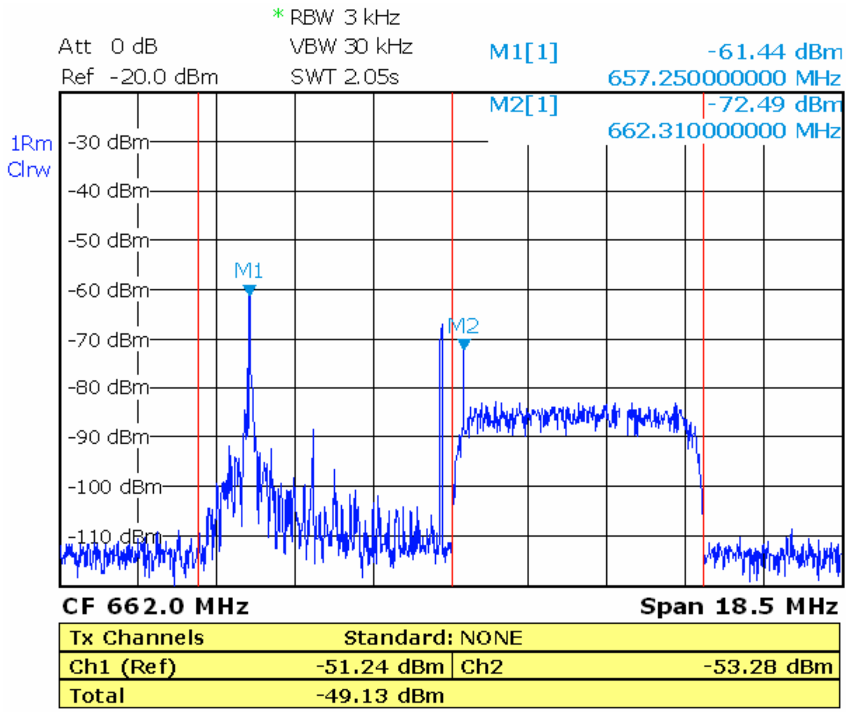


Figure 9 Wanted ATSC signal with lower adjacent NTSC signal

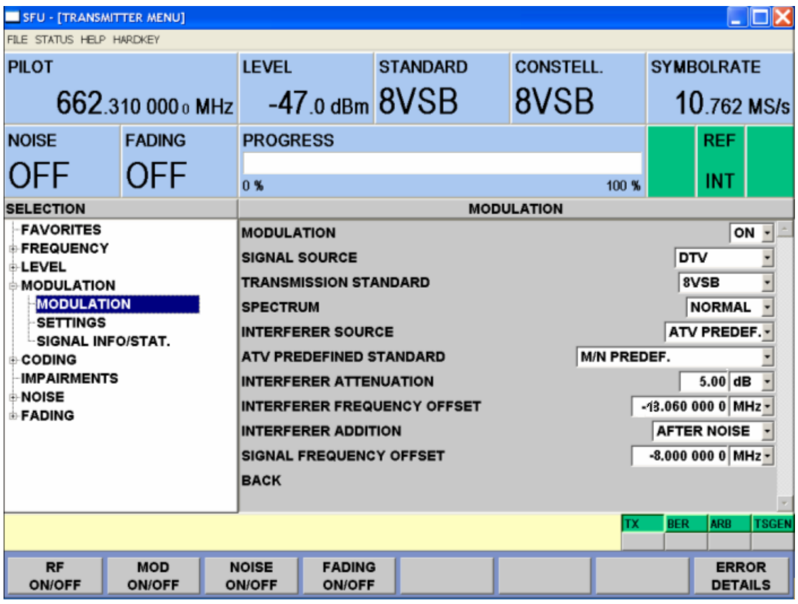


Figure 10 Offset and S/I setting for lower adjacent channel test

3.5.2.4 Test procedure ATSC interferer

- Follow the same test procedure as defined in 3.5.3/4 however this time with an interferer offset of 6.0 MHz respectively -6.0 MHz.
- Repeat the test with the Level settings and minimum S/I tolerances defined in the following table.

Table 10 Minimum S/I limits for an ATSC adjacent channel

Wanted signal level dBm	**Minimum S/I level** dB
-68.0	-33
-53.0	-33
-28.0	-20

3.5.3 Taboo channel rejection

3.5.3.1 Test setup

- Maintain the set-up of figure 1.

3.5.3.2 Test procedure NTSC interferer

- Follow the same test procedure as defined in 3.5.2 however this time with the Interferer Frequency Offset, Signal Frequency Offset settings and Offset setting in the Frequency menu defined in column 3, 4, and 5 of table 9.
- Set the Level of the *R&S® SFU* at -68.0 dBm.
- Repeat the test for the lower taboo channels with the values from table 10.
- Repeat all tests with Level settings of -54.0 and -28.0 dBm.
- Record the Interferer Attenuation setting for every test. This figure must be better than the limit for that particular neighboring channel specified in table 9 or 10.

1) The total number of tests mount up to 72 excluding n+14 and n+15 (2x12x3=72).

2) The Interferer Frequency Offset and Signal Frequency offset settings of the *R&S® SFU* are limited to -40.0 to +40.0 MHz. Since the frequency of neighboring channels n+/-14 and n+/-15 are more than 80 MHz away from the wanted signal the instrument does not allow you to generate an interferer at this frequency. This means that the test can

only be performed with one of the multi-test transmitter set-up defined in table 2.

3) It is possible that if the wanted channel is at the upper or lower edge of the TV (VHF/UHF) spectrum one or more neighboring channels are outside this spectrum.

Table 11 Minimum S/I limits and frequency offset settings for upper ATSC/NTSC neighboring "taboo" channels

Upper neighboring "taboo" channel (n = wanted channel)	**Absolute frequency offset ATSC (NTSC)** MHz	**Signal frequency offset setting on SFU ATSC (NTSC)** MHz	**Interferer frequency offset setting on SFU ATSC (NTSC)** MHz	**Offset setting in Frequency menu on SFU ATSC (NTSC)** MHz	**Minimum S/I level for -68 dBm wanted signal** dB	**Minimum S/I level for -53 dBm wanted signal** dB	**Minimum S/I level for -28 dBm wanted signal** dB
n+2	12.0 (12.94)	0.0 (0.0)	12.0 (12.94)	0.0 (0.0)	-44.0	-40.0	-20.0
n+3	18.0 (18.94)	0.0 0.0)	18.0 (18.94)	0.0 (0.0)	-48.0	-40.0	-20.0
n+4	24.0 (24.94)	0.0 (0.0)	24.0 (24.94)	0.0 (0.0)	-52.0	-40.0	-20.0
n+5	30.0 (30.94)	0.0 (0.0)	30.0 (30.94)	0.0 (0.0)	-56.0	-42.0	-20.0
n+6	36.0 (36.94)	0.0 (0.0)	36.0 (36.94)	0.0 (0.0)	-57.0	-45.0	-20.0
n+7	42.0 (42.94)	-36.0 (-36.0)	6.0 (6.94)	-36.0 (-36.0)	-57.0	-45.0	-20.0
n+8	48.0 (48.94)	-36.0 (-36.0)	12.0 (12.94)	-36.0 (-36.0)	-57.0	-45.0	-20.0
n+9	54.0 (54.94)	-36.0 (-36.0)	18.0 (18.94)	-36.0 (-36.0)	-57.0	-45.0	-20.0
n+10	60.0 (60.94)	-36.0 (-36.0)	24.0 (24.94)	-36.0 (-36.0)	-57.0	-45.0	-20.0
n+11	66.0 (66.94)	-36.0 (-36.0)	30.0 (30.94)	-36.0 (-36.0)	-57.0	-45.0	-20.0
n+12	72.0 (72.94)	-36.0 (-36.0)	36.0 (36.94)	-36.0 (-36.0)	-57.0	-45.0	-20.0
n+13	78.0 (78.94)	-39.0 (-39.0)	39.0 (39.94)	-39.0 (-39.0)	-57.0	-45.0	-20.0
n+14 1)	84.0 (84.94)	n/a (n/a)	n/a (n/a)	n/a (n/a)	-50.0	-45.0	-20.0
n+15 1)	90.0 (90.94)	n/a (n/a)	n/a (n/a)	n/a (n/a)	-50.0	-45.0	-20.0

1) The *R&S®SFU's* 80 MHz I/Q bandwidth limit does not allow this test. The test can only be performed with a multiple test transmitter set-up.

Table 12 Minimum S/I limits and frequency offset settings for lower ATSC/NTSC neighboring "taboo" channels

Lower neighboring "taboo" channel (n = wanted channel)	**Absolute frequency offset ATSC (NTSC)** MHz	**Signal frequency offset setting on SFU ATSC (NTSC)** MHz	**Interferer frequency offset setting on SFU ATSC (NTSC)** MHz	**Offset setting in Frequency menu on SFU ATSC (NTSC)** MHz	**Minimum S/I level for -68 dBm wanted signal** dB	**Minimum S/I level for -53 dBm wanted signal** dB	**Minimum S/I level for -28 dBm wanted signal** dB
n-2	-12.0 (-11.06)	n/a (0.0)	n/a (-11.06)	0.0 (0.0)	-44.0	-40.0	-20.0
n-3	-18.0 (-17.06)	n/a 0.0)	n/a (-17.06)	0.0 (0.0)	-48.0	-40.0	-20.0
n-4	-24.0 (-23.06)	n/a (0.0)	n/a (-23.06)	0.0 (0.0)	-52.0	-40.0	-20.0
n-5	-30.0 (-29.06)	n/a (0.0)	n/a (-29.06)	0.0 (0.0)	-56.0	-42.0	-20.0
n-6	-36.0 (-35.06)	n/a (0.0)	n/a (-35.06)	0.0 (0.0)	-57.0	-45.0	-20.0
n-7	-42.0 (-41.06)	36.0 (36.0)	-6.0 (-5.06)	36.0 (36.0)	-57.0	-45.0	-20.0
n-8	-48.0 (-47.06)	36.0 (36.0)	-12.0 (-11.06)	36.0 (36.0)	-57.0	-45.0	-20.0
n-9	-54.0 (-53.06)	36.0 (36.0)	-18.0 (-17.06)	36.0 (36.0)	-57.0	-45.0	-20.0
n-10	-60.0 (-59.06)	36.0 (36.0)	-24.0 (-23.06)	36.0 (36.0)	-57.0	-45.0	-20.0
n-11	-66.0 (-65.06)	36.0 (36.0)	-30.0 (-29.06)	36.0 (36.0)	-57.0	-45.0	-20.0
n-12	-72.0 (-71.06)	36.0 (36.0)	-36.0 (-35.06)	36.0 (36.0)	-57.0	-45.0	-20.0
n-13	-78.0 (-77.06)	39.0 (39.0)	-39.0 (-38.06)	39.0 (39.0)	-57.0	-45.0	-20.0
n-14 2)	-84.0 (-83-06)	n/a (n/a)	n/a (n/a)	n/a (n/a)	-50.0	-45.0	-20.0
n-15 2)	-90.0 (-89.06)	n/a (n/a)	n/a (n/a)	n/a (n/a)	-50.0	-45.0	-20.0

2) The *R&S®SFU's* 80 MHz I/Q bandwidth limit does not allow this test. The test can only be performed with a multiple test transmitter set-up.

3.5.3.3 Test procedure ATSC interferer

- Please follow the same test procedure as defined in 3.5 though this time with Interferer Frequency Offset and Signal Frequency Offset settings defined in column 3 and 4 of table 9.
- Set the Level of the *R&S® SFU* at -68 dBm.
- Repeat the test with the Interferer Frequency Offset and Signal Interferer Frequency settings respectively “absolute frequency offset” from table 10.
- Repeat all tests with Level settings of -54 and -28 dBm.
- Record the Interferer Attenuation setting for every test. This figure must be better than the limit for that particular neighboring channel specified in table 9 or 10.

The total number of tests mount up to 72 (2x12x3=72).

3.6 Multipath fading

3.6.1 Single static echo

3.6.1.1 General

The test requires the receiver to be subjected to a direct path and one single indirect path with variable delay and attenuation. Define the following paths in the Profile menu of the *R&S® SFU-K30* fading simulator and save the settings under SSEcho.fad. During the test only one echo (Path 1-1 to 1-4 and 2-1 to 2.5) is active together with the direct path (Path 1-5). The grayed column is the direct path.

Table 13 Required R&S®SFU-K30 path configuration (echos) for single static echo test (Grayed column is direct path).

Designation	Path 1	Path 2	Path 3	Path 4	Path 5	Path 6	Path 7	Path 8	Path 9
State	---	---	---	---	On	---	---	---	---
Path	Path 1-1	Path 1-2	Path 1-3	Path 1-4	Path 1-5	Path 2-1	Path 2-2	Path 2-3	Path 2-4
Profile	Constant Phase	Constant Phase	Constant Phase	Constant Phase	Pure Doppler	Constant Phase	Constant Phase	Constant Phase	Constant Phase
Path loss dB	16.0	7.5	5.0	2.0	1.0	2.0	3.0	6.0	16.0
Basic delay µs	0.0	0.0	0.0	0.0	0.0	30.0	30.0	30.0	30.0
Additional delay µs	0.0	5.0	10.0	20.0	25.0	0.0	5.0	15.0	35.0
Resulting delay µs	0.0	5.0	10.0	20.0	25.0	30.0	35.0	45.0	65.0
Constant Phase °	0	0	0	0	n/a	0	0	0	0
Speed m/s	---	---	---	---	0.02	---	---	---	---
Frequency ratio	---	---	---	---	1.0	---	---	---	---
Doppler shift Hz	---	---	---	---	0.05	---	---	---	---

Choose Doppler Frequency as Reference in the Settings menu. In this mode the *R&S® SFU-K30* calculates the Speed automatically with the following equation.

$$v_d = \frac{f_d . c}{f_c \cdot r}$$

Where: v_d is the velocity in m/s. f_d is the Doppler frequency in Hz. f_c is the ATSC carrier frequency in Hz. c is the light speed 299792458 m/s. r is the frequency ratio [-1…1].

3.6.1.2 Test setup

- Maintain the set-up of figure 1.

3.6.1.3 Test procedure

- Press the Preset button, set-up an ATSC service on the *R&S® SFU* and tune the receiver under test at the service.
- Set the Level at -28 dBm.

With fading on, the instrument's Level indication reflects the power that results from the vector summation of the different paths. The level ratios of the echos defined in *Doc.A/74* are always with respect to the direct path as if the direct path existed on its own. This means that you cannot directly enter the Level setting, but instead a correction needs to take place first. A tool named *SFU Fader Mainpath GUI* is available from the Rohde & Schwarz customer support. The tool allows you to enter the level of the direct signal (Main path) and calculates the SFU's level setting from the current fading configuration. The image below reflect a situation where path 4 is activated (3 dB below main path)

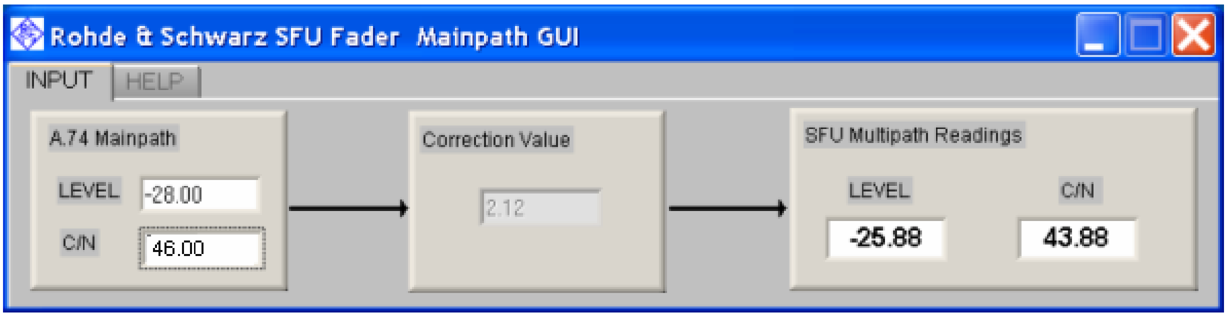


Figure 11 SFU Fader Mainpath GUI tool included in FW 1.7

- Load SSEcho.fad in the fading generator and switch the Fading State to On.
- Enable Path1-5 (Direct path). Enable the first echo Path1-1.
- Observe if the receiver shows signs of failure (POF).
- Disable Path1-1 and enable Path1-2. Repeat the test until all paths are done.
- The receiver under test must pass echos Path1-3 to Path2-4. It is advisable though that the receiver also passes all other paths.

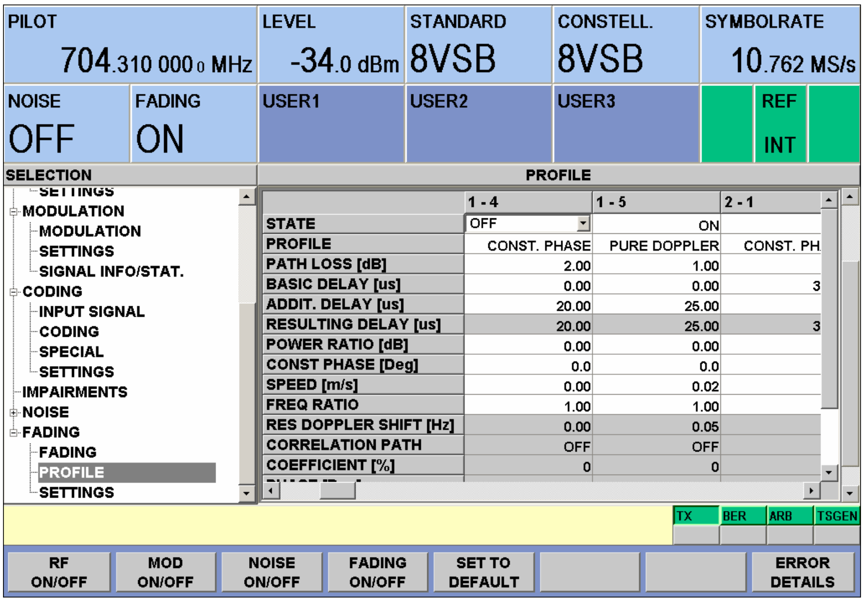


Figure 12 Fading settings for single static echo test

3.6.2 Single dynamic echo

3.6.2.1 General

Define the following paths in the Profile menu of the *R&S® SFU-K30* fading simulator and save as SDEcho.fad.

Table 14 Required R&S®SFU-K30 path configuration (echos) for single dynamic echo test (Grayed column is direct path).

Designation	Path 1	Path 2	Path 3	Path 4	Path 5	Path 6	Path 7	Path 8	Path 9	Path 10	Path 11
State	On	On	---	---	---	---	---	---	---	---	---
Path	Path 1-1	Path 1-2	Path 1-3	Path 1-4	Path 1-5	Path 2-1	Path 2-2	Path 2-3	Path 2-4	Path 2-5	Path 3-1
Profile	Const. Phase	Pure Doppler	Pure Doppler	Pure Doppler	Pure Doppler	Pure Doppler	Pure Doppler	Pure Doppler	Pure Doppler	Pure Doppler	Pure Doppler
Path loss dB	0.0	---	---	---	---	---	---	---	---	---	---
Basic delay µs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Additional delay µs	0.0	---	----	----	----	----	----	----	----	----	----
Resulting delay µs	0.0	---	----	----	----	----	----	----	----	----	----
Constant Phase °	0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Speed m/s	---	---	---	---	---	---	---	---	---	---	---
Frequency ratio	0.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Doppler shift Hz	---	0.05	0	0.25	0.50	0.75	1.00	1.25	1.5	1.75	2.00

3.6.2.2 Test setup

- Maintain the set-up of figure 1.

3.6.2.3 Test procedure

- Press the Preset button, set-up an ATSC service on the *R&S® SFU* and tune the receiver under test at the service.
- Step 1: Set the Level at -28 dBm.

Observe the level correction described in 3.8.1.

- Step 2: Load SDEcho.fad and switch the Fading State to On
- Step 3: Enable the Path1-1 (Direct path) and Path1-2 (Echo 1).
- Step 4: Enable the Path1-3 (Echo2).
- Step 5: Set the Additional Delay of Path1-2 (Echo1) and Path1-3 (Echo 2) to 0.2 µs
- Step 6: Set the Path Loss of Path1-2 (Echo 1) and Path1-3 (Echo 2) to 7 dB.
- Step 7: Decrease Path Loss of Path1-2 (Echo 1) and Path1-3 (Echo 2) simultaneously in 0.5 dB steps until the receiver-under test reaches the POF.
- Step 8: Increase Additional Delay of Path1-2 (Echo1) and Path1-3 (Echo 2) simultaneously in 0.2 µs steps until 2 µs while repeating steps 6, 7. Record the, Resulting Delay, Path Loss at the POF.
- Step 9: Disable Path1-3 (Echo2). Enable Path1-4. Repeat steps 6 to 9 for Path1-4, Path1-5… to Path3-1.

3.6.3 Multiple static and dynamic echos R2.1

3.6.3.1 General

This test requires 4 different 6-path fading configurations (Ensembles). If the instrument includes the *R&S® SFU-K30* fading option these four fading configurations are present under CRC Dynamic#1 to Dynamic#4 in the *ATTC folder.*

Table 15 R&S®-K30 Path configuration for test R2.1 Ensemble 1

Designation	Path 1	Path 2	Path 3	Path 4	Path 5	Path 6
State	On	On	On	On	On	On
Path	Path 1-1	Path 1-2	Path 1-3	Path 1-4	Path 1-5	Path 2-1
Profile	Constant Phase	Constant Phase	Constant Phase	Constant Phase	Pure Doppler	Constant Phase
Path loss dB	0.0	20.0	20.0	10.0	---	18.0
Basic delay µs	0.0	0.0	0.0	0.0	0.0	0.0
Additional delay µs	1.8	0.0	1.95	3.6	7.5	36.8
Resulting delay µs	1.8	0.0	1.95	3.6	7.5	36.8
Constant Phase °	0	125	80	45	---	90
Speed m/s	---	---	---	---	---	---
Frequency ratio	0.0	0.0	0.0	0.0	1.0	0.0
Doppler shift Hz	---	---	---	---	1 or 5	---

Table 16 R&S®-K30 Path configuration for test R2.1 Ensemble 2

Designation	Path 1	Path 2	Path 3	Path 4	Path 5	Path 6
State	On	On	On	On	On	On
Path	Path 1-1	Path 1-2	Path 1-3	Path 1-4	Path 1-5	Path 2-1
Profile	Constant Phase	Constant Phase	Constant Phase	Constant Phase	Pure Doppler	Constant Phase
Path loss dB	0.0	17.0	17.0	7.0	---	15.0
Basic delay µs	0.0	0.0	0.0	0.0	0.0	0.0
Additional delay µs	1.8	0.0	1.95	3.6	7.5	36.8
Resulting delay µs	1.8	0.0	1.95	3.6	7.5	36.8
Constant Phase °	0	125	80	45	---	90
Speed m/s	---	---	---	---	---	---
Frequency ratio	0.0	0.0	0.0	0.0	1.0	0.0
Doppler shift Hz	---	---	---	---	1 or 5	---

Table 17 R&S®-K30 Path configuration for test R2.1 Ensemble 3

Designation	Path 1	Path 2	Path 3	Path 4	Path 5	Path 6
State	On	On	On	On	On	On
Path	Path 1-1	Path 1-2	Path 1-3	Path 1-4	Path 1-5	Path 2-1
Profile	Constant Phase	Constant Phase	Constant Phase	Constant Phase	Pure Doppler	Constant Phase
Path loss dB	0.0	14.0	14.0	4.0	---	12.0
Basic delay µs	0.0	0.0	0.0	0.0	0.0	0.0
Additional delay µs	1.8	0.0	1.95	3.6	7.5	36.8
Resulting delay µs	1.8	0.0	1.95	3.6	7.5	36.8
Constant Phase °	0	125	80	45	---	90
Speed m/s	---	---	---	---	---	---
Frequency ratio	0.0	0.0	0.0	0.0	1.0	0.0
Doppler shift Hz	---	---	---	---	1 or 5	---

Table 18 R&S®-K30 Path configuration for test R2.1 Ensemble 4

Designation	Path 1	Path 2	Path 3	Path 4	Path 5	Path 6
State	On	On	On	On	On	On
Path	Path 1-1	Path 1-2	Path 1-3	Path 1-4	Path 1-5	Path 2-1
Profile	Constant Phase	Constant Phase	Constant Phase	Constant Phase	Pure Doppler	Constant Phase
Path loss dB	0.0	11.0	11.0	1.0	---	9.0
Basic delay µs	0.0	0.0	0.0	0.0	0.0	0.0
Additional delay µs	1.8	0.0	1.95	3.6	7.5	36.8
Resulting delay µs	1.8	0.0	1.95	3.6	7.5	36.8
Constant Phase °	0	125	80	45	---	90
Speed m/s	---	---	---	---	---	---
Frequency ratio	0.0	0.0	0.0	0.0	1.0	0.0
Doppler shift Hz	---	---	---	---	1 or 5	---

3.6.3.2 Test setup

- Maintain the basic test set-up of figure 1.

3.6.3.3 Test procedure

- Press the Preset button, set-up an ATSC service on the *R&S® SFU* and tune the receiver under test at the service.
- Load the first fading parameter set (R2.1 Ensemble 1 or *CRC Dynamic#1*). Switch the Fading State to On.
- Set the Level at -53.0 dBm.

Observe the level correction described in 3.8.1.

- Step 1: Set the Path loss of Path1-5 at 50.0 dB.
- Step 2: Set the Doppler shift of Path1-5 (Beige column) at 1Hz.
- Step 3: Decrease the Path loss setting of Path1-5 in a stepwise fashion until the receiver reaches its POF.
- Step 4: Record the Path loss and Doppler shift reading.
- Step 5: Repeat steps 1 to 4 with Doppler shift settings of 2, 3, 4, and 5Hz.
- Repeat the test for the remaining three fading ensembles.

3.6.4 Multiple static and dynamic echos R2.2

3.6.4.1 General

Define the following 3 fading configurations and save them under an appropriate name. Leave the parameters that are not stated at the default value. Grayed columns represent direct paths.

Table 19 R&S®-K30 path configuration for test R2.2 Ensemble 1

Designation	Path 1	Path 2	Path 3	Path 4	Path 5	Path 6
State	On	On	On	On	On	On
Path	Path 1-1	Path 1-2	Path 1-3	Path 1-4	Path 1-5	Path 2-1
Profile	Constant Phase	Constant Phase	Constant Phase	Constant Phase	Pure Doppler	Constant Phase
Path loss dB	0.0	15.0	15.0	7.0	7.0	15.0
Basic delay µs	0.0	0.0	0.0	0.0	0.0	30.0
Additional delay µs	1.8	0.0	1.95	3.6	7.5	11.6
Resulting delay µs	1.8	0.0	1.95	3.6	7.5	41.6
Constant Phase °	0	125	80	45	---	90
Speed m/s	---	---	---	---	---	---
Frequency ratio	0.0	0.0	0.0	0.0	1.0	0.0
Doppler shift Hz	---	---	---	---	1 or 5	---

Table 20 *R&S®-K30 path configuration for test R2.2 Ensemble 2*

Designation	Path 1	Path 2	Path 3	Path 4	Path 5	Path 6
State	On	On	On	On	On	On
Path	Path 1-1	Path 1-2	Path 1-3	Path 1-4	Path 1-5	Path 2-1
Profile	Constant Phase	Constant Phase	Constant Phase	Constant Phase	Pure Doppler	Constant Phase
Path loss dB	0.0	8.0	3.0	4.0	3.0	12.0
Basic delay µs	0.0	0.0	0.0	0.0	0.0	30.0
Additional delay µs	1.8	0.0	1.95	3.6	7.5	11.6
Resulting delay µs	1.8	0.0	1.95	3.6	7.5	41.6
Constant Phase °	0	125	80	45	---	90
Speed m/s	---	---	---	---	---	---
Frequency ratio	0.0	0.0	0.0	0.0	1.0	0.0
Doppler shift Hz	---	---	---	---	1 or 5	---

Table 21 *R&S®-K30 path configuration for test R2.2 Ensemble 3*

Designation	Path 1	Path 2	Path 3	Path 4	Path 5	Path 6
State	On	On	On	On	On	On
Path	Path 1-1	Path 1-2	Path 1-3	Path 1-4	Path 1-5	Path 2-1
Profile	Constant Phase	Constant Phase	Constant Phase	Constant Phase	Pure Doppler	Constant Phase
Path loss dB	0.0	3.0	1.0	1.0	3.0	9.0
Basic delay µs	0.0	0.0	0.0	0.0	0.0	30.0
Additional delay µs	1.8	0.0	1.95	3.6	7.5	11.6
Resulting delay µs	1.8	0.0	1.95	3.6	7.5	41.6
Constant Phase °	0	125	80	45	---	90
Speed m/s	---	---	---	---	---	---
Frequency ratio	0.0	0.0	0.0	0.0	1.0	0.0
Doppler shift Hz	---	---	---	---	1 or 5	---

3.6.4.2 Test setup

- Maintain the basic test set-up of figure 1.

3.6.4.3 Test procedure

- Press the Preset button, set-up an ATSC service on the *R&S® SFU* and tune the receiver under test at the service.
- Load the first fading parameter set (R2.2 Ensemble 1).
- Set the Level at -53.0 dBm.

 Observe the level correction described in 3.8.1.

- Switch the Fading State to On.
- Switch the AWGN in the Noise menu on. Switch the Bandwidth Coupling off and set Receiver BW at 6 MHz.
- Set the C/N in the AWGN menu at 30 dB.
- Step 1: Set the Doppler shift of Path1-5 (Beige column) at 1 Hz.
- Step 2: Decrease the C/N setting in a stepwise fashion until the receiver reaches the POF.
- Step 3: Record the C/N reading. This reading should be lower that 18 dB.

- Step 4: Repeat steps 1 to 3 with Doppler shift settings of 2, 3, 4, and 5 Hz.
- Repeat the test for the remaining three fading ensembles.

3.6.5 Dynamic Multipath, Doppler shift and airplane flutter

This test is to determine the receiver's sensitivity to echo signals with a high Doppler frequency shift. Such situation may occur in the proximity of airports where the metallic surface of an aircraft together with its high speed results in strong echos with a considerable amount of frequency shift.

Doc.A/74 does not specify any specific requirements or test procedures other than a recommendation to test the receiver under such conditions. If life (or recorded) signals are not available one can consider the following method as an alternative.

Define the following paths in the Profile menu of the *R&S® SFU-K30* fading simulator and save as DMP_DS_FLEcho.fad.

Table 22 R&S®-K30 Path configuration for Doppler frequency shift

Designation	Path 1	Path 2	Path 3	Path 4	Path 5	Path 6
State	On	---	---	---	---	---
Path	Path 1-1	Path 1-2	Path 1-3	Path 1-4	Path 1-5	Path 2-1
Profile	Constant Phase	Pure Doppler	Pure Doppler	Pure Doppler	Pure Doppler	Pure Doppler
Path loss dB	0.0	30	30	30	30	30
Basic delay µs	0.0	0.0	0.0	0.0	0.0	0.0
Additional delay µs	0.0	5.0	5.0	10.0	10.0	20.0
Resulting delay µs	0.0	5.0	5.0	10.0	10.0	20.0
Constant Phase deg	0	---	---	---	---	--
Speed m/s	---	---	---	---	---	---
Doppler shift Hz	---	50	75	100	125	150

3.6.5.1 Test setup

- Maintain the basic test set-up of figure 1.

3.6.5.2 Test procedure

- Press the Preset button, set-up an ATSC service on the *R&S® SFU* and tune the receiver under test at the service.
- Load DMP_DS_FLEcho.fad and switch the Fading State to On.

- Set the Level at -28.0 dBm.

Observe the level correction described in 3.8.1.

- Switch the AWGN in the Noise menu on. Switch the Bandwidth Coupling off and set Receiver BW at 6 MHz.
- Set the C/N in the AWGN menu at 30 dB.

- Switch Path1-2 on.
- Decrease the Path Loss until the receiver reaches the POF.
- Record the Path loss, Total Delay and Doppler shift reading.
- Switch Path1-2 off.
- Repeat the test for path Path1-3 to Path2-1. Apart from the main path Path1-3 only one path is switched on at one time.

3.6.6 Dynamic Multipath, Doppler shift and airplane flutter test with live signals

The procedures described in application note RAC0607-0021 *"Generating multiple interferers with the SFU-K35 Arbitrary waveform generator"* may also be used to record live ATSC signals. To record signals the application note features an *R&S®FSx* spectrum analyzer, which is not necessarily the ideal instrument to pick up signals from the air. Therefore for improved selectivity use an *R&S®EFA50* test receiver as front-end (Spectrum analyzer connected to IF output).

ATSC's 6 MHz bandwidth requires a sampling rate of at least 12 Msps. The following table shows the available recording time at 16 Msps for different spectrum analyzers.

Table 23 Available recording time at 16 Msps vs spectrum analyzer model sampling rate.

Memory size *R&S®FSU* Msample	0.512			
Memory size *R&S®FSL* Msample	0.512			
Memory size *R&S®FSQ* Msample		16	235	705
Maximum recording time s	0.032	1.0	14.68	44.06

The recorded signals can be downloaded in the *R&S®SFU-K35* or *R&S®AFQ100* in a set-up shown in figure 16 to subject the receiver to a live signal in a lab environment. Seen the latter's larger memory one may concatenate multiple recordings eventually taken at different times.

Table 24 Total live signal time vs generator memory size. Sampling rate16 Msps.

Memory size *R&S®SFU-K35* Msample	128		
Memory size *R&S®AFQ100* Msample		256	1000
Maximum duration recorded signal s	8	16	62.5

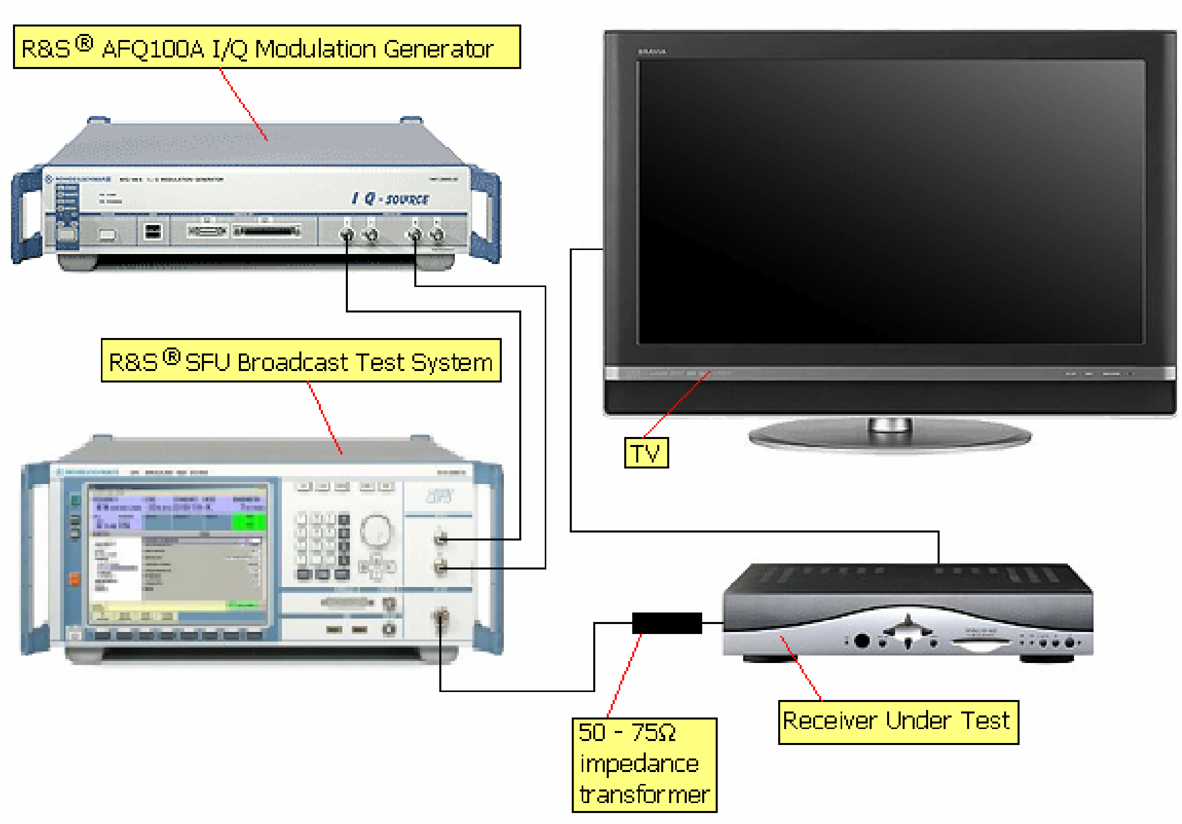


Figure 13 Test set-up for receiver tests with live recorded waveforms. (Signal duration up to one minute)

4 Summary

The *R&S®SFU Broadcast Test System* includes almost all the required functionality to perform the tests defined in the ATSC *Doc.A/74 Receiver Performance Recommended Practice* without anything more than a spectrum analyzer.

For the more complex tests which make use of live captured signals the instrument can be used in conjunction with an *R&S®AFQ100A I/Q Modulation Generator.*

5 Literature

[1] Application Note 7BM63 "Phase Noise Profile Creator for the R&S® SFU", Rohde & Schwarz, H.Gsoedl

[2] Application Note 7BM50_0E *"Tolerance to noise tests for DTV receivers with the SFU-K41-42-43 Part I Impulsive Noise"* Rohde & Schwarz, H.Gielen.

[3] Application Note 7BM51_0E *"Measuring Bit Error Rate using the R&S® SFU*-K60 Option*"* Rohde & Schwarz, CK Tan.

[4] Application Note RAC0607-0021 *"Generating multiple interferers with the SFU-K35 Arbitrary waveform generator*" Rohde & Schwarz, H.Gielen *(Internal document)*

[5] ATSC Recommended Practice "Receiver Performance Guidelines Doc.A/74", 18 June 2004, Advanced Television Systems Committee, 1750 K Street, N.W. Suite 1200, Washington, D.C. 20006 www.atsc.org.

6 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@rsd.rohde-schwarz.com

7 Ordering information

R&S®SFU

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-B30	Fading Simulator	2110.7530.02
R&S SFU-B31	Fading Simulator Extension to 40 Paths	2110.7547.02
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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
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R&S SFU-K194	ATV Standard L Coder	2110.8072.02
R&S SFU-K199	Multi ATV Predefined	2110.8089.02
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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
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R&S SFU-K354	DTV Interferer Waveforms	2110.4690.02
R&S SFU-K355	MediaFLO™ Waveforms	2110.2974.02
R&S SFU-K356	Cable Interferer Waveforms	2110.3212.02
R&S SFE-K40	AWGN Generator	2113.4910.02
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