

A/74:2010 ATSC Receiver Performance Testing with BTC Application Note

Products:

| R&S®BTC

Nearly all analog NTSC broadcasting has ended in the US, Canada and South Korea. The digital switchover to ATSC in Mexico is expected to be completed by the end of 2016. ATSC receivers must fulfill the recommendations described in “ATSC Recommended Practice: Receiver Performance Guidelines” (document A/74:2010) before they can be sold freely in the markets that have adopted the standard.

In addition, Recommendation ITU-R BT.2036-1 (07/2016), titled “Characteristics of a reference receiving system for frequency planning of digital terrestrial television systems”, includes the planning factors for an ATSC reception system, with a reference to ATSC Recommended Practice A/74:2010, because operation is in a more dynamic environment.

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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 document A/74:2010 'Receiver Performance Guidelines' (see 5.1.1) defines five principal tests with the aim to ensure adequate ATSC receiver performance under unfavorable conditions. These five principal tests are:

- Sensitivity
- Multi-signal overload
- Phase noise
- Selectivity
- Multipath

Anyone familiar with NorDig Unified or 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 parts of the selectivity test is limited to one.

Owing to the fact that ATSC uses a residual carrier, some tests defined in document A/74:2010 are unique. This includes phase noise and certain multi-path fading conditions. The multi-path fading conditions are used 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®BTC Broadcast Test Center incorporates all the functionality to execute most A/74:2010 tests directly without any additional test equipment. For the multi-signal overload test and parts of the selectivity tests a BTC equipped with a second signal path or one additional test transmitter is required. The following chapters describe the configuration and execution of the defined tests in detail.

2 Test Equipment

Most tests defined in ATSC document A/74:2010 can be performed directly with only one single R&S®BTC. A medium range spectrum analyzer like the R&S®FSL or R&S®FSP is additionally recommended to verify the setup. Table 1 shows the R&S®BTC options required for the particular tests.

R&S®BTC option	Sensitivity	Multi-signal overload	Phase noise	Selectivity	Multipath
ATSC-MH/8VSB Coder (R&S®BTC-K518)	X	X	X	X	X
Arbitrary Generator (R&S®BTC-K35)		X ²		X	X ¹
Analog Signals (R&S®WV-K816)		X ²		X	
DTV Interferers (R&S®WV-K1114)		X ²		X	
Fading Simulator (R&S®BTC-B1031)					X
AWGN Generator (R&S®BTC-K1040)					X
Ext. Noise Generator (R&S®BTC-K1043)			X	X	

Table 1: Required R&S®BTC options for the particular tests



It is recommended for all devices to use the latest firmware version.

¹ Required for testing with field ensemble waveforms.

² Not all of these options may be required. See Chapter 3.2.

³

3 Test Procedures

3.1 Sensitivity

3.1.1 General

Document A/74:2010 states that an ATSC receiver must successfully operate in a noiseless channel with signal levels between -83 dBm and -5 dBm at the antenna input.

3.1.2 Test Setup

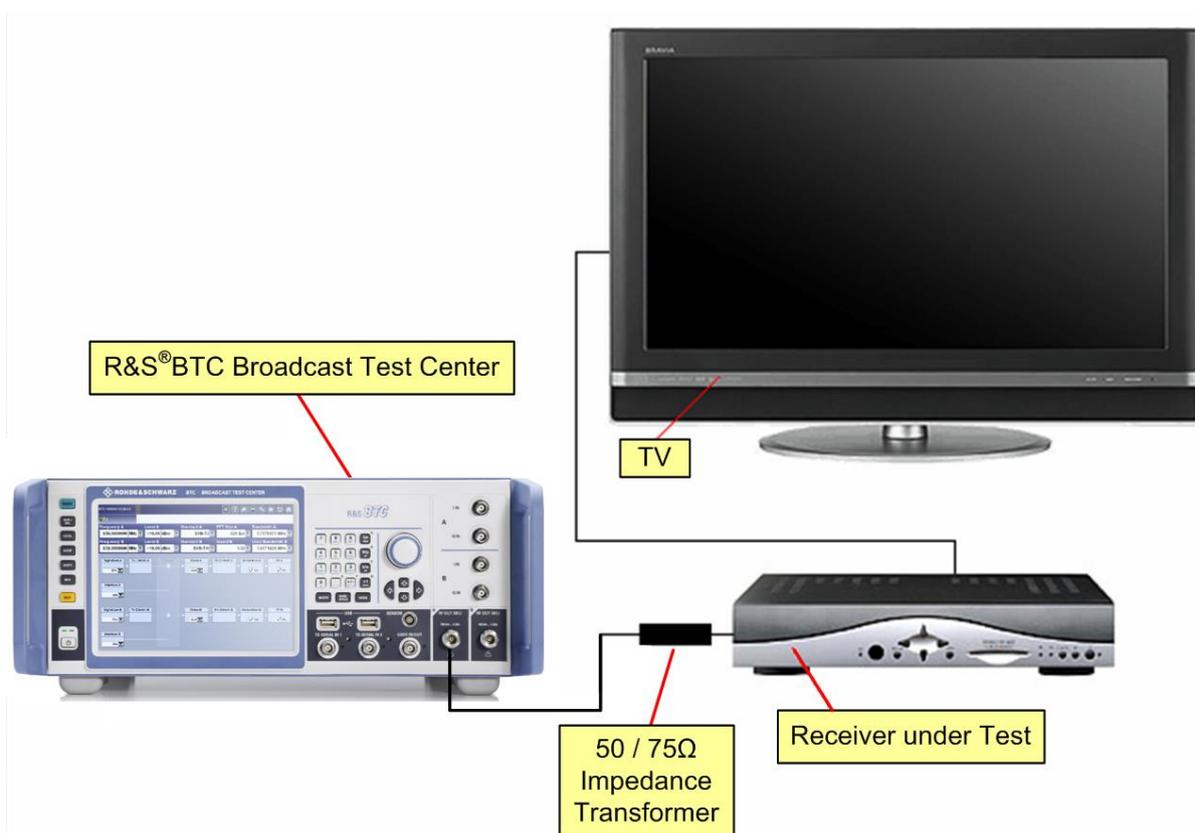


Figure 1: Receiver sensitivity test setup

Connect the R&S®BTC'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 matching pad to convert the impedance.

3.1.3 Test Procedure

- Press the 'PRESET' button, setup an ATSC service on the R&S®BTC and tune the receiver under test to the service.
- Minimum sensitivity: Decrease the 'Level' setting until you reach the point-of-failure (POF). This value must be lower than -83 dBm.
- 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 -5 dBm. Do not exceed the receivers maximum input level specification.



It is possible that certain receiver models pass the maximum sensitivity test and even exceed the maximum output power of the R&S®BTC.



Take the insertion loss of the cabling and the matching pad into consideration, when rating absolute levels. This external attenuation can be automatically considered in the R&S®BTC's level indication by entering a corresponding level offset value. Alternatively, the exact input power at the receiver can be precisely measured with an additional spectrum analyzer or a power sensor (e.g. R&S®NRP-Z91). The power sensor reading can directly be shown within the R&S®BTC's graphical user interface (GUI) with option R&S®BTC-K2055.

3.2 Multi-Signal Overload

3.2.1 General

Document A/74:2010 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 does however not guarantee reproducible results for a laboratory setting.

3.2.2 Test Setup

Start with setup of Figure 1. Apart from the wanted channel, the R&S®BTC can directly generate up to eight additional NTSC or ATSC signals by means of the interferer management. It is also possible to generate more than one ATSC interferer. Just initially run the free of charge software R&S®WinIQSim2 (see 5.2.1) and compose the desired multi-channel interferer waveform based on the '8VSB_Pilot.wv' ATSC signal of the R&S®WV-K1114 DTV Interferer Library. Leave one channel empty for the real-time coded signal.

If the test should also comprise more NTSC channels and/or a frequency interval greater than 160 MHz for the used channels, the signal of one or more R&S®SFC equipped with either an NTSC or ATSC real-time coder can be added to the R&S®BTC output by external combiners. Also further signal generators like SFE or SFE100 with equivalent functionality can be used for this purpose.



Figure 2: The R&S®SFC Compact Modulator can provide an additional NTSC or ATSC signal

3.2.3 Test Procedure

- Press the 'PRESET" button, setup an ATSC service on the R&S®BTC and tune the receiver under test to the service.

The screenshot shows the R&S BTC software interface. At the top, it displays 'R&S BTC' and 'BTC-100012 V2.1.0.6 BETA'. Below this is a toolbar with various icons. The main area is titled 'TX Interferer A' and 'MMGen'. It shows settings for 'Pilot A' with a frequency of 662.310 000 000 MHz, Level A at -10.00 dBm, Standard A as 8VSB, Constellation A as 8VSB, and Symbol Rate A as 10.762 238 MS/s.

Below the settings is an 'Arbitrary Waveform Generator' table with 8 columns (Generators 1-8). The 'State' for Generator 1 is 'On', while others are 'Off'. The 'Usage' for all is 'Interferer'. The 'Waveform' for Generator 1 is '8VSB_Pilot', while others are '---'. The 'Required Option' for Generator 1 is 'WV-K1114', while others are 'None'. The 'Samples /MS' for Generator 1 is 1.042, while others are 0.000. The 'Sample Rate /MS/s' for Generator 1 is 21.524 476, while others are 0.000 400. The 'Sequence Dur. /s' for Generator 1 is 0.048, while others are 0.000. The 'Attenuation /dB' for Generator 1 is 0.00, while others are 20.00. The 'Freq. Offset /MHz' for Generator 1 is -5.060 000 0, while others are 0.000 000 0.

At the bottom, there is a 'Memory Usage' bar showing 0% usage and a 'Defrag.' button. The 'Signal' tab is selected, and 'Arb' is also visible.

Figure 3: R&S®BTC-Interferer settings

- Configure additional signals on the R&S®BTC:

– Either setup one NTSC signal:
In block 'Interferer' set 'Source' to 'ARB' and activate the 'NTSC_M_1CH_6MHZ.wv' NTSC waveform of the R&S®WV-K816 library on generator 1.

– Or setup one ATSC signal:
In block 'Interferer' set 'Source' to 'ARB' and activate the '8VSB_Pilot.wv' ATSC waveform of the R&S®WV-K1114 library on generator 1.

Finally adjust the 'Freq. Offset', so that the interferer signal does not overlap into the wanted channel.

Enter e.g. -6 MHz to get a lower adjacent channel.

– Or setup several ATSC or NTSC signals:
In block 'Interferer' set 'Source' to 'ARB' and activate the appropriate waveform on other generators (2 to 7) with different frequency offsets.

- Set the 'Attenuation' of all generators to 0 dBm and the 'Level' to -20 dBm, then increase the 'Level' until you reach the POF.
Perform a channel power measurement with a spectrum analyzer.
This value must be larger than -8 dBm.
Do not exceed the receivers maximum input level specification.

3.3 Phase Noise

3.3.1 General

Phase locked loop carrier regeneration in the receiver is sensitive to phase noise. Thus document A/74:2010 specifies the receiver at TOV should tolerate a phase noise level that equals or exceeds -80 dBc/Hz at 20 kHz away from the carrier. The recommended phase noise profile decays at a rate of 20 dB per decade of frequency offset over a range of at least 500 Hz to 100 kHz.

3.3.2 Test Setup

Maintain the test setup of Figure 1.

3.3.3 Test Procedure

- Press the 'PRESET' button, setup an ATSC service on the R&S®BTC and tune the receiver under test to the service.
- Since document A74:2010 does not specify any certain level, set a moderate 'Level', e.g. -53 dBm.

- Set 'Noise' to 'Add'. In the 'Phase Noise' menu set 'Phase Noise' to 'On', and load the file 'D:\NOISE\PhaseNoise\A74_2010.fcf' for 'SSB shape profile'.
- Set phase noise value for 100 Hz to -54 dBc/Hz. According to the decay of 20 dB per decade of frequency, this equals -94 dBc/Hz at 10 kHz. The value at 20 kHz is not shown in the R&S®BTC phase noise settings (Figure 4), but can easily be determined (-100 dB) by subtracting 6 dB from the 10 kHz value.

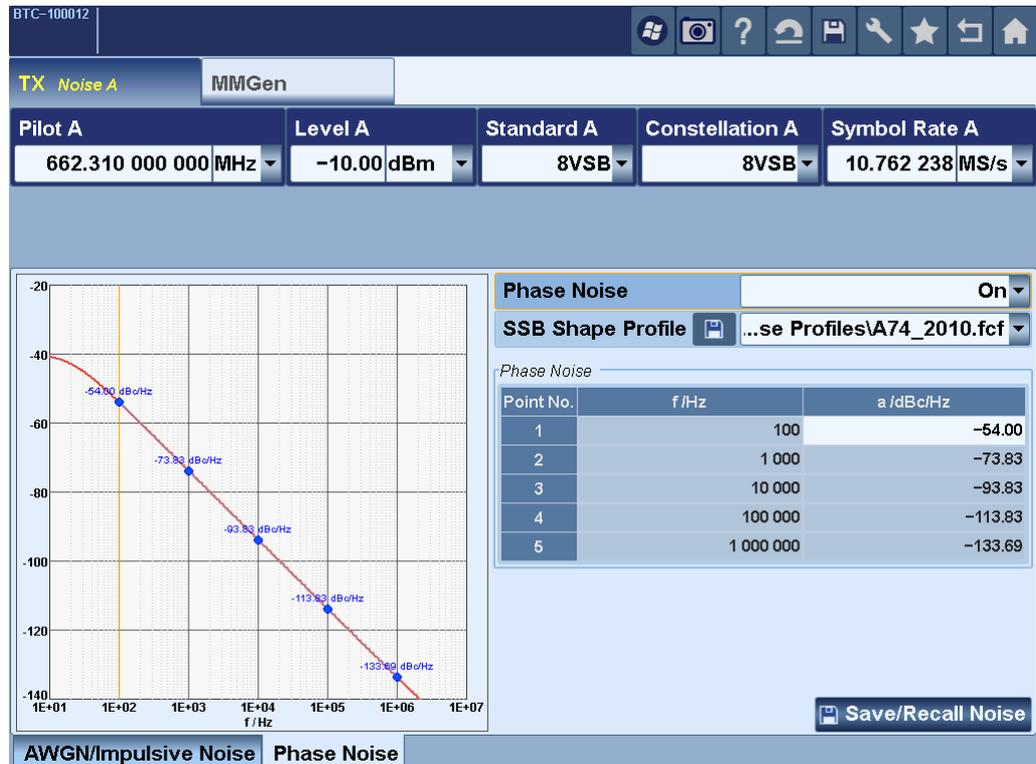


Figure 4: R&S®BTC-Phase noise settings

- Increase the phase noise value for 100 Hz setting until you reach the TOV. The value at 20 kHz (= value at 10 kHz minus 6 dB) should exceed -80 dBc/Hz.

3.4 Selectivity

3.4.1 Co-Channel Rejection

3.4.1.1 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. Document A/74:2010 recommends that the receiver tolerates ATSC and NTSC co-channel interferers with levels equal or exceeding the ones specified in the following table for two different wanted signal levels.

Wanted Signal Level [dBm]	Co-Channel Minimum S/I Ratio [dB]	
	NTSC	ATSC
-68	+2.5	+15.5
-53	+2.5	+15.5

Table 2: Minimum wanted signal to interferer (S/I) limits for NTSC and ATSC co-channels.

3.4.1.2 Test Setup

Maintain the test setup of Figure 1.

3.4.1.3 Test Procedure NTSC Interferer

- Press the 'PRESET' button, setup an ATSC service on the R&S®BTC and tune the receiver under test to the service.
- Set 'Level' to -68 dBm.
- In block 'Interferer' set 'Source' to 'ARB' and activate the 'NTSC_M_1CH_6MHZ.wv' waveform of the R&S®WV-K816 library on generator 1.
- Set 'Freq. Offset' to 0 MHz.
- Set 'Attenuation' to +20 dB, then decrease until the receiver reaches the TOV. This value must not exceed +2.5 dB.
- Repeat the test with a level setting of -53.0 dBm.

3.4.1.4 Test Procedure ATSC Interferer

- Press the 'PRESET' button, setup an ATSC service on the R&S®BTC and tune the receiver under test to the service.
- Set 'Level' to -68 dBm.
- In block 'Interferer' set 'Source' to 'ARB' and activate the '8VSB_Pilot.wv' waveform of the R&S®WV-K1114 library on generator 1.
- Set 'Freq. Offset' to 0 MHz.
- Set 'Attenuation' to +20 dB, then decrease until the receiver reaches the TOV. This value must not exceed +15.5 dB.
- Repeat the test with a 'Level' setting of -53.0 dBm.

3.4.2 Adjacent Channel Rejection

3.4.2.1 General

This test determines the sensitivity (selectivity) of the receiver to strong signals transmitted in the upper and lower adjacent frequency channel. Document A/74:2010 recommends that the receiver tolerates NTSC and ATSC adjacent channel interferers with levels equal or exceeding the ones specified in the following table for three wanted signal levels.

Wanted Signal Level [dBm]	Adjacent Channel Minimum S/I Ratio [dB]	
	NTSC	ATSC
-68	-40	-33
-53	-35	-33
-28	-26	-20

Table 3: Minimum S/I limits for NTSC and ATSC adjacent channels.

3.4.2.2 Test Setup

Maintain the basic test set-up of Figure 1.

3.4.2.3 Test Procedure NTSC Interferer

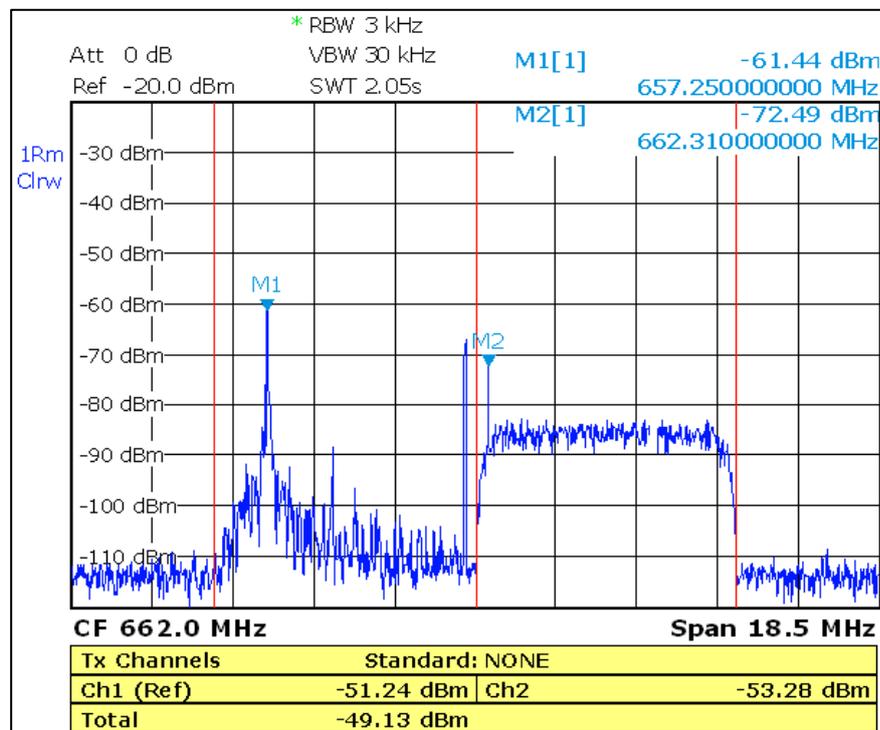


Figure 5: Wanted ATSC signal with lower adjacent NTSC signal

Follow the same test procedure as defined for the co-channel test (3.4.1.3). This time however apply the limits of Table 3 and:

- Set 'Freq. Offset' to 12.0 MHz for the upper adjacent channel, respectively -14.0 MHz for the lower adjacent channel.
- In menu 'Signal Gen.' set 'Frequency Offset' to 6.0 MHz respectively -8.0 MHz.
- In menu 'RF - Frequency' adjust the 'Pilot' frequency by -6.0 MHz, respectively 8.0 MHz to compensate for the non-zero signal frequency offset.



In principle one can perform this test with the originally expected interferer frequency offset of 6.0 MHz respectively -6.0 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 residual carrier inside the wanted signal resulting in distorted test results. The residual carrier can be shifted out of the wanted signal band by using the proposed signal frequency offset.

3.4.2.4 Test Procedure ATSC Interferer

Follow the same test procedure as defined for the co-channel test (3.4.1.4). This time however apply the limits of Table 3 and:

- Set 'Freq. Offset' to 6 MHz for the upper adjacent channel, respectively -6 MHz for the lower adjacent channel.

3.4.3 Taboo Channel Rejection

3.4.3.1 Test Setup

Maintain the setup of Figure 1. For some parts of the tests, one additional test transmitter like the R&S®SFC is required like described below.

3.4.3.2 Test Procedure

Follow the same test procedure as defined for the co-channel test (3.4.1). This time however:

- In menu 'Signal Gen. - Signal' set 'Frequency Offset' and in menu 'Interferer - ARB' set 'Freq. Offset' according to Table 4. Again, compensate a non-zero signal frequency offset by adjusting the 'PILOT FREQUENCY' accordingly.

Due to the R&S®BTC's maximal IQ output bandwidth of 160 MHz and the finite dynamic range, some S/I limits cannot be tested with the integrated interferer functionality. These limits have been underlined in Table 4 to indicate, that these interfering signals have instead to be generated by one additional test transmitter like the R&S®SFC.

Before combining this interferer signal with the wanted signal of the R&S®BTC, it has to be filtered with a tunable bandpass to get a narrowband interferer. Otherwise the broadband noise floor would unintentionally affect the wanted signal.

Taboo Channel	Signal Frequency Offset	Interferer Freq. Offset	Minimum S/I Ratio [dB] for		
			-68 dBm	-53 dBm	-28 dBm
N-15	8	-42	<u>-57</u>	-45	-20
N-14	48	-36	<u>-57</u>	-45	-20
N-13	48	-30	<u>-57</u>	-45	-20
N-12	36	-36	<u>-57</u>	-45	-20
N-11	36	-30	<u>-57</u>	-45	-20
N-10	36	-24	<u>-57</u>	-45	-20
N-9	36	-18	<u>-57</u>	-45	-20
N-8	36	-12	<u>-57</u>	-45	-20
N-7	36	-6	<u>-57</u>	-45	-20
N-6	0	-36	<u>-57</u>	-45	-20
N-5	0	-30	<u>-56</u>	-42	-20
N-4	0	-24	<u>-52</u>	-40	-20
N-3	0	-18	<u>-48</u>	-40	-20
N-2	0	-12	-44	-40	-20
N+2	0	12	-44	-40	-20
N+3	0	18	<u>-48</u>	-40	-20
N+4	0	24	<u>-52</u>	-40	-20
N+5	0	30	<u>-56</u>	-42	-20
N+6	0	36	<u>-57</u>	-45	-20
N+7	-36	6	<u>-57</u>	-45	-20
N+8	-36	12	<u>-57</u>	-45	-20
N+9	-36	18	<u>-57</u>	-45	-20
N+10	-36	24	<u>-57</u>	-45	-20
N+11	-36	30	<u>-57</u>	-45	-20
N+12	-36	36	<u>-57</u>	-45	-20
N+13	-48	30	<u>-57</u>	-45	-20
N+14	-48	36	<u>-57</u>	-45	-20
N+15	-48	42	<u>-57</u>	-45	-20

Table 4: R&S®BTC settings and S/I limits for the taboo channel rejection tests. Testing the underlined S/I limits requires an additional test transmitter.



The total number of tests mounts up to 168:

- 2x14 Channels
- Each for either NTSC or ATSC (x2)
- Each for three different wanted signal levels (x3)

3.4.4 Burst Noise Performance

3.4.4.1 General

Document A/74:2010 specifies that the receiver at TOV must tolerate an impulsive noise signal with a signal-to-interference ratio of 5 dB or less. This impulsive white noise burst must have a duration of 165 μs and repeat itself at a rate of 10 Hz. Such a signal is depicted in Figure 6.

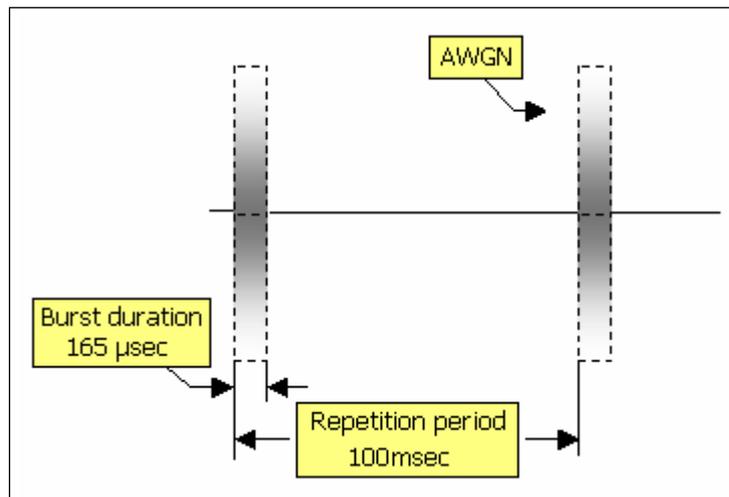


Figure 6: Impulsive noise burst as specified in document A/74:2010

3.4.4.2 Test Setup

Maintain the test setup of Figure 1.

3.4.4.3 Test Procedure

- Press the 'PRESET' button, setup an ATSC service on the R&S®BTC and tune the receiver under test to the service.
- Since document A74:2010 does not specify any certain level, set a moderate 'Level', e.g. -53 dBm.
- Set 'Noise' to 'Add' and 'Impulsive Noise' to 'On'.
In the 'Impulsive Noise' menu, set the 'C/I' to 15 dB and 'Frame Duration' to 100 ms.
Since a basic impulse duration comprises 250 ns, enter 660 for the 'Pulses per Burst' setting to achieve an effective burst duration of 165 μs ($660 \times 0.25 \mu\text{s} = 165 \mu\text{s}$).

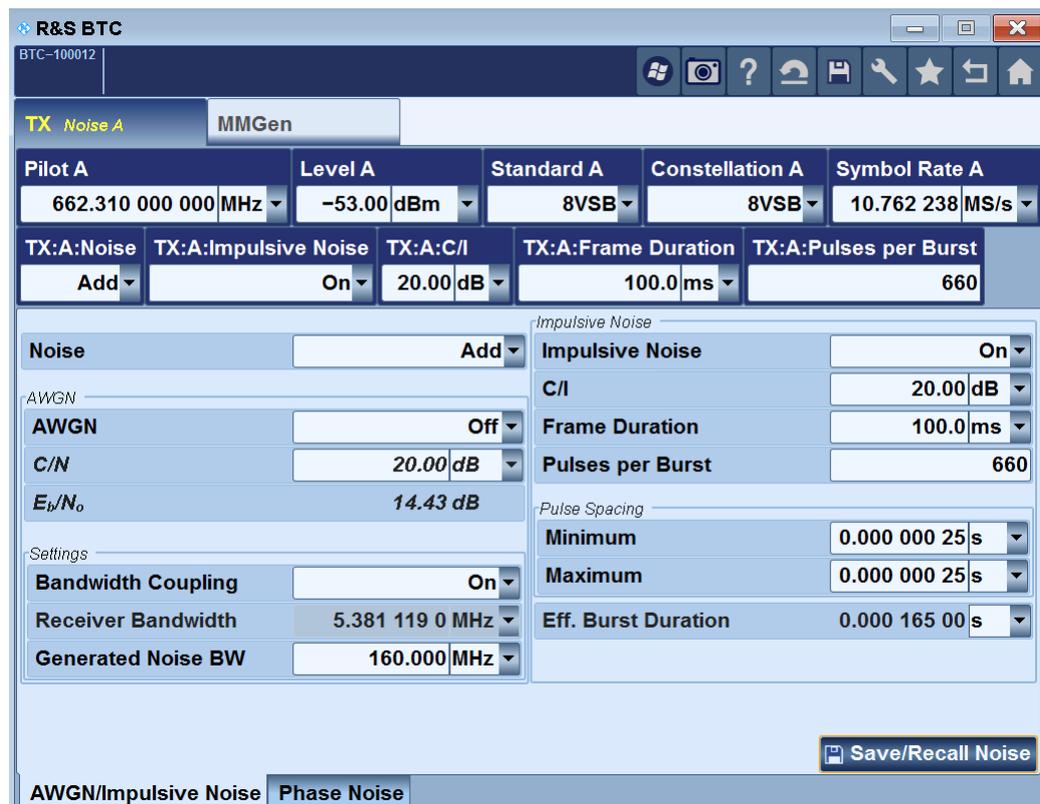


Figure 7: R&S®BTC-Impulsive noise settings

- Decrease the 'C/I' setting in the impulsive noise menu until the receiver reaches the TOV. This value must be lower than 5 dB.



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 'Tolerance to Noise Tests for DTV Receivers' (see 5.3.1).

3.5 Multipath

3.5.1 Field Ensembles

The field ensembles waveforms available from the ATSC on request contain multiple multipath related stress tests for the receiver. Each waveform has a runtime of approx. 25 s and a file size of 1 GByte.

With the R&S®ARB Toolbox software, which is freely available as part of application note 1GP88 (see 5.3.2), these ATSC waveforms can be quickly converted for use with the R&S®BTC's arbitrary waveform generator. This generator supports up to 4 Gbytes waveform file size and thus the full 25 seconds of runtime.

3.5.2 Single Static Echoes

3.5.2.1 General

The test requires the receiver to be subjected to a direct path and one single indirect path with variable delay and attenuation. This configuration can quickly be set by loading the fading profile 'A74_2010_Single_Static_Echo.fad'. This file is distributed together with this application note. During the test only one echo (Path 1-1 to 2-1 and 2-3 to 3-4) is active together with the main path (Path 2-2).

Designation	Path 1-1	Path 1-2	Path 1-3	Path 1-4	Path 1-5	Path 2-1	Path 2-2	Path 2-3	Main Path 2-4	Path 2-5
State	---	---	---	Not used	Not used	---	---	---	On	---
Profile	Pure Doppler	Constant Phase	Pure Doppler							
Path Loss /dB	15.00	7.00	7.00	50.00	3.00	5.00	3.00	0.5	0.0	0.5
Basic Delay /μs	0.0	0.0	0.0	0.0	0.0	25.0	25.0	25.0	25.0	30.0
Additional Delay /μs	0.0	10.0	20.0	0.0	0.0	25.0	30.0	5.0	10.0	15.0
Resulting Delay /μs	0.0	10.0	20.0	25.0	30.0	25.0	30.0	35.0	40.0	45.0
Constant Phase /Deg	0	0	0	0	0	0	0	0	0	0
Speed m/s	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	---	0.02
Frequency Ratio	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	---	1.0
Doppler Shift /Hz	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	---	0.05

Designation	Path 3-1	Path 3-2	Path 3-3	Path 3-4	Path 3-5	Path 4-1	Path 4-2	Path 4-3	Path 4-4	Path 4-5
State	---	---	---	---	Not used	---	---	Not used	Not used	Not used
Profile	Pure Doppler									
Path Loss /dB	1.0	1.0	2.0	3.0	50.0	4.0	15.0	50.0	50.0	50.0
Basic Delay / μ s	50.0	50.0	50.0	50.0	50.0	80.0	80.0	80.0	80.0	80.0
Additional Delay / μ s	0.0	5.0	10.0	20.0	0.0	0.0	10.0	30.0	30.0	30.0
Resulting Delay / μ s	50.0	55.0	60.0	70.0	50.0	80.0	90.0	80.0	80.0	80.0
Constant Phase /Deg	0	0	0	0	0	0	0	0	0	0
Speed m/s	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Frequency Ratio	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	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05

Table 5: R&S®BTC fading configuration for single static echo test.



In the fading settings menu, the 'Reference' was set to 'Doppler Frequency'. In this mode the R&S®BTC calculates the 'Speed' automatically according to the following equation.

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

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 speed of light.

r is the frequency ratio [-1...1].

3.5.2.2 Test Setup

Maintain the setup of Figure 1.

3.5.2.3 Test Procedure

- Press the 'PRESET' button, setup an ATSC service on the R&S®BTC and tune the receiver under test to the service.
- Load the fading profile 'A74_2010_Single_Static_Echo.fad' (see 3.5.2.1).
- Set 'Level' to -28 dBm.



With fading on, the instrument's level indication reflects the power that results from the vector summation of all active paths. The level ratios of the echoes defined in document A/74:2010 are always with respect to the direct (main) path as if the main path existed on its own. This means that you cannot directly enter the 'Level' setting, but instead a

correction needs to take place first. The installer of the tool 'R&S®BTC Fader Mainpath GUI' is distributed together with this application note. It allows you to enter the desired level of the main path (-28 dBm) and calculates the R&S®BTC's 'Level' setting based on the current fading configuration. Future changes on the fading configuration are automatically accounted for. After installation, the shortcut to execute the tool is located within the startup menu under 'Programs\Fadergui'.

State	On	On	On	On	On	On	Off
Profile	Const. Phase	Const. Phase	Const. Phase	Const. Phase	Pure Doppler	Const. Phase	Rayleigh
Path Loss /dB	0.00	15.00	15.00	7.00	7.00	15.00	0.00
Basic Delay /µs	0.000 000 0	0.000 000 0	0.000 000 0	0.000 000 0	0.000 000 0	30.000 000	30.000 000
Additional Delay /µs	1.800 000 0	0.000 000 0	1.950 000 0	3.600 000 0	7.500 000 0	11.600 000 0	0.000 000 0
Resulting Delay /µs	1.800 000 0	0.000 000 0	1.950 000 0	3.600 000 0	7.500 000 0	41.600 000 0	30.000 000 0
Power Ratio /dB	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Frequency Spread	0.100 0	0.100 0	0.100 0	0.100 0	0.100 0	0.100 0	0.100 0
Const Phase /Deg	0.0	125.0	80.0	45.0	0.0	90.0	0.0
Speed	m/s	0.000	0.000	0.000	1.000	0.000	0.000
Freq. Ratio		1.00	1.00	1.00	1.00	1.00	1.00

Figure 8: Fading settings for single static echo test including main path level correction.

- Switch 'Fading' on.
- The state of Path '2-2' (Direct path) should already be set to 'On'. Now start testing by also enabling the first echo Path '1-1'.
- Observe if the receiver shows signs of failure (TOF).
- Disable Path '1-1' and enable Path '1-2'. Repeat the test until all echo paths have been separately tested.



In practice, the position of the spectral notches caused by destructive echo interference depends on the carrier frequency. In order to get a reproducible laboratory setup, the R&S®BTC references the resulting phase offset of an echo delay to the pilot phase (if the frequency setting 'VSB Frequency' is set to 'Pilot', otherwise it is referenced to the center frequency).

The spectral notch positions of a certain echo delay can be determined and adjusted as follows:

- The constant frequency spacing of the notches (f_{notch}) is always equal to the reciprocal delay.
- Referencing the echo phase offset to the pilot phase results in a symmetrical notch placement around the pilot frequency, so that the distance between the pilot and the first lower notch is $-(f_{\text{notch}})/2$ and $+(f_{\text{notch}})/2$ for the upper notch.

For instance, an echo delay of $0.2 \mu\text{s}$ gives 5 MHz for f_{notch} . Thus we observe the first notches at ± 2.5 MHz around the pilot frequency:

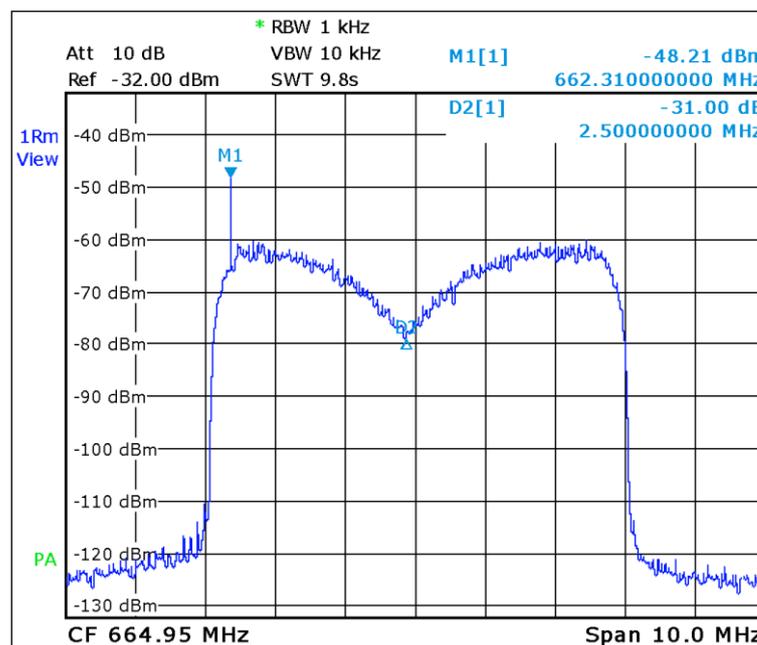


Figure 9: Resulting notch position for an echo delay of $0.2 \mu\text{s}$.

- One can equally shift the positions of all notches by assigning a constant phase offset (ph_{offset}) for the echo path:

$$f_{\text{shift}} = f_{\text{notch}} * \frac{ph_{\text{offset}}}{360}$$

3.5.3 Single Dynamic Echoes

3.5.3.1 General

The test requires the receiver to be subjected to a direct path and one single indirect path with variable delay and attenuation. This configuration can quickly be set by loading the fading profile 'A74_2010_Single_Dynamic_Echo.fad'. This file is distributed together with this application note.

Designation	Main 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
State	On	On	---	---	---	---	---	---	---	---	---
Profile	Const. Phase	Pure Doppler									
Path Loss /dB	0.0	---	---	---	---	---	---	---	---	---	---
Basic Delay / μ s	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Additional Delay / μ s	0.0	---	---	---	---	---	---	---	---	---	---
Resulting Delay / μ s	0.0	---	---	---	---	---	---	---	---	---	---
Constant Phase /Deg	0	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

Table 6: R&S®BTC fading configuration for single dynamic echo test.

3.5.3.2 Test Setup

Maintain the setup of Figure 1.

3.5.3.3 Test Procedure

1. Press the 'PRESET' button, setup an ATSC service on the R&S®BTC and tune the receiver under test to the service.
2. Load the fading profile 'A74_2010_Single_Dynamic_Echo.fad' (see 3.5.2.13.5.3.1).
3. Set 'Level' to -28 dBm, considering the level correction described in 3.5.2.3.
4. Switch 'Fading' on.
5. Verify that only Path '1-1' (Main path) and Path '1-2' (Echo 1) are enabled ('State' is set to 'On').
6. Additionally enable Path '1-3' (Echo 2).
7. Set 'Additional Delay' of Path '1-2' (Echo 1) and Path '1-3' (Echo 2) to 0.2 μ s.
8. Set 'Path Loss' of Path '1-2' (Echo 1) and Path '1-3' (Echo 2) to 7 dB.

9. Decrease 'Path Loss' of Path '1-2' (Echo 1) and Path '1-3' (Echo 2) simultaneously in 0.5 dB steps until the receiver reaches the TOV.
10. Increase 'Additional Delay' of Path '1-2' (Echo 1) and Path '1-3' (Echo 2) simultaneously in 0.2 μs steps until 2 μs while repeating steps 8 and 9. Record the all particular achieved echo delays and path losses at the observed TOVs.
11. Disable Path '1-3' (Echo 2). Enable Path '1-4'. Repeat steps 8 to 11 for Path '1-4', Path '1-5' ... to 'Path 3-1'.



The total number of tests mounts up to 90:

- 9 different paths for the second echo
- 10 different delays for the echo paths

3.5.4 Multiple Dynamic Echoes R2.1

3.5.4.1 General

This test requires four different 6-path fading configurations (Ensembles). Each of these fading configurations can quickly be activated in the fading configuration menu on the R&S®BTC. Just set 'Standard' to 'ATTC', and then one of the four 'CRC Dynamic' entries within the 'Parameter Set' list.

Designation	Path 1-1	Path 1-2	Path 1-3	Path 1-4	Path 1-5	Path 2-1
State	On	On	On	On	On	On
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
Constant Phase /Deg	0	125	80	45	---	90
Frequency Ratio	0.0	0.0	0.0	0.0	1.0	0.0
Doppler Shift /Hz	---	---	---	---	0 to 5	---

Table 7: ATTC 'CRC Dynamic 1' fading configuration for dynamic echo test R2.1, Ensemble 1

Designation	Path 1-1	Path 1-2	Path 1-3	Path 1-4	Path 1-5	Path 2-1
State	On	On	On	On	On	On
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 / μ s	0.0	0.0	0.0	0.0	0.0	0.0
Additional Delay / μ s	1.8	0.0	1.95	3.6	7.5	36.8
Constant Phase /Deg	0	125	80	45	---	90
Frequency Ratio	0.0	0.0	0.0	0.0	1.0	0.0
Doppler Shift /Hz	---	---	---	---	0 to 5	---

Table 8: ATTC 'CRC Dynamic 2' fading configuration for dynamic echo test R2.1, Ensemble 2

Designation	Path 1-1	Path 1-2	Path 1-3	Path 1-4	Path 1-5	Path 2-1
State	On	On	On	On	On	On
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 / μ s	0.0	0.0	0.0	0.0	0.0	0.0
Additional Delay / μ s	1.8	0.0	1.95	3.6	7.5	36.8
Constant Phase /Deg	0	125	80	45	---	90
Frequency Ratio	0.0	0.0	0.0	0.0	1.0	0.0
Doppler Shift /Hz	---	---	---	---	0 to 5	---

Table 9: ATTC 'CRC Dynamic 3' fading configuration for dynamic echo test R2.1, Ensemble 3

Designation	Path 1-1	Path 1-2	Path 1-3	Path 1-4	Path 1-5	Path 2-1
State	On	On	On	On	On	On
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 / μ s	0.0	0.0	0.0	0.0	0.0	0.0
Additional Delay / μ s	1.8	0.0	1.95	3.6	7.5	36.8
Constant Phase /Deg	0	125	80	45	0	90
Frequency Ratio	0.0	0.0	0.0	0.0	1.0	0.0
Doppler Shift /Hz	0.0	0.0	0.0	0.0	0 to 5	0.0

Table 10: ATTC 'CRC Dynamic 4' fading configuration for dynamic echo test R2.1, Ensemble 4

3.5.4.2 Test Setup

Maintain the basic test setup of Figure 1.

3.5.4.3 Test Procedure

1. Press the 'PRESET' button, setup an ATSC service on the R&S®BTC and tune the receiver under test to the service.
2. Set 'Level' to -53 dBm, considering the level correction described in 3.5.2.3.
3. Load the first fading parameter set ('CRC Dynamic 1'). Switch 'Fading' on.
4. In the fading settings menu, set 'Reference' to 'Doppler Freq'.
5. Set 'Path Loss' of Path 1-5 to 50 dB.
6. Set 'Res Doppler Shift' of Path 1-5 to 0 Hz.
7. Decrease 'Path Loss' of Path 1-5 in a stepwise fashion until the receiver reaches the TOV. Record the path loss and Doppler shift reading.
8. Repeat steps 5 to 7 with 'Doppler Shift' settings of 1, 2, 3, 4, and 5 Hz.
9. Repeat steps 3 to 8 for the remaining three fading ensembles.



The total number of tests mounts up to 24:

- 6 different Doppler shifts for path 1-5
- 4 different fading ensembles

3.5.5 Multiple Dynamic Echoes R2.2

3.5.5.1 General

For this test, three particular 6 path fading profiles (Ensembles) have been defined. Each of these configurations can quickly be set by loading the fading profile corresponding 'A74_2010_Multi_Dynamic_Echoes_[1...3].fad'. These files are distributed together with this application note.

Designation	Path 1-1	Path 1-2	Path 1-3	Path 1-4	Path 1-5	Path 2-1
State	On	On	On	On	On	On
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 / μ s	0.0	0.0	0.0	0.0	0.0	30.0
Additional Delay / μ s	1.8	0.0	1.95	3.6	7.5	11.6
Constant Phase /Deg	0	125	80	45	0.0	90
Frequency Ratio	---	---	---	---	1.0	---
Doppler Shift /Hz	0.0	0.0	0.0	0.0	0 to 5	0.0

Table 11: R&S®BTC fading configuration for echo test R2.2, Ensemble 1

Designation	Path 1-1	Path 1-2	Path 1-3	Path 1-4	Path 1-5	Path 2-1
State	On	On	On	On	On	On
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 / μ s	0.0	0.0	0.0	0.0	0.0	30.0
Additional Delay / μ s	1.8	0.0	1.95	3.6	7.5	11.6
Constant Phase /Deg	0	125	80	45	0	90
Frequency Ratio	---	---	---	---	1.0	---
Doppler Shift /Hz	0.0	0.0	0.0	0.0	0 to 5	0.0

Table 12: R&S®BTC fading configuration for echo test R2.2, Ensemble 2

Designation	Path 1-1	Path 1-2	Path 1-3	Path 1-4	Path 1-5	Path 2-1
State	On	On	On	On	On	On
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 / μ s	0.0	0.0	0.0	0.0	0.0	30.0
Additional Delay / μ s	1.8	0.0	1.95	3.6	7.5	11.6
Constant Phase /Deg	0	125	80	45	---	90
Frequency Ratio	---	---	---	---	1.0	---
Doppler Shift /Hz	0.0	0.0	0.0	0.0	0 to 5	0.0

Table 13: R&S®BTC fading configuration for echo test R2.2, Ensemble 3

3.5.5.2 Test Setup

Maintain the test setup of Figure 1.

3.5.5.3 Test Procedure

1. Press the 'PRESET' button, setup an ATSC service on the R&S®BTC and tune the receiver under test to the service.
2. Set 'Level' to -53 dBm, considering the level correction described in 3.5.2.3.
3. In the noise menu, switch on 'Noise' and 'AWGN'. Switch off 'Bandwidth Coupling' and set 'Receiver Bandwidth' to 6 MHz.

4. Load the first fading configuration (R2.2 Ensemble 1) as described in 3.5.5.1. Switch on 'Fading'.
5. Set C/N in the 'R&S®BTC Fader Mainpath GUI' tool (see 3.5.2.3) to 30 dB.
6. Set 'Doppler Shift' of Path 1-5 to 0 Hz.
7. Decrease the C/N setting in a stepwise fashion until the receiver reaches the TOV. Record the C/N reading, which should be lower than 18 dB.
8. Repeat steps 5 to 7 with 'Doppler Shift' settings of 1, 2, 3, 4, and 5 Hz.
9. Repeat the steps 4 to 8 for the remaining two fading ensembles.



The total number of tests mounts up to 18:

- 6 different Doppler shifts for path 1-5
- 3 different fading ensembles

3.5.6 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 echoes with a considerable amount of frequency shift.

Document A/74:2010 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 fading profile 'A74_2010_Airplane_Flutter.fad'. This file is distributed together with this application note.

Designation	Path 1-1	Path 1-2	Path 1-3	Path 1-4	Path 1-5	Path 2-1
State	On	---	---	---	---	---
Profile	Constant Phase	Pure Doppler				
Path Loss /dB	0.0	30	30	30	30	30
Basic Delay / μ s	0.0	0.0	0.0	0.0	0.0	0.0
Additional Delay / μ s	0.0	5.0	5.0	10.0	10.0	20.0
Doppler Shift /Hz	0	50	75	100	125	150

Table 14: R&S®BTC fading-configuration for high airplane flutter Doppler frequency shift testing

3.5.6.1 Test Setup

Maintain the test setup of Figure 1.

3.5.6.2 Test Procedure

- Press the 'PRESET' button, setup an ATSC service on the R&S®BTC and tune the receiver under test to the service.
- Set 'Level' to -28 dBm, considering the level correction described in 3.5.2.3.
- In the noise menu, switch on 'Noise' and 'AWGN'. Switch off 'Bandwidth Coupling' and set 'Receiver Bandwidth' to 6 MHz.
- Load the fading profile 'A74_2010_Airplane_Flutter.fad' (see 3.5.6). Switch on 'Fading'.
- Set C/N in the 'R&S®BTC Fader Mainpath GUI' tool (see 3.5.2.3) to 30 dB.
- Switch on 'State' of Path '1-2'.
- Starting with a 'Path Loss' of 30 dB, decrease this value until the receiver reaches the TOV. Record the path loss, delay and Doppler shift reading.
- Switch off 'State' of Path '1-2'.
- Repeat the test for path Path '1-3' to Path '2-1', so that only one additional path is switched on at one time apart from the main path Path '1-1'.

4 Abbreviations

ATSC Advanced Television Systems Committee

BER Bit Error Ratio

CI Common Interface

GUI Graphical User Interface

POF Point of Failure

TOV Threshold of Visibility

TS Transport Stream

5 References

5.1 Documents

5.1.1 ATSC Document A/74:2010

'ATSC Recommended Practice: Receiver Performance Guidelines'

<http://www.atsc.org> >> Standards >> Recommended Practices >> A/74

5.2 Software

5.2.1 R&S®WinIQSim2

'Generation of Digital I/Q Signals According to Various Radio Standards'

<http://www2.rohde-schwarz.com/product/WinIQSIM2.html>

5.3 Application Notes

5.3.1 7BM64

'Tolerance to Noise Tests for DTV Receivers'

<http://www.rohde-schwarz.com> >> Downloads >> Application Notes >> 7BM64

5.3.2 1GP88

1GP88: R&S ARB Toolbox

<http://www.rohde-schwarz.com> >> Downloads >> Application Notes >> 1GP88

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 and suggestions about this Application Note to customersupport@rohde-schwarz.com.

7 Ordering Information

Sorted as introduced in Chapter 2.

Designation	Type	Order No.
R&S®BTC Broadcast Test Center		
Broadcast Test System	R&S®BTC	2112.3000.02
ATSC M/H/8VSB Coder	R&S®BTC-K518	2114.7135.02
Arbitrary Waveform Generator	R&S®BTC-K35	2114.6974.02
Analog Signals	R&S®WV-K816	2116.9935.02
DTV Interferers	R&S®WV-K1114	2116.9964.02
Fading Simulator	R&S®BTC-B1031	2114.3700.02
AWGN Generator	R&S®BTC-K1040	2114.7070.02
Extended Noise Generator	R&S®BTC-K1043	2114.7235.02
Recommended		
RF Power Measurements ¹	R&S®BTC-K2055	2114.7258.02

¹ Can be used with R&S®NRP sensors, e.g. R&S®NRP-Z91 (1168.8004.02)

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