Products: R&S®SFU

Phase Noise Profile Creator V. 1.2 for the R&S®SFU

Basics and Applications of the R&S®SFU-K41 Phase Noise Option

Application Note

This Application Note briefly explains the theoretical background regarding phase noise before describing the phase noise option for the R&S®SFU. You will see how the phase noise profile creator application software can be used to approximate specific phase noise curves and how to output them with the aid of the R&S®SFU.

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Contents

1   Overview

An important characteristic of an oscillator is its spectral purity. The spectral purity, generally referred to as phase noise, is a measure of the short-term stability of oscillators.

In the case of the R&S®SFU Broadcast Test System from Rohde & Schwarz, the oscillator has outstanding phase noise characteristics.

At the receiver end, the quality of the received signal is mainly determined by the phase noise of the oscillators used in the transmission path.

To allow manufacturers of receivers to thoroughly analyze the behavior of a device under test (DUT), the R&S®SFU offers a special feature: the R&S®SFU-K41 phase noise option.

This Application Note briefly explains the theoretical background regarding phase noise before describing the phase noise option of the R&S®SFU. You will see how the phase noise profile creator application software of the R&S®SFU can be used to approximate specific phase noise curves and how to output them with the aid of the R&S®SFU.

2   Where to get the application software?

Please contact the Customer Support Center and provide the serial number of your device. CS will grant you access to one of our file servers via HTTP.

Customer Support Europe

Telephone: +49 180 512 4242

Fax: +49 89 4129 63778

E-mail: customersupport@rohde-schwarz.com

3   Software Features

The phase noise profile creator software application of the R&S®SFU allows users of the R&S®SFU to generate user-specific phase noise profiles with the R&S®SFU-K41 phase noise option.

For this purpose, the user defines five typical phase noise values with an offset of 100 Hz, 1 kHz, 10 kHz, 100 kHz and 1 MHz from the actual carrier. Based on these values, a phase noise curve is to some extent generated automatically, can be adjusted manually afterwards and stored or loaded into the R&S®SFU.

4   Hardware and Software Requirements

PC Hardware Requirements

	Minimum
CPU	Pentium II 450 MHz or better
RAM	128 Mbyte
Hard disk	50 Mbyte free hard disc space
Monitor	SVGA color monitor, resolution 1024 x 768 or better

PC Software Requirements

	Recommended
OS	Windows 98 / 2000 / Me / XP
OS add-ons	.NET Framework 2.0 or better

R&S®SFU Requirements

Software option	PHASE NOISE	R&S®SFU-K41	2110.7660.02

5   General Remarks on Phase Noise

Phase noise can be considered as a random frequency modulation around an "ideal" carrier.

The following equation describes an ideal carrier:

$$s(t) = A \cdot \cos(2 \cdot \pi \cdot f_1 \cdot t)$$

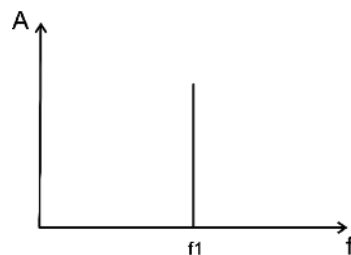As a result, a discrete spectral line is displayed in the frequency spectrum:

Fig. 1: Ideal oscillator

In reality, however, an oscillator cannot maintain this frequency .Thus, the following equation describes the carrier:

$$s(t) = A \cdot \cos(2 \cdot \pi \cdot f_1 \cdot t + \rho_n(t))$$

This kind of phase modulation (PM) results in a "broader" carrier in the frequency spectrum.
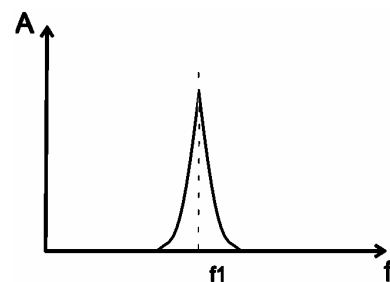

Fig. 2: Real oscillator with phase noise

Two important parameters are used to determine phase noise:

- Single sideband noise
- Double sideband noise

Single Sideband Noise

The most frequently used phase noise parameter is single sideband noise $£_\phi(f)$. It is defined as the spectral density of noise sidebands:

$$£_\phi(f) = \frac{N(f)}{B \cdot P_{sig}}$$

where: N (f)   = Noise power of a sideband
           B   = Measurement bandwidth
           P_{sig} = Total signal power

Single sideband noise is typically specified by the unit dBc/Hz. This parameter is used to describe the phase noise for the R&S®SFU.

Double Sideband Noise

Double sideband noise is the basic noise parameter from which all other noise parameters are derived. It is defined as the square of the phase oscillation referenced to the measurement bandwidth.

$$S_\phi(f) = \frac{\Delta\phi_{rms}^2}{B}$$

→ $S_\phi(f) \cong 2 \cdot £_\phi(f)$

(for small phase deviations)

6 R&S$^®$SFU-K41 Phase Noise Option

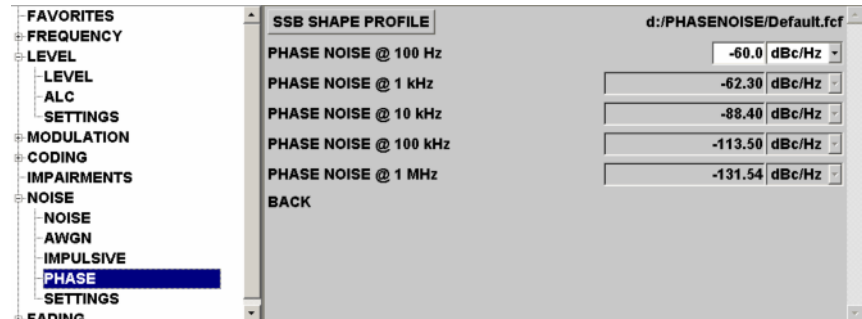## Graphical User Interface of the R&S$^®$SFU

Fig. 3: Phase noise generation with the R&S$^®$SFU

By using the SSB SHAPE PROFILE menu item, you can choose between different profiles for the frequency response of single sideband phase noise. Upon selection, a window opens where the profile files available on the R&S$^®$SFU can be selected. These are coefficient sets for digital filters. If a file is selected and confirmed with SELECT, the software configures the phase noise generator with the corresponding data.

The indicated single sideband spectrum (SSB PHASENOISE) of the signal carrier, or – in the case of multicarrier method – of all individual carriers, then follows the characteristics of the filter curve from the profile file.

Format of the Profile Files

When needed, separate profile files can be created in accordance with the example file in Fig. 4.

```
% Phase Noise Filter Coefficient File


SOS matrix:
1  -0.3098602294921875   0.0028991699218750   0.2500000000000000   -1.0389251708984375   0.0399322509765625
1  -1.0959930419921875   0.0994567871093750   1.0000000000000000   -1.0389251708984375   0.0399322509765625
```

Fig. 4: Example of a profile file

ASCII text must be used as the file format, the file extensions *.fcf and *.txt are permitted. The file is configured in such a way that after a random number of comment lines with the keyword "SOS Matrix" (second-order section matrix) there are two lines with six coefficients each, separated by spaces. Each line corresponds to a second-order section (filter elements with two zeros and two poles). The coefficients are in the sequence b0 b1 b2 a0 a1 a2 so that the following filter function applies to each line:

$$\underline{H} = a_0 \cdot \frac{b_0 + b_1 \cdot \underline{z}^{-1} + b_2 \cdot \underline{z}^{-2}}{1 + a_1 \cdot \underline{z}^{-1} + a_2 \cdot \underline{z}^{-2}}$$

From the above display of coefficients, conversion into a zero and pole display is possible.

The two sections, in turn, are cascaded. This corresponds to a multiplication of the two functions. Thus, a digital filter must be designed to generate a specific curve. Moreover, the individual coefficients must be within the range of [-2; 2).

Internal Phase Noise Generation

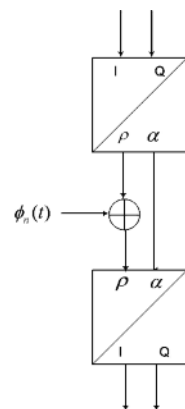The useful I and Q data is linked with the phase noise signal as follows:

Fig. 5: Generation principle

The above graphic shows that the generated noise signal is "genuine" phase noise. The amplitude of the noise signal is maintained at a constant level, the phase is varied.

The useful signal is converted from I and Q into phase (ρ) and amplitude (α). The noise phase ($\phi_n(t)$) is then added to the signal phase. The total signal is finally reconverted into its I and Q components.

7 Installation Instructions for the Phase Noise Profile Creator

Follow the installation steps below to install the phase noise profile creator of the R&S®SFU on your computer:

1. Installation of .NET Framework version 2.0 or better

2. Installation of the application from Rohde & Schwarz

Installation of .NET Runtime 2.0 or Better

The installation routine for the application from Rohde & Schwarz checks whether .NET Framework version 2.0 is installed. If this is not the case, you will be asked if the installation routine should be obtained from the Internet:
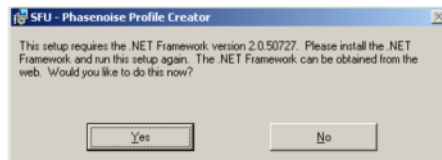

Fig. 6 Framework download window

If you confirm with YES, a browser window opens to the Microsoft web server. A download link (free of charge) can be selected for .NET Framework.
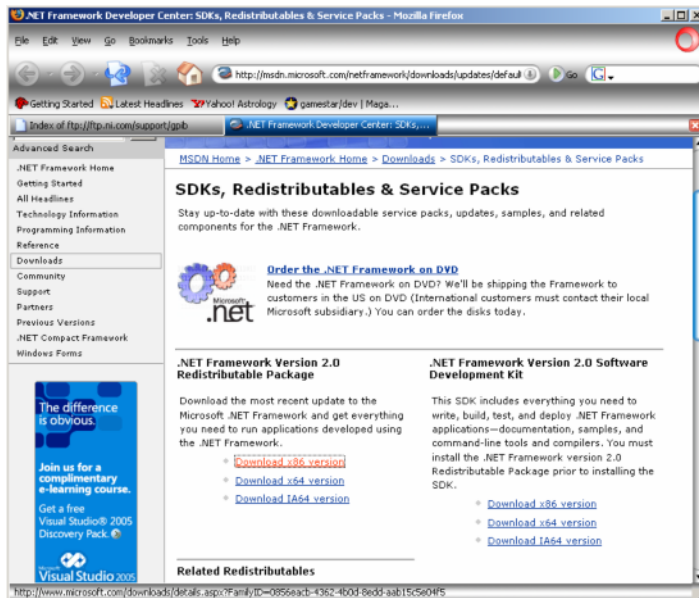

Fig. 7: Download page for .NET Framework

After the file is downloaded, start the Framework installation routine and follow the directions on the screen.

Installation of the Actual Program Files

After carrying out the installation routine for the application from Rohde & Schwarz, follow the directions on the screen. Before the application can be installed, the general conditions of use from Rohde & Schwarz have to be accepted.

The installation routine stores the program files in a user-selectable directory. Links to the program and the documentation are added to the start menu.

8 Application: Phase Noise Profile Creator

The following section describes how user-specific phase noise profiles can be generated with the phase noise profile creator of the R&S®SFU and displayed by means of the R&S®SFU.

The following screenshot shows the main application window:

General Functional Description

Based on five phase noise values at 100 Hz, 1 kHz, 10 kHz, 100 kHz and 1 MHz, an approximation of the phase noise characteristic is possible by semi-automatically adjusting the filter transfer function. In the implementation of the R&S®SFU a fourfold Infinite Impulse Response (IIR) filter is used. Through filter coefficients or respectively gain, zeros and poles in the discussed application, the definition of the curve characteristic is feasible.

Procedure

Generation is done essentially as follows:

1. Configuration of the optimization parameters via "Optimization conditions" in the menu. These optimization values are used to define an abort criterion for the phase noise curve calculation:
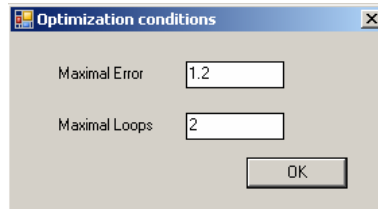
The abort criterion can either be the maximum permissible average square error (see previous section) or the maximum number of optimization loops.

The maximum average square error is defined as follows:
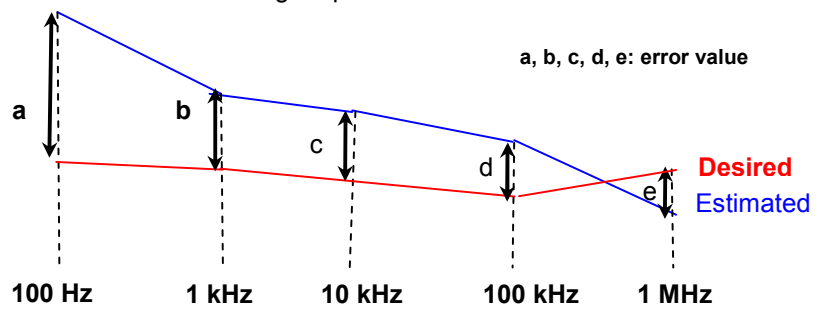
$$Error = \frac{a^2 + b^2 + c^2 + d^2 + e^2}{5}$$

The calculation does not always lead under all conditions to an optimal phase noise curve. Therefore manual adjustment can be carried out. See 5 and 6 for more details.
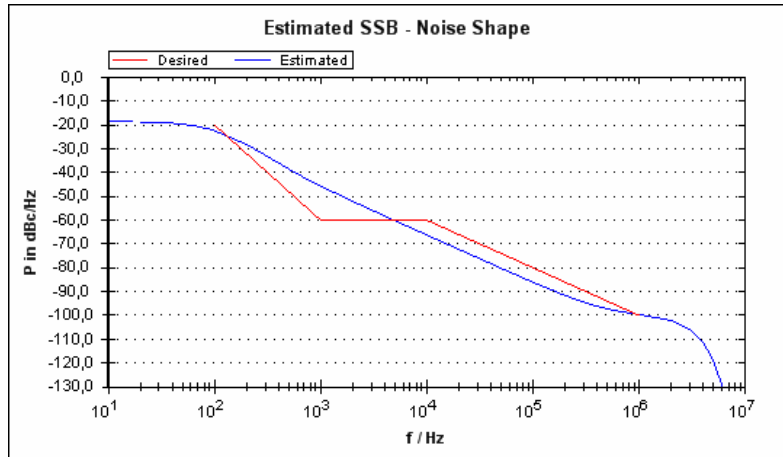
2. Entry of the desired phase noise values at 100 Hz, 1 kHz, 10 kHz, 100 kHz and 1 MHz:

3. Calculation of the automatic coefficient determination by selecting:

4. After optimization has been carried out, the current calculated graph is displayed in blue in addition to the "desired" graph (defined under 2).

Estimated SSB - Noise Shape

Legend: — Desired — Estimated

Y-axis: P in dBc/Hz, values from 0,0 down to -130,0 in steps of 10,0
X-axis: f / Hz, from 10^1 to 10^7

5. If this optimization is not sufficient (see 1), you can adjust the zeros and poles of the filter transfer function by manually configuring them. Another alternative is to carry out optimization with altered abort criteria. The "Manual Settings" selection must be activated to manually change the filter curve:

☑ Manual Settings
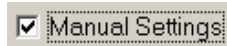
6. The four pairs of zeros and poles can now be entered manually in the activated range (Z1 to Z4, P1 to P4; Cartesian coordinate system).

   The parameters can have the following value ranges:

   I.   Gain: $0 < x < 4$

   II. Poles:

        Radius: $0 <= x < 1$ (polar coordinate system)

   III. Zeros:

        Radius: $0 <= x < 2$ (polar coordinate system)

   The results of the modified gain value and the zeros and poles are immediately visible in the SSB graphic. Subsequent manual optimization is now possible.

The relation between poles and coefficients (please refer to chapter 6) is as follows:

```
b01 = 1;
b11 = -(double)((double)z1 + (double)z2);
b21 = (double)((double)z1 * (double)z2 + (double)z1_j * (double)z1_j);

a11 = -(double)((double)p1 + (double)p2);
a21 = (double)((double)p1 * (double)p2 + (double)p1_j * (double)p1_j);

b02 = 1;
b12 = -(double)((double)z3 + (double)z4);
b22 = (double)((double)z3 * (double)z4 + (double)z3_j * (double)z3_j);

a12 = -(double)((double)p3 + (double)p4);
a22 = (double)((double)p3 * (double)p4 + (double)p3_j * (double)p3_j);
```
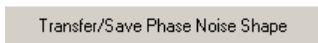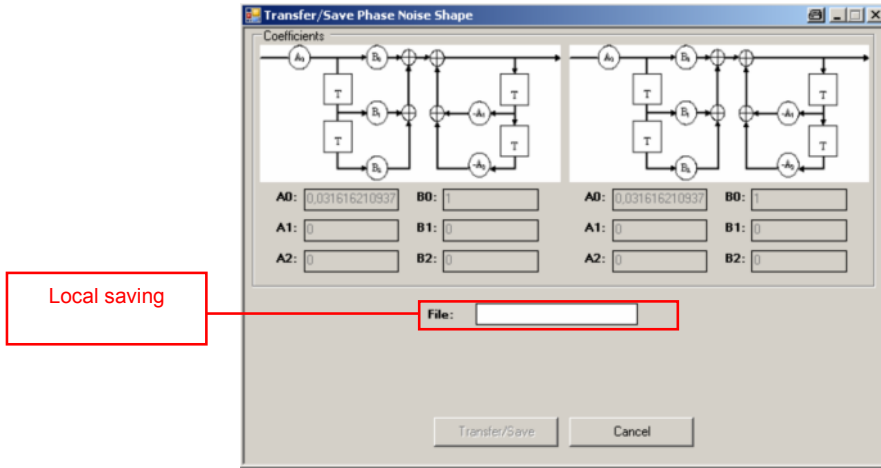
zx: Zero x (real)
zx_j: Zero x (imaginary)
px: Pole x (real)
px_j: Pole x (imaginary)

7. Press the "Transfer/Save Phase Noise Shape" button to transfer the configured phase noise profile.

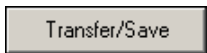Transfer/Save Phase Noise Shape

8. Now you can save the filter coefficients to a file. This file can later be loaded through the measurement instrument.

Local saving

When you select "File", a storage dialog opens, which specifies the name of the file to be stored.
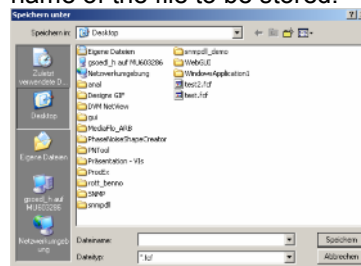
9. By clicking "Transfer/Save" the phase noise profile is written to the specified site.

Transfer/Save

10. To start the specific phase noise profile on the R&S®SFU, refer to Section 6.

9 Checking the Phase Noise Curve

It is recommended to check the self-generated phase noise curves by means of a spectrum analyzer with a phase noise measurement option. Spectrum analyzers such as the R&S®FSP, R&S®FSQ and R&S®FSUP, for example, are suitable:

Fig. 8: Test setup

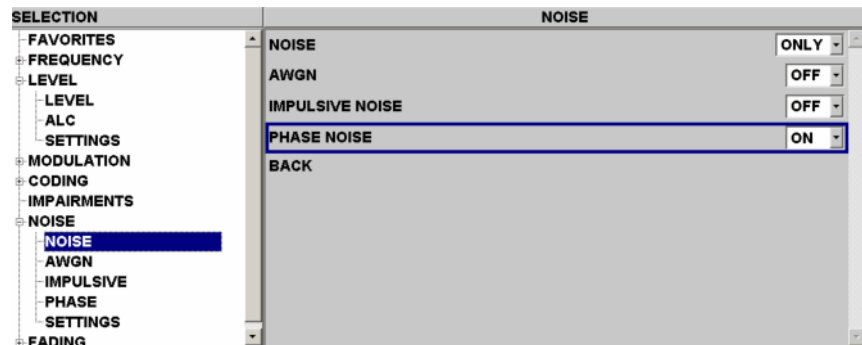The "Noise only" mode on the R&S®SFU must be selected to enable the measurement.

Fig. 9: The R&S®SFU noise menu

The phase noise personality of the spectrum analyzer allows a simple determination of the phase noise behaviour of the carrier:

PHASE NOISE			
Settings	**Residual Noise**		**Spot Noise**
Signal Freq: 442.000007 MHz	Evaluation from 100 Hz to 1 MHz		1 kHz	-62.37 dBc/Hz
Signal Level: -19.24 dBm	Residual PM	3.128 °	10 kHz -88.01 dBc/Hz
Signal Freq ?: -5.02 Hz	Residual FM	383.475 Hz	100 kHz -111.60 dBc/Hz
Signal Level ?: 0.01 dBm	RMS Jitter	19.6554 ps	1 MHz -130.01 dBc/Hz

PH Noise
RF Atten   0 dB
Top -40 dBc/Hz
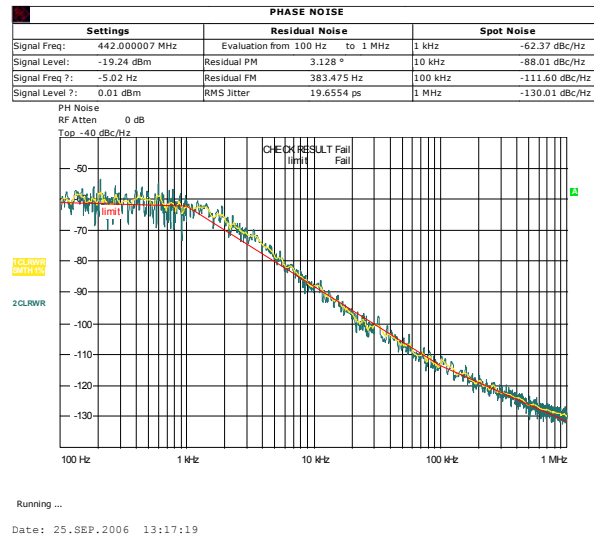
Running ...

Date: 25.SEP.2006 13:17:19

Fig. 10: Phase noise measurement using a spectrum analyzer

10 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

11 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
R&S SFU-K21	TS Recorder	2110.7482.02
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-K37	Interferer Management	2110.7647.02
R&S SFU-K40	Noise AWGN	2110.7653.02
R&S SFU-K41	Phase Noise	2110.7660.02
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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