Phase Noise Measurement up to 50 GHz with High Dynamic Range

Application Note

Products:

- R&S®FSUP

This application note describes how to configure the signal source analyzer R&S FSUP for highest dynamic range phase noise measurement in the microwave frequency range up to 50 GHz. It compares performance in terms of phase noise sensitivity using an additional internal down converter versus an external down converter or a frequency divider. Both methods are described and differences are shown.

Application Note

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ROHDE&SCHWARZ

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1 Overview

The microwave frequency range becomes more and more interesting, especially for RADAR applications. X band radar has a variety of types. Some of these types are continuous-wave, pulsed, single-pole, dual-pole, SAR, or phased array. X band radar has various applications in civil, military and government institutions; in roles such as weather monitoring, air traffic control, maritime vessel traffic control, defense tracking, and vehicle speed detection for law enforcement. The relative short wavelength at X-band frequencies enables high-resolution imaging radars for target identification and target discrimination.

For all these applications excellent phase noise performance is of crucial importance for accurate results for **ra**dio **d**etection **a**nd **r**anging (RADAR). Microwave frequency range measurement setups for phase noise test have been complex and expensive in the past, because very clean reference sources or extremely expensive down converters have been necessary. Thanks to a 2nd receive channel used for cross correlation the R&S FSUP offers very high dynamic range up to 50 GHz. Compared to a single receiver concept cross correlation improves dynamic range by up to 20 dB. Dependent on the model of the R&S FSUP cross correlation is available up to 8 GHz, 26.5 GHz or 50 GHz.offering a single box solution for highly sensitive phase noise measurements in the microwave range. This is an easy setup and easy to operate at lower costs compared to earlier solutions.

In addition, it is possible to extend the frequency range for cross correlation to X-band using the R&S FSUP with option R&S FSUP-B60 or any other phase noise test system by an **external** divider (see application note 1EF56) or downconverter. However, this solution has some limitations, which will be shown.

2 Extension of cross correlation range with R&S FSUP-B61

With cross correlation two symmetrical receiver paths are used (see figure 1). The input signal from the DUT is fed into both paths, captured and Fourier transformed. Therefore, both paths measure the sum of the phase noise generated by the device under test (DUT, **A**) and the additional inherent phase noise generated by the amplifiers, oscillators or phase detectors within the FSUP frontend ($\mathbf{N_1}$, $\mathbf{N_2}$). Then the results are Fourier transformed and cross correlated. This can basically be regarded as a vector addition of the measurement samples from both signal parts with subsequent averaging. As the signal noise vector components coming from the DUT are correlated, they'll ideally have identical phase in both paths and will be summed in magnitude, whereas the signal parts coming from the two receiver paths are uncorrelated as different oscillators are used. Averaging of uncorrelated signals ideally leads to a magnitude of zero. With Signal Source Analyzer R&S FSUP equipped with R&S FSUP-B60 cross correlation up to 8GHz is available, means the instrument comes with two receiver paths, which improves the dynamic range of the instrument by up to 20 dB offering very high sensitivity for phase noise test.

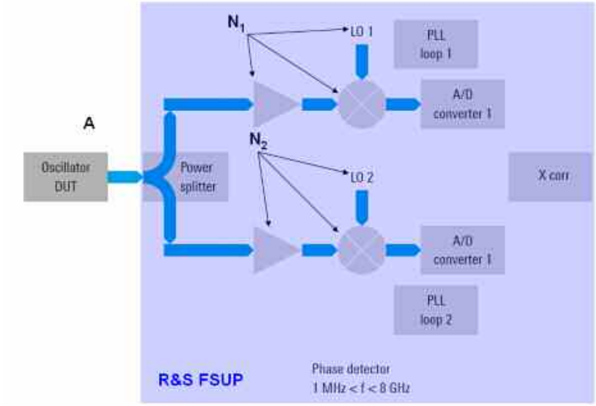


Figure 1: Cross correlation architecture: the signal from the DUT is divided into two paths by a power splitter and the noise (A) is correlated in the two receiver paths. Additional noise coming from amplifiers, local oscillators and phase detectors (N_1, N_2) is not correlated and eliminated.

To extend the cross correlation range to higher frequencies the option R&S FSUP-B61 can be used, which adds an additional down converter. Due to the symmetrical architecture the phase noise of the down converters can be eliminated by cross correlation as well (see figure 2).

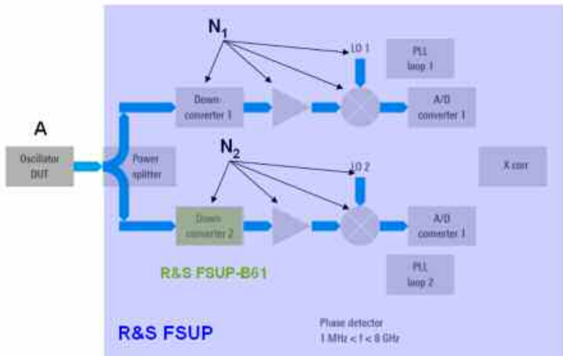


Figure 2: An additional down converter extends the cross correlation range to 26/50 GHz, depends on the model. The Noise of the down converter 1 and 2 is not correlated and eliminated by cross correlation.

Figure 3 shows a measurement of a very clean comb generator. For accurate measurement of phase noise of this frequency source we need more than 20000 averages for cross correlation in the offset frequency range > 1 kHz (see figure 3) to meet the specified values. However, even this huge amount of data can be handled by R&S FSUP in less than 10 minutes.

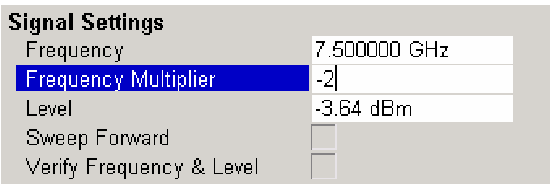
Downconverter noise floor
(all oscillators locked)

Input frequency		Offset from carrier (Hz) 1	10	100	1k	10k	100k	1M	10M
18.0 to 26.5 GHz	Typical	32	62	82	110	122	130	130	130
	Specification	27	57	77	105	117	125	125	125

Figure 3: Measurement of a very clean microwave source without cross correlation (pink), with about 100 (blue), 1000 (green) and 20000 (yellow) averages at 25.2 GHz.

3 Extension of Cross Correlation Range with an external Divider or Down Converter

An external divider can extend the cross correlation range as well. It is located after the DUT in the signal path (see figure 6). Signal sources at frequencies >8 GHz can be measured at half or quarter of the frequency and cross correlation without the frequency extension R&S FSUP-B61 can be used. However, the displayed noise must be corrected by 20 x lg (dividing factor). In case of R&S FSUP user can set this factor in the GENERAL SETTINGS menu. For dividers a negative number must be used, because the exponent is the number of interest in the menu, which originally was designed for multipliers.



The limitation when using an external divider is that additional noise N_D (residual phase noise) from the divider is directly added to the noise of the DUT. It is correlated in the two receiver paths and therefore not eliminated by cross correlation (see figure 6).

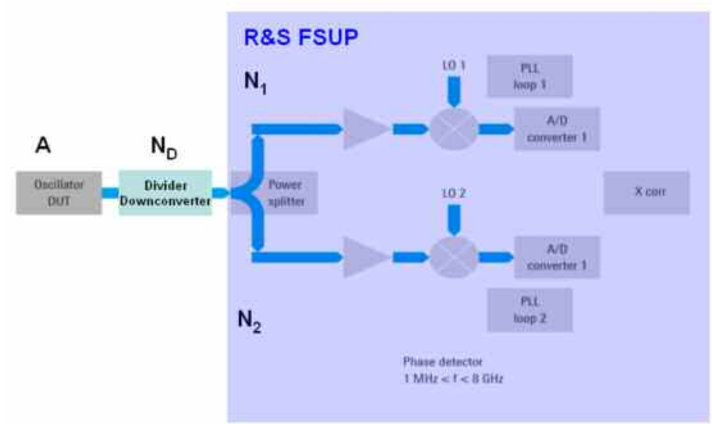


Figure 6: Extension of cross correlation range with an external divider or down converter

Figure 7 shows a measurement of the signal from R&S SMF signal generator at 15 GHz using a divider by 2 compared with a measurement using the cross correlation extension R&S FSUP-B61. Due to correction by 6 dB according to the entry in the GENERAL SETTINGS menu the measurements show the same result nearly in the whole frequency range. However, at large offsets we see that we get much better results using the R&S FSUP-B61. The reason is that the residual phase noise of the divider N_D is added to the phase noise of the DUT and cannot be eliminated by cross correlation. For the divider, which we have used the residual phase noise is specified to -150 dBc/Hz. In addition, when using dividers the input level is restricted to the specified divider parameters. When the input level gets to low, it might start to oscillate or stop dividing.

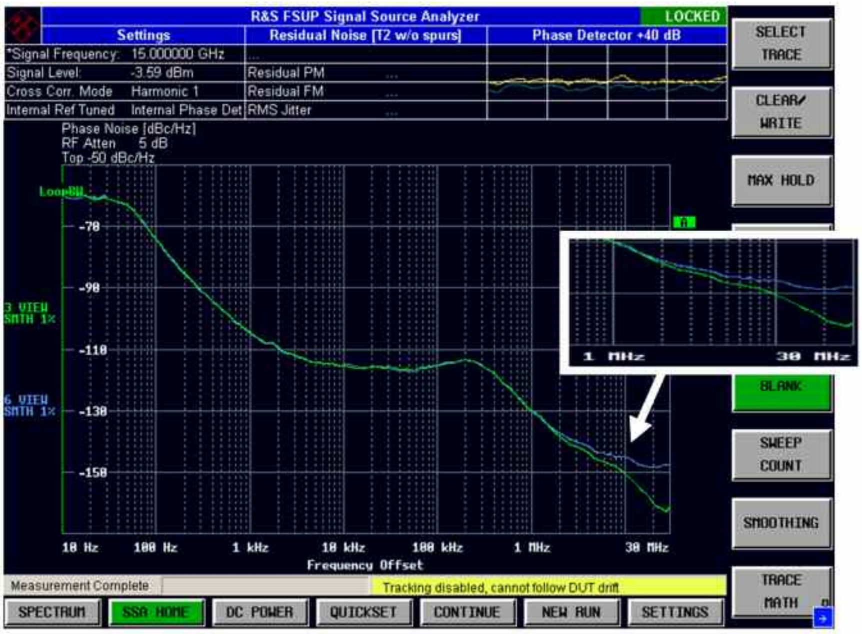


Figure 7: Phase noise measurement of signal generator R&S SMF at 15 GHz using a divider (blue) or the cross correlation extension R&S FSUP-B61 (green). The blue trace shows, that at offset frequencies > 1 MHz the sensitivity is limited by the residual phase noise of the divider.

If an external down converter is used instead of a divider the phase noise of the down converter N_D is added to the signal and cannot be eliminated with cross correlation. If users do not want to corrupt the results by the converter a highly clean source for the local oscillator of the converter is necessary, which in general is very expensive.

4 Summary

If the phase noise of very pure signal sources has to be measured in the microwave frequency range, cross correlation technique in combination with high end local oscillators and down converters in the two signal paths shows the best results. External dividers or single path down converters mostly corrupt the signal and make the setup more complex and more expensive. With R&S FSUP equipped with R&S FSUP-B60/61users get a one box solution with very high sensitivity for phase noise test up to frequencies of 50 GHz without the need of external down converters. This is an easy setup compared to former solutions, which is easy to use as well.

5 Ordering Information

Rohde&Schwarz

Designation	**Type**	**Ordering number**
Signal Source Analyzer 20 Hz to 8 GHz	R&S FSUP8	1166.3505**K09**
Signal Source Analyzer 20 Hz to 26 GHz	R&S FSUP26	1166.3505**K27**
Signal Source Analyzer 20 Hz to 50 GHz	R&S FSUP50	1166.3505**K51**
Low-Aging OCXO	R&S®FSU-B4	1144.9000.02
Low Phase Noise	R&S®FSUP-B60	1169.5544.**03**
Correlation Extension for R&S FSUP26	R&S®FSUP-B61	1305.2500.**26**
Correlation Extension for R&S FSUP26[1]	R&S®FSUP-B61	1305.2500.**23**
Correlation Extension for R&S FSUP50	R&S®FSUP-B61	1305.2500.**50**

[1] This version is needed, if preamplifiers R&S FSU-B23 and R&S FSU-B25 are installed

About Rohde & Schwarz
Rohde & Schwarz is an independent group of companies specializing in electronics. It is a leading supplier of solutions in the fields of test and measurement, broadcasting, radiomonitoring and radiolocation, as well as secure communications. Established 75 years ago, Rohde & Schwarz has a global presence and a dedicated service network in over 70 countries. Company headquarters are in Munich, Germany.

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