Application Note

IMPROVING R&S®FSWP MEASUREMENT SPEED

Products:

► R&S®FSWP

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https://www.rohde-schwarz.com/appnote/GFM354

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Contents

1 Introduction

For automated test applications, measurement time is often as important as the quality of the measurement. As with many situations, time is money. In practice, phase noise measurements are generally not considered fast, but test engineers still desire to save as much test time as possible. The Rohde & Schwarz®FSWP (FSWP) is a modern, digital signal processing based, phase-noise test set that performs many tasks in parallel in an effort to improve measurements speed. However, several measurement settings drastically affect measurement speed. This paper will discuss these settings and provide suggestions on improving overall measurement speed.

The three key instrument parameters that affect FSWP measurement speed are:

1. Number of cross correlations
2. Resolution bandwidth (RBW)
3. Offset frequency span

2 Cross Correlation

FSWP is a two-channel cross correlation phase noise test set. The FSWP input signal is split and independently processed by two measurement channels, as shown in the figure below. Each channel has independent local oscillators (reference oscillators), and ADC clock oscillators. Therefore, the primary sources of instrumentation noise between the two channels are not correlated.

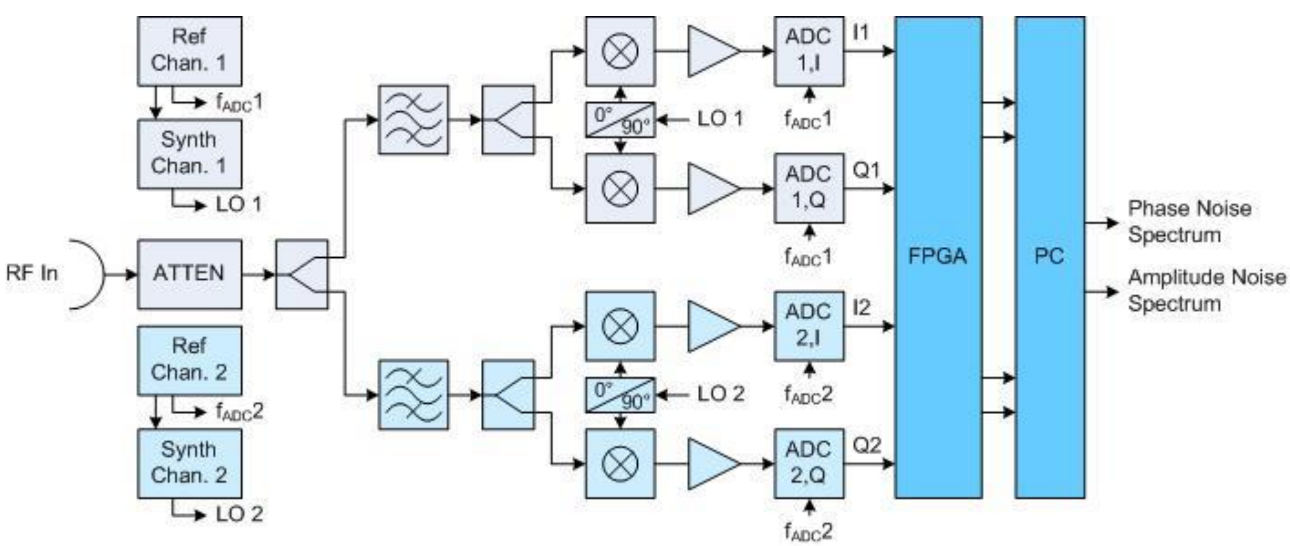

Figure 1, FSWP Simplified Analog Block Diagram

The only noise that is correlated between the two channels is the RF input signal from the device under test (DUT). Cross correlation reduces uncorrelated measurement noise by a factor of $5 \cdot \mathrm{Log}_{10}(M)$ dB, where M is the number of cross correlations. The improved signal to noise performance achieved through cross correlation does not come without a cost and that cost is measurement speed.

In addition, cross correlation can quickly reach a point of diminishing returns where additional cross correlation does little to improve the measurement. To assist the FSWP user in determining how much cross correlation is sufficient, FSWP graphically displays a cross-correlation-gain indicator shown as the gray band below the measurement trace, see Figure 2. If the measurement trace touches, the gray band more cross correlation could improve the measurement.

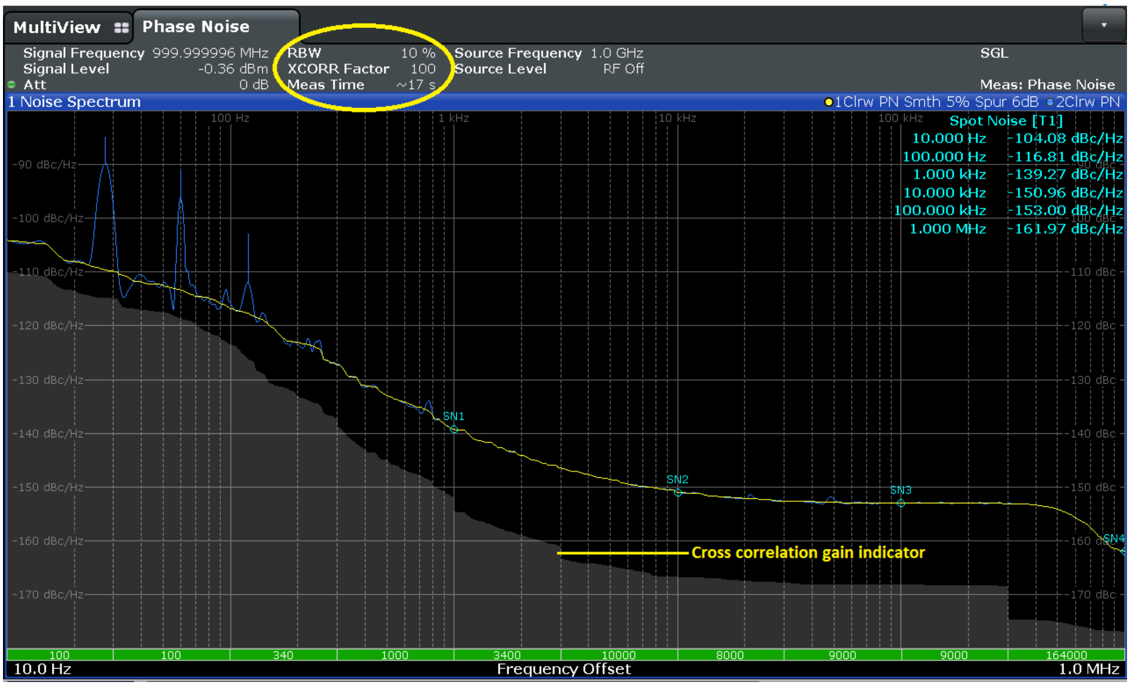

Figure 2, Screen Shot of a Typical FSWP Phase Noise Measurement

The above measurement represents a typical phase noise measurement of a 1 GHz signal source. The measurement was set up using 100 cross correlations with an RBW of 10% (which is the default). The offset frequency span was set at a start frequency of 10 Hz and a stop frequency of 1 MHz. FSWP establishes the RBW of each FFT segment based on a percentage of the segment start offset, with the exception of the first segment, which is based on the stop offset of the segment. Therefore, for the above measurement the 10% RBW corresponds to 3 Hz RBW for the first FFT segment (10 % of 30 Hz, which is the stop-offset frequency of the first FFT segment).

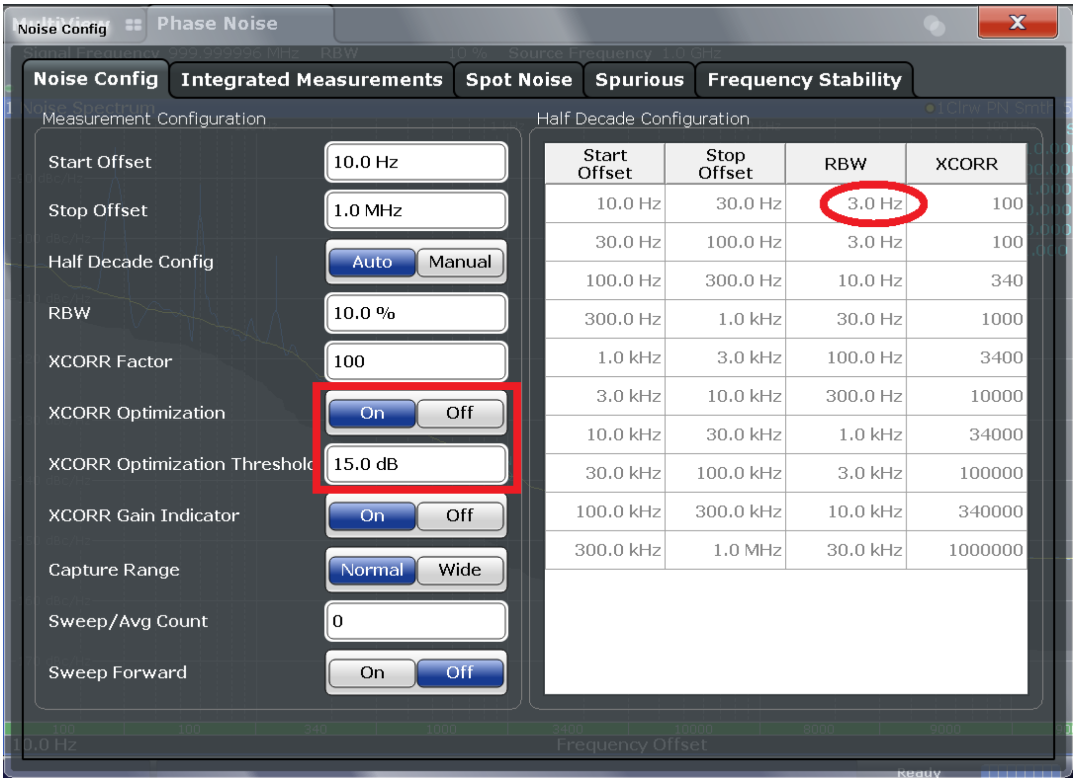

Figure 3, FSWP Noise Configuration Menu--Showing the FFT Segment Table

As can be seen in the above screen shot of the FSWP FFT segment table (to view the segment table on the instrument, press the **[MEAS CONFIG]** hard key followed by the **{Noise Config}** soft key), both the global cross correlation and RBW settings are simply seed values that are used to populate the segment table. Referring back to Figure 2, notice that the measurement time for this measurement was approximately 17 seconds. As mentioned above, measurement time is based on:

► Number of cross correlations

► Resolution bandwidth (RBW)

► Offset frequency span

Now, let us assume that we hold all of the measurement settings, for the measurement show in Figure 2, constant except the number of cross correlations and graph the measurement time as a function of the number of cross correlations.

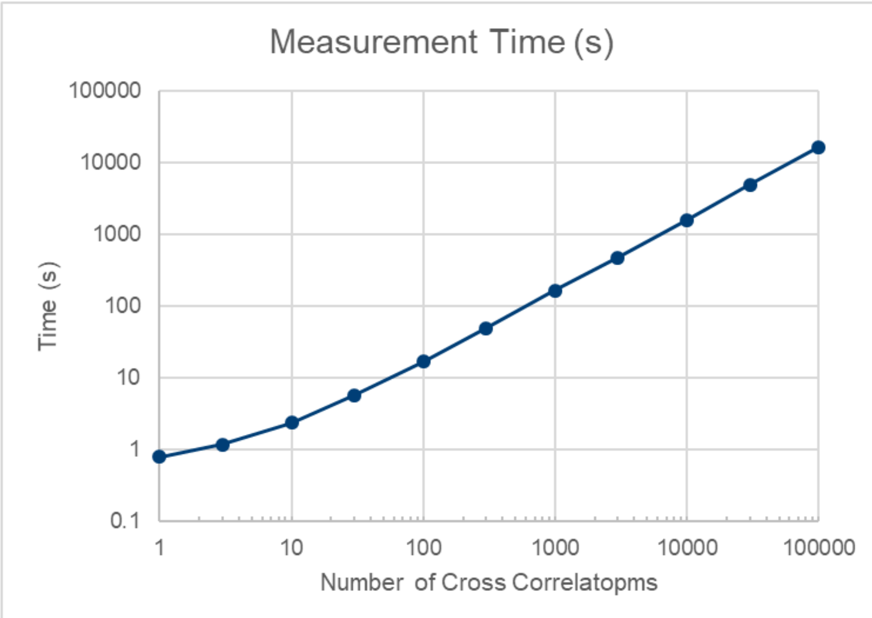

Figure 4, FSWP Measurement Time as a Function of Number of Cross Correlations

Since Figure 4 is plotted on a Log-Log scale. You can see that FSWP measurement time increases exponentially as the number of cross correlations is increased. It works just like compound interest on a savings account, because the number of cross correlations in each segment increases with each higher FFT segment in the segment table. See Figure 3.

From Figure 4, it becomes apparent that the FSWP user must strike a balance between measurement uncertainty (keeping the measurement trace above the gray cross-correlation-gain indicator) and measurement time. FSWP provides two tools to assist the user in minimizing measurement time as driven by cross correlation. Referring back to Figure 3, notice the Xcorr Optimization radio buttons (On / Off). With this function turned on, the instrument will stop cross correlating in a given segment if the trace is X-dB above the cross-correlation-gain indicator. Where X is the value specified in the cross-correlation-threshold window. The default setting for this parameter is 15 dB. Therefore, once the trace is 15 dB above the cross-correlation-gain indicator, in any given segment, the analyzer will discontinue cross correlation in that segment and subsequently shorten measurement time. If desired, the user may decrease the cross-correlation threshold to shorten overall measurement time.

The second of these speed improvement functions is called "Finish Segment." The Finish Segment function can be found in the sweep menu by pressing the **[Sweep]** hard key followed by pressing the **{Finish Segment}** soft key. Finish segment is kind of a manual version of the Xcorr Optimization function. If the operator is satisfied with the measurement results in the highest active half-decade segment, he can press the **Finish Segment** key and the instrument will stop cross correlating in this segment and focus its processing power on remaining segments, again shortening measurement time.

2.1 Tips for Improving Measurement Time, based on Cross Correlation

The following tips can be used to improve measurement time using of cross correlation:

1. Select the minimum number of cross correlations based on desired measurement results. If the gray band is 20 to 40 dB below the measurement trace, the measurement speed could be improved by using less cross correlations.
2. Use the cross-correlation-optimization function to avoid excessive cross correlation and wasted time. In many cases, a 7 to 10 dB Xcorr optimization threshold will provide adequate measurement results.

3. If your measurement needs additional cross correlation in one or two specific FFT segments, use a manual (custom) half-decade configuration by selecting manual in the **Noise Config** menu and adding extra correlations to the desired segments.

3 Resolution Bandwidth (RBW)

RBW settings for a phase noise measurement are much like those for spectrum analysis. Reducing RBW allows one to better resolve details in frequency and like a spectrum analyzer measurement time is increased. Reducing RBW is especially important when analyzing spurious signals. In many cases, reducing RBW will turn bumps in the phase noise trace into a group of spurs or a spur forest.

The FSWP RBW control changes the analyzer's frequency resolution by increasing or decreasing the number of time samples used in each of the FFT segments. Reducing the RBW by a factor of 2 increases the number of FFT time samples in the segment by a factor of 2 and reduces the phase noise power in the segment by 3-dB. Since the phase noise is normalized per Hertz, the spur curve increases by 3-dB instead. Measurement time will increase by a factor of 2, also. The disadvantage of reducing RBW is, if the spur frequency is not stable during one FFT the spur detection algorithm may fail and not recognize the spur. However, reducing RBW is generally the right choice to identify spurs.

Much like our previous discussion on cross correlation, the user must strike a balance between desired frequency resolving power and measurement time. Referring back to the measurement show in Figure 2 and holding the number of cross correlations constant at 100. The effect of reducing RBW is shown below:

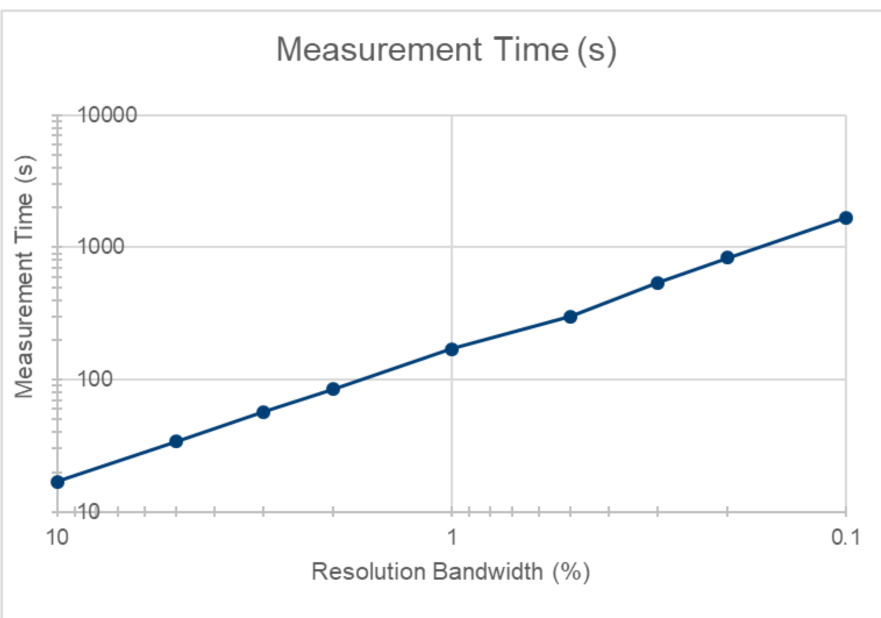

Figure 5, Measurement Time as a Function of Resolution Bandwidth

Figure 5 shows the multiplicative nature of RBW on measurement time for each factor of 10 reduction in RBW the measurement time increases by a factor of 10. This becomes particularly important as the measurement start offset frequency is reduced (refer back to our discussion on Page 2 regarding the RBW selected for the first FFT segment. Each time the start-offset frequency is reduced by a factor of 10, the RBW for the first FFT segment will decrease by a factor of 10 and similarly increase measurement time by a factor of 10.

In addition to considerations of the span start-offset frequency, keeping the stop-offset frequency below 1 MHz can also greatly influence measurement time. For stop offsets greater than 1 MHz, FFT processing proceeds at a slower rate than for offsets below 1 MHz, especially for offsets greater than 30 MHz where the analyzer breaks the span into 30 MHz chunks for processing.

3.1 Tips for Improving Measurement Time, Based on RBW Setting

1. Select the widest RBW setting, based on desired frequency resolution requirements
2. If your measurement needs increased frequency resolution in a specific portion of the phase noise graph, use a manual half-decade configuration by selecting manual in the Noise Config menu and decrease the RBW for the specific segments where additional frequency resolution is needed.
3. In some situations where both phase noise and spurious measurements are required, overall measurement time can sometimes be reduced by splitting the measurement into two measurements. The logic behind this statement is that often a very low phase noise floor is desired which can be achieved by using more cross correlations. Whereas, the required spur levels may be quite a bit higher than the required phase noise floor. In this case, the number of cross correlations can be reduced to speed up the measurement and the RBW reduced to improve spurious frequency detection.

4 Additional Suggestions to Reduce Test Time

In addition to the suggestions associated with cross correlation and RBW settings, several other settings can help reduce overall measurement time.

► If the device under test's (DUT's) output frequency is known, measurement time can improved by turning off the analyzer's auto search function and directly entering the DUT frequency in the "**Auto Search Config**" menu, see Figure 6 below. Turning off the "**Signal Count Function**" can further reduce measurement time; however, the instrument will make a measurement even if no signal is found. If the DUT's output frequency is not exactly know, the **Auto Search** frequency limits can be reduced to minimize signal capture time.

► It is generally a best practice to make phase noise measurements with the analyzer in single-sweep mode. Single sweep can be activated by pressing the **[RUN / SINGLE]** hard key on the instruments front panel. Single sweep prevents the instrument from starting a new measurement once the current measurement is completed and overwriting measurement data. If an external computer is controlling the instrument, the single sweep function can be invoked by sending the "`INIT:CONT OFF`" SCPI command. Completion of the sweep can be monitored by using the `*OPC?` query in conjunction with `INIT:IMM`, which will return a 1 when the operation is complete. For example, `INIT:IMM; *OPC?`

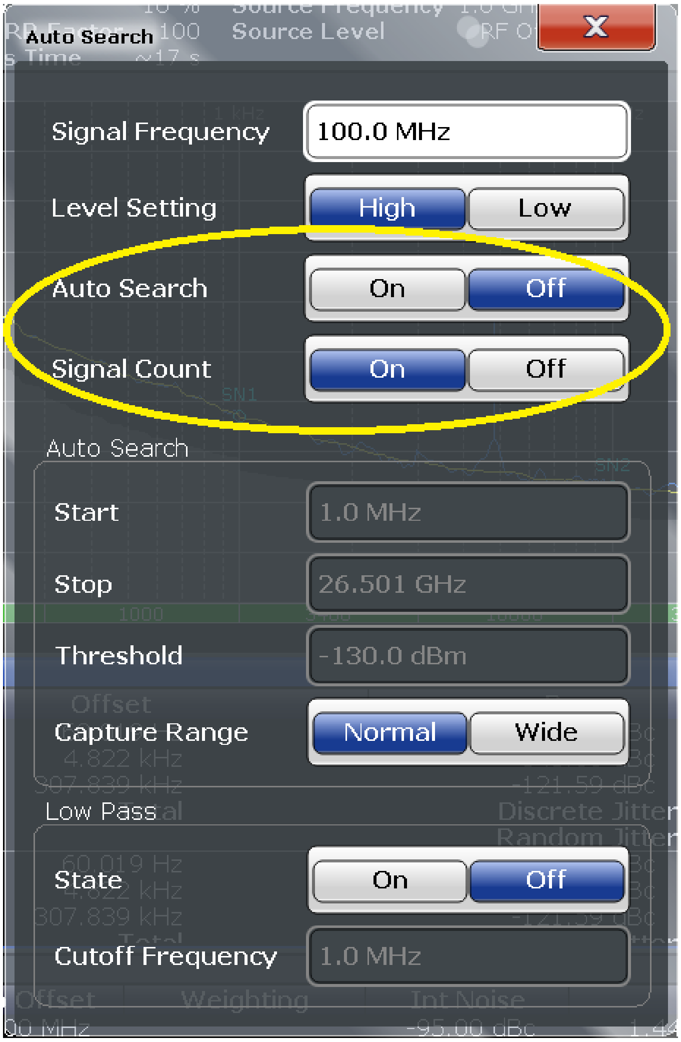

Figure 6, FSWP Frequency-Auto Search Configuration Menu

5 Summary

The three major factors influencing FSWP measurement time are:

► Number of cross correlations

► Resolution bandwidth setting, and

► Offset frequency span start and stop frequencies

In Section 3, we discussed how reducing the start-offset frequency directly affects measurement time. In addition, offset frequencies greater than 1 MHz process slower than those below 1 MHz. Therefore, keeping the offset frequency span as narrow as possible can greatly improve measurement speed.

Lastly, for offset frequencies less than 1 MHz measurement time is mainly a function of the capture time required to achieve the desired RBW. For these conditions, measurement time can be estimated by the following relationship[1]:

$$T_{capture} = \frac{2}{RBW[1 + 0.25(Xcorr - 1)]}$$

Where RBW in the above equation is the RBW used for the first FFT segment, as shown in the red ellipse in Figure 3.

6 Ordering Information

Designation	Type	Order No.
Phase Noise Analyzer, 1 MHz to 8 GHz	R&S®FSWP8	1322.8003.08
Phase Noise Analyzer, 1 MHz to 26.5 GHz	R&S®FSWP26	1322.8003.26
Phase Noise Analyzer, 1 MHz to 50 GHz	R&S®FSWP50	1322.8003.50

[1] Feldhaus, A; and Roth A. "A 1 MHz to 50 GHz Direct Down Conversion Phase Noise Analyzer with Cross-Correlation". IEEE, 2016

Options

Designation	Type	Order Number	Retrofitable	Remarks
Cross-Correlation, 8 GHz	R&S®FSWP-B60	1322.9800.08	yes	for R&S®FSWP8; contact service center
Cross-Correlation, 26 GHz	R&S®FSWP-B60	1322.9800.26	yes	for R&S®FSWP26; retrofittable in factory
Cross-Correlation, 50 GHz	R&S®FSWP-B60	1322.9800.50	yes	for R&S®FSWP50; retrofittable in factory
Cross-Correlation (low phase noise), 8 GHz	R&S®FSWP-B61	1325.3719.08	yes	for R&S®FSWP8; contact service center includes R&S®FSWP-B4
Cross-Correlation (low phase noise), 26 GHz	R&S®FSWP-B61	1325.3719.26	yes	for R&S®FSWP26; retrofittable in factory includes R&S®FSWP-B4
Cross-Correlation (low phase noise), 50 GHz	R&S®FSWP-B61	1325.3719.50	yes	for R&S®FSWP50; retrofittable in factory includes R&S®FSWP-B4
High Stability OCXO	R&S®FSWP-B4	1325.3890.02	Yes	Not available for FSWP-B61
Additive Phase Noise Measurements	R&S®FSWP-B64	1322.9900.26	yes	frequency range 10 MHz to 8 GHz for R&S®FSWP8, 10 MHz to 18 GHz for R&S®FSWP26 and R&S®FSWP50; R&S®FSWP-B60 or B61 option required; contact service center
High Stability OCXO	R&S®FSWP-B4	1325.3890.02	yes	user-retrofittable
Spectrum Analyzer, 10 Hz to 8 GHz	R&S®FSWP-B1	1322.9997.08	yes	for R&S®FSWP8; retrofittable in factory
Spectrum Analyzer, 10 Hz to 26 GHz	R&S®FSWP-B1	1322.9997.26	yes	for R&S®FSWP26; retrofittable in factory
Spectrum Analyzer, 10 Hz to 50 GHz	R&S®FSWP-B1	1322.9997.50	yes	for R&S®FSWP50; retrofittable in factory
External Generator Control	R&S®FSWP-B10	1325.5463.02	yes	contact service center
Resolution Bandwidth > 10 MHz	R&S®FSWP-B8	1325.5028.26	no	for R&S®FSWP8/26 with R&S®FSWP-B1 option; the signal analysis bandwidth is defined by the R&S®FSWP-B80 option, not by the R&S®FSWP-B8 option.
Resolution Bandwidth > 10 MHz	R&S®FSWP-B8	1325.5028.02	no	for R&S®FSWP50 with R&S®FSWP-B1 option; the signal analysis bandwidth is defined by the R&S®FSWP-B80 option, not by the R&S®FSWP-B8 option; export license required
High-pass Filter for Harmonic Measurements	R&S®FSWP-B13	1325.4350.02	yes	for R&S®FSWP8/26/50 with R&S®FSWP-B1 option; user-retrofittable
LO/IF Connections for external mixers	R&S®FSWP-B21	1325.3848.02	yes	for R&S®FSWP26/50; contact service center
RF Preamplifier, 100 kHz to 8 GHz	R&S®FSWP-B24	1325.3725.08	yes	for R&S®FSWP8 with R&S®FSWP-B1 option; contact service center
RF Preamplifier, 100 kHz to 26.5 GHz	R&S®FSWP-B24	1325.3725.26	yes	for R&S®FSWP26 with R&S®FSWP-B1 option; contact service center
RF Preamplifier, 100 kHz to 50 GHz	R&S®FSWP-B24	1325.3725.50	yes	for R&S®FSWP50 with R&S®FSWP-B1 option; contact service center
80 MHz Analysis Bandwidth	R&S®FSWP-B80	1325.4338.02	yes	for R&S®FSWP8/26/50 with R&S®FSWP-B1 option; user-retrofittable

Designation	Type	Order Number	Retrofitable	Remarks
Spare Solid State Drive (removable hard drive)	R&S®FSWP-B18	1331.4313.02	yes	user-retrofittable

Firmware

Designation	Type	Order No.	Remarks
Pulsed Phase Noise Measurements	R&S®FSWP-K4	1325.5043.02	
Pulse Measurement Application	R&S®FSWP-K6	1325.4421.02	R&S®FSWP-B1 option required
Pulse Stability Measurements	R&S®FSWP-K6P	1338.3106.02	R&S®FSWP-B1 option required
Time Sidelobe Measurements	R&S®FSWP-K6S	1325.5363.02	R&S®FSWP-K6 option required
Analog Modulation Analysis for AM/FM/φM	R&S®FSWP-K7	1325.4238.02	R&S®FSWP-B1 option required
Noise Figure Measurements	R&S®FSWP-K30	1325.4244.02	R&S®FSWP-B1 option required
Security Write Protection of solid state drive	R&S®FSWP-K33	1325.5040.02	
Spurious Measurements	R&S®FSWP-K50	1338.3358.02	R&S®FSWP-B1 option required
Transient Measurements	R&S®FSWP-K60	1338.4525.02	R&S®FSWP-B1 option required
Transient chirp Measurements	R&S®FSWP-K60C	1338.4531.02	R&S®FSWP-B1 option required
Transient hop Measurements	R&S®FSWP-K60H	1338.4548.02	R&S®FSWP-B1 option required
Vector Signal Analysis	R&S®FSWP-K70	1325.4280.02	R&S®FSWP-B1 option required

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Data without tolerance limits is not binding | Subject to change