Single-Instrument Calibration of Signal Generators to 50 GHz

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As a fundamental tool of virtually every microwave and many digital design engineers, the accuracy of a signal generator is critical, whether in the laboratory, design, or production environments. To ensure that this accuracy is maintained over time, the instruments must be calibrated periodically to ensure that their performance in all critical areas continues to meet stated specifications. This has traditionally required a large array of individual instruments that were cabled together to produce a dedicated signal generator calibration solution. The FSMR measuring receiver recently introduced by Rohde & Schwarz was designed to solve this problem.

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This has traditionally required a large array of individual instruments that were cabled together to produce a dedicated signal generator calibration solution. For many years, this approach has been the industry standard for signal calibration, and was recently modernized and reduced to two instruments and a PC. There has been no single-instrument solution that contains all of the elements necessary to perform signal generator calibration, a system that would reduce the overall complexity of the process, reduce cost, size, and weight, yet still deliver all of the capabilities required to perform all elements of the calibration process.

The FSMR measuring receiver recently introduced by Rohde & Schwarz was designed to solve this problem. It is the only signal generator calibration solution that requires only a single bench-top instrument, taking up a fraction of the size and weight of conventional solutions while providing comparable or better performance.

The FSMR measuring receivers combine several test functions once associated with a rack of equipment: RF power measurements (power meter), spectral analysis (spectrum analyzer), modulation measurements (modulation analyzer), and audio signal measurements (audio analyzer). The FSMR receivers, in fact, are built upon the mainframe of the company's FSU high-performance spectrum analyzer, offering three models that match three of the five frequency ranges of FSU instruments: 20 Hz to 3.6 GHz (model FSMR3), 20 Hz to 26.5 GHz (model FSMR26), and 20 Hz to 50.0 GHz (model FSMR50). Like the spectrum analyzers, the FSMR receivers incorporate a wide array of resolution-bandwidth (RBW) and video filters for isolating channels and signals of interest. But the FSMR receivers also share many of the traits of a microwave power meter in their capability of measuring a wide dynamic range of RF power levels, from -130 to +10 dBm, with high accuracy. A summary of FSMR specifications is shown below.

The FSMR measuring receivers (Fig. 1) offers all the test functions needed to

FSMR Feature Summary

Frequency range	
FSMR3	20 Hz to 3.6 GHz
FSMR26	20 Hz to 26.5 GHz
FSMR50	20 Hz to 50.0 GHz
RF level range	-130 to +30 dBm
RF level accuracy	0.001 dB + 0.005 per 10-dB step
Internal reference source	10 MHz
Demodulation	AM, FM, phase
Demodulation accuracy	1%
Audio frequency range	DC to 100 kHz

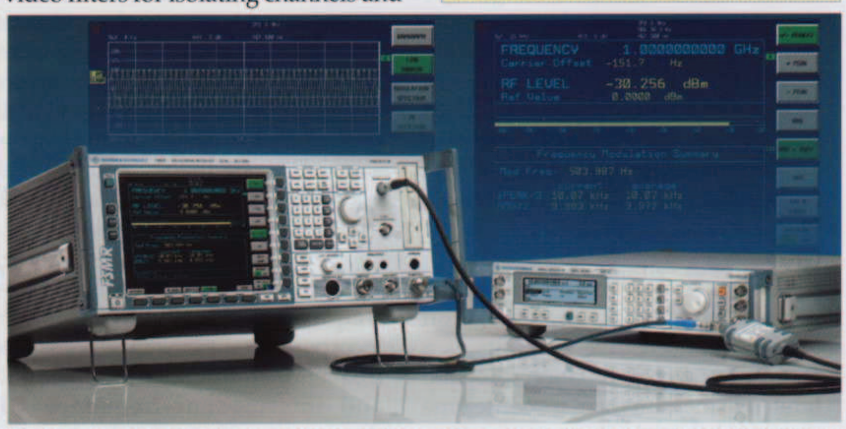

Figure 1. The Rohde & Schwarz FSMR measuring receivers provide level measurement range of -130 to +10 dBm at frequency ranges of 20 Hz to 3.6 GHz, 20 Hz to 26.5 GHz, and 20 Hz to 50 GHz.

calibrate an RF and microwave signal generator or microwave attenuator. Since each receiver replaces a rack of single-function instruments, the instrument is ideal for calibration labs where instrument rack space is limited or for firms which have many signal generators and rely heavily on their accuracy in research and development (R&D) as well as production testing.

Ensuring correct RF power output is perhaps the most basic element in the calibration process. Although a power meter can provide a high degree of accuracy for low-and moderate-level signals, a measurement receiver such as the FSMR can provide more flexibility and measurement speed especially for extremely low-level signals, covering a total RF level range of -130 to +10 dBm. The FSMR relies on very-high-speed analog-to-digital conversion to sample input signals for digital processing. But where the power meter measures power levels with a wide bandwidth, the FSMR measuring receivers benefit from a superheterodyne front-end architecture crafted of linear components that are selectively bypassed to achieve power-meter-like accuracy during narrowband, low-level measurements.

A single CW power meter is capable of measuring power levels across a dynamic range of 90 dB or more, although individual sensors cover only a fraction of that total range. For example, thermistor power sensors provide accuracy that can be traced to calibration references at widely accepted standards institutions, such as the United States' National Institute of Standards and Technology (NIST) in Boulder, CO, and the British National Physical Laboratory (NPL) in Malvern, UK.

Since thermistor sensors essentially measure changes in bias energy on temperature-sensitive elements as a result of power dissipation, they are limited in measurement response time compared to typically more sensitive diode sensors (which are conversely more limited in power-handling

Figure 2. The actual linearity performance of the FSMR receivers is well within the specified limits.

capability). Diode sensors feature about 30 dB more typical sensitivity than a similar-frequency thermistor sensor, with diode sensor sensitivity of -60 dBm or better. Both types of sensors are capable of covering frequency ranges of 40 GHz or more in a single unit.

When attenuation or power levels below about -60 dBm must be measured, filtering and frequency selection become more critical to accurately determine low-level signals. The FSMR measuring receivers provide this control over the measurement bandwidth by combining the strong spectrum-analyzer capabilities of an FSU spectrum analyzer with the additional capabilities of a built-in power meter, frequency counter, audio analyzer, and modulation analyzer. The FSMR receivers also include a high-speed microwave frequency counter with 1-mHz frequency resolution across the full frequency range.

Unlike a power meter, which samples the power level of a single test frequency, the FSMR receivers incorporate a superheterodyne swept-frequency front end with analog RF and intermediate-frequency (IF) downconversion stages leading to a high-speed analog-to-digital converter (ADC). Once test signals are digitized, additional signal processing is handled by means of a digital signal processor (DSP) and its digital filters. For improved accuracy, all components known for amplitude drift or gain uncertainty are disabled or bypassed in the FSMR when it is in measuring receiver mode. For validation/calibration, one of the company's NRP series power sensors can be connected directly to the front panel of the receiver, so that no additional power meter is needed for accurate power measurements.

And unlike previous generations of precision measurement receivers, which required microwave signals to be externally downconverted to the lower-frequency IF input range of the instrument, the FSMR receiver contains all necessary downconversion circuitry to handle direct input signals as high as 50 GHz. At the other end of the spectrum, the FSMR receiver also provides a front-panel, high-impedance input port for testing the power and quality of audio signals to 1 MHz using the internal audio analyzer circuitry.

Because of the extremes of power handled by a measuring receiver, calibration of the receiver's total dynamic range is usually performed in subranges, and the instrument

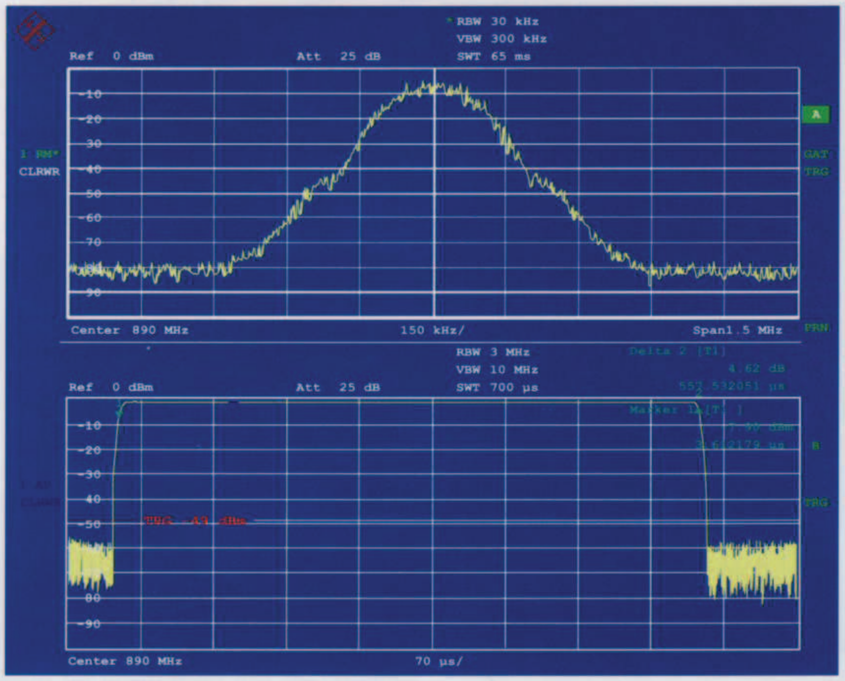

Figure 3. Split screen displays provide users with two different views of a measurement.

switches among these subranges during a measurement. A power sensor is also calibrated at the factory, with calibration factors stored in EEPROM within the sensor for download to the meter prior to making a measurement.

Achieving Level Accuracy

Similarly, the FSMR achieves its wide dynamic range through three level ranges. An autoranging function automatically switches among the three ranges during measurements, with factors applied automatically to correct for any errors resulting from the range changing. These correction factors are referenced to a power meter calibration performed with the FSMR receiver prior to power measurements. The three measurement ranges and switching enable the FSMR receivers to achieve a level measurement range of greater than 140 dB, compared to the approximately 90 dB available from power meters.

Of course, this wide measurement dynamic range would be meaningless without good level accuracy. The level accuracy of the FSMR receivers can be demonstrated during measurements on calibrated attenuators with attenuation values that can be traced to national standards (Fig. 2). The company offers a kit of such attenuators as an accessory (model FSMR-Z2) for the FSMR receiver.

Level errors in the three ranges of the FSMR measuring receivers are eliminated by a simple instrument calibration procedure with an external power meter. The procedure calibrates the FSMR's built-in IF gain stages and attenuators to achieve the rated value of 0.001 dB + 0.005 dB deviation per 10 dB across the complete level measurement range. In this four-step procedure, the external power meter is connected to the FSMR receiver and controlled from the receiver's front panel. The steps are as follows:

1. Set the measurement frequency. The autoranging function then sets the receiver to the level of the incoming signal.
2. Use the power meter to perform a reference measurement.
3. Reduce the level of the device to be calibrated until the test signal falls outside the limit of the current measurement range.
4. Calibrate the adjacent range in a similar fashion, and so on.

Filtering in the digital realm is essential to achieving such good level accuracy. A key to measuring low-level signals is the use of narrow measurement bandwidths to minimize the effects of noise on the measure-ment. At extremely low signal levels, for example, the FSMR receivers combine narrow filter bandwidths with Fast Fourier Transform (FFT) capability to extract the desired signal levels from the noise floor. In the analog realm, the receiver's measurement accuracy is essentially influenced by the linearity of the receiver's IF stages.

For example, crystal filters may be used in these stages, and an optional YIG tracking preselector filter provides image rejection of better than 80 dB when making higher frequency (above 3.6 GHz) measurements. Any components, such as the YIG and crystal filters, which can contribute to drift and errors, are switched off during level calibration. At lower levels, accuracy is limited by the input noise and measurement time. Since signals from the final IF stage are digitized by an ADC, the linearity of the ADC will also impact the accuracy of the level measurements. Once signals are digitized, filtering, scaling, and level calculations are performed digitally.

Analyzing Modulation

Since calibration of a signal generator often involves far more than testing CW signals, the FSMR receivers are equipped with a full function modulation analyzer as well as complete demodulation capabilities for measuring both RF and baseband modulated signals. A front-panel audio port, for example, allows measurements of total harmonic distortion (THD) and signal to noise

Summary

The equipment required to calibrate signal generators has not progressed much over the years, and until recently required a rack of single-function instruments that were assembled to perform the task. The FSMR measuring receivers bring this process into the realm of the modern measurement environment, by essentially combining all measurement, display, and analysis functions into a single instrument, without the need to rely on an external PC or other instruments. The resulting solution provides results that are more than satisfactory for even the most demanding calibration laboratory, while reducing the size, space, complexity, and cost of the process.

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About the authors

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