MEASUREMENT METHODS FOR A NEW RF & MICROWAVE CALIBRATION SOURCE

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Abstract

This paper describes measurement techniques developed for design evaluation, manufacturing test, and routine user re-calibration of a new signal source designed specifically for RF and Microwave calibration applications.

Introduction

The signal sources used in RF and Microwave calibration applications are usually general purpose signal generators, not optimised for calibration requirements. Many generators widely regarded as best suited for calibration use are now obsolete. A new signal source has been specifically developed for RF and Microwave calibration applications, providing high-purity precision level outputs covering a wide amplitude range over an extended bandwidth, with precision modulation capability. Performing measurements to evaluate the performance achieved against aggressive target specifications during development and also testing products in the manufacturing process present a variety of technical challenges:

- Identifying methods capable of providing low uncertainties over the range of values required.
- Lack of traceability for certain parameters.
- Identifying alternative techniques suitable as cross-checks to validate the chosen methods.

Appropriate methods are also required for users to carry out routine re-calibration with readily available equipment. The following sections of this summary paper briefly describe relevant aspects of the instrument design architecture and outline the measurement methods used.

Design Architecture and Features

The source frequency range is from 10Hz to 4GHz at amplitudes from +24dBm to -130dBm. It is designed to generate the signals necessary for the most common RF & Microwave calibration applications and provide inherent accuracy without the need to monitor or characterise the output with additional equipment during use. (For example, measuring of the output amplitude with a power splitter and power sensor, monitoring of the achieved modulation levels with a modulation analyzer, etc).

In order to facilitate delivery of the output signal direct to the load or Unit Under Test (UUT) input and minimize performance degradation due to cabling and interconnections, the instrument has an external leveling head (see figure 1). Signals are generated in the mainframe and fed to the leveling head containing the level detector and attenuator circuits.

Figure 1: Instrument mainframe and leveling head.

Obtaining high signal purity is important for many calibration applications, often requiring the use of external filters. In this design low levels of harmonic and spurious content are achieved by the use of appropriate filters within the output signal path. It also features internal analog modulation capability. FM is generated within the frequency synthesizer at rates up to 300kHz and AM is generated within the output amplification and leveling circuits at rates up to 220kHz.

Measurement Methods

Measurement requirements include Level (RF Power), Output VSWR, and Modulation.

Level. RF level is measured as an absolute value at a reference frequency, followed by frequency response (flatness) measurements relative to the value at the reference frequency. For the reference point (100kHz), an AC Voltage Measurement Standard measures the RMS voltage developed across an accurately known 50Ω termination, and the corresponding power level is calculated. An RF power meter and power sensor head is used for the high frequency measurements. This is a common technique, capable of extremely low uncertainty traceable measurements if appropriately calibrated power sensors with correction data are used. However, it cannot provide sufficiently low uncertainty below about -50dBm. Measurements can be made at lower levels by taking advantage of the extremely linear amplitude response of a modern spectrum analyzer [1]. The linearity of such an instrument is almost exclusively determined by the A/D converter used to digitize its IF signal for subsequent processing in the digital domain. Measured analyzer linearity errors are generally much less than the estimated uncertainty of the test (< 0.02dB for a 70dB range). The spectrum analyzer is normalized against the UUT output as measured by the power sensor at -47dBm and without changing analyzer settings, measurements are made over a 50dB range down to -97dB. The spectrum analyzer is then re-normalised at -97dBm to make measurements down to -130dBm.

VSWR Having knowledge of the output impedance of the source (source match) is important not only to confirm specifications, but also to allow users to estimate mis-match uncertainty contributions in their applications. Applying VSWR or Return Loss measurement techniques generally used for passive devices to a leveling source can cause difficulties and erroneous results. At the time of this work, it was not possible to find a laboratory offering an accredited measurement of source match for a generator, and very few equipment manufacturers document methods in their literature. The chosen method uses a return loss bridge, as shown in figure 2.

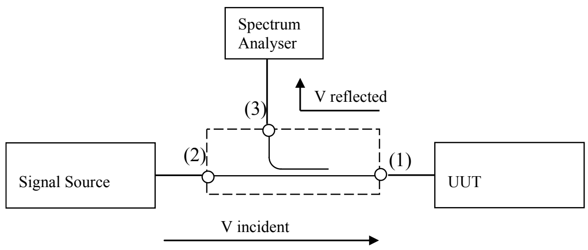

Figure 2: Source VSWR measurement.

A signal generator injects a signal with a small fixed frequency offset, say 10 Hz, from the UUT output frequency. The UUT output and reflected signals will add and subtract at a rate of 10 Hz. This signal is detected with a spectrum analyzer set to ‘zero span’ mode, using the cursors to measure the maxima and minima of the amplitude variations with time. A reference level is also measured with the UUT replaced with an open and a short. Voltage Reflection Coefficient and hence VSWR is calculated.

Modulation. AM and FM design goals of accuracy better than 0.1% and distortion <0.05% (-66dB) are difficult to measure with traditional methods. Measurements are made using a spectrum analyzer featuring a measurement demodulator. The demodulator uses digital signal processing to extract the required signal characteristics from data obtained by digitizing the IF signal, illustrated in figure 3 [2].

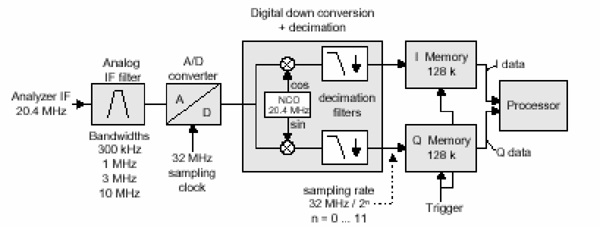

Figure 3: Spectrum analyzer signal processing.

For AM and FM, measurements of modulation rate, depth/deviation, and distortion are made. For example, for distortion measurements the demodulator is configured to display the signal’s audio spectrum and its THD measurement algorithm is used to determine the total of the harmonic content present in the required bandwidth. Figure 4 shows results for a test of FM deviation accuracy (-0.0034%) and distortion (-78.2dB).

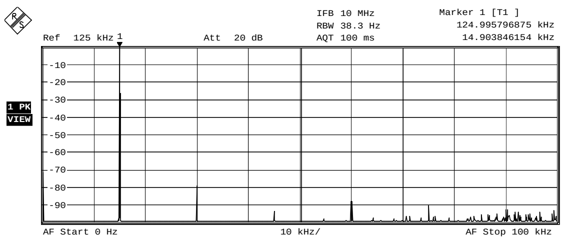

Figure 4: Audio spectrum of 100MHz carrier with FM at 125kHz deviation, 15kHz rate. Deviation error is -0.0034%, THD is -78.2dB.

Analysis of the inherent error sources within the spectrum analyzer and measurement demodulator suggest extremely accurate modulation measurements should be obtained, much better than its specifications suggest. Apart from use of the Bessel Null technique for FM deviation measurement, it has not been possible to identify methods or other laboratories which can provide sufficiently low traceable uncertainties to fully evaluate the potential performance.

Conclusion

Additional details of measurement methods and results will be provided in the full presentation of this paper.

References

[1] Rhode & Schwarz application note “RF Level Test System +20dBm to -130dBm” .

[2] Operators Manual, Rhode & Schwarz FS-K7 Measurement Demodulator option for FSU Spectrum Analyzer.