EXTENDING THE RANGE FOR PRECISION AM NOISE MEASUREMENTS

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Abstract

Developed as an extension of the existing NIST phase noise measurement system, the AM measurement system presently covers carrier frequencies from 5 MHz to 70 GHz. Our new technique relies on a wide-band AM modulator to calibrate frequency dependent errors. The system, utilizing a double-balanced mixer as the detector, works in two passes. In the first pass, the modulator is used to sweep a known modulation level across the Fourier frequencies of interest. This level is detected by three different spectrum analyzers that cover Fourier frequencies from 1 Hz to 1 GHz. The data is then compiled into a calibration curve that is used to correct frequency dependent errors in the noise data measured in the second pass. The entire system is computer controlled via the GPIB bus enabling measurements to be made with minimal user intervention.

Introduction

There is only limited information available about AM noise characteristics of devices, especially in the microwave region. Recent increased awareness that AM noise is an important aspect in the design of such microwave devices[1-2], requires improved and accurate measurement systems and techniques. In this paper, we present a technique to make very precise measurements of amplitude modulation (AM) noise out to 100 MHz from a microwave carrier. Traditional approaches are hampered both by the lack of convenient high bandwidth detectors, and the lack of sources with flat wide-band modulation capability to calibrate the frequency dependence of such measurement systems. Results from the NIST wide-band phase noise measurement system (Figure 1)[3], and data showing that double-balanced mixers can have lower noise floors then traditional AM detectors[1-2], led us to the conclusion that an AM measurement system could be designed by modifying the existing PM measurement system.

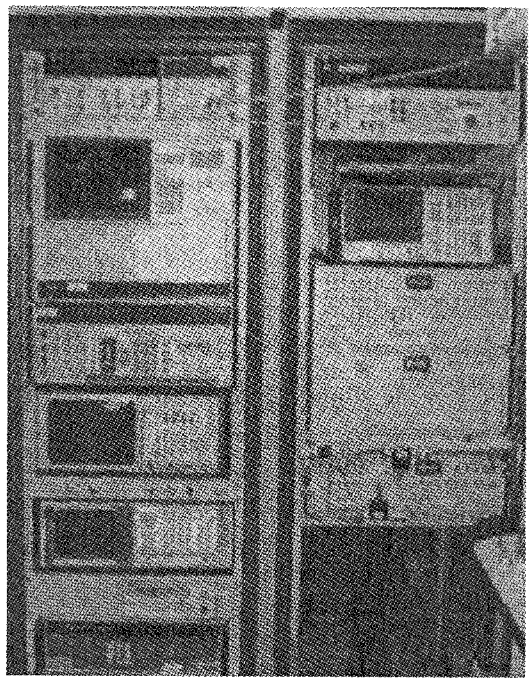

Figure 1. NIST AM/PM Measurement system

AM noise measured in an x-band synthesizer is also shown in Figure 6. The bump at 20 MHz corresponds to the dip in the gain curve in Figure 4. Since the gain drops at this point and the noise does not, this indicates that the noise floor is being measured.

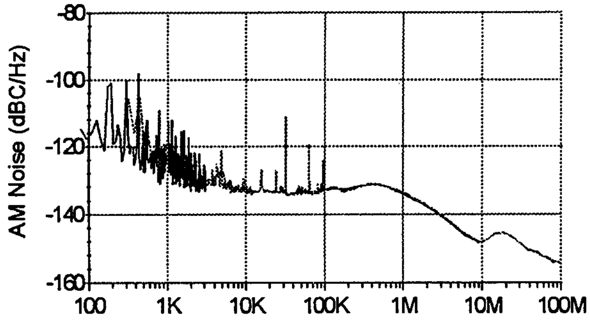

Figure 6. AM noise in a x-band synthesizer

Evaluation

NIST's AM/PM noise standards were used extensively in testing of the accuracy and flatness of the new measurement system. Using the calibrated flat noise level provided by AM/PM noise standard, small errors in the power spectral density function (PSD) were found in the swept and tuned receiver spectrum analyzers (Figure 7). These errors, most likely due to incorrect estimation of the measurement bandwidth, were corrected for in software.

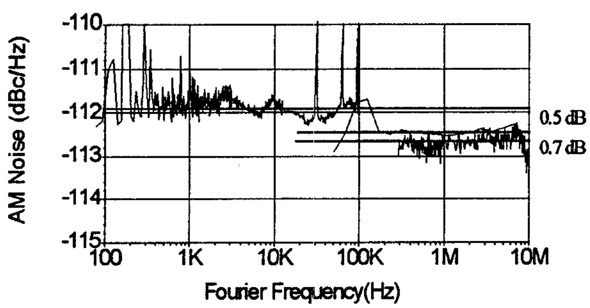

Figure 7. Errors in power spectral density functions

With the PSD errors corrected, the noise standards showed accuracies in the measurement systems of +/- 1 dB for all carrier frequencies tested 5 MHz to 42 GHz. Sample graphs are shown in Figures 8 and 9.

System noise floors were not explicitly measured, rather only estimated by observing decreases in the gain curves that were not matched with decreases in the noise level at the same Fourier frequencies. A summary of noise floor and accuracy results is shown in Table 1. These noise floors can be reduced by 15-20 dB if cross-correlation is used. Cross-correlation would also aid in a more careful study of the noise floor of the measurement system.

	Noise Floor	Accuracy
5 to 1500 MHz	-150 dBc/Hz	+/- 1 dB
1.5 to 26 GHz	-155 dBc/Hz	+/- 1 dB
33 to 50 GHz	-150 dBc/Hz	+/- 1 dB
50 to 75 GHz	Complete but not	yet evaluated
75 to 110 GHz	Under	development

Table 1

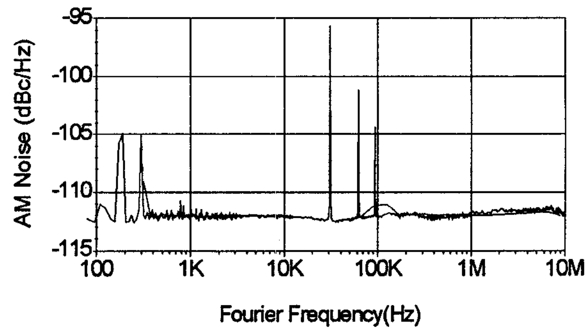

Figure 8. Measurement system evaluation at 100 MHz

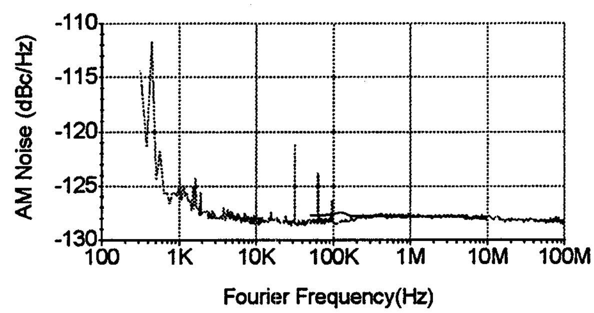

Figure 9. Measurement system evaluation at 10.6 GHz

Software

The measurement system is software controlled using over digital i/o and IEEE 488 GPIB bus. The software was developed entirely in C++ and utilizes exception handling for error control. A high level of flexibility was built into the software interface to allow for unusual or difficult measurement conditions.

Conclusion

Preliminary tests, utilizing new AM noise standards at 10.6, 21.2 and 42.4 GHz, indicate we have developed

System Description

Figure 2 shows a block diagram of the AM measurement system. The signal under test is split in a reactive power splitter and applied to a double balanced mixer. The connections to the mixer are made via a modulator and phase shifter in the RF and LO paths respectively. For a double balanced mixer to detect AM, the IF output of the mixer is amplified by an AC coupled low noise amplifier.

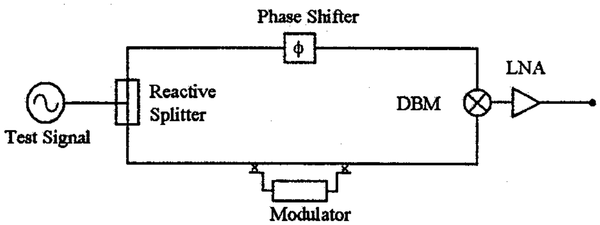

Figure 2. Block Diagram

The measurement system contains four of the above described units covering the following frequency bands, 5-1500 MHz, 1.5-26 GHz, 33-50 GHz, and 50-75 GHz. The IF outputs are multiplexed to 3 different spectrum analyzers covering frequencies from DC-100 kHz, 10 kHz - 32 MHz, and 10 kHz - 26 GHz. This allows coverage of Fourier frequencies from 0.1 Hz to 1 GHz, with reasonable overlap between analyzers.

System Calibration

The absolute system calibration is measured and calculated at one frequency using either an AM noise standard[4-5], or a substitution synthesizer with calibrated amplitude modulation capability. Gain versus Fourier frequency is then measured relative to the absolute calibration using a swept modulation technique similar to the PM method discussed in [1]. For review the modulator is shown in Figure 2.

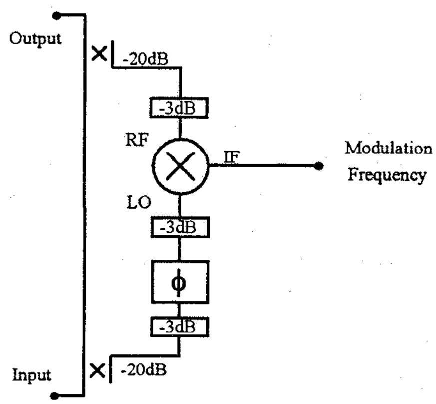

Figure 3. NIST modulator

A small portion of the carrier power is coupled off the input port using a directional coupler. Then after being phase shifted by (ϕ) it is amplitude modulated and re-inserted into the signal path with a directional coupler. When a tone is applied at the IF port, the resulting amplitude and phase modulations are proportional to $\cos(\phi)$ and $\sin(\phi)$ respectively.

With ϕ set to zero degrees, the modulator is set up to produce pure amplitude modulation. An AM tone is then swept across the Fourier frequencies of interest and measured in all three spectrum analyzers. This process, under computer control, takes a variable number of points per decade depending on the slope of the gain curve.

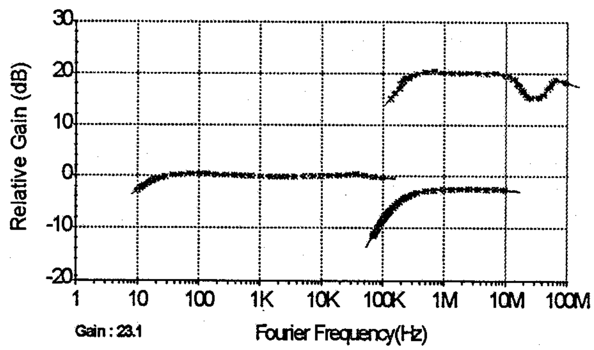

Figure 4. Gain curve at x-band

Once the frequency dependency of the system has been measured, a calibration curve is constructed for each analyzer using either linear or cubic spline interpolation. (Figure 4.) The dip in the gain curve at 30 MHz is present in all four measurement front ends, and is therefore thought to be a resonance in the DC block used to ac couple the IF amplifiers.

Noise measurements can now be made in each spectrum analyzer and the frequency dependence of the measurement system can be compensated. A noise measurement for a commercial analog 10 MHz synthesizer is shown in Figure 5.

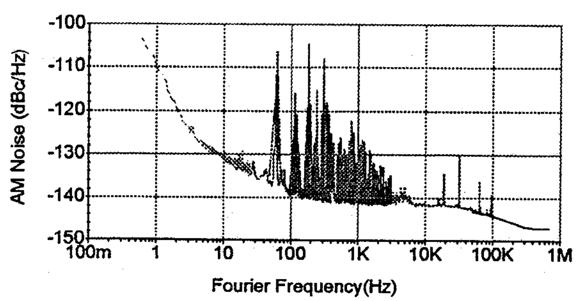

Figure 5. AM noise in a 10 MHz synthesizer

a very wide-band AM measurement system with accuracies of +/- 1 dB for Fourier frequencies out to 100 MHz from the carrier. By controlling the impedance of the DC block on the output of the mixer, we might be able to reduce the gain variations at 30 MHz and beyond 100 MHz. We expect to ultimately achieve approximately +/- 3 dB accuracy out to 1 GHz from the carrier. This new wide-band AM measurement technique is very general and we are presently working on extending the carrier frequency range out to 110 GHz.

References

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