

Selecting High Linearity MMIC Amplifiers for use with Complex Digital Waveforms

By Ted Heil, Mini-Circuits® Labs, and Steve Crain, Agilent Technologies

This month's cover features the new E-PHEMT amplifier products offered by Mini-Circuits, with low noise figure and high dynamic range performance

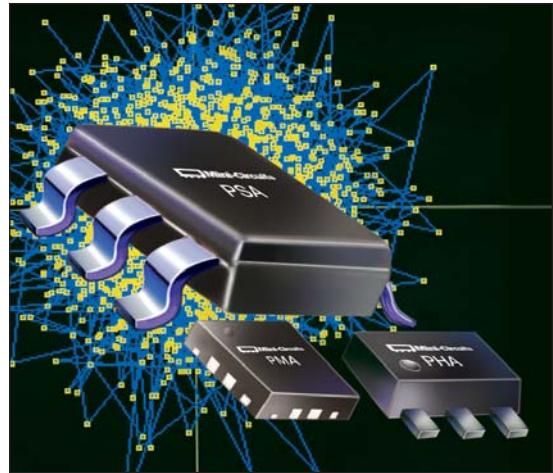
Enhanced Mode GaAs PHEMT (E-PHEMT) based MMIC amplifiers provide users advantages in both broadband noise figure and intermodulation performance, setting them apart from previous generations of GaAs MMIC amplifier designs. Historically known for their extremely low noise figure, PHEMTs have also been used extensively for power applications in the mobile PA market; however, recent designs possess a combination of low noise and high intermodulation distortion suppression that improves both ends of the dynamic range over broad frequency range.

The new lineup of low noise, high dynamic range, MMIC amplifiers from Mini-Circuits includes the PSA, PMA and PHA families. These are broadband, single stage, Class A, 50 ohm MMIC amplifiers. All offer outstanding noise figure and intermodulation performance; the PHA-1X+, being the most recent generation of E-PHEMT, is distinguished through its higher IP₃ performance at reduced DC power consumption and intermodulation performance extended to lower frequencies. Table 1 shows key performance parameters for these amplifier families.

Characterizing Amplifiers for Complex Waveforms

Historically, amplifiers were characterized using CW signals to take relatively simple measurements, such as intercept point and compression (AM to AM and AM to PM). While these measurements remain quite useful, the wireless industry discovered that

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This issue's cover features Mini-Circuits' line of GaAs E-PHEMT MMIC amplifiers.

amplifiers behave differently when stimulated with complex signals that have higher peak to average ratios than an unmodulated CW signal. As a result, it is desirable for the characterization of wireless amplifiers to include measurements made with "real world" complex waveforms. The most common measurements are Adjacent Channel Power Ratio (ACPR) and Modulation Accuracy.

Accurate ACPR measurements can be challenging when using older spectrum analyzers. Features have been added to the modern spectrum analyzer to make measurements easier and more accurate. RMS averaging is used to eliminate errors that occur when averaging on a log scale. An average detector is also used because it accurately measures complex waveforms with noise-like characteristics. In addition to having these core features, modern analyzers also offer one-button mea-

High Frequency Products

GaAs E-PHEMT MMICs

Model	NF (dB)	P _{1dB} (dBm)	OIP3 (dBm)	DC Supply
PSA-545+	0.80	+19.6	+36	3V, 80 mA
PMA-545+	0.96	+19.8	+36	3V, 80 mA
PHA-1+	2.48	+22.6	+41	5V, 180 mA
PHA-1X+	2.2	+22.6	+43	5V, 140 mA

All data is at 2 GHz

Table 1 · MMIC amplifier performance summary.

surement capability for easy and repeatable standard compliant measurements.

Modulation Accuracy measurements have also become valuable during amplifier characterization because they represent a summation of all impairments on the signal. The most common Modulation Accuracy measurement is referred to as Error Vector Magnitude (EVM), quantitative figure of merit that represents the quality of digitally modulated signals. Different applications may use different terms, such as Relative Constellation Error (RCE) in WiMAX or Modulation Error Ratio (MER) in Cable TV applications, but the fundamental measurement is essentially the same—the difference between the measured signal and an ideal reference signal.

In making these measurements, the analyzer creates a reference signal by demodulating the measured signal

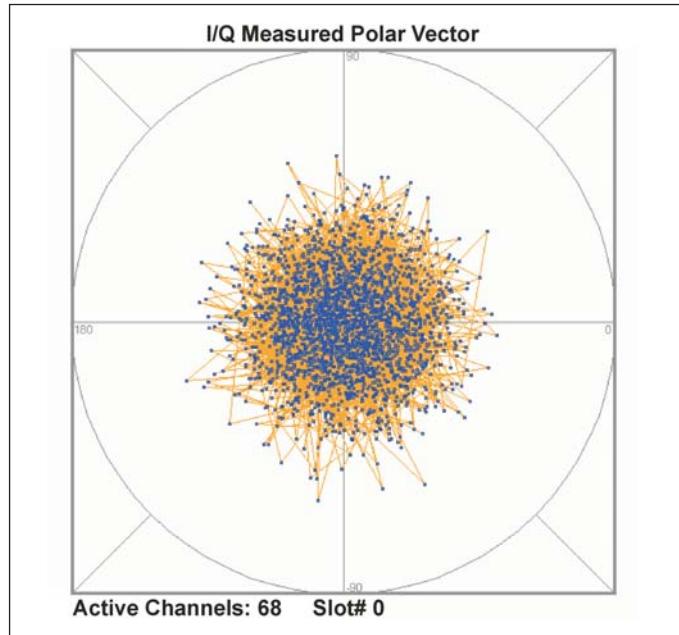


Figure 1 · IQ polar plot.

and recovering the intended symbols. It then mathematically re-modulates the signal to create an ideal reference. EVM is the resulting vector between the two, representing both the amplitude and phase errors. Typically it is

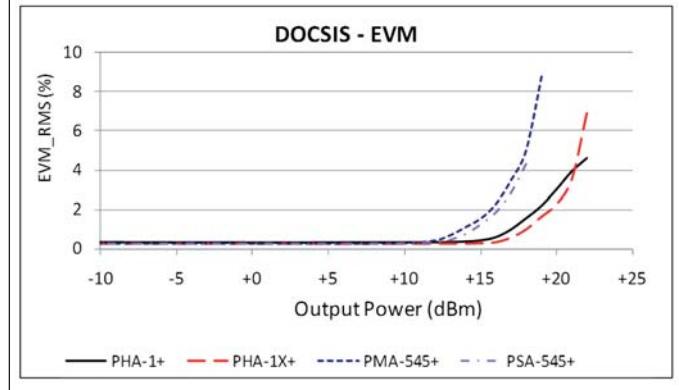
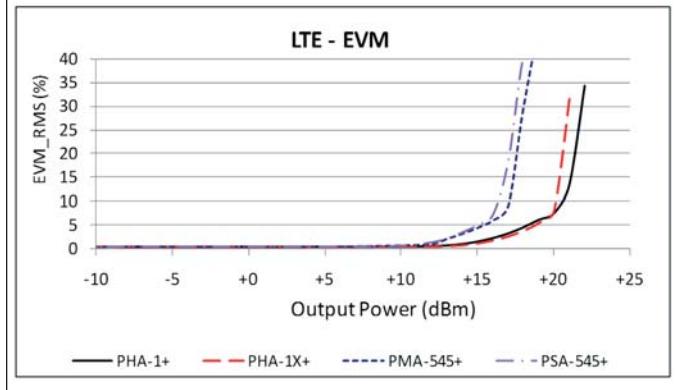
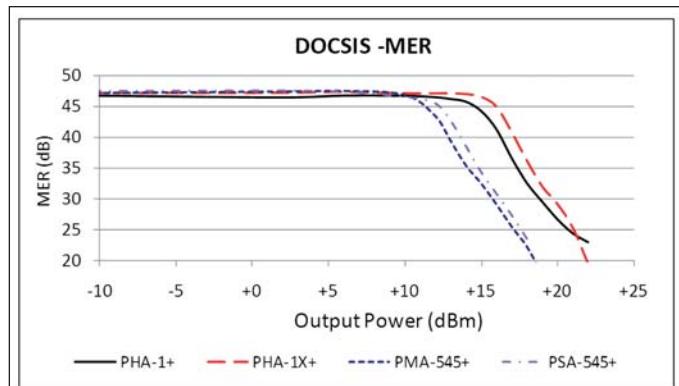
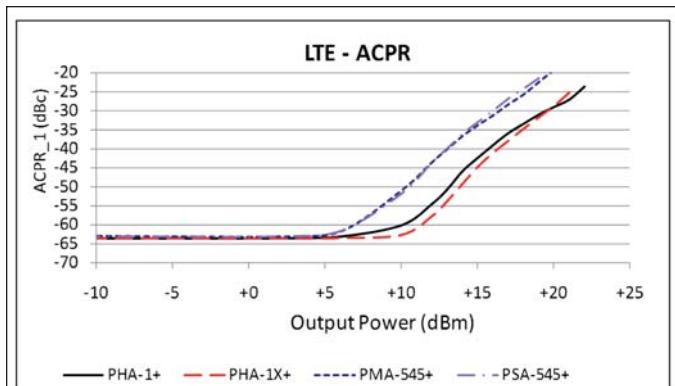


Figure 2 · LTE — FDD, 700 MHz, 1 Carrier, 10 MHz.

Figure 3 · DOCSIS — 64 QAM_1C, 500 MHz.

expressed as a percentage of the peak ideal signal.

For signals such as CDMA, OFDM or QAM, the measured signal is represented in an I/Q polar graph or constellation diagram, as in Figure 1, and the EVM is a calculated value.

Complex digital waveform characterization is often performed in accordance with industry standard test model, which defines the center frequency, channel bandwidth, number of carriers, number of active channels and a number of other parameters that detail the digital signal structure. From the perspective of the amplifier, these parameters manifest themselves in a power distribution. The Complementary-Cumulative-Distribution-Function (CCDF) defines the statistics of a test signal and specifies the signals' probability of exceeding a specific power threshold.

Digital waveforms are configured using Agilent's Signal Studio software suite and generated using the Agilent MXG-N5182A Vector Signal Generator. Both spectrum and modulation accuracy measurements are made using the MXA-N9020A Vector Signal Analyzer, which provides a variety of different measurements; however, as previously described, the most commonly used test parameters are ACPR and EVM.

A summary of performance over a range of output powers is the ideal means of comparison and model selection. These measurements were automated using the same equipment

sweeping input power; however, since each amplifier has different gains, the measurements are all referenced to the power at the output of the device. Performance relative to commonly used LTE and DOCSIS signals are shown in Figure 2 and Figure 3.

All E-PHEMT MMIC amplifiers are readily characterized using off-the-shelf equipment and waveforms. This capability is easily extended to many digital modulation schemes such as WCDMA, CDMA-2000, WiMAX, EDGE, DVB-T, etc. In both the case of spectral regrowth and modulation accuracy, there is an observable difference between the PSA, PMA and PHA series. This is expected based upon the 1 dB compression and intercept point data. However, it is also apparent that it is impossible to directly correlate either compression or two-tone intermodulation performance to spectral regrowth or modulation accuracy.

Therefore, when making use of high dynamic range amplifiers within digital communication systems using complex, high peak to average ratio signals, the proper means to determine the contribution to system error and spectral degradation, and to select the proper amplifier, is direct measurement using waveforms and measurement systems similar to the one described in this article.

Author Information

This article was written by Ted Heil of Mini-Circuits Labs and Steve Crain of Agilent Technologies. Additional information on this product line is available on the Mini-Circuits Web site.

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