

Dynamic Range Optimization of Broadband MMIC Amplifiers

by Mini-Circuits

Traditional small-to-medium power MMIC amplifiers are designed to deliver specified performance in a 50 ohm environment over a defined frequency band. These amplifiers include internal matching circuits to achieve a balance of dynamic range performance and return loss over frequency; however, in reality, even an internally matched 50 ohm MMIC amplifier may reveal untapped performance improvement when the output load impedance is optimized over frequency for specific performance requirements.

Optimizing Dynamic Range

The technique of optimizing an amplifiers' dynamic range performance through matching

the output of the device to an optimal load impedance is a common approach, often used in the final stages of communications band amplifiers.

Load Pull measurement systems have been used for many years to characterize semiconductor device performance across a matrix of complex load impedances. Traditionally, these measurement systems have been used to characterize high power transistors used in the final stage of a transmitter; however, it is only recently that similar techniques are used to characterize devices used further back in the transmit chain.

Mini-Circuits new Output Load Impedance Contours make use of this characterization method to provide data

enabling customers to design output matching circuits that optimize critical parameters such as Output Intercept Point (IP3) and Output Power Compression (P1dB) for a wide variety of small-to-medium power catalog MMIC Amplifiers. In some cases, optimizing performance through output matching circuits can even save the engineer from the decision to design in higher power devices to get comparable performance, saving cost, current consumption, thermal management and promoting overall reliability.

Mini-Circuits ultra-high dynamic range PHA-1+ amplifier is a perfect example of a driver amplifier that demon-

strates the added value of using load impedance optimization. Designed to operate over the range of 50 MHz to 6 GHz, the PHA-1+ has typical IP3 of +41 dBm and Output Power at 1 dB Compression of +23 dBm. This is a broadband internally matched MMIC Amplifier, specifically designed to present a nominal 50 ohm impedance over the entire frequency range.

The performance in the datasheet for the PHA-1+ includes S parameters, Noise Figure, P1dB and IP3. These parameters are measured and represented in a 50 ohm environment as shown in Figure 1 and Figure 2.

Operating over this broad

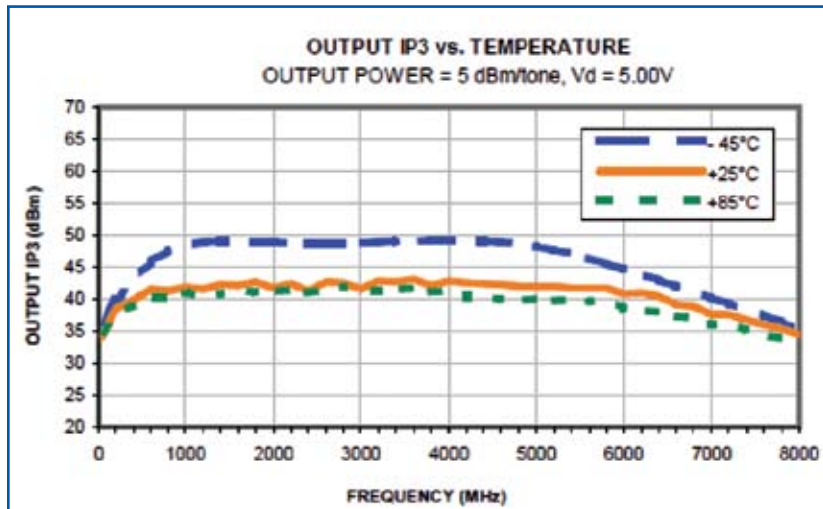


Figure 1: PHA-1+ Output IP3 versus Frequency

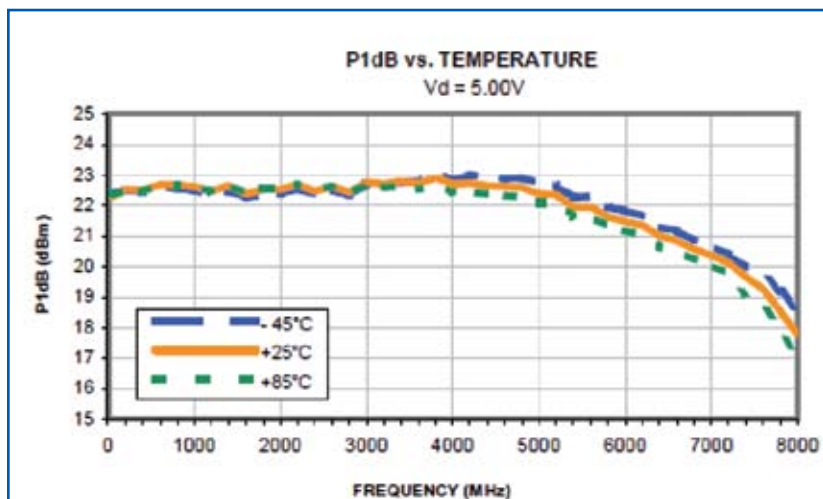


Figure 2: PHA-1+ Output Power at 1dB Compression versus Frequency

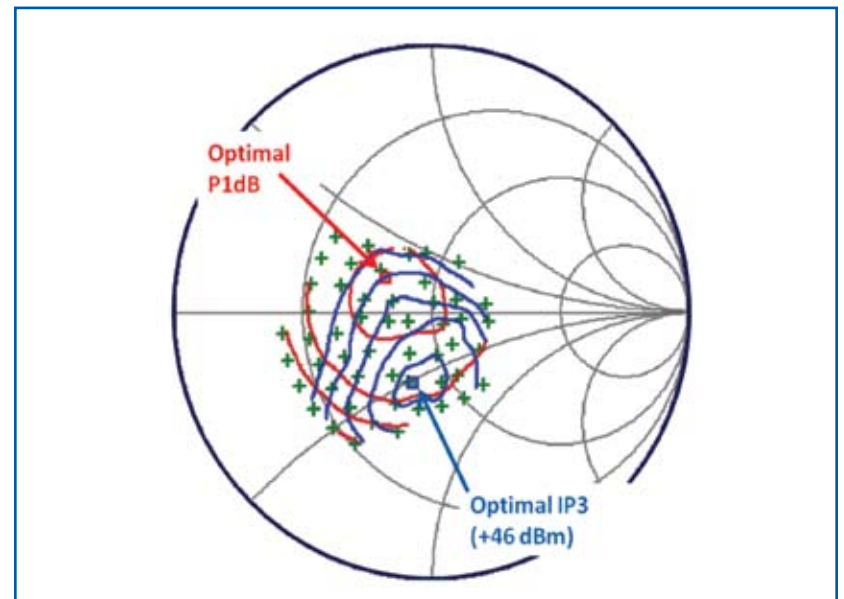


Figure 3: Optimized Impedances for IP3 and P1dB

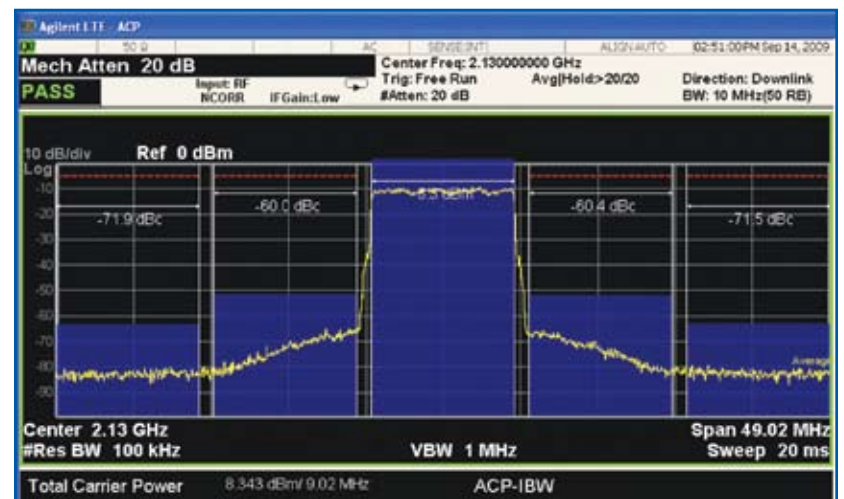


Figure 4: Adjacent Channel Power Ratio

frequency range, the PHA-1+ is ideal for use in broadband applications such as CATV systems, defense applications or test and measurement equipment. However, there are a wide range of applications that do not require such bandwidths and could benefit from performance which is optimized over narrower frequency ranges. Both Commercial and Military communications are ideal candidates especially with the use of complex digital modulation which greatly stress the dynamic range of an RF chain.

Figure 3 shows Output Compression and IP3 contours for the PHA-1+. From this plot, we can see that by adding a simple matching network at the output of the amplifier, the IP3 can be improved (over 50 ohm performance) by up to 5 dB, from +41 dBm to +46 dBm. In a two-tone environment, this optimization yields a 10 dB improvement in dynamic range for a minimal investment of a few lumped elements components at the output of the amplifier.

An additional observation from studying the load pull contours in **Figure 3** is that the optimal impedance for IP3 may not always be same the optimal impedance for P1dB. Furthermore, common digital communication systems utilize phase and amplitude modulated signals to increase spectral efficiency and signal density; these signals are affected by both AM-AM and AM-PM compression and by multi-tone intermodulation performance as shown in **Figure 4**. Therefore, the optimal output load impedance may not be 50 ohms, and may not be the same as the optimal load for IP3 or P1dB.

Conclusion

Traditional Amplifier characterization of IP3 and P1dB using a 50 ohm load impedance provides valuable information to the system engineer. Although 50 ohm measurements are the accepted method to characterize a device over a broad frequency range, over narrower

bands, significant performance improvements can be achieved through presenting an optimal load impedance to even internally matched 50 ohm MMIC Amplifiers.

Furthermore, one cannot conclude that an optimal match for all dynamic range parameters is the same. We have shown that the optimal match for intermodulation (IP3) may not be the optimal match for compression and also may be different for digital modulated parameters such as ACPR and EVM.

Load Pull characterization and the use of load pull contours for dynamic range parameters is an effective technique to develop simple L-C matching circuits that can be used at the output of 50 ohm MMIC Amplifiers to optimize dynamic range performance of RF transistors. Mini-Circuits has taken this method and extended it to small-to-medium power MMIC amplifiers enabling customers to improve the performance of these existing amplifiers, adding value to the design process by increasing flexibility in choosing and customizing MMIC Amplifiers for specific systems requirements.

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