NXP Semiconductors
Application Note

AN5296
Rev. 0, 01/2017

Effective Small Cell Solutions for MIMO Radios

New Family of Wideband Doherty RFIC Power Amplifiers Linearized with Dual Path Adaptive Predistortion Device

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INTRODUCTION

When supplying components for small cell radios, there are three major factors that come into the decision making process. Do the components perform well, are they easy to use and do they leverage integration to help shrink the overall size of the radio? This application note covers the excellent RF performance capabilities of NXP's new family of RF power LDMOS ICs for 1 to 5 watt small cell applications. These products are designed for compact Doherty power amplifier (DPA) configurations. They are driven by NXP GaAs pHEMT linear amplifiers and are shown to linearize with a Maxim Integrated SC2200, a fourth generation adaptive predistortion device. Two different frequency range DPAs are tested under various LTE test signals. The results show best in class bandwidth and DC-to-RF power conversion efficiency while still maintaining stringent linearity requirements.

MIMO Small Cell Solutions

The cellular user's demand for data has been growing exponentially. In response to these increasing data rate requirements, cellular service providers are deploying heterogeneous networks made up of variously sized base stations. Ranging from macro cells, with coverage of several kilometers to femtocell and picocell solutions, with coverage areas in the range of several meters. These smaller cell implementations will use distributed antenna and multiple antenna MIMO architectures in order to provide high data rates for quality streaming video. This will simultaneously connect a multitude of devices while providing extremely low latency in any communication environment.

Increasing user density drives the need for an increased number of channels and wider signal bandwidth capability, higher linearity and high DC-to-RF conversion efficiency. Collectively, this drives the need for new components requiring higher levels of integration and smaller form factors, which must be done cost-effectively to enable these system level network improvements.

Improving Amplifier Efficiency

In all amplifier systems there is a fundamental tradeoff between linearity and conversion efficiency. Class A amplifiers are very linear in back-off with low efficiency, whereas Class D amplifiers can theoretically be 100 percent efficient but also nonlinear with very high distortion products. Class D amplifiers are also difficult to implement at higher frequencies due to bandwidth crippling device parasitic effects. Typically, for lower power cellular radios, the final PA device is operated in a Class AB quasi linear mode and then backed off from the P1dB compression point until the desired linearity is achieved. This method produces amplifier systems with 8 to 15 percent conversion efficiency. This implementation might be acceptable if RF power requirements are very low, where wasted power has minimal cost. As RF output power increases, suddenly that wasted power can take on significant cost in the form of higher temperatures, more expensive heat transfer solutions and higher operating costs. To achieve efficiencies over 40%, a low complexity, cost-effective middle ground can be found with the implementation of Doherty PAs (DPA). However, DPAs are inherently less linear than Class AB PAs operating in back-off. The large jump in efficiency from the nonlinear DPA justifies the use of linearization systems to allow for operation of higher efficiency while maintaining exceptional linearity.

Compare and Contrast Linearization Techniques

Just like the tradeoff of efficiency versus linearity in power amplifiers, there are tradeoffs in the type of linearization techniques applied. The simplest and lowest cost to implement is non-adaptive linearization that can take the form of a lookup table either in an analog circuit or in the digital domain. Non-adaptive linearization systems use a predefined model of a PAs transfer function. Therefore, it cannot account for changes that may occur in a PAs behavior over power levels, frequency, temperature or time. Due to the demands placed on modern outdoor radio systems, radio architects must look to adaptive forms of linearization. Adaptive linearization is equipped to handle nonlinear PA changes in time (memory effects) along with changes in power, frequency and temperature. Just like non-adaptive, adaptive linearization can come in the form of analog or digital (baseband). Both have their benefits in terms of power consumption and their ability to handle large amounts of memory effects generated in the PA. It is important for the radio architect to weigh all the options that are available to implement the most effective solution in terms of cost and performance. In this application note, an adaptive RF domain (non-baseband) linearizer from Maxim Integrated Products is used to characterize the targeted PAs. Figure 1 shows the typical block diagram configuration of the DPA with linearizer.

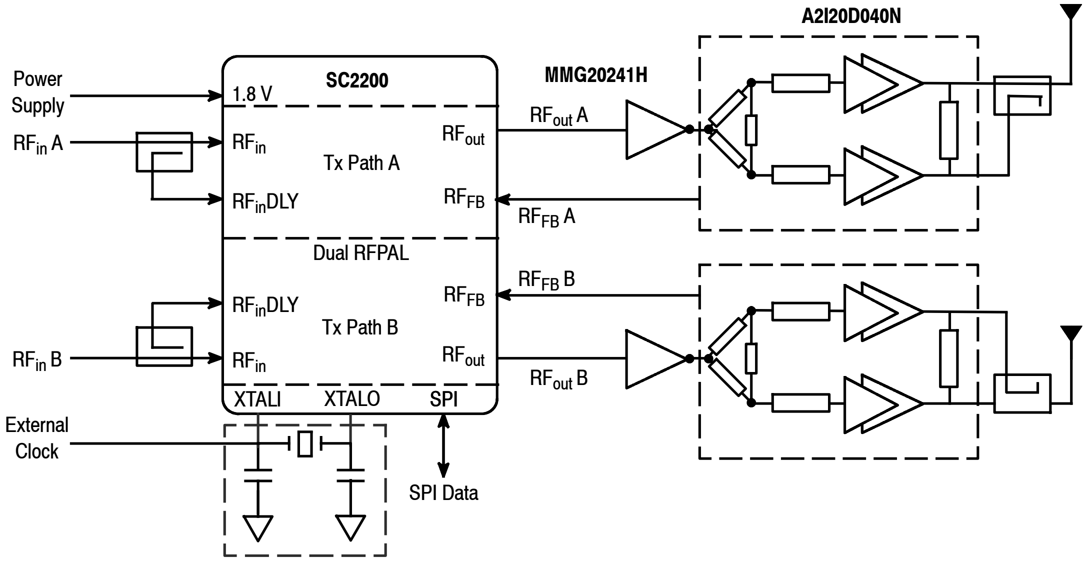

Figure 1. Small Cell Transmit Chain with A2I20D040N Final, MMG20241H Driver and SC2200

Table 1 shows the typical performance of the two-stage NXP A2I20D040N final with 30 dB gain and a single-stage MMG20241H driver with 17 dB gain over the 1800–2200 MHz frequency range linearized with a Maxim SC2200 dual path adaptive device.

Table 1. Linearized NXP A2I20D040N Final and MMG20241H Driver over 1800–2200 MHz

Signal	Output Power @ –50 dBc ACPR	PAE (%)	Input Signal PAR (dB)
20 MHz LTE	39 dBm	41	7
2-Carrier 20 MHz LTE	39 dBm	41	7

Table 2 shows the performance of the two-stage NXP A2I25D025N final with 29 dB gain and a single-stage MMG20241H driver with 15 dB gain over the 2300–2800 MHz frequency range linearized with a Maxim SC2200 dual path adaptive device.

Table 2. NXP A2I25D025N Final and MMG20241H Driver over 2300–2800 MHz

Signal	Output Power @ –50 dBc ACPR	PAE (%)	Input Signal PAR (dB)
20 MHz LTE	38 dBm	37	7
2-Carrier 20 MHz LTE	37 dBm	35	7
3-Carrier 20 MHz LTE	35 dBm	30	7.5

Benefits of NXP's RF Power LDMOS Products

NXP is one of the world's largest providers of RF power LDMOS transistors. NXP owns this top position due to advanced die technologies and in-house plastic packaging coupled with world-class thermal management. NXP's devices offer excellent product solutions that include high efficiency, symmetrical and asymmetrical single package Doherty components. These products are made easy to use with integrated 50 ohm, DC decoupled input matching, multi-stage designs incorporating thermal compensation and ESD protection circuitry. NXP's LDMOS RFIC products are available in a wide range of rated power levels from 4 to 60 watts for a variety of small cell sizes.

Figure 2 shows a typical small cell, symmetrical Doherty design.

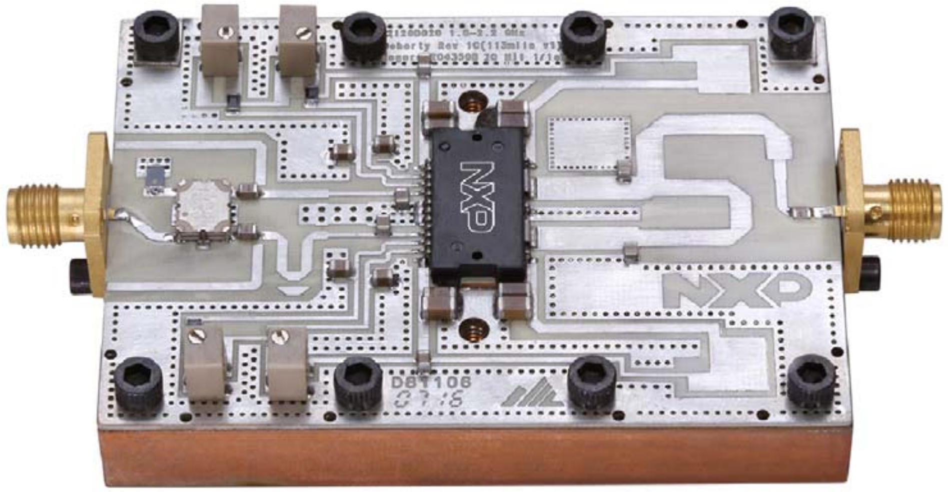

Figure 2. A2I20D040N 8 W Average, Symmetrical Doherty Reference Design

Benefits of NXP's GaAs pHEMT Linear Drivers

To get exceptional system performance, it is important to use a similarly high performance driver device. GaAs pHEMT delivers excellent bandwidth, linearity and efficiency for devices under one watt. NXP complements their high performance LDMOS finals with a large product portfolio of cost-effective, GaAs pHEMT devices. They are offered in Class A and Class AB, low power, linear driver devices optimized for base station applications. These devices are typically 50 ohm input and output matched and operate with a 5 V supply. Designed with ease of use in mind, only simple external circuit components are required and industry standard, cost-effective SOT-89 packaging is used. NXP's universal drivers are differentiated by higher P1dB and third-order intercept levels with exceptionally high multi-stage gain and excellent instantaneous signal bandwidths (ISBW) greater than 60 MHz. Figure 3 shows a typical GaAS pHEMT driver design.

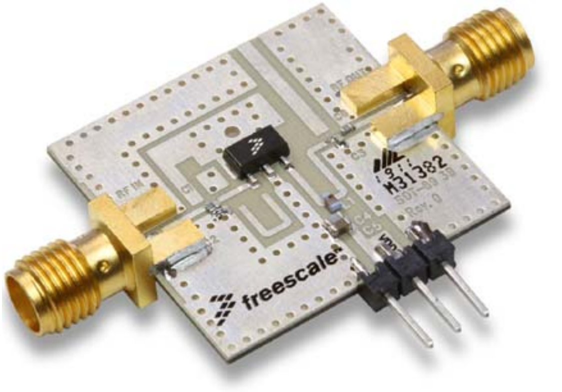

Figure 3. MMG20241H GaAs pHEMT MMIC Driver Reference Design

Benefits of Fully Adaptive RF Predistortion Linearizers

The Maxim SC2200 belongs to the fourth generation family of RF PA linearizers (RFPAL). The Maxim SC2200 provides increased integration, functionality and ease of use over the previous generations with fewer external circuit board components. The device is a dual path, fully adaptive, RF in and out predistortion linearization solution optimized for a wide range of amplifiers, power levels and communication protocols. It supports cellular 2G to 4G standards (FDD and TDD) from 698 to 2700 MHz. It also has an expanded range of signal bandwidths from 1.2 MHz up to 60 MHz. The SC2200 operates single ended and features a mirrored pinout facilitating designs of both paths. By sampling both the input signal to the PA lineup and the DPA output, the device adaptively generates an optimized error correction function to minimize the DPA's distortion. The device uses the ninth-order polynomial Volterra series to create the pre-correction signal that is coupled back into the input signal to the PA. The use of RF domain analog signal processing enables the SC2200 to operate over wide bandwidths with very low power consumption. The dual linearizer can be used for MIMO small cell, active antenna systems as well as remote radio heads and distributed antennas. Figure 4 shows a typical RFPAL layout with external PCB components.

Figure 4. SC2200 RFPAL Layout Showing External PCB Components

NXP Family of Power Amplifiers

The MMG20241H is a 24 dBm P1dB, one-stage GaAs pHEMT with more than 17 dB of gain housed in a cost-effective SOT-89 package. This device is capable of handling a 20 MHz wideband LTE signal at 13 dBm with ACPR of –45 dBc and at 8 dBm with ACPR of –55 dBc. Its excellent linearity as a driver is critical for the wideband performance in this application.

The A2I20D040N is a two-stage, dual path RFIC LDMOS component with 33 dB Class AB gain and a 40 W P1dB rating. This product is packaged in an industry-standard TO-270-WB package using the exclusive NXP path isolation technology and internal temperature compensation circuitry.

The A2I25D025N is a two-stage, dual path RFIC LDMOS component with 32 dB Class AB gain and a 25 W P1dB rating. This product is also packaged in an industry-standard TO-270-WB package using the exclusive NXP path isolation technology and internal temperature compensation circuitry.

Table 3 provides an overview of the NXP family of 28 V LDMOS RFICs with a two-stage, dual path configuration.

Table 3. Recommended Small Cell Portfolio of NXP 28 V LDMOS RFICs

Antenna Power	Up to 1000 MHz	1400–2200 MHz	2300–2900 MHz	3400–3800 MHz
5 W	A2I08H040N	A2I20D040N	A2I25H060N	A2I35H060N
1–2 W	MD8IC925N	A2I20D020N	A2I25D025N	

The following before and after drive up curves show that the incorporation of the Maxim SC2200 predistortion device into the A2I20D040N DPA allows the system to achieve 39 dBm PA output power with 41% efficiency and ACPR at –50 dBc. The great linearity of the MMG20241H driver is critical for wideband performance. At 8 dB or higher output back-off, the ACPR for 2-carrier 20 MHz LTE at 7 dB PAR is –51 dBc or better.

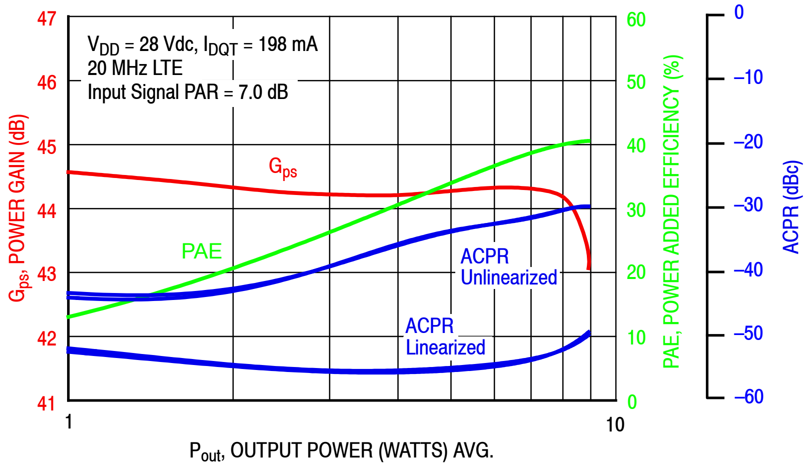

Figure 5. Test Results with A2I20D040N: 20 MHz LTE, 7 dB PAR with SC2200 at 1860 MHz

Here the results on the same amplifier system are shown in Figure 6, this time with a much more challenging 2-carrier 20 MHz wideband LTE test signal.

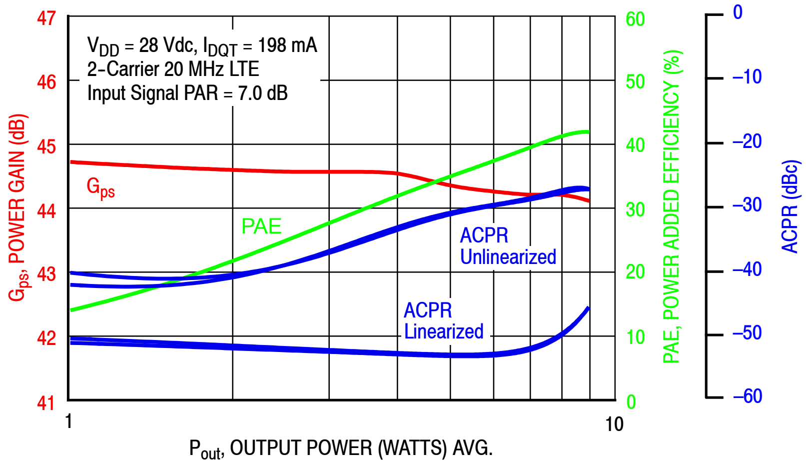

Figure 6. Test Results with A2I20D040N: 2-Carrier 20 MHz LTE, 7 dB PAR with SC2200 at 1860 MHz

With a single-carrier 20 MHz LTE signal, the A2I25D025N power amplifier system with SC2200 can achieve 37% efficiency at 38 dBm average output power.

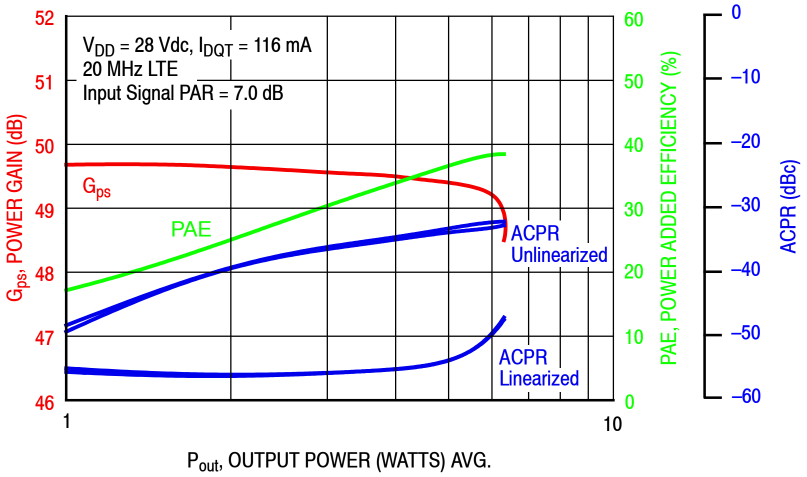

Figure 7. Test Results with A2I25D025N: 20 MHz LTE, 7 dB PAR with SC2200 at 2660 MHz

With a 3-carrier 20 MHz LTE signal (60 MHz total), the A2I25D025N power amplifier system with SC2200 can achieve 30% efficiency at 35 dBm average output power.

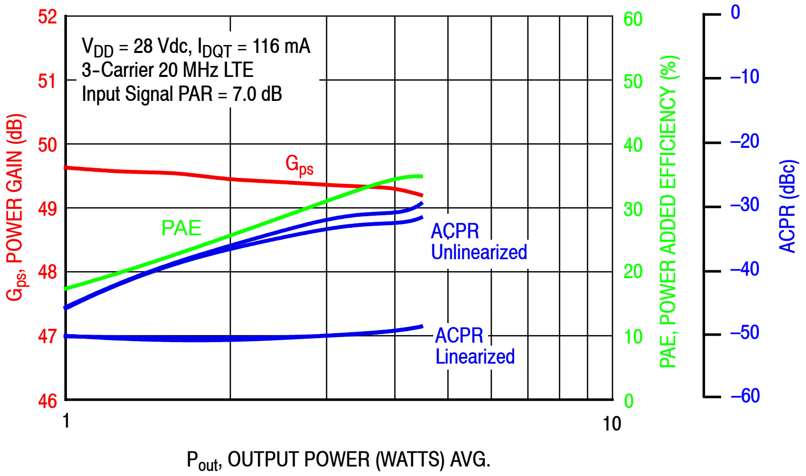

Figure 8. Test Results with A2I25D025N: 3-Carrier 20 MHz LTE, 7 dB PAR with SC2200 at 2660 MHz

Conclusion

This application note has demonstrated a high performance, easy to use and highly integrated linearized power amplifier system through the implementation of a Doherty configuration with the latest NXP family of LDMOS RFICs linearized with the Maxim SC2200 dual path predistortion device. The overall solution presented is cost-effective with a low order of complexity for MIMO small cell, active antenna systems as well as remote radio heads and distributed antennas. The native high linearity of the NXP LDMOS RFICs and GaAs MMIC devices is enhanced with the Maxim SC2200 dual path predistortion device for LTE signals as wide as 60 MHz. The Maxim RFPAL device provides up to 28 dB of ACPR improvement and 38 dBm of IMD improvement. Data sheets and references designs are available for all components shown.

For more information on this family of NXP LDMOS RFICs and GaAs low power devices, visit www.nxp.com/RFoutdoorsmallcell.

For more information on the SC2200, visit www.maximintegrated.com/SC2200.

REVISION HISTORY

The following table summarizes revisions to this document.

Revision	Date	Description
0	Jan. 2017	• Initial Release of Application Note

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