WiMAX - Revolutionizing the Art of Linear HPA's

by Aethercomm

Table 1: SSPA 2.30-2.40-400 Typical Performance at 40 Watts Average Output Power

Freq (GHz)	P1dB (dBm)	Small Signal Gain (dB)	Noise Figure (dB)	2nd Harmonic (dBc)	3rd Harmonic (dBc)	OIP3 (dBm)	Lower ACPR	Upper ACPR
2.300	56.2	53.5	4.8	-54.0	<-60.0	73.0	-44.3	-45.0
2.335	56.3	53.7	4.9	<-60.0	<-60.0	73.0	-44.5	-45.9
2.370	56.2	53.5	4.9	<-60.0	<-60.0	72.0	-44.0	-44.3
2.400	56.1	53.4	4.9	<-60.0	<-60.0	71.0	-43.5	-43.5

Introduction

The emergence of WiMAX has enabled opportunities to transform personal communication and multimedia in the commercial marketplace. At the heart of this technology is a scalable orthogonal frequency division multiple access (OFDMA) modulation scheme (IEEE 802.16e-2005) that is capable of transmitting and receiving information over various sub-carriers within a scalable bandwidth. This modulation topology provides an efficient way to securely transmit large amounts of data with very high spectral efficiency while remaining resistant to multipath fading and inter-symbol interference.

To capture the potential commercial advantages of WiMAX, it is necessary to transmit high power levels with minimum distortion keeping the error vector magnitude (EVM) low and minimizing the bit error rate (BER). These high power levels must maintain a low adjacent channel power ratio (ACPR) when transmitted to ensure adjacent channels are not swamped with spectral energy. WiMAX signals contain high crest factors of 9.8 dB on the complementary cumulative distribution function (CCDF) that contain complex modulation that is very sensitive to amplitude and phase integrity. These stringent system demands require ultra-linear high power amplification with minimal signal degradation.

With these goals in mind, Aethercomm has developed an ultra linear solid state power amplifier module called the SSPA 2.30-2.40-400. The RF amplifier does not contain any linearization. Operating through the 2.30 to 2.40 GHz frequency range, it fully supports the WiMAX profiles 1A and 2B. The amplifier provides high gain, an extremely flat gain response, high OIP3 and high peak power capabilities. It maintains excellent ACPR over the entire operating band with only slight deviation when subjected to extreme operating temperatures.

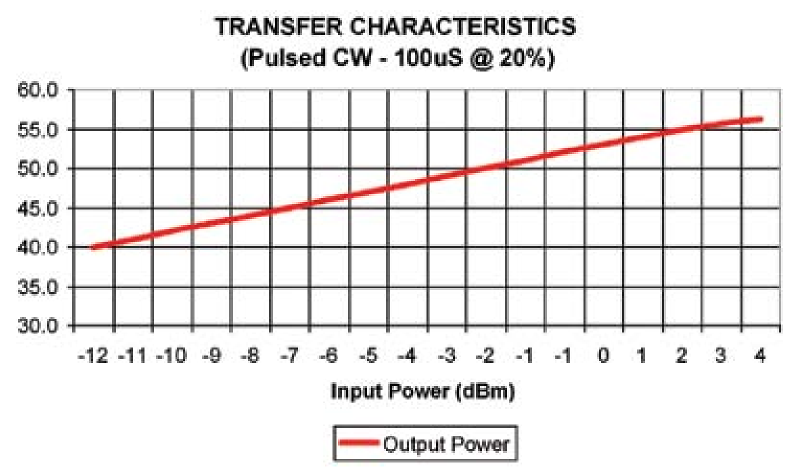

Figure 1: Power Amplifier Transfer Function

This power amplifier is designed to operate from a +36.0VDC power source. Each power transistor incorporates a DC-DC regulation subcircuit which provides excellent isolation from external noise and transients. The power amplifier includes proprietary switching circuitry allowing the unit to settle to within 95% of its final output power within 1.5 uS. This allows the unit to be well suited for basestation applications requiring Tx and Rx operation. Additional features include protection against input RF overdrive faults, voltage standing wave ratio (VSWR) faults and power supply voltage faults that could degrade the performance the amplifier. Table 1 summarizes the recorded performance results at an average output power of 40 Watts.

To test the frequency capabilities of the power amplifier, the frequency range was expanded between 2.30 to 2.50 GHz. Under these experimental conditions, the power amplifier demonstrated it could fully support the WiMAX profile 1A, 1B and 2B bands.

Design Methodology

This RF amplifier incorporates GaAs and LDMOS devices to achieve the high system linearity. Historically, GaAs and LDMOS technologies have been ideal choices for linear applications due to their low inter-modulation distortion (IMD) products, consistent gain and consistent phase properties over various output power levels. In fact, these technologies exhibit better linearity characteristics than newer transistor technologies such as Gallium Nitride (GaN) and Silicon Carbide (SiC).

In WiMAX applications, an OFDMA signal is comprised of data sub-carriers that contain parts of a data stream that are modulated with an Amplitude Modulation (ie: 256QAM). Since this modulation scheme is sensitive to the amplitude and phase properties of each sub-carrier, an amplified signal must have a low EVM in order to maintain the signal integrity. This minimizes the BER when the signal is received and the data package is reconstructed. The amplitude errors associated with the EVM are addressed by the power amplifier's transfer function which yields a linear gain response up to a high P1dB power level.

Since spectral efficiency is very important for WiMAX, it is necessary to minimize the ACPR while maximizing the available power to be transmitted. This ensures that adjacent channels are not swamped by the spectral energies that result from non-linear effects of the power transistors. This RF amplifier achieves excellent ACPR due to the enhanced linear performance and consistent PM-AM characteristics throughout the power range.

In WiMAX applications, it is very important to ensure that the modulated signal is minimally distorted during amplification. This can be accomplished by ensuring the peak-to-average ratio (PAR) of the modulated signal is not reduced after amplification. The RF amplifier accomplishes this task by the balanced final amplification stage that maintains sufficient margin between the peak and the average power levels of the modulated signal.

Amplifier Performance

The Aethercomm SSPA 2.30-2.40-400 is characterized with a WiMAX signal modulated with 256QAM that exhibits a PAR of 9.8 dB at 0.01% CCDF. The power amplifier module produces a minimum average output power of +46.0 dBm (40 Watts) and does not exhibit a reduction of the PAR on the CCDF. All data presented is characterized with these

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signal parameters unless otherwise stated.

Since WiMAX signals have a specific peak power response, it is important to characterize the peak power capability of the power amplifier to ensure that the PAR of the amplified signal is preserved. From the transfer function detailed in Figure 1, the power amplifier exhibits 1dB gain compression P1dB at an output power level of +56.0dBm (400W). This reveals that the optimal average output power is +46.0dBm (40W), which is predictable based on the input signals PAR.

To determine the ACPR performance of this RF amplifier, the power spectral density (PSD) is measured 1MHz above and below the main channel bandwidth. The PSD measured from the power amplifier module is displayed graphically over different average output power levels in Figure 2.

As can be seen from the figure, a noticeable "knee" occurs at the point where the average power is backed off 9.8 dB from the P1dB of the amplifier. This coincides with a nominal performance average output power of +46.0 dBm and results in an ACPR of -43.5 dBc over the entire operating band. As output power increases beyond this point, signal peaks are not amplified linearly and become distorted while the ACPR degrades at a constant rate of 3.8 dBc per each 1 dB increase in output power. Thus depending on the desired ACPR and EVM, average output power can be scaled based on the requirements of the system.

Since ACPR is closely linked to the IMD products of a power amplifier, it is important to reduce these in-band distortion effects to optimize the ACPR. This was accomplished by biasing the power transistors in a Class AB mode and resulted in an OIP3 of +73.0dBm. This bias condition allows the amplifier to take advantage an improved IMD3 product at higher output power levels. Figure 3 demonstrates the IMD characteristics over various tone power levels.

Since WiMAX is targeted for commercial markets, it is necessary to ensure thermal stability of the power amplifier over various temperature ranges. As can be seen from Figure 4, the power amplifier module

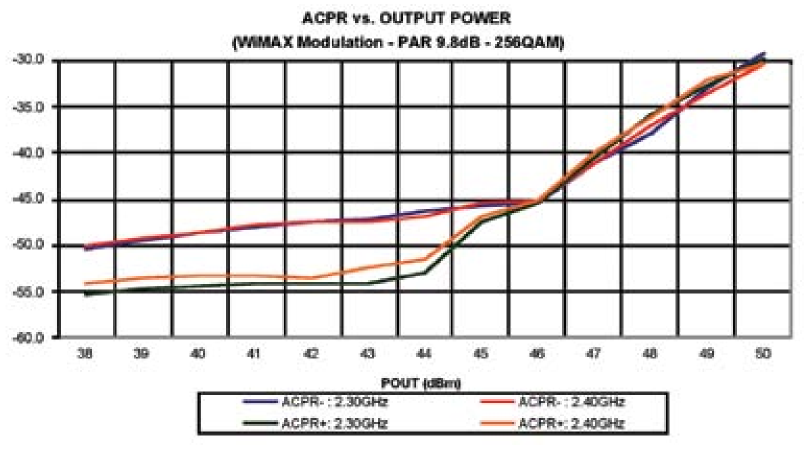

Figure 2: ACPR Performance Over Average Output Power

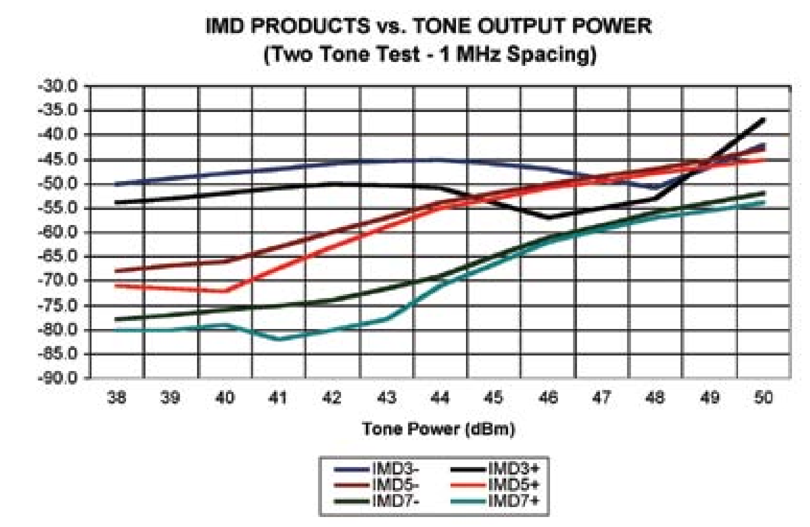

Figure 3: Class AB bias IMD products

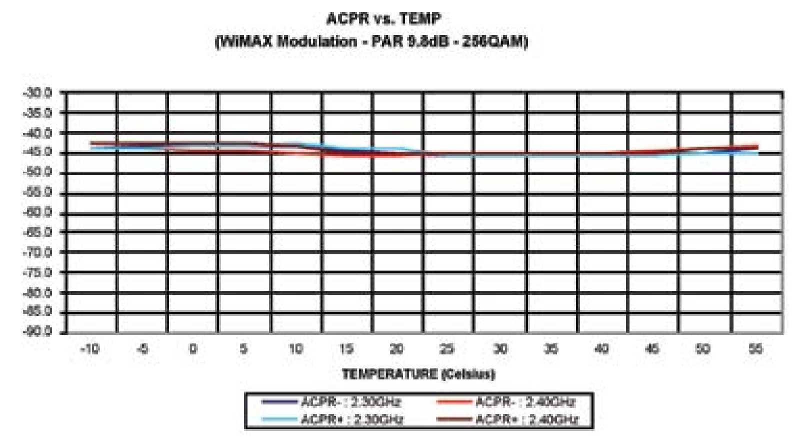

Figure 4: ACPR Performance over 40 Watts Average Output Power

exhibits excellent ACPR stability with a variation of +/-1.0dB over the entire temperature range tested. Since LDMOS FET's have a negative temperature coefficient and are generally thermally stable, ACPR stability is easy accomplished using passive temperature compensation techniques that continuously monitor and adjust the bias levels for each power transistor. Additional thermal management provisions include an integrated heat-sink that helps maintain consistent performance through various temperatures at altitudes up to 10,000 feet.

Conclusion

Aethercomm has successfully manufactured a 2.30 to 2.40 GHz solid state power amplifier module that can be easily expanded to cover the 2.30 to 2.50 GHz frequency range. This power amplifier module demonstrates high peak power capabilities, low distortion effects and good bandwidth making it well suited for basestation applications. The result is an ultra-linear high power amplifier that can maintain signal integrity and maximize system performance.

With the superior performance characteristics of the amplifier, Aethercomm is developing a variant of this amplifier; the SSPA 2.496-2.700-400. This power amplifier will expand the operating frequency range between 2.5 to 2.7 GHz to fully support the WiMAX profile 3A with similar performance characteristics as is delivered to the lower WiMAX profile bands.

References:

1. Kensington P. B., High Linearity RF Amplifier Design, Artech House, Massachusetts, USA, 2000
2. "Mobile WiMAX From OFDM-256 to S-OFDMA", ATDI, January 2007
3. "Mobile WiMAX - Part1: A Technical Overview and Performance Evaluation", WiMAX Forum, August 2006

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