

RFICS

PA proves crucial in WiMAX designs

Under pressure to get WiMAX products to market, it may be tempting to overlook the power amplifier, but designers who do so risk degrading system links and reducing battery life, say **Glenn Eswein** and **Ray Waugh** from Anadigics.

As an emerging global standard for broadband wireless access, WiMAX is undoubtedly a growing opportunity. Fixed WiMAX products are hitting the market, and the race is on to develop integrated components for mobile WiMAX. Initially hailed as an economical way to provide “last mile” connectivity to homes and businesses, WiMAX is now poised to dramatically impact the mobile market as well. In fact, service providers in Korea have already rolled out WiBro systems (a subset of mobile WiMAX).

For designers feeling the pressure to get next-generation fixed systems and first-generation mobile systems to market, it is important to remember that WiMAX has significantly different requirements to other wireless technologies and, as a result, the importance of the power amplifier (PA) in WiMAX systems should not be overlooked.

Performance metrics

As with other wireless technologies, the key RF specifications for a WiMAX transmitter include linearity, output power, and efficiency. However, each technology has unique performance requirements, and certain semiconductor processes lend themselves better to PAs for specific applications. As an example, one can draw a comparison with another broadband wireless technology that is available today – wireless LAN (WLAN) or WiFi.

There are multiple WiFi (802.11) standards, and PA requirements differ between them. For example, 802.11b technology does not use a very complex modulation scheme, so it does not require extremely high transmitter linearity. Output powers for these applications are usually in the range of 16–23 dBm out of the PA (from the antenna port, expect 2–3 dB less). Because these are not high-performance applications, the PA can be manufactured in silicon, although a process such as InGaP would improve linearity and consequently network range and data rate performance.

Later generations of WiFi, such as 802.11g and 802.11a, use orthogonal frequency division modulation (OFDM), which requires higher linearity than 802.11b. In OFDM systems, the transmit signal integrity is particularly affected by the linearity of the PA, because OFDM signals have a higher peak-to-average ratio (PAR) than those using single-carrier modulation schemes.

802.11 a/g systems require output powers in about the same range as their 802.11b counterparts, spanning 17–20 dBm out of the PA. Because of the need for high linearity at relatively high output powers, PAs for these applications tend to be made using advanced semiconductor processes, such as InGaP heterojunction-bipolar transistor (HBT).

WiMAX, in both its fixed and mobile flavors, requires even better linearity than WiFi to supply robust link at high data rates. WiMAX supports mul-

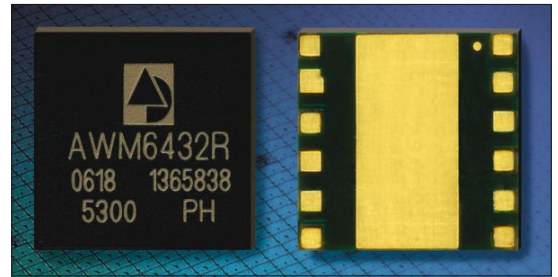


Fig. 1. Anadigics' AWM6432 power amplifier is designed for fixed-point WiMAX while, at February 2007's 3GSM World Congress, the company launched a new product aimed at the mobile version of the technology.

iple modulation formats, including 64-quadrature amplitude modulation (QAM), 16-QAM and quadrature phase-shift keying (QPSK), with 64-QAM systems requiring the highest linearity.

The WiMAX standards include additional features, such as quality of service (QoS). These system enhancements require even lower levels of distortion for a given modulation, as defined by system error vector magnitude (EVM). EVM is a measure of the distortion in a QAM constellation diagram and the resulting uncertainty (or error) for each point therein. To satisfy the WiMAX standard and achieve a robust link, WiMAX PAs must not exceed an EVM of 2.5% for 64-QAM and 4% for 16-QAM modulation. For comparison, a WiFi PA need only limit the EVM to a maximum of 4% in order to support 64-QAM modulation.

To meet the linearity demands of these enhanced requirements, WiMAX PAs need to operate at average power levels well below the maximum output power a device is capable of achieving in order to meet the linearity demands. When evaluating PAs for WiMAX applications, knowing the EVM performance for a given rated output power is essential. This will distinguish which PAs are truly capable of meeting a system's maximum output power requirements.

As the deployment of fixed WiMAX moves forward, the trend is to use higher output power from the PA. This is driving the industry to create better PAs. For instance, Anadigics' AWM6432 power amplifier module (figure 1) is currently being used in WiMAX customer premises equipment (CPE) to deliver a typical output power of +24 dBm from the PA (or 21–22 dBm at the antenna) with a 2.5% or better EVM. While this level of performance is sufficient for most CPE applications, many designers are looking for PAs with +27 dBm output power or more, in order to distinguish their products from the competition.

The best PAs will have an optimized combination of linearity (in terms of output power) and efficiency. In mobile WiMAX, PA efficiency is especially crucial because it has a direct impact on battery life. The

PA's efficiency is greatly affected by its bias scheme, i.e. whether it is a Class A or Class AB design (see below). In fixed-point applications, efficiency will impact the total cost of a solution as it will influence the power supply and thermal design of the unit.

WiMAX PA design considerations

For WiMAX, PA design considerations encompass process technologies, the device type (field-effect transistor vs. bipolar), and how the device is biased. Process technology alternatives for PAs for CPE applications realistically come down to GaAs or silicon.

Although silicon CMOS is finding its way into low-power PA applications, some types of GaAs offer significant performance advantages for high-power, high-frequency applications, such as WiMAX. In addition, advanced GaAs processing methods are enabling new levels of integration.

For example, our patented "InGaP-Plus" technology combines bipolar and FET devices on the same GaAs die. This combination of multiple device technologies enables designers to integrate more levels of functionality than with bipolar or FET structures alone, improving the capacity for integration. For instance, InGaP-Plus WiMAX PAs incorporate an attenuator feature to boost the dynamic range of the system's gain control (figure 2).

A major design alternative in WiMAX PAs is the bias structure, with options including Class A or Class AB design. The advantage to designing a Class A power amplifier is that it is easier to achieve a wide bandwidth and to maintain EVM performance over a wide dynamic range. However, this feature could be a disadvantage. For instance, if a mobile WiMAX handset moves closer to a base station, or if a fixed-point CPE is located close to the base station, the output power of the transmitter can be reduced without degrading the data link. But despite the lower output power, a Class A amplifier will provide no actual saving in power consumption.

In contrast, with a Class AB design, as the output power is reduced, the current consumption drops accordingly (until it reaches a lower limit, referred to as quiescent current). This difference between Class A and Class AB designs indicates that, when selecting a WiMAX PA, it is important to look carefully at its efficiency across a range of output powers. Some data sheets only disclose efficiency for the highest output power that supports a given linearity. It is true that as the output power of any PA is reduced, its efficiency degrades; however, with Class A designs the loss is much more dramatic than with Class AB designs.

As an example, consider two PAs: one Class AB (based on our AWM6432), and one Class A. Each operates from a 6 V supply and can provide +24 dBm output power with a current consumption of 275 mA, thus operating at 15% efficiency. When the output power is reduced by half to +21 dBm, the Class A design still consumes 275 mA, resulting in an operating efficiency of 7.5%, while the Class AB design consumes only 210 mA, and is now 10% efficient. Reducing the output power by half again to +18 dBm, the Class AB amplifier consumes only 175 mA, and is now 50% more efficient than the Class A design.

This is another area where WiMAX differs in its

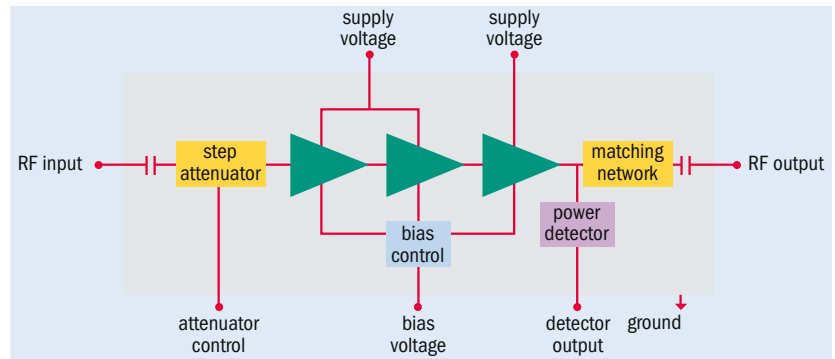


Fig. 2. A block diagram of a WiMAX power amplifier with an integrated attenuator. The additional features of WiMAX when compared with existing WiFi standards mean that advanced GaAs processes with high levels of integration can help the dynamic range of the system's gain control.

requirements from WiFi. Typically, WiFi has a fixed output power with no gain control in the transmit path. WiMAX systems, especially the mobile variants, require transmit gain control, so a Class AB amplifier design provides greater efficiency. There are varying degrees of Class AB bias, however. For instance, some PAs are biased more closely to Class A than to Class B, and will thus not have as quick a reduction in current with reduced output power.

WiMAX is an evolving market, and specific applications and system requirements will define the specifications for the PA. For instance, in fixed WiMAX, most PAs are band-specific because different countries have different frequency spectra allocated for broadband wireless networks. Similar trends are apparent for early mobile WiMAX systems, where time to market is paramount. However, the ultimate product for mobile WiMAX is a radio solution that supports all the major broadband wireless frequencies around the globe. Such a solution requires PAs with wider bandwidths.

Currently, most WiMAX systems are being deployed in the 2.5 and 3.5 GHz bands. (WiBro is using 2.3–2.39 GHz.) An ideal PA would support 2.3–2.7 GHz and 3.3–3.8 GHz for worldwide applications, making it a universal WiMAX device. Initial mobile WiMAX PAs, however, will be band-specific. In the US, the prominent WiMAX band is 2.5–2.7 GHz. Other markets in Asia, Europe, North Africa, and South America are primarily using subsets of the 3.5 GHz band. India is promoting applications in the 3.3–3.4 GHz range.

System integrators are looking for PAs with the best output power, highest efficiency, highest linearity, and broadest bandwidth. For PA designers, the greatest challenge is the trade-off between bandwidth and efficiency. Fortunately, a great deal of the design expertise gained from WiFi PAs can be applied to minimize the effects of this trade-off in WiMAX PAs. Currently, mobile WiMAX PAs are available as samples, and first-generation fixed WiMAX PAs are in production. As technologies and methodologies evolve and market needs are better understood, we can expect WiMAX PAs to evolve and improve as well.

Further reading

L Litwin and MPugel 2001 The principles of OFDM *RF Design* January 2001. <http://rfdesign.com/images/archive/0101Puegel30.pdf>



About the authors

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