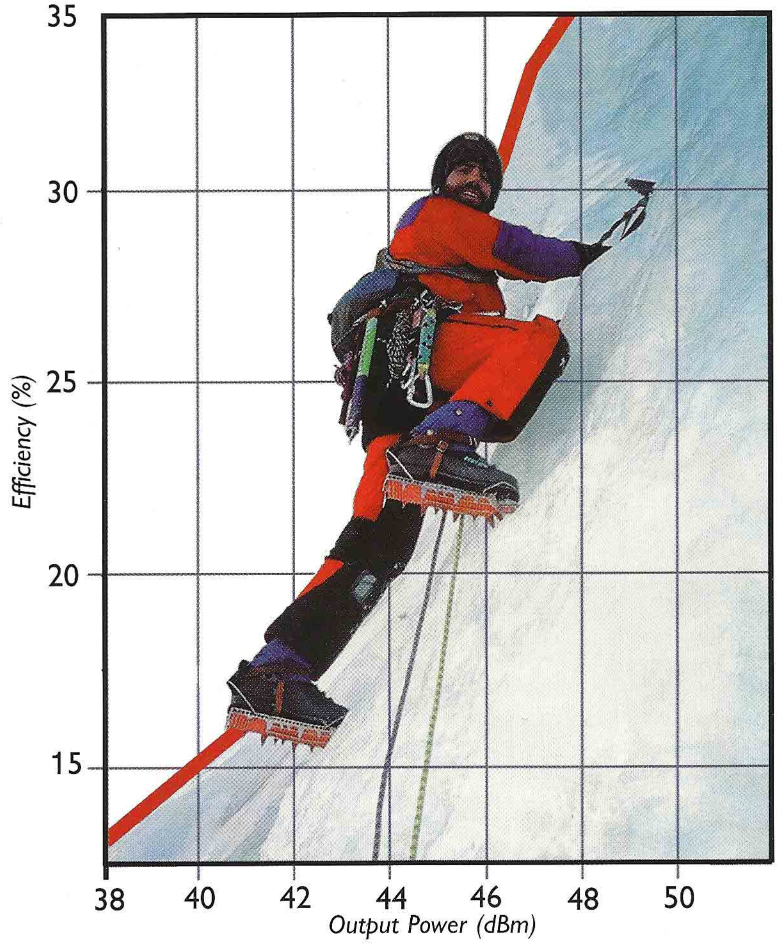

Amplifying With W-CDMA

BY RICHARD POSNER, BILL VASSILAKIS & MATT HUNTON

Transmission of wideband CDMA requires a new approach.

The new 3G technologies, W-CDMA and cdma2000, are considerably more sophisticated than previous generations, and the requirements on system performance have increased immeasurably. The challenge of transmitting the new 3G CDMA signals through base-station amplifiers is increased when multiple signals are transmitted. W-CDMA signals are allocated a 5MHz channel and have an occupied bandwidth of 3.84MHz. The spectrum-mask requirements for W-CDMA are given in Figure 1 on page 54. Service providers can transmit up to four contiguous channels for a total allocated bandwidth of 20MHz.

Meeting the spectral-mask requirements is especially difficult due to the high crest factor of W-CDMA signals. The crest factor for a typical single W-CDMA signal can be as high as 11dB. Further, the overall dynamic range of this signal is infinite.

Signal Amplitude Variation

Amplifiers operating well within class A limits are extremely linear. When operating at class A limits, the maximum RF-output-power level is well below device-saturation level, and power consumption is independent of RF-output power. The penalty for achieving this linearity is efficiency. Typical operating efficiencies for a truly class A linear operation are less than 5%. Low efficiency is only acceptable when amplifying very low power signals (in the milliwatt range). At high-transmission power levels, however, poor efficiency results in unacceptable power consumption, heat generation, and, perhaps of most significance, poor reliability. High junction temperatures required by high-power class A amplifiers cause poor reliability. These high temperatures have been shown to cause low mean time between failure.

To improve the efficiency of an amplifier, it's necessary to operate the amplifier much closer to device saturation and to bias the devices in a more efficient manner. Typical wireless-transmitter systems are biased in class AB mode. In this mode of operation, dc power consumption increases as the RF-output power increases. Figure 2 is a graph showing typical class-AB efficiency as a function of RF output power. The particular device shown is a 90W device operating between 2.1GHz and 2.17GHz. As shown, efficiency increases as output power increases. This increase ultimately is limited by the available saturated RF-output power of the amplifier circuits. A simplified theoretical analysis of class AB operation shows that efficiency is approximately proportional to the square root of RF-output power. Figure 2 demonstrates this relationship over the upper 11dB of operation. Efficiency decreases further at lower power levels as the power consumption becomes more constant at lower RF-output-power levels.

The efficiency of signal amplification is a function of signal statistics. Usually, signal statistics are represented by the complementary-cumulative-probability distribution function (CCDF). The CCDF shows the time fraction a signal spends above a specific power level. Figure 3 show a typical CCDF plot for a W-CDMA signal. The signal spends 20% of the time 2dB above the average power, 2% of the time 6dB above average power, 0.2% of the time 8dB above average power and so on. The maximum peak power is about 11dB above average power. If the amplifier represented by Figure 2 were driven by the signal defined in Figure 3 with the average RF output power set to 30W, the above CCDF points would represent 11W, 28W, 45W and 90W, respectively. The amplifier efficiency for these points is 15%, 25%, 31% and 40%, respectively. The time average efficiency of this signal can be calculated from Figures 2 and 3 by integrating the dc power consumed at each power level times the probability the power will be at this level and dividing this total dc power into the average RF output power. The greater the percentage of time that the amplifier spends at high power levels, the higher the average efficiency.

The downside to operating a power amplifier at high power levels is that the distortion increases. The primary cause of distortion is a combination of non-linear gain and non-linear

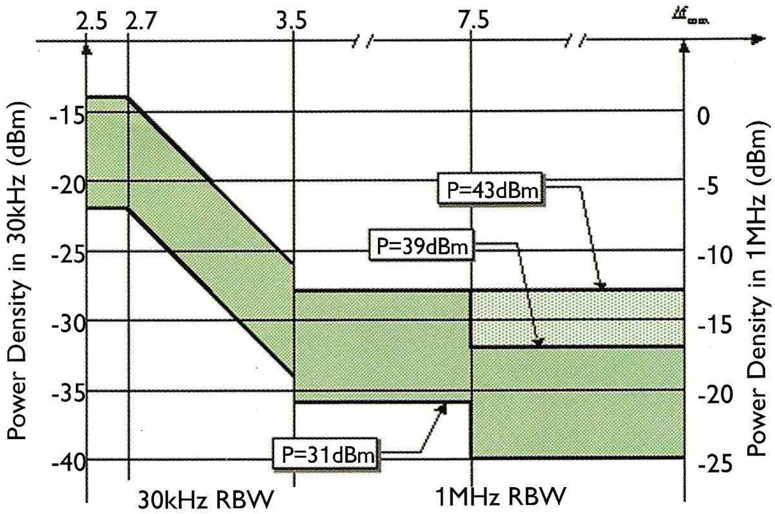

Figure 1. Spectrum-mask requirements for W-CDMA

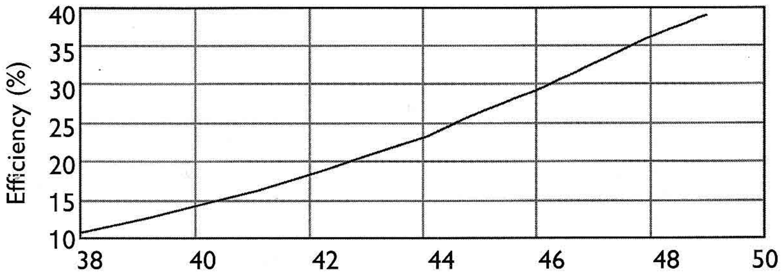

Figure 2. Class-AB efficiency vs. transmit power for 90W PEP amplifier

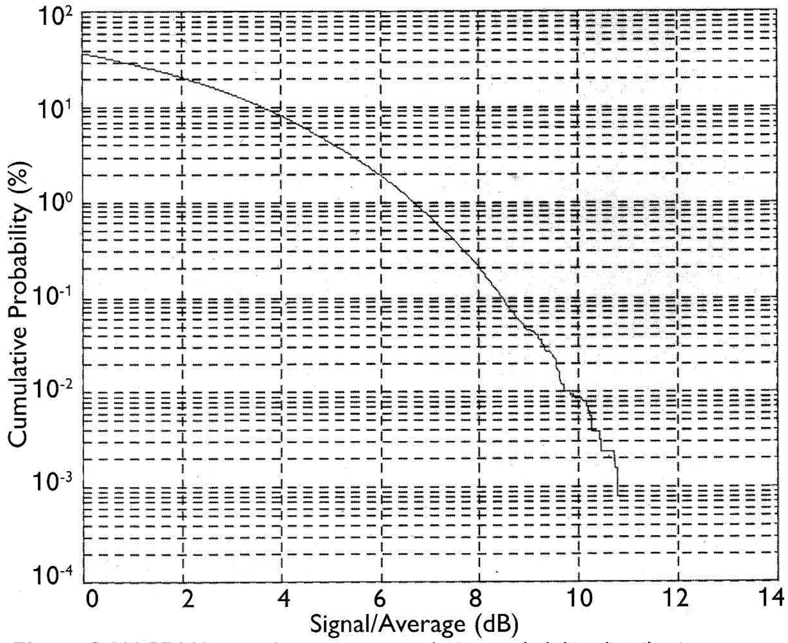

Figure 3. W-CDMA complementary-cumulative-probability distribution

phase transfer. Ideally, both gain and phase would remain constant vs. RF input power. Both gain and phase change with input power drive. These changes are the result of increased self-bias current with increased RF drive level. Eventually, the gain falls off rapidly as the amplifier saturates. The maximum linear RF output power corresponds to the point where the gain falls to 1dB below the low power gain. This point is known as the 1dB compression point.

Calculating the amplifier-output spectrum is complicated by changes due to temperature, frequency, signal bandwidth and voltage. Further, there are memory effects due to dynamic junction temperature variation when the signal spends a significant time at one power level prior to changing to another power level.

Figure 4 shows the spectrum produced when amplifying a single W-CDMA signal with a typical class AB amplifier. The plot shows spectra with and without linear correction. Without linear correction, the amplifier would not comply with TS25.104 specifications given above. ■

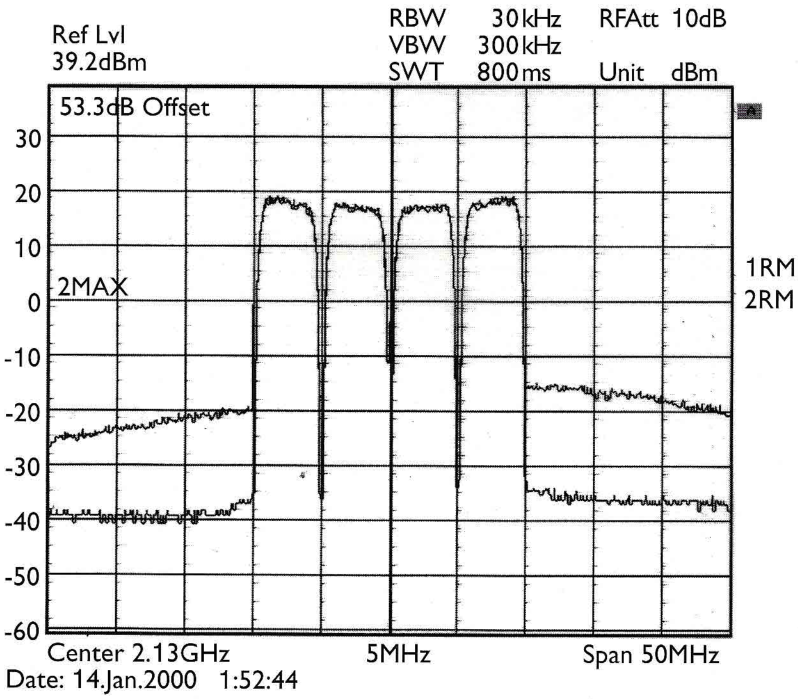

Figure 4. Multi-channel spectrum plot with and without feed-forward correction

Posner is CTO, Vassilakis is director of research & development and Hunton is manager of systems engineering, at Powerwave Technologies.