Challenges in Chipset Design for EDGE Terminals

Challenges in developing handsets and other terminal devices for EDGE

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With second-generation (digital) cellular standards fully deployed worldwide, it is time to look forward to the future of wide-area wireless communications in practical terms. Several versions of third-generation &quot3G&quot standards have been developed in an effort to provide higher data rates for advanced mobile services, and some commercial deployments have begun (primarily Japan), it will be quite a while before true 3G is available worldwide. There are several versions of 3G air interfaces developed and maintained by different organizations: the 3GPP organization is responsible for the standard generally referred to as W-CDMA &#151 in many countries, this system will be used in conjunction with GSM networks to provide &quotUMTS" the 3GPP2 organization is driving the cdma2000 family of standards &#151 the &quot1XRTT&quot version uses a single radio carrier to provide higher data rates, while the &quot3XRTT&quot version uses three carriers to provide even higher data rates; a Chinese-government-backed group is backing the third version, called TD-SCDMA.

The W-CDMA standard is expected to be the most widely deployed of the 3G systems, with cellular operators in Japan, Europe, and North American committed to using it. However the economic realities of the past few years have forced operators to take a hard look at the costs associated with deploying a new system in newly allocated spectrum, since it means new cell sites, towers, and equipment. Most have delayed or even cancelled their plans for 3G deployment until economic conditions improve. Some observers point out that operators using the cdma2000 1XRTT system already provide 3G-like services in Korea, Japan and some parts of the U.S. However, switching to the cdma2000 standard is not an option for operators with major investments in GSM protocol-related infrastructure.

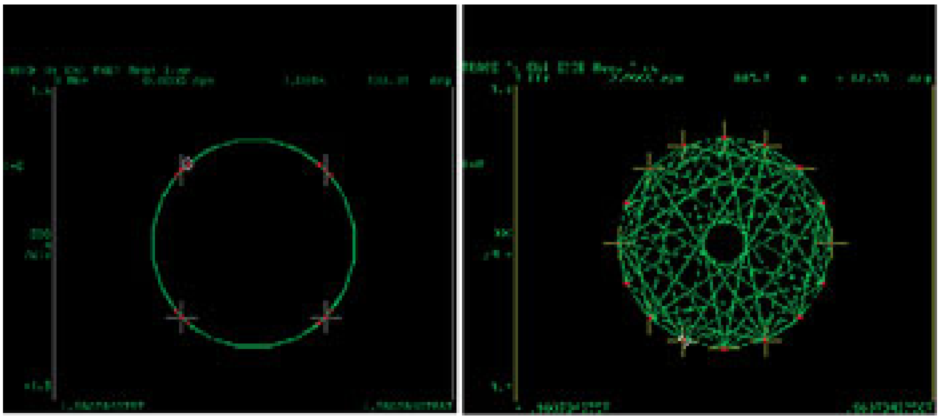

Figure 1. Block diagram of typical Cellular Terminal Chipset

EDGE to the Rescue

Fortunately, in the GSM family of cellular standards, an intermediate step exists between today's GSM system and true 3G. It is called &quotEDGE&quot, for Enhanced Data rates for GSM Evolution, and offers 3 to 5 times higher data rates than standard GSM. It uses the same frequency bands, the same channel width and spacing, and the same protocol as GSM/GPRS. In addition, since EDGE has been in the 3GPP roadmap, most currently available GSM/GPRS infrastructure equipment (base stations) has been designed with EDGE capability. An operator can upgrade the network from GSM/GPRS to EDGE almost instantly. All that is needed for widespread deployment of EDGE (and the delivery of services that can take advantage of the higher data rates) is handsets. And at present, there are very few available, owing to the lack of complete chipsets available until recently.

Figure 1 shows the block diagram of a typical high-end cellular terminal. There are serious challenges in developing handsets and other terminal devices for EDGE, compared to GSM/GPRS terminals. The biggest challenge is in the radio section, which requires higher performance in the receiver chain compared to conventional GSM/GPRS receivers to accommodate the EDGE signal, and a different architecture than usually used in GSM/GPRS radios to generate the EDGE waveform as well as a more linear power amplifier than required for GSM/GPRS. The baseband section includes additional challenges, such as better A/D converters and getting a fast enough processor core to handle the more complex equalizer and demodulation tasks. Without belittling the challenges in the baseband design, the architecture is not much different than standard GSM/GPRS. However, the radio section requires significant redesign.

How EDGE Differs from GSM/GPRS

To achieve the higher data rates that EDGE promises, the modulation spectral efficiency and complexity is increased. The rather simple GMSK modulation used in GSM/GPRS is replaced with a more complicated 3pi/8-shifted 8 PSK. The pre-modulation filter that shapes the spectrum is also more complex.

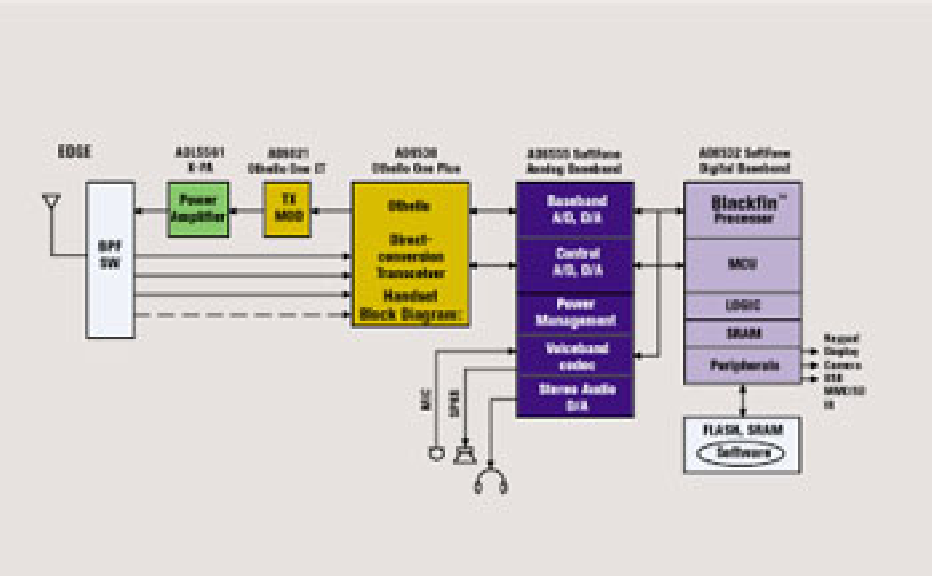

Figure 2. Comparison of GMSK signal used in GSM/GPRS with 8PSK signal used in EDGE

The 3pi/8-shifted 8-PSK modulation of EDGE presents a complicated picture to the data receiver (see Figure 2). The number of phase states is increased (from 4 to 8), and the pre-modulation filter is not a simple Gaussian filter. Instead, the filter is constructed from a series of segments that are assembled in the time domain to create a response that is compatible with the EDGE equalizer. This makes for an efficient equalizer implementation, but the computations required are still formidable.

Transmitter Architecture

In most implementations of the modulator in a GSM/GPRS transmitter, a form of an offset PLL or &quottranslation loop&quot is used. These transmitters rely on the fact that the modulation is phase only, with no modulation information in the amplitude (envelope) of the signal. The transmitter VCO is locked in some way to the local oscillator of the modulator, typically with feedback from the transmitter VCO's output driving a phase detector and being compared to the modulator's output frequency or the local oscillator output.

While this method can work for the phase portion of the EDGE signal, it is not enough to create the signal necessary for EDGE. The EDGE modulator must create the phase portion and also create the envelope fluctuations that occur due to the modulating signal. Several methods of creating the EDGE signal are possible, though most architectures are moving towards a polar modulation scheme. In a polar modulator, the phase and amplitude of the modulated signal are generated and applied to the carrier separately.

An advantage of the polar modulator is that existing GSM hardware can be used for the phase modulation portion of the EDGE modulator. An amplitude path of some sort must be added to complete the platform. The amplitude can be added by modulating the power amplifier directly, or by modulating the output of the phase path prior to the power amplifier input. In either case, the timing of the amplitude and phase blocks is critical to achieving good error vector magnitude (EVM) performance.

Receiver performance

The more complex EDGE modulation also affects portions of the receiver. The receiver must still attain the target sensitivity that was required in GSM, but several of the coding rates and fading profiles place strict requirements on the receiver chain and its noise level above the target sensitivity levels. The higher order modulation of 8 PSK is inherently more difficult to receive than GMSK in a similar channel, due to the smaller decision distances between states. This places stricter requirements on the receiver in terms of noise performance as well as rejection of other in-band, off-channel signals with AM content.

EDGE and the Power Amplifier

The EDGE modulation affects several aspects of the power amplifier. The PA operation and its control are both complicated by the non-constant envelope nature of EDGE modulation. Developing a cost-effective EDGE radio requires innovative techniques in the power amplifier section to efficiently address these issues.

Power Amplifier Efficiency

GMSK modulation is a constant envelope scheme that can tolerate the power amplifier running in a highly efficient saturated state. The amplifier's high efficiency translates directly to longer talk times for the mobile appliance. In EDGE, even with the shifting of the constellation each symbol time to reduce envelope fluctuations, there is a non-constant envelope on the transmitted signal. In fact, the EDGE signal can have a large variation in its amplitude of up to 17 dB. The non-constant envelope requires the power amplifier to be linearized in some fashion.

Linearization of the power amplifier tends to lower its efficiency, causing it to draw more current for a given output power than for GSM. This will end up driving down the talk time of the mobile appliance.

Power Amplifier Ramping and Control

The power amplifier must be ramped in a controlled fashion to avoid causing excessive switching transients and unwanted spectral products. The addition of EDGE modulation only complicates this process, because its non-constant envelope is different from the constant envelope of GSM modulation. The EDGE modulation has envelope fluctuations as high as 17 dB, making typical GSM power controllers unusable. These controllers must be modified or abandoned for other solutions.

Several options for power ramping and control exist. The most basic is simply operating the power amplifier without a control loop. The advantage is that this has very little required hardware, but it is also vulnerable to battery voltage droops and temperature drift. Mobile appliance designers will have to spend considerable energy to properly evaluate and characterize the power amplifiers and the whole appliance across various perturbations of battery voltage and temperature variations.

A second option can be called &quottrack and hold&quot. In this method, the EDGE timing can be leveraged to allow for closed loop operation during ramping, and then a switch can be thrown to &quothold&quot the final voltage during the traffic portion of the burst. This opening of the loop allows the envelope fluctuations to occur without the loop attempting to filter them out. At the end of the burst, the loop is closed again for the ramp down. The advantage of this approach is that the critical ramp up and ramp down portions of the burst are done &quotclosed loop&quot, allowing better control over switching transients, etc. The disadvantage is that the output power is still subject to any variations in environment that happen during the burst.

The third option is closed loop operation. In this method, the control loop is always closed, and is therefore able to compensate for any changes in battery voltage, temperature differences, load changes (caused by moving the antenna close to other objects, etc.), or other environment changes. The challenge is to implement this closed loop power control without stripping the envelope fluctuations from the signal, which would introduce error vector magnitude (EVM) degradations.

Future is EDGE

The technical challenges of EDGE chipset design are formidable, with the radio and baseband sections needing major upgrades from their GSM counterparts. These challenges are being met, and the result is a new generation of mobile terminals that will enable the hundreds of millions of GSM/GPRS customers worldwide to experience and enjoy the benefits that the higher data rates of 3G systems promise. In this way, EDGE is the future of 3G systems, and it has arrived.

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