Reducing the design complexity of next-generation handsets

This article will discuss the many available modulation technology options that are used for various EDGE systems, including direct-launch conversion transmitter (DCT), small-signal polar modulation (sometimes called “polar lite”), and large-signal open polar modulation, and compare them to the more effective, large-signal closed polar loop solution that delivers the best overall system performance and ease of manufacturing.

By Jennifer Chou

The original global system for mobile communications (GSM) technical standard has evolved in recent years to include multislot operation as well as the definition of additional radio-frequency (RF) bands and the inclusion of the enhanced data for GSM evolution (EDGE) modulation format, which effectively triples transmission rate using the same bandwidth as the earlier Gaussian minimum shift keying (GMSK) modulation. Because EDGE introduces amplitude modulation variation (a range of approximately 17 dB) as compared to the earlier constant-envelope GMSK modulation format, EDGE radio architectures must deliver better spectral purity and modulation quality in order to deliver the necessary linear performance.

The use of polar loop transmitter technology has solved this design conflict between improving power efficiency or maintaining amplifier linearity and is most effective when implemented as a closed loop system. Its feedback loop enables a self-correction mechanism that simplifies factory calibration, improves field performance and minimizes sensitivity to changes in test conditions, power amplifiers (PAs) or other system parameters while eliminating the need for extensive calibration that is otherwise required in open loop systems.

Polar modulation and polar loop defined

Polar modulation is a modulation technique where the amplitude component and phase component are modulated separately and recombined at a later circuit stage, and there are many different implementation options.

The term “polar loop” refers to a polar modulation transmitter architecture that applies closed loop feedback control for both the phase and amplitude of the transmitted signal (Figure 1). With this approach, the problems with amplitude modulation to phase modulation conversion (AM to PM) as well as amplitude modulation to amplitude modulation conversion (AM to AM) of the non-linear PA are essentially eliminated. In addition, this architecture allows for a large dynamic output power control range as required by the GSM specification.

Architectures for EDGE transmitters

Several types of circuits and architectures have been proposed for EDGE transmitters. The most common are the following:

- direct-launch conversion transmitter;
- small-signal polar modulation (polar lite);
- large-signal open loop polar modulation; and
- large-signal closed polar loop (polar loop).

Direct-launch conversion transmitter

Direct-conversion architecture (Figure 2) is used in many transmitter designs for different standards and modulation formats. The amount of circuit blocks is minimal. For several applications, this is the architecture that offers the best compromise of performance vs. power consumption and circuit complexity.

However, this is not necessarily the case for GSM and EDGE applications, since the GSM standard imposes stringent requirements on the noise emitted by the transmitter outside the transmit band. These requirements translate to a total required noise floor of less than...
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Small-signal polar modulation (polar lite)

A different class of transmitters divides the signal into its amplitude and phase components. These are generally designated polar modulation transmitters, or simply polar transmitters.

Polar modulation architecture (Figure 3) is attractive for GSM and EDGE applications because it is relatively easy to combine with the traditional phase-only architecture used for GMSK. In principle, all that is needed is an additional mixer to apply the amplitude modulation. However, the AM and PM components are recombined in the phase-frequency detector (PFD) to obtain the full modulation before the signal reaches the PA, so the complexity of output power control scheme as well as lower PA efficiency that are associated with DCT also apply to this implementation of polar transmitters.

Large-signal open loop polar modulation

In an effort to overcome the efficiency limitations and issues with output power level control, this architecture applies AM directly to the PA by controlling the bias current, the collector voltage, or a combination of both to the PA using an analog voltage control input. However, due to the stringent requirements for modulation accuracy and spectral purity, as well as output power range and accuracy, this architecture (Figure 4) faces several serious design challenges.

First, there are significant requirements to the linearity and range of the PA power control input. Even with a highly linear control range, it is almost certainly required to have some predistortion of the AM signal to have sufficiently accurate control of the amplitude variations over the full range of output levels. It is also necessary to take into account the AM to PM characteristics of the PA by either applying predistortion to the phase modulation or using a phase-correcting feedback loop.

The applied predistortions for both amplitude and phase need to take into account any variations over temperature, supply voltage and output power. Substantial characterization and individual calibration of each transmitter is often required. With this approach, the issues of accurate predistortion and power control are often the most severe at the lowest output power levels, where accurate calibration is the most difficult and non-linearities are significant. Hence, the trade-off between the amount of calibration and performance often gives unsatisfying results.

Large-signal closed polar loop (polar loop)

Polar loop architecture uses separate amplitude modulation and phase modulation feedback control of the output signal. By using closed loop control of the transmitted phase as well as the amplitude modulation, the limitations of the open loop polar architecture can be overcome almost entirely. By taking the feedback signal for the phase loop from the output of the PA, the AM to PM conversion in the PA can be corrected to a high degree and non-linearities of the PA control

162 dBc/Hz. The direct-conversion transmitter, therefore, often needs additional filtering after the PA. This architecture also requires a PA with good linearity, which compromises the potential for high-power efficiency. Also, the requirement of the GSM standard for a 30 dB range of output power levels and an additional range for burst ramping complicates this transmitter approach, since the power level control needs to be applied before the signal reaches the PA. In summary, the simple circuit design achieved by DCT is complicated by the output power control scheme while the overall system efficiency suffers due to use of a linear PA.

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same point, at the output of the PA, and the IF path (with downconversion, filtering and amplification of the IF signal) is common for the two loops. This architecture ensures good synchronization of the amplitude and phase components within the bandwidth of the two loops.

The dual feedback loop ensures robust performance even under voltage-standing wave ratio (VSWR) variations without using an isolator. No external PA filtering is required to meet the transmitter noise in the receive band. To minimize integration difficulty, polar loop transmitters use a standard in-phase and quadrature (I/Q) interface and do not require the extraction of AM and PM signals in the digital domain. There is no mode change between GMSK and 8-PSK modulation, and the transmitter operates seamlessly in multislot enhanced general packet radio service (EGPRS). The polar loop transmitters meet or exceed GSM-type approval requirements for EDGE and GSM/GPRS in quad-band operation (850 MHz, 900 MHz, 1800 MHz and 1900 MHz) with little to no calibration.

The polar loop architecture offers excellent and robust system performance with minimum sensitivity to changes in test conditions, PA or other system parameters. It offers closed loop power-level control, high PA efficiency by use of saturated operation, and provides the lowest overall system cost (no SAW filter or isolator is required). Additionally, the polar loop architecture features a standard I/Q interface and no mode change between GMSK and EDGE.