Analog RF Front-End

Simplifying RF front-end design in multiband handsets

The convergence of requirements demands that new design measures be adopted in the cell phone RF front-end electronics. Polar modulation-based solutions for multiband, multimode transceivers is discussed in this article.

By Duncan Pilgrim

Ruthless competition in the handset market continues to drive manufacturers to search for new opportunities to drive down cost, printed circuit board (PCB) area and power consumption. Simultaneously, the rollout of third-generation (3G) networks has opened the door to a variety of new multimedia and data-based applications, from wireless Internet access and mobile video to text messaging and mobile TV.

As demand for new applications rises and the market becomes more globalized, handset makers face a quandary. How can they support the increasing number of frequency bands to support global platforms and the multiple high-bandwidth technologies needed to deliver these revenue-enhancing services without violating the market’s cost, footprint and power constraints? The number of frequencies supported by the latest 3G partnership program (3GPP) standard has increased from three to 10 and will continue to expand. The current frequency bands and their associated bandwidths are shown in Figure 1.

One thing seems clear; to succeed, handset designers need to deliver multiband, multimode capability. While existing 2G GSM/GPRS networks continue to thrive and represent the largest percentage of networks today, shipments of handsets based on EDGE technology, which boosts data rates by introducing a second modulation format into the GSM system, are rapidly growing. At the same time, network operators are continuing to roll out 3G wideband CDMA (WCDMA) networks. Based on the universal mobile telecommunications system (UMTS) network topology, this technology is rapidly becoming the leading global mobile-broadband solution. Industry analysts predict WCDMA and EDGE will represent the two fastest-growing segments of the handset market over the next few years. To meet demand for IP-based services, a growing number of UMTS operators worldwide are deploying high-speed downlink packet access (HSDPA) capability. High-speed uplink packet access (HSUPA) is ready to follow in the near future. Figure 2 offers an overview of each cellular standard and associated up and downlink data rate.

Carriers and service providers believe the time has come to accelerate the WCDMA evolution path toward the 3GPP’s long-term evolution (LTE) initiative. LTE is emerging as the leading technology for next-generation wireless broadband networks. It will deliver data rates up to 100 Mbps for downlink and 50 Mbps for uplink and improve network coverage and efficiency by using orthogonal frequency-division multiplexing (OFDM) transmission with multiple-input, multiple-output (MIMO) smart antenna technologies.

While LTE will lay the groundwork for 4G technologies, it requires network operators to support another modulation scheme. To capitalize on the capabilities these network topologies offer, network operators must address two obstacles: higher costs and higher power consumption. The BOM costs for WCDMA handsets are double that for EDGE handsets and nearly triple those for GSM/GPRS devices. At the same time, GSM handsets offer twice the talk time of WCDMA phones—a key factor in customers’ perception of the quality of a phone.

Those distinctions are attributable to the higher complexity of WCDMA front-end architectures. WCDMA is a spread-spectrum technology that spreads its transmissions across a wide 5 MHz carrier. Since WCDMA uses full-duplex communication, the receive and transmit functions operate simultaneously. This requires front-end

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*Figure 1. 3GPP GSM/EDGE and WCDMA frequency bands.*
electronics that attenuate the transmitter’s wideband noise to prevent degradation of the receiver’s sensitivity. Typically, this is accomplished using a duplexer along with additional bandpass filters in the transmit and receive paths. Moreover, designers commonly use external LNAs as well. The additional component count and area contribute to WCDMA’s higher cost relative to GSM/GPRS and EDGE alternatives.

Power efficiency is also a challenge. The output power amplification stage consumes a large percentage of the battery capacity in any wireless device. Unlike the power amplifiers (PAs) in GSM handsets, which are used in saturated mode, PAs in WCDMA systems operate in linear mode. The use of complex quaternary phase shift keying (QPSK) modulation techniques requires the PA stage to be highly linear so as not to degrade the quality of the signal or to smear it into adjacent channels. Accordingly, WCDMA designers face a trade off between the high linearity needed to ensure excellent WCDMA performance and the high levels of power efficiency required for longer battery life in handset designs.

**Front-end duplication**

Traditionally, handset designers seeking to support multiple air interface standards in the same device have resorted to stacked radio architectures with separate radio transceivers for different standards. Although the industry has made advances over the past few years in packaging technology, and designers have made progress integrating portions of the receive path of a multiband, multimode phone, it is not yet the case that the receive path of a multiband, multimode phone, the same cannot be said of the transmit side. Typically, the use of multi-air interface standards in the same device has resorted to stacked radio architectures with separate radio transceivers for different standards. A typical seven-band WEDGE radio block diagram is shown in Figure 3. It shows that currently four PAs, 10 SAW filters, three LNAs, three duplexers and a nine-throw switch are required to realize this front-end function.

Designers building handsets for worldwide markets need an architecture that eliminates the redundancies inherent in the stacked radio approaches. A single, common transmit path could maximize on-chip circuit re-use and reduce system BOM costs. It would also save PCB area and simplify the design of the handset’s front-end. Moreover, since linear PAs consume a large proportion of the battery capacity in handsets, a single transmit path capable of using non-linear power amplifiers (PAs) could dramatically reduce power consumption and extend handset battery life.

**Extending polar modulation**

How can designers achieve that goal while maintaining RF spectral performance? One strategy is to use polar modulation for WCDMA and other higher-bandwidth technologies. Widely used in GSM and EDGE systems, polar modulation eliminates the inherent conflict between power efficiency and amplifier linearity by allowing the input signal of the power amplifier to be constant envelope or to contain no amplitude variations.

In a polar-modulation architecture, the I and Q rectangular baseband signals sent to the transceiver in a direct upconversion architecture are converted to a polar format having amplitude and phase components. This allows designers to apply the two modulation components differently and more efficiently. The phase signal is fed to the phase-locked loop (PLL) that’s used as a phase/frequency modulator. The PLL-VCO output signal is then fed to a VGA or PA that operates near saturation/clipping level. Amplitude modulation is accomplished by controlling the gain of the VGA or PA. Since the amplitude of the phase-modulated signal produced by the PLL remains constant, it can be amplified using more efficient non-linear Class E or F amplifiers. This significantly reduces power consumption by the transmitter and ultimately contributes to longer battery life.
GSM systems use constant envelope modulation with Gaussian minimum shift keying (GMSK). Since the trajectory of the complex signal lies on a unit circle, the modulation can be described by its phase component. EDGE systems triple the GSM data rate using differentially encoded 3π/8 8-phase shift keying (PSK) modulation. AM is added to the signal so that the transmit signal occupies the same 270 kHz bandwidth as GSM. These similarities simplify the extension of a GSM polar transceiver to EDGE.

WCDMA presents different challenges. This technology bundles multiple data channels and uses spread-spectrum hybrid PSK (HPSK) modulation to achieve higher data rates. The use of multiple channels creates a set of superimposed quaternary PSK (QPSK) patterns with different gains resulting from different spreading factors. A root raised cosine filter limits symbol smearing and restricts the transmit signal bandwidth to 3.84 MHz.

These distinctions place different demands on the design of the transmitter. GSM and EDGE systems require excellent phase linearity, low phase noise and high efficiency. WCDMA systems demand high levels of accuracy over very wide bandwidths and wide amplitude ranges.

The polar architecture has been proven in GSM/EDGE solutions to deliver the lowest noise performance, which led to the removal of the transmit SAW filters. This concept can be extended to remove the transmit SAW filter in WCDMA without excessive current consumption required with linear type architectures. These savings are set to increase because the next-generation modulation schemes have increasing peak-to-average ratios. Since it supports all modulation formats, the polar architecture is inherently suited to support true multimode power amplifiers. These factors will significantly reduce the overall size and complexity of next-generation solutions as shown in Figure 4.

New approach

To simplify the development of front-ends in multimode phones and allow designers to reduce cost and PCB area, Sequoia Communications has developed an architecture that takes advantage of polar modulation techniques to offer a single transmit path for all modes. The FullSpectra architecture provides the foundation for a family of monolithic, multimode RF transceivers. Its second-generation SEQ7400 supports tri-band WCDMA/HSDPA, quad-band EDGE, GPRS and GSM across seven frequency bands simultaneously, making this HEDGE transceiver applicable to most major networks worldwide. To help reduce component count and cost, the transceiver integrates all receive LNAs and WCDMA interstage filters. The device offers a standard analog interface and SCI or DigRF 2.5G control interfaces in a compact RF footprint.

The benefits such a device offers in a multimode, multiband design are formidable. A single integrated device reduces engineering effort by eliminating the complexity and duplication of a stacked design. By integrating LNAs and eliminating receive interstage WCDMA SAW filters it drives down cost by reducing the design’s BOM and minimizing PCB area. With this technology, designers can reduce RF board area by up to 70% and shrink RF component count by more than 40%.

By supporting quad-band EDGE and tri-band WCDMA interfaces in the same device, this approach offers design teams flexibility to develop platforms for use in different regions and markets. By adding autonomous calibration and eliminating time-consuming manufacturing tasks, this architecture promises to accelerate factory throughput and improve handset-manufacturing costs. Finally, by reducing transmit and standby current requirements, this approach allows designers to extend battery life in next-generation handset designs.

Conclusion

In today’s handset market, traditional stacked radio architectures are no longer a viable design option for multimode, multiband handsets. Their duplication of functions, higher BOM cost, and larger PCB area are a competitive liability. To meet demand, designers need a more efficient approach to the front-end design of multimode, multiband handsets.

Polar modulation offers a promising transmit architecture option. Polar allows a single path to be used for all modulation schemes providing a size-optimized silicon approach that can support next-generation multimode PAs. The inherent low-noise performance of the solution provides a battery-efficient approach to eliminating the WCDMA transmit SAW filters. Moreover, this efficiency will increase as the industry moves to high-order modulation schemes such as HSUPA and LTE.

ABOUT THE AUTHOR

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