Paving the Way for Software Definable Radios

Handsets that support multi-operational modes and frequency bands will rely on "breakthrough technology" to achieve advanced functionality.

By David McCartney, e-tenna Corporation

In order to realize a handset that supports three, four or more operational modes and frequency bands, the wireless design industry will rely on true &quotbreakthrough technology&quot to achieve this advanced level of functionality in a lightweight and low-cost handset.

Mobile phone handsets have evolved from simple single-mode, single-band analog architectures of 1G and early 2G systems into the multi-band, multi-mode digital or hybrid digital/analog phones of today's 2.5G systems. This trend will continue with the deployment of 3G systems and the integration of additional wireless functionality offered by systems such as Bluetooth and the Global Positioning System (GPS). Due in part to the desire to provide greater and more seamless coverage across the globe (world phone) and greater functionality to the customer, the migration to multi-mode, multi-band, and multi-functional handsets will culminate in the realization of software defined radio (SDR).

We have all heard about SDR, a technology originally developed by the military and now being pursued by several companies for commercial wireless application. However, successful commercialization of SDRs depends on key technical advances in a number of areas, including high-speed digital signal processors (DSPs), data converters with wide dynamic range, efficient and compact software, and broadband high efficiency radio frequency (RF) technology. And unlike military systems where cost is secondary to performance, these advances must be accomplished in a way consistent with high-volume and low-cost production.

To date, one of these areas, RF technology for the transceiver portion of the handset, has advanced little towards meeting the goals of SDR, and one critical element of the transceiver has been virtually ignored - namely, the antenna. e-tenna Corporation is working to solve this problem by combining a number of proprietary RF and antenna technologies to form its RF2IF line of products.

RF2IF Technology

Current mobile phones and other wireless devices include a significant amount of analog RF hardware dedicated to requirements of specific air interface standards such as CDMA, TDMA, and GSM. Current approaches to building new handsets for multi-mode and multi-standard operation, as depicted by the block diagram in Figure 1, require selection among multiple parallel RF chains each of which must be realized in hardware. This architecture results in increased complexity, greater component parts count and higher manufacturing cost. A number of companies are solving parts of this problem with reconfigurable hardware (focused on the power amplifier and IF to baseband section) and software (focused on the DSP)

approaches. However, none of these companies are integrating the off-chip analog components such as the antenna, diplexer, switches and filters that are dedicated to a specific function or interface standard. e-tenna's RF2IF products will achieve hardware commonality by replacing the antenna and filters with integrated reconfigurable antenna/filters. e-tenna's intellectual property portfolio includes patented designs for internal reconfigurable antennas that are highly efficient and can meet the stringent size and data rate demands of tomorrow's 2.5G and 3G handsets.

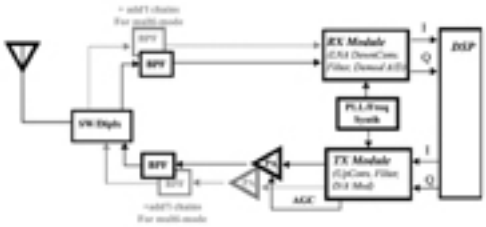

Figure 1. Typical mobile wireless terminal block diagram.

The system architecture shown in Figure 1 is typical of portable handsets that support wireless standards in use today using frequency (FDMA), time (TDMA) or code division (CDMA) multiple access schemes. Link margin limitations, combined with demanding Eb/N0 requirements and rapidly changing channel conditions, put stringent requirements on the RF components of the system and limit the choice of possible transmit-receive (Tx/Rx) architectures.

e-tenna's RF2IF solution greatly simplifies the RF system as shown in Figure 2, where all RF filters, diplexers and switches are eliminated by employing two separate antennas. MEMs technology is used to tune the antennas over the required frequency bands. The antenna control unit (ACU) is an additional baseband function that regulates the antenna's frequency of operation, but adds negligible cost and complexity to the system. The e-tenna approach utilizes two antennas but eliminates the filter blocks and the switch/diplexer, which are part of current architectures. Additionally, e-tenna's tunable antenna approach results in smaller size with much higher efficiencies and impedance optimization for transmit and receive functions.

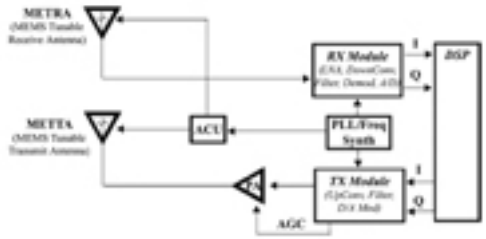

Figure 2. e-tenna Corporation mobile wireless block diagram.

At its most basic, the antenna can be viewed as a simple transducer that converts an electrical signal into electromagnetic radiation and vice-versa. For mobile wireless devices the antenna is typically an electrically small device and therefore subject to certain gain-bandwidth product limitations.

The gain-bandwidth product of an electrically small antenna is a fundamental law of physics that bounds the ability of the wireless system engineer to reduce the

footprint of the antenna while simultaneously maintaining high efficiency over a given operational bandwidth. A traditional approach for coping with this limit has been to accept low antenna efficiency to achieve small size, and consequently limit RF system performance. With current trends in wireless handsets and PDAs, this mode of thinking will only lead to further degradation in efficiency leading to lower battery life, ever increasing complexity (and hence cost) of the RF/IF circuitry needed to compensate for lower efficiency, and diminishing quality of service.
A revolutionary approach to circumventing this limitation is to construct small, highly efficient antennas that exhibit narrow instantaneous bandwidth but can be tuned over a much wider operating bandwidth. This novel tunable antenna concept was first implemented1 in a small, low profile antenna that provides efficient performance over the UHF band (240 - 320 MHz) for a high performance military aircraft where weight, and especially size, are significant constraints. The antenna uses more than 60 individual tuning states, each with at least 2 MHz of instantaneous bandwidth with 70% efficiency. If required to cover the entire bandwidth instantaneously, an antenna of this size could only be 20% efficient, and unable to support the data rate requirements for this specific application.
e-tenna is now applying this same technology to wireless mobile devices with its RF2IF product line. The RF2IF architecture incorporates 2 or more small, internal, tunable antennas, each providing connectivity at a specified frequency. Because tunability allows the tradeoff between antenna gain and bandwidth, RF2IF antennas will perform substantially better than other internal antennas.

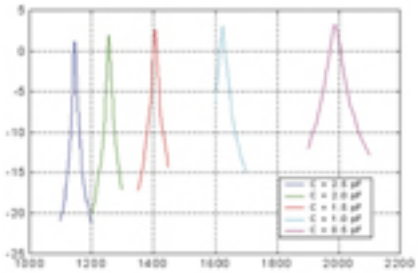

Figure 3. Frequency response of tunable antenna.
Figure 3 shows representative frequency responses of such an antenna in several tuning states. The plot shows that each tuning state exhibits a highly selective frequency response, and these states collectively allow the antenna to cover a broad operating frequency range. Each tuning state produces high antenna gain at the selected frequency and also significant rejection at out-of-band frequencies. This type of frequency response incorporates filter-like functionality into the antenna and offers the potential to eliminate filters and diplexers from the RF chain. An obvious benefit of the filter-like response is the ability to place multiple antennas within a very small space while minimizing interference. e-tenna has demonstrated closely spaced high-Q electrically small antennas that provide isolation of 30 to 35 dB, which meets GSM duplex requirements, and work is proceeding to achieve 50 to 60 dB to meet CDMA isolation needs. The implications of this are that the transmit/receive switch can be eliminated, since both antennas can be now fit easily into the device. To date, such a switch has been used to allow alternate operation of the transmit/receive paths to avoid mutual interference.
Another significant advantage to having separate Tx and Rx antennas is the ability

to independently impedance match the transmit and receive paths, which usually have different impedance values and matching requirements. In addition, to high isolation, the transmit and receive antennas can be designed with sharp frequency roll-off thus allowing RF designers to reduce requirements on, or even eliminate, multiplexers and bandpass filters. A dual-band GSM phone typically has three diplexers while a CDMA phone has one 6-mm-high duplexer.

Conclusion

The growth of wireless services (3G, IEEE 802.11, Bluetooth and others) will require more spectrum and more instantaneous bandwidth than ever before to achieve data rates up to 2 million bits per second (required by streaming video and multimedia applications) to users with portable terminals that will resemble today's cellular phone handsets. These demands translate into a requirement for more power. However, added power is far more easily obtained in a base station than in a small, lightweight mobile phone.

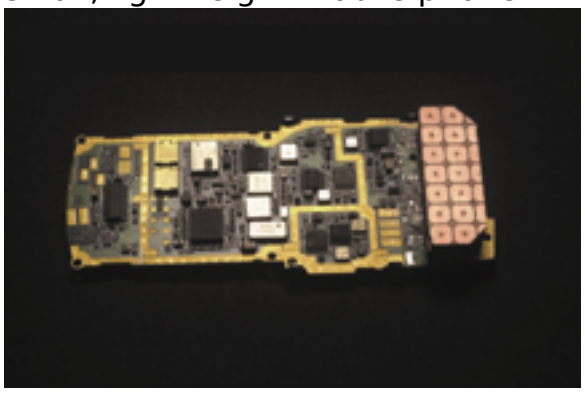

Figure 4. Conceptual design of RF21F module for handsets.

A number of companies are solving parts of this problem with reconfigurable hardware (focused on the power amplifier and IF to baseband section) and software (focused on the DSP) approaches. However, little effort appears focused on integrating the off-chip analog components such as the antenna, diplexer, switches and filters that are dedicated to a specific function or interface standard. As shown in Figure 4, e-tenna plans to achieve hardware commonality by replacing the antenna and filters with integrated reconfigurable antenna/filters.

Benefits of this RF2IF approach include the following:

&#149Elimination of several separate discrete analog RF components
&#149Simplification of the RF system block diagram for multi-mode implementations
&#149Increased performance for higher data rates using a more efficient antenna
&#149Individual transmit and receive antennas provide optimized impedance match to their respective components
&#149Higher efficiency antennas result in lower battery cost and size or longer talk times
&#149Compatible with current heterodyne receivers as well as evolving direct conversion and software defined radio (SDR) transceivers
&#149An estimated 10% to 20% cost reduction in the total bill of materials based on current 2.5G handset designs

As with most engineering endeavors, the evolution of wireless appliances necessitates the need to satisfy specifications with conflicting requirements. The

need for higher data rates, increased radiated power and multi-mode, multi-band, and multi-function radios is in direct conflict with the other requirements for future portable devices, namely, higher levels of integration, smaller size, and longer battery life. e-tenna's core technology includes patented designs for internal reconfigurable antennas that will help satisfy these requirements and meet the demands of tomorrow's 2.5G and 3G handsets.

David McCartney is president of e-tenna Corporation, a developer and licensor of unique radio frequency (RF) technologies for the commercial wireless market (http://www.etenna.com).

References

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