RF Mobile Communication Circuits - Comparison of Technologies

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Abstract

This paper will outline the technological challenges faced in mobile telephones, specifically related to RF signal processing. Transceiver architectures are mostly based on the traditional superheterodyne architecture. The architecture involves a variety of components, such as IC's, filters, oscillators, resonators and other key components. The level of integration is typically low, and the mix of different technologies is wide.

In the future new transceiver architectures are needed, which support multimode operation and next generation wireless systems, are software configurable and can benefit from the advancements in CMOS technology.

Introduction

Mobile communications is the fastest growing consumer electronics segment in all parts of the world with growth rates exceeding that of PC's. Most users today are using the first generation analogue systems. The main growth, however, is in the second generation, digital systems which enables new services and improved performance of networks and terminals.

Digital services, Internet and multimedia are all getting mobile. First generation digital systems, GSM, US TDMA, US CDMA, DCS 1800/1900, PCS etc. enable low speed data services. The next generation systems, including UMTS, will allow data services up to 2 Mb/s and are going to be a strong challenger to wired communication systems.

The variety of standards and network technologies is not going to decrease in the future. All new systems have to be both compatible with the old ones and also support seamless transition to use the new systems and new services. The old systems will stay operational while new systems are being introduced.

The challenge is even bigger remembering that many of the systems use different frequency bands, different access schemes, different modulation and different coding schemes. The increasing diversity of services and network technologies present a major challenge to the underlying technology in future low-cost terminals.

Evolution of terminals

The major challenges in wireless communications terminals are cost, weight, size and power consumption. Price erosion is of the order of 25% annually and the size and weight reduction have had about the same rate. Usage times will increase significantly in the near future.

The developments in the electronics of the transceiver, the engine part of the product, has been the main contributor to both size reduction and usage time improvement. The biggest changes have occurred in integration and packaging technologies. The number of components has dropped from 1000 level in 1992 to current 500 level and will approach 100 level in 2000. The silicon area of all ICs has respectively dropped from 600 mm^2 level to 200 mm^2 level.

The biggest advancement affecting cellular products has happened in CMOS technology. CMOS is used to integrate the baseband parts of the product including microprocessors, memories, digital logic and digital signal processor. DSP's are used in voice coding, channel coding, modulation and channel equalisation, which are the functions requiring the most computing performance in the digital phone.

Reduction of CMOS linewidth and operating voltage have been the key parameters to increased performance and reduced size, a trend which continues. CMOS performance has developed to the point where it soon will be possible to integrate RF functionality.

RF will always need some hardware

Discrete passive components are dominating in the RF part. More than 90% of all components are passives and 70 % of the cost comes from these. The level of integration is increasing, but the most space consuming components, filters, resonators, matching circuitry, oscillators etc. are hard to integrate. Also, today many capacitors, resistors and inductors are needed in second priority tasks like biasing, bypassing, interference filtering etc.

Filtering is the key element affecting complexity of multimode terminals. RF filters are needed to suppress unwanted out-of-band signals both in the receiver and transmitter. In multiband systems these components have to be duplicated for each frequency band. Typically more than 100 dB dynamic range has to be handled by the receiver and this is too much for any practical active device to handle regardless of the integration technology or receiver architecture used. That is why miniaturisation of passive filters is one of the main focus areas. Ceramic filters, dielectric filters and SAW (Surface Acoustic Wave) filters have shown fast development, but yet a real breakthrough in filter technology has not occurred .

IF filters have to be optimised for the channel bandwidth. If several access techniques and modulation methods are used in a multimode terminal, then several parallel filters are needed. Adaptive filters can be implemented using DSP, but yet the inband dynamic range of the order of 100 dB sets tough requirements for today's AD converters. Evolution in CMOS technology will take care of this problem. Sub-harmonic IF sampling architectures utilising sigma-delta type converters will offer one solution.

Oscillators, which are needed to both create reference frequencies (TCXO - temperature compensated crystal oscillators) and local oscillator signals (VCO - voltage controlled oscillators), are also key devices from multimode terminal point of view.

Power amplifiers of cellular terminals are today highly integrated and the effective area of the active device is very small. In multiband terminals the PA will be duplicated. Packaging and matching the device to the environment is a key issue impacting the size and performance. If designed properly, then multiband operation adds the complexity only marginally.

Antennas for multiband operation are already available in conventional forms. Dual band helix/whip antenna combinations, which have two resonances, are almost the same size as single band antennas. Different integrated antenna structures based on patch type construction and having directional or adaptive characteristics are evolving. These constructions can be designed for multi resonant operation for multi mode systems.

Transceiver architectures have been mostly based on superheterodyne principles having two conversions in receiver and one in transmitter. Other structures, such as direct conversion, have been presented, but in most systems these are not applicable because of the tough intermodulation and interference suppression requirements. If in the future systems like UMTS these requirements are released by putting more effort to adaptive control of system parameters (transmitter power levels, interference prevention schemes etc.), then direct conversion would offer radical reduction of complexity in the terminal and make SW based channel processing possible.

IF sampling architectures have also been presented and can be implemented with today's technologies. These architectures enable DSP processing to get closer to RF, but yet the IF filtering and handling of wide dynamic range channel is a challenge. If the IF filter requirements are equal in all modes of operation, i.e. same basic access and modulation is used, then this option will give benefits.

New transceiver architectures are being developed to minimize the need for discrete components and utilize the advancements in CMOS technology towards RF frequency operation. Today a mix of bipolar, BiCMOS and GaAs technologies is being used. The drawback is low levels of integration and, consequently, high complexity and component count.

Steps towards SW radio

Today's products are based on electronics, optimised for single system operation. The next step will be to develop optimised engines for multimode systems. This would mean one common engine for TDMA based systems and another engine for CDMA based systems. Adding frequency bands and modes of operation mainly adds the cost and complexity in the RF part.

The third step, the ultimate general purpose platform for SW configurable or SW processing based radio, will become feasible on the desired cost and performance level in a five year time frame. UMTS can be the first generation of system standards capable to fully utilise the benefits of SW platforms.

Conclusions

Developments in CMOS technologies have made it possible to increase the user friendliness of wireless communication terminals including reduced size and weight, increased usage time and reduced cost. Continuing fast evolution of CMOS allows more and more radio channel handling functions to be shifted from HW to SW.

Although the CMOS interface is stretching towards the antenna, there will be constraints due to the characteristics of radio environment. Filters, converters, oscillators and other RF circuitry need further innovations in integration and packaging in order to provide fully adaptive platform to multimode, SW configurable radios.

When specifying and standardising new systems, small things can have a big impact on the feasibility of multimode equipment. For example, if the main parameters of radio protocols, like bit rates, channel spacing and frame structures are based on a single frequency reference, this will lead to more user friendly implementation of terminals as well as more efficient utilisation of radio resources.

From multimode operation point of view a product based on a generic DSP platform would be ideal. The only add to complexity is increased memory size, if the radio access protocols are compatible with each other.