Technology options for multimode terminals

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Trends of key technologies of multimode terminals

Technology Options for Multimode Terminals

Multimode terminals built around generic platforms will be an essential requirement for next-generation wireless systems. Such terminals must cope with different radio interface standards, allow multienvironment operation and adapt to a range of radio access techniques.

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Mobile communications is the fastest growing consumer electronics segment in all parts of the world. Most of the users are today using the first-generation analogue systems. The main growth, however, is in the second-generation, digital systems. The annual market of mobile terminals is increasing with 50 % growth rate and will exceed 100 million units in 1999. Data through wireless will be one of the biggest drivers and catalysts in the whole consumer electronics marketplace. 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 UMIS, will allow data services up to 2 Mbit/s and are going to be a strong challenger to wired communication systems (fig. 1).
Evolution towards third-generation systems will be a challenge for regulatory and standardization bodies, network operators and equipment manufacturers. 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. For the transition period multimode and multifrequency terminals are needed. Increasing diversity of services and network technologies will also drive the need for multimode and multifrequency terminals. Different frequency ranges will serve different service needs. In 1-GHz range, voice and low-speed data will be the dominant services, but 2-GHz and higher ranges will specialize into higher speed data.
The challenge is even bigger remembering that most of the first- and second-generation systems have not been developed to be compatible with each other. Many of the systems use different frequency bands, different access schemes, different modulation and different coding schemes (table 1).

Evolution of terminals

The major challenges in the wireless communication 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 time, on the other hand, is increasing about 50 % annually.
The first GSM hand-portables were of about 350 cm^3 in 1992. Today we are on the level of 100 cm^3, and in the year 2000 we will be on the level of 50 cm^3. Yet, the usage time (both talk and standby) of the products has increased about tenfold in five years.
The developments in the electronics of the transceiver, the engine part of the product, have been the main contributor to both size reduction and usage time improvement (fig. 2). The biggest changes have occurred in integration and packaging technologies. The number of components has dropped from a 1000-level in 1992 to the current 500-level and will approach a 100-level in 2000. The silicon area of all ICs has dropped respectively from a 600-mm^2 level to a 200-mm^2 level.
Soon the electronics would be small enough to put several transceiver engines into single mechanics and thus build 'quick and dirty' multistandard ter-

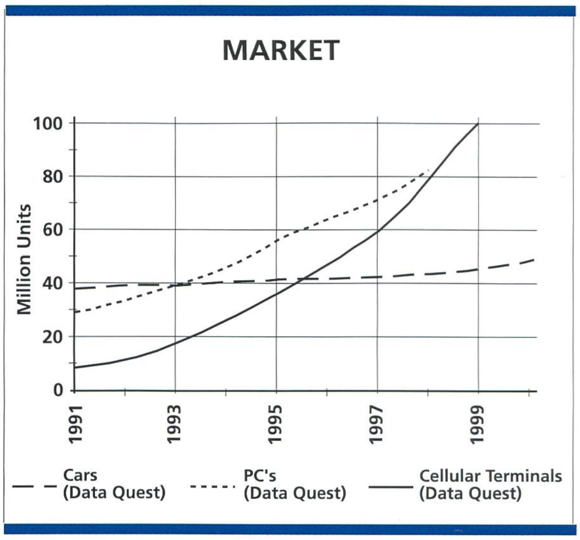

Fig. 1. Annual market volumes of PC's and cellulars have exceeded those of cars.

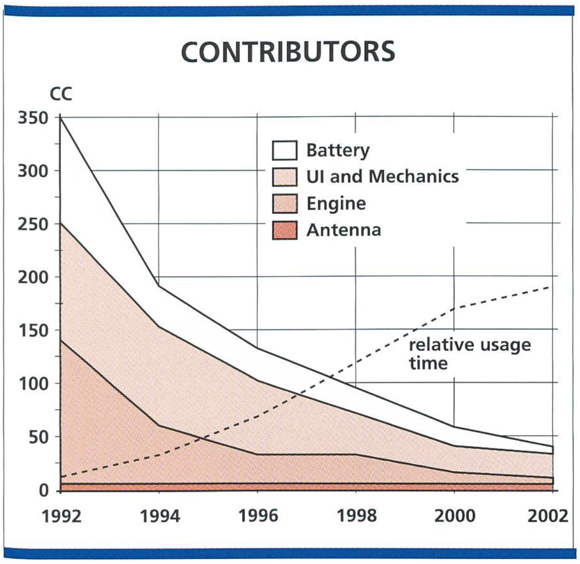

Fig. 2. Main contributors to the size of GSM hand-portables are user interface, mechanics and transceiver electronics.

minals. This was what happened in the evolution of broadcasting. The first dual-mode FM/AM radios had in practice two radios in one, and it took some time before these had been integrated together sharing the same components.
The 'quick and dirty' route is not the optimum one in cellular market. The technologies available now and in the near future offer several options for a more cost-optimized solution.

DSP power comes for 'free'
The biggest advancement affecting cellular products has happened in CMOS technology. CMOS is used to integrate the base band parts of the product including micro-processors, memories, digital logics and digital signal processor (DSP). DSP is used in voice coding, channel coding, modulation and channel equalization, 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. The same trend continues (table 2).
Increasing DSP processing power is needed for new functions like half-rate voice coding (15 MIPS), enhanced full-rate coding (15 MIPS), voice recognition (50 MIPS), high-speed packet data, image coding, etc. Also, more and more processing of the radio channel functions can be shifted to DSP. How close to the antenna the base band interface can be extended depends on the system standard. For example, TDMA systems tend to be better suited for SW-based processing than CDMA because of the lower radio channel bit rates.
From a multimode operation point of view a product based on a generic DSP platform would be ideal. The only addition to complexity is increased memory size, if the radio access protocols are compatible with each other. If not, then some additional logic circuitry is needed as well.
One of the areas of development impacting the base band is electronics packaging. 80 % of the size of the base band part comes from ICs. The traditional SMD (surface mount device) technology is not ideal from a packaging density point of view. If size is the driver, then new advanced technologies like CSP (chip scale packaging) or flip chip will offer more options. Multistandard products which combine advanced computing and data features with cellular are the first ones, where these are needed. The speed of standardization and qualification of new packages and development of manufacturing infra is a limitation.

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 come 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. (fig. 3).

Filtering
is the key element affecting complexity of multimode terminals. RF filters are

	system	frequency range (MHz)	multiple access methode	channel bit rate (kbit/s)
Digital cellular and personal communication systems	**GSM** Global System for Mobile Communications	900	TDMA/FDD	270.833
	DCS 1800/1900 Global GSM-based PCN/PCS	1800/1900	TDMA/FDD	270.833
	IS-54/IS-136 North American Digital TDMA Cellular/PCS	800/1900	TDMA/FDD	48.6
	IS-95 North American Digital CDMA Cellular/PCS	800/1900	CDMA/FDD	1228/5000
	PDC Japanese Personal Digital Cellular	800/1500	TDMA/FDD	42
Digital cordless systems	**CT2/CT2+** Cordless Telephone 2	800/900	TDMA/TDD	72
	DECT Digital European Cordless Telephone	1900	TDMA/TDD	1152
	PHS Personal Handy Phone System of Japan	1900	TDMA/TDD	384

Table 1. Main digital cellular, personal communication and cordless standards.

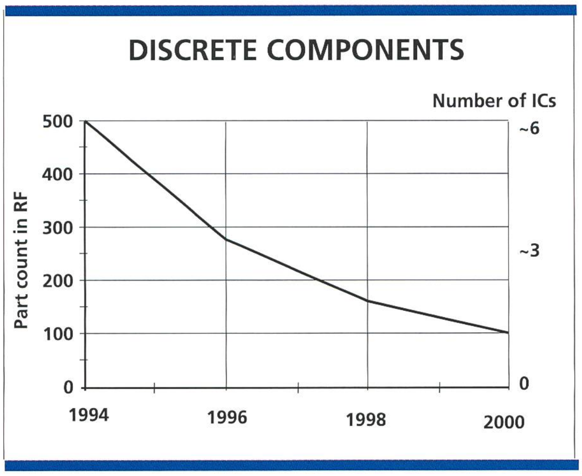

Fig. 3. Discrete components dominate in the RF part of a typical GSM phone.

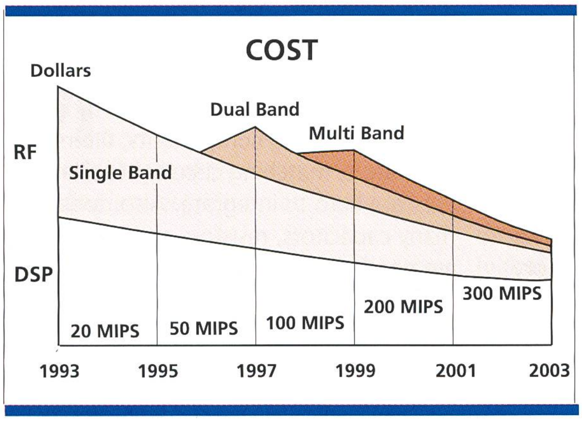

Fig. 4. Technology cost trend of single- and multiband terminals.

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 miniaturization 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 optimized 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. Subharmonic IF sampling architectures utilizing sigma-delta type converters will offer one solution.

Oscillators

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

Very basic selection of system parameters will have great impact on the complexity of the overall system. If all the bit rates, frame frequencies, channel separation, etc., are based on a single-frequency reference, then there are more options to simplify the overall system architecture and reduce the number of oscillators as well as reduce the interference rejection requirements. For example, in GSM-based systems, including DCS 1800/1900, a 13-MHz basic frequency reference has been selected. Thus, the multimode architectures are well supported by the system parameters.

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 to 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 multiresonant operation of multi-mode systems.

Transceiver architectures

have been mostly based on superheterodyne principles having two conversions in the receiver and one in the transmitter. In multimode operation this approach may not be the most economical because of the high number of filters needed.

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 UMIS these requirements are released by putting more effort to adaptive control of system parameters (transmitter power levels, interference prevention schemes, etc.), then

	1992	1994	1996	1998	2000
Gate density (gates/mm^2)	2000	5000	15 000	30 000	50 000
Processing power (MIPS)	20	50	80	120	200
Relative power consumption (1/MHz)	100	30	10	3	1
Relative power with max. MIPS	100	75	40	18	10

Table 2. CMOS and DSP evolution.

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 a 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.

Steps towards SW radio

Today's products are based on electronics, optimized for single-system operation. The next step will be to develop optimized engines for dual- or triple-mode systems. This would mean one common engine for TDMA-based systems and another engine for CDMA-based systems. A third engine would be needed for mixed systems. Adding frequency bands and modes of operation mainly adds to the cost and complexity in the RF part (fig. 4).
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 five year's time frome now.

Conclusions

Mobile communications is evolving towards a digital multiservice environment. Introduction of new systems and services drives the need of multimode and multiband terminal equipment capable to operate in different systems and provide a multitude of services to the user.
Developments in CMOS technologies especially 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 a fully adaptive platform to multimode SW-configurable radios.
When specifying and standardizing 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 utilization of radio resources. 14

Source:
Conference 'Multi-Mode/Band Mobile Terminals'.
IBC UK, Conferences Ltd, April 1997.

Erkki Kuisma *joined Nokia Mobile Phones to manage the research and development of digital cellular technologies. Since then he has been working in different managerial positions in the research and development of cellular products and technologies both in Finland and the USA. He is holder of eight patents related to cellular products. From 1980 to 1983 he worked for Helsinki University as a research engineer, pioneering the research related to the Pan-European Digital Cellular System (GSM standard).*

Zusammenfassung

Technologieoptionen

Auf einer generischen Plattform basierende Multimode-Terminals werden eine wichtige Anforderung für drahtlose Systeme der nächsten Generation sein. Solche Terminals müssen kompatibel zu zahlreichen Funkschnittstellen sein, den Betrieb in verschiedenen Umgebungen ermöglichen und sich an verschiedene Funkanschlusstechnologien anpassen lassen, die eine kostenwirksame Realisierung von Multimode-Terminals ermöglichen.

BUCHBESPRECHUNG

W. Nachtigall
Bionik-Design für funktionelles Gestalten
Springer-Verlag GmbH, Heidelberg. 1997, 173 S., 108 Abb., Fr. 35.50, DM 39.80, öS 290.60, ISBN 3-540-63245-X.

Was haben ein Delphin und ein Schiffsrumpf gemeinsam? Zu welchem Ergebnis kommt man, wenn man analoge Hochbaukonstruktionen der Natur und Technik vergleicht? Wäre ein 3 m breiter Schornstein so gut konstruiert wie ein Grashalm, könnte er 1,2 km hoch gebaut werden. Kann das stimmen? Das Sachbuch Vorbild Natur, Bionik-Design für funktionelles Gestalten, gibt faszinierende Einblicke in die Gestaltungsvielfalt der Natur und beleuchtet Bionikdesign unter Berücksichtigung technologischer Zukunftsaspekte. Die Natur hat mit ihren Strukturen, Funktionen und Strategien Vorbildcharakter und dient als Ideengeber. Direkte Naturkopie ist Scharlatanerie, es gilt die Erfindungen der Natur zu durchforsten, zu erforschen und umzusetzen und so dem Menschen technisch nutzbar zu machen.
Anschauliche Beispiele bieten dem interessierten Laien einen Einstieg in die Geheimnisse biologischer Prozesse und Konstruktionsprinzipien: der Vogelflügel als Vorbild für das Focksegel, die Bienenwabe als Musterbeispiel für hochstabile Gebilde mit einem Minimum an Materialeinsatz. Sie vermitteln die Philosophie von bionischem Design als unverzichtbares Forschungsverfahren mit naturnahem Systemansatz, das dem Menschen dienen muss.