Wirelessness - An Emerging Craze
An Overview of Wireless Applications, Technology and Issues

APS Khanna
Avantek / Hewlett Packard
Santa Clara CA. USA

Introduction:

The first "wireless craze" began in the 1920's with the incredible demand for radio broadcast services by the public. Of course the demand for radio communications has grown over the years, with progress including the satellite communications of the 1970's. The recent "wireless craze," though, may be even more significant for the human race. Since the 1920's the wireless technology has literally gone through a metamorphosis. Our world has greatly shrunk due to vast expansion in means of transportation and communication. The needs of people are very different today and the emerging wireless craze will influence, include almost every sphere and aspect of life.

The surge in growth of applications for microwave and RF technology in the commercial markets has been a pleasant surprise for every one in the field. In the past, developments in microwave technology have traditionally been driven by defense applications. Now, however, the global political movement toward peace and demilitarization has for the past few years caused a significant downtrend in the defense applications for microwave and RF equipment -- creating a great deal of pressure on technologists and investors to look for new applications of this mature technology.

In less than a five years a number of exciting applications have appeared and a great number more are on the way. Global wireless communications are now in sight, the cellular radio market is well established, high-speed wireless LANs are a reality, and the first of the PCS and CT-2 have been deployed. People's freedom of movement will no longer be determined by the length of a telephone cord. The need for complex wiring plans to service computer networks will soon disappear. Of course, there are still questions regarding standards, spectrum allocations and modulation schemes, but the future is clear and it is *wireless.*

In this paper we will review some of the applications of the wireless technology. Communications being the single largest application, the focus of the discussion will be on communications related applications, with a relatively brief recognition being given to non-communications applications. We will review the status and future needs of the technology driving the wireless applications, as well as the regulatory, standardization and health issues affecting the applications.

Communications Applications:

Presently the main application of wireless being cellular, sometimes wireless seems to be meaning only cellular. In reality however if you start looking at the full spectrum of applications, wireless really turns into a potentially huge market with growth opportunities never seen before in the area of RF/microwave applications. The most attractive part of the wireless media is in its flexibility, low cost easy to install capability. Unlike copper and fiber, microwave networks can be installed or removed almost as fast as the changing traffic needs and applications. Undoubtedly the main application of the wireless technology is the transmission of voice, data and video.

Voice Communications: In the field of voice where 800 to 1 GHz frequencies are used for cellular applications, higher frequency radios at C, Ku or K band serve as an access to the telephone company or linking private networks. With the cellular communications, microwave radio is often the medium of choice linking cellular metropolitan area locations in countries that lack an adequate public networking infrastructure and want to advance telecommunication services rapidly.

In the cellular world, the digital cellular link is replacing the analog to enhance the quality and capacity of the cellular systems. The digital systems can handle 15 times the number of calls compared to that of an analog system. The requirements of the user community are rapidly changing to "instant information" to better match the prevalent frantic life-styles. The next step in the evolution of communication technology is the Personal Communications commonly referred to as PCN or PCS. Personal communication refers to a variety of non-vehicle wireless communications including personal telephones, cordless as well as networks. The telephone users will no longer be calling places but will rather call people on their personal communicator, independent of location.

One of the well known digital wireless system introduced recently, is the European GSM (Groupe Speciale Mondiale). It uses the 810-960 MHz band and uses one of the most advanced digital switching circuitry. Though the present use of GSM is a basic phone, it has been designed with the capability of becoming a personal communication center. Transmitting and receiving text or data will be added as the demand evolves. Some of the other digital wireless systems in the world are NADC (US) 824-894 MHz, JDC (Japan) 810-956 MHz, 1429-1513 MHz, CT-2 (UK) 864-868 MHz, DECT (Europe) 1.88-1.9 GHz, PHP(Japan) 1.895-1.905 GHz.

The SS wireless technology is also being targeted for small private telephone exchanges which can be set up at a short notice without the hassles of complex wiring requirements. Some of the products in this area are already in the market and wired exchanges for small companies may soon be a thing of past.

Data Communications (WLAN): In view of the fact that the laptop computers and mobile voice communications are booming now, the wireless data communications are one of the next segment of electronics industry to take off. Given the expense and performance limitations of hardwired networking for in-building applications, the concept of using electromagnetic (RF) energy to transmit and receive data becomes an attractive alternative for LANs. Interesting applications are the outcome of marriage between the data processing and wireless applications. For example the specialized telemetry system between a transducer and a data acquisition system and a broad spectrum PCS system to provide voice and data communications in a small handset. The high speed LANs require very large bandwidths, clear spectrum, confinement of signals in a predetermined area. Compatibility of the existing wired networks is another major issue for WLANs. Frequencies around 900 MHz, 2 GHz, 6 GHz and 18 GHz are presently being applied for the wireless LAN applications. The 900 MHz Part 15 band where a number of WLAN products have been made available in the USA, does not have international appeal, as in Europe the 900 MHz band is solely reserved for mobile voice communications. Looking at the technology and cost/performance benefits, the frequency band of 1.9 to 2.5 GHz seems ripe for international acceptance.

A major merger of computing and communication technology and industries is expected in the next five years. Development work is already in progress on Personal Digital Assistants (PDA) and Personal Information and communication devices.(PCIDs). These products are expected to appeal not only to mobile professionals but also to consumers who thus far have not really embraced PC's. Wireless computer may eventually become as ubiquitous as the compact-disk player.

Video Communications: Wireless video communications are one of the newest applications emerging on business as well as educational campuses around the world. Microwave video teleconferencing is becoming a popular business tool in the corporate world. It not only saves the money otherwise necessary for travel, it also more efficiently uses the time of the people involved and can be arranged at a much shorter notice than a personal conference. With the aid of microwave radios, remote interactive classroom links can now be established to allow students at various campuses to participate in the same lecture.

CDMA vs. TDMA: The future communication systems are expected to use the advanced form of digital radio transmission called Spread Spectrum. Presently the time division multiple access system is more commonly used. The recently introduced GSM system in Europe is based on the frequency hopping TDMA system. The spread spectrum technology has been used by military for a long time. The main advantage of this technology is the ability to share the same frequency by multiple users. The modulation scheme involves the Code Division Multiple Access (CDMA) and the radio signal is spread across a broad range of frequencies. The ratio of original data bandwidth to the spread spectrum bandwidth represents the "processing gain" which is one of the figure of merits of the SS system. At the receiver end the signal is again compressed into its original narrowband using the code which only the desired user's receiver recognizes. Spread spectrum techniques inherently offers security, reduction in interception capability and protection against jamming. In the cellular configuration the SS also offers the capability of soft handover as it uses the same frequency while the information is moved from one cell to another. SS also offers higher capacity than the competing TDMA technique. TDMA on the other hand is a more mature technology for multiplexing digital signals on wires. CDMA is also more complex system to handle and will need significant effort in developing the necessary chips and devices to make the system user friendly for practical use.

The future of the wireless communications will be in smaller network configurations such as cellular networks or companies with campus environments. Microwave has already become a sought after media and technology around the world - providing diverse communication solutions for data, voice and video.

Non - Communication Applications:

A number of applications have been identified to use the new wireless technology.
These applications can be subdivided into following categories:

Navigational Applications:

The availability of Global Positioning System, coupled with the wireless communication capability has resulted into new applications not possible before. One of the applications is the truck tracking capability. The trucks equipped with the GPS receiver can continuously update its coordinates which with the help of a wireless communication system is transmitted to the central monitoring and control location. This system is very effective for the trucking agencies and have potential to be used by major taxi tracking and control services.

Telemetry Applications: There are a number of short range telemetry applications. Two of the most interesting are for utility-meter reading and supermarket retail store display systems. Utility companies need a system to gather accurately the data and relieve themselves from having to read the utility meters manually. One solution would be to equip the utility meters with spread spectrum Tx which would transmit the meter reading to the centrally located utility pole on each block to gather data from the home based transmitters. A dedicated phone line would then transmit the meter readings from the pole to the utility company's billing service. Another application is the intelligent monitoring of the electric utility network. No longer will the utilities have to wait for customers to report the bad news. A spread spectrum radio designed for automated reporting will step in instantly and handle the emergency. Through a communication network, the system will report, locate and isolate the cause of outage automatically. These applications not only save costly man-hours of searching but also significantly speeds the power restoration

In the supermarket/retail store display application, wireless LCD display units mounted on the store shelves would show up-to-the-minute prices, which could be adjusted as quickly as new goods are purchased or as quickly as price changing decisions are made. SS radio offers an attractive alternative to wiring the shelves and aisles.

RF identification / Tagging Applications:
The wireless technology lends it self to the identification application in a neat way. An active transponder interrogates a coded passive RF identity device (also called RF tag). The reflected signal from the device contains the necessary information. Identification cards for security purposes is one of the applications. Another application is the wireless scanners to replace the bar coded optical wired scanners. The cars will eventually be equipped with a RF tag. It will not only simplify parking and toll payments but also will enhance the security of the vehicle by carrying an RF identity which can be interrogated at many check points.

The emerging wireless applications span over a large frequency range from less than 1 GHz to 60 GHz. The present thrust however is limited to frequencies of 0.5 to 2.5 GHz and a few sets of frequencies in C, X, Ku, K and Ku band. Figure 1 below summarizes the frequencies of interest and their applications:

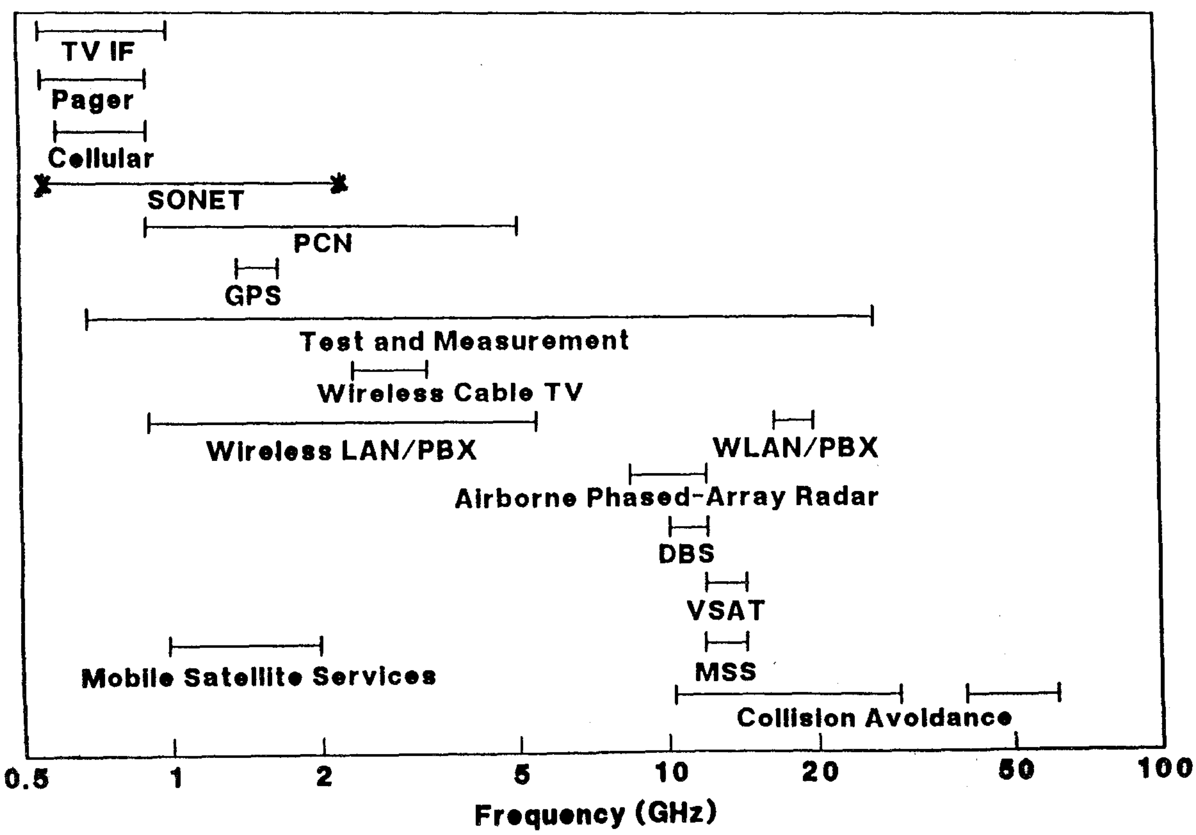

Figure 1. Wireless Applications by Frequency

Role Of Technology in the Wireless Revolution:

The semiconductor technologies will play a key role in shaping the wireless applications. Today we are at the cross roads of competing standards for the new wireless applications. The major drivers for the technology today are the user requirements and the industry as well as regulatory body standards. Fortunately the technologies required to support a multitude of the emerging applications and competing standards have common characteristics. The primary semiconductor technology however will not drastically change from what we know today. The enabling technologies are being driven mainly by the portable personal communicators and the high speed wireless LANs. Innovative solutions are required to meet the optimum price/performance characteristics.

Continuous improvement in the existing processes as well as development of new processes and devices are the key necessities for the wireless applications. Following processes have been identified to be important to support the wireless market through the nineties:
Advanced low cost silicon bipolar process for RF applications up to 2.5 GHz, A Bi CMOS process for mixed signal applications up to 3 GHz, A silicon process for monolithic microwave applications up to 5 GHz and GaAs process for low-noise, high-efficiency yet moderate cost applications to 18 GHz In many ways, the frequency range of 0.5 to 5 GHz is going to be the wireless battle field for competing technologies. Figure 2 below represents the present status and options of the different technologies for various functions of the wireless communication front ends:

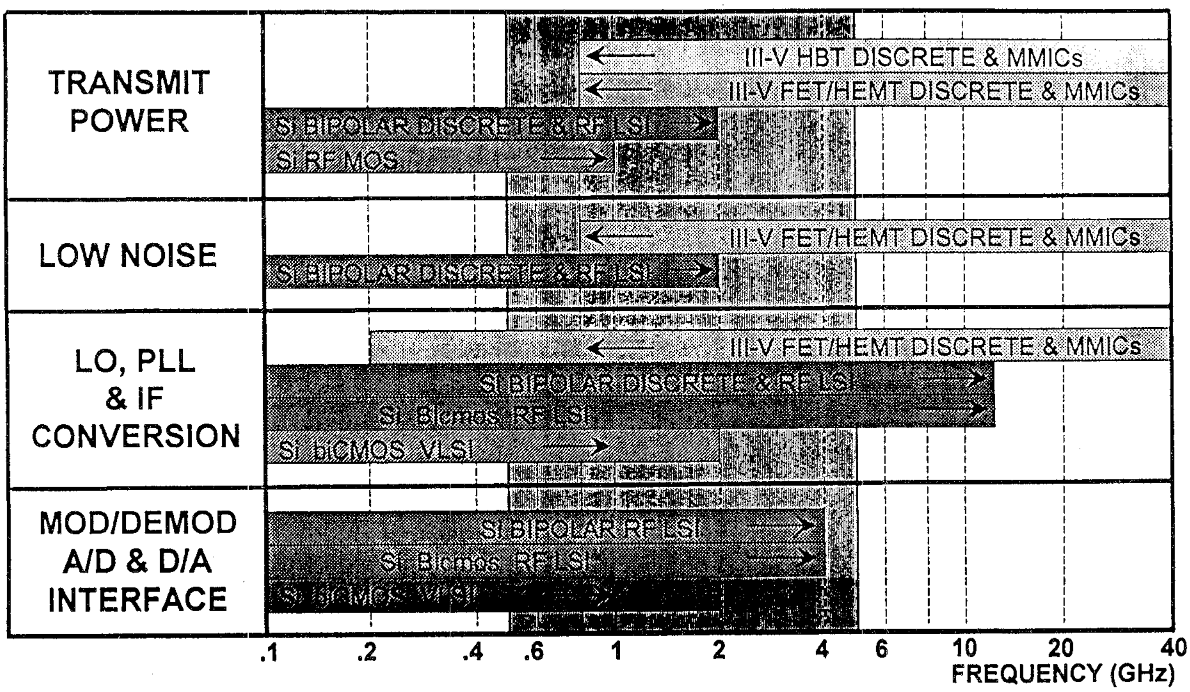

Fig. 2 Technology Options for Wireless Communication Frontends

The amount of effort going into these necessities in the industry today promises that the challenging process needs will be met. In addition to the new processes for the present devices, there is a dire need for new type of devices and MMICs. The light weight constraint of the wireless portable products require fewer batteries. The goal today is two batteries in the handset, which equates to 2.7 V operation and implies very low power consumption. HBTs are one of the hot devices, the RF industry is looking at seriously to help increase the device efficiencies at low voltage as well as low cost. Advanced GaAs processes will be required to achieve the low current very high dc/RF efficiency of GaAs at a moderate cost. Other technical parameters important for the RF components are higher linearity with higher efficiency and low noise.

The RF analog devices and the digital signal processing devices have been evolving separately in the past. The time has come to develop chips capable of integrating the two technologies. The development of the so-called mixed signal processing capability is necessary for the cost reduction as well as the miniaturization of the components. BiCMOS technology is one of the promising ways to achieve integration of RF/microwave front end, analog baseband (ADC/DAC/STR), and digital baseband (CMOS standard cells) functions. The focus is on higher level integration of as many functions as possible. Efforts on coming out with a single MMIC ROC (Receiver on a Chip) chip containing all basic functions of a receiver are on their way. The integration of functions in a chip offers a number of advantages: decreased size & weight, reduced system design cycle, simplified power management and decreased test time. Another technology which will enable faster growth of devices like PICDs is the Field Programmable Gate Arrays (FPGA). These devices will enable the vendors to update the performance and features in response to consumers' changing tastes. In fact, beyond the RF, processor, memory & communication chips FPGA is the only additional logic device needed to complete a PCID design.

Another important technology requirement is the dense packaging capability. RF chips particularly are sensitive to the parasitics. Multi chip modules along with flip chip assembly techniques will be required to achieve the desired integration. Chip packaging technology is also being challenged for low cost, reduced parasitics and ease of use in volume. The push to higher frequencies calls for tighter tolerances and use of RF guidelines for the I/O connections. It is not uncommon presently to find the situations where package cost is significantly higher than the die cost. Plastic surface mount packages for the RF are coming of age. In order to be successful a broad spectrum of standardized packages are necessary for the semiconductor industry.

Standardization and Regulatory Issues:

Standardization of the wireless communication related products and services is an absolute necessity. Lack of standards and proliferation of proprietary frequencies, modulation schemes and interfaces can put a heavy and unnecessary burden on network providers, device manufacturers, and end users alike. Conflicting national or regional standards, or different variations of the same international standards, increase the manufacturing and operating cost of the companies in the field. Compatibility of the wireless devices has several dimensions, including multi-vendor compatibility, upgrade compatibility and product line compatibility. Fortunately we can learn a lot from the growth and evolution of computer industry in the last decade. Early computer systems operated more or less independently without any pressure to achieve compatibility. However the sheer difficulty and cost of developing and maintaining multiple proprietary architecture and the requirements from large customers to interconnect multi-vendor equipment, has encouraged the development of standardized open computer interfaces.

The regulatory and standardization bodies in a way, are there to attach the necessary strings to the otherwise wireless technology. The major players for the development of standards on frequency spectrum for commercial applications and the wireless transmission characteristics are WARC for international, FCC for USA, CTIA for US cellular applications, CCITT for modulation codes and IEEE for wireless LAN standards. It is a tremendous challenge to coherently understand the activities of a multitude of national and international bodies in order to decide on the future direction. Some important features/concerns about the regulatory aspects are:

a) WARC'92 decision to allow wireless applications related to FPLMTS in the 2 GHz band is a major milestone in the wireless area. The decision specifically states: " The frequency bands 1850-2025 MHz and 2110-2200 MHz are intended for use on a worldwide basis by administrations wishing to implement FPLMTS. Such use does not preclude the use of these bands by other services to which these bands are allocated." It will help coordinate the activities between different countries, telecom operators and manufacturers. The conference also allocated 1670-1675 MHz (ground to air) and 1800-1805 MHz (Air to ground) bands for aeronautical public correspondence on a world wide basis. A footnote was also adopted that enables Argentina, Canada, Mexico, and the US to provide aeronautical public correspondence in the 849-851 MHz and 894-896 MHz bands on a primary basis.

b) In Europe the 900MHz band is exclusively reserved for mobile communication while in USA similar band is available under Part 15 unlicenced applications. In the US a number of WLAN products are now available in that band but the restriction in other countries effects the growth of these products. An IEEE standardization committee P802.11 is presently looking into various aspects of the future wireless LANs. Frequencies around 2 GHz and/or around 5 GHz are prime candidates for being recommended for the wireless computer communications.

c) Europe has also the lead in standardizing the standards for not only the digital cellular system at 900 MHz (GSM) but also on the Digital European Cordless Telecommunications (DECT) standards at 1.88 to 1.9 GHz. The DECT standard specifies the radio characteristics and communication protocols for systems capable of transmitting voice and data over 200 meters. The technology is also usable for wireless PBXs. It was completed by a technical committee of the ETSI organization.

d) CDMA vs. TDMA: The debate on the digital modulation schemes is far from over. The TDMA is a more mature technology at this time but the CDMA standardization work has already started. In some ways this controversy reminds us the situation of VHS and Video-8 controversy for the video standards in the past. It is very likely that once again both schemes will continue into the future. The consumers main benefit will be the optimum performance they will automatically get due to competitive reasons.

Health Issues:

One of the issues which concerns the user the most is the possible negative health effects of the personal wireless transmissions. Presently the cellular portable phone are 0.6W max. devices. Generally these phones are designed to automatically adjust the power output so they generate only enough power to reach a Rx/Tx station. In a typical urban market sampled by CTIA, cellular phones operate at full power only 5% of the time. Rest of the time they operate at less than ½ of the maximum power. Even at 0.6W, the power is still 15% below FCC's safety threshold. Although the Electromagnetic field or EMF levels produced by the portable phones are below those of other manmade devices we are exposed to every day the questions being asked are a) Is the EMF radiation really safe at the levels, so far believed to be safe & b) How high is the risk because the portable phone or communicator device is held close to user's head. It is not possible to make a quick and direct correlation between EMF and health as the use of these devices is very recent. Studies under the direction of various agencies like the blue ribbon panel of CTIA and COMAR group of IEEE, are under way. It is important to prove that sooner than later that there are no harmful effects of the wireless radiation at the present levels. In view of the controversy, however there will be a tendency towards lower powers for the personal communicators, requiring larger number of base stations as well as the development of components for higher sensitivity receivers.

Conclusion:

The emerging wireless market has tremendous growth potential but successful participation is a challenge. The customers can appreciate technology, but what they ultimate require is the performance at an acceptable price. Wireless solutions are not being developed, to exploit the available technology, they are a result of customer's needs which cannot be accommodated in existing wireline services. The future of wireless Voice, Data & Video communications depends upon its ability to integrate the invisibility with the existing systems as well as on the flexibility and cost. The challenge of developing functionally integrated chips, low cost packages will have to be met to be successful. The requirements of continuous performance improvement and continuous cost reduction will be the keys to successfully participate and benefit from this emerging craze of wirelessness.

Glossary

CDMA: Code-division multiple access
CT-1: Cordless Telephone - 1
CTIA: Cellular Telecommunications Industry Association
DBS: Direct Broadcast System
DECT: Digital European Cordless Telecommunications
FCC: Federal Communications Commission
EMF: Electromagnetic Field
ETSI: European Telecommunications Standards Institute
FPGA: Field Programmable Gate Array
FPLMTS: Future Public Land-Mobile Telecom Service
GSM: Groupe Speciale Mobile
(Pan-European Digital Cellular)
MSS: Mobile Satellite Service
PCN: Personal Communication Network
PCS: Personal Communication Services
PDA: Personal Digital Assistant
PICD: Personal Information and Communication Devices
PHP: Personal Handy Phone
TDMA: Time division multiple access
SS: Spread Spectrum
VSAT: Very Small Aperture Terminals
VDV: Voice, Data & Video
WARC: World Administrative Radio Congress
WLAN: Wireless Local-Area Network
WPBX: Wireless Private Branch Exchange