

Wireless Communications: A Spectrum of Opportunities

William J. McFarland

The tremendous growth in the consumer market for wireless communications products, such as cellular and cordless telephones, has created a parallel growth in research and development for higher-performance components for these products.

In the past five years consumer and manufacturer interest in wireless communication have exploded. Fueled by the tremendous acceptance of cellular telephones, cordless telephones, pagers, satellite delivered video, and simple infrared communications, the market for wireless communication hardware has grown to well over U.S. \$10 billion per year worldwide. These market advances were enabled by tremendous reductions in cost and power consumption of wireless communications technologies.

Beyond the success of these established technologies, a wide range of new wireless communications services are being developed. Many of these services are substantial enhancements to existing systems, such as two-way paging, digital cellular service with short messaging capability, and sophisticated local communication using infrared such as the IrDA-NG (Infrared Data Association-Next Generation) standard. Other fast-growing systems will provide totally new capabilities. For example, the Global Positioning System for determining location (based on satellite communication) may eventually be used in all automobiles. Wireless multimedia networks and infrared-based control networks may someday be in every home.

The desire to communicate without wires appears natural. However, the value proposition for most wireless technologies is more diverse and subtle than the simple image of untethered information access would portray.



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Advantages

In each application, the use of wireless communications provides the following advantages in varying degrees:

- Eliminates wiring
- Provides wide area coverage
- Allows mobility while using the service.

It is interesting to examine which of these advantages are fundamental to popular services. Cellular telephones provide mobility and wide area coverage, but since most homes and workplaces still get wired telephone service, cellular telephones have not reduced the amount of telephone wiring. Cordless telephones provide mobility within the home, but do not provide wide area coverage, nor have they eliminated much wiring (most homes have a telephone jack in many different rooms). On the other hand, direct broadcast satellite (DBS) systems do not provide mobility. What DBS provides is a way to compete with cable companies without having to string cable to every home. DBS is described in greater detail in **Article 6**.

Depending on the value of these wireless advantages, wireless systems must still compete with wired solutions on the basis of cost and performance. Despite the tremendous improvements in technology in the last few years, wireless communications circuits are generally more expensive and provide lower-bandwidth communication than wired solutions.

Wired (or fibered) solutions will always have an advantage in terms of bandwidth. Because signals on different wires interact very little, each new wire can use the same part of the electromagnetic spectrum as all others. Unfortunately, with wireless communication there is only one spectrum that must be shared among all users that are within range (coverage) of each other. In the case of services with nationwide coverage, such as cellular telephones and satellite systems, the spectrum allocated for those services typically can only be used for that one application. This situation limits the amount of bandwidth such a service could fairly use and has created government regulation to prevent interference.

Although the electromagnetic spectrum is infinite, not all of it is of equal value. The propagation properties, the cost of the technologies required, the regulatory issues, and available bandwidth all determine the value of a given piece of the spectrum.

Propagation

Frequencies between 10 and 30 MHz are able to propagate around the world with remarkably low transmit powers. Above 100 MHz, signals do not propagate over the horizon. Signals from 100 MHz to approximately 1 GHz can still penetrate most buildings, trees, and people fairly well, and can diffract easily around objects they cannot penetrate. From 1 GHz to approximately 100 GHz, signals progressively lose their ability to penetrate and diffract. Above 100 GHz, propagation is line-of-sight and has properties similar to light.

Technology

Technology is advancing rapidly, so any statement about relative costs holds only for a short time. Presently, there is an increase in cost somewhere between 1 and 5 GHz, with further increases somewhere between 12 and 30 GHz. An exception to the higher-frequency, higher-cost rule is infrared communications. The LEDs and photodetectors used to transmit and receive infrared signals (~ 500 THz) have become very inexpensive. However, these devices are noncoherent and must compete with the noise of sunlight. Therefore, infrared communication presently requires a great deal more transmitted power to reach a given range of communication. One potential advantage of higher frequencies (above 10 GHz, including infrared) is the small size and simplicity of highly directional antennas.

Regulation

Regulation is also changing (although much less quickly than technology). Presently, frequencies above 300 GHz are not regulated. Frequencies below 300 GHz fall into two regulation categories, licensed and unlicensed. To coordinate users and avoid potential interference, government agencies throughout the world require users to obtain a license for the use

of most frequencies. While a licensed service has the advantage of protection from interference, the cost and administrative difficulties of obtaining a license for each transmitter are often prohibitive. Government agencies have set up some unlicensed frequencies. Transmitters in these bands do not need individual licenses. Instead, they must abide by certain rules, which are verified through type certification. * **Table I** lists some of the most important unlicensed bands and their properties. **Table I** also shows a general property that holds true for licensed and unlicensed frequencies—the higher the frequency, the more bandwidth available for the service.

Frequency	Bandwidth	Geographic Availability	Power Level
900 MHz	26 MHz	North America	Up to 1W
2.4 GHz	84 MHz	United States	Up to 1W
2.4 GHz	84 MHz	Europe	Up to 100 mW
2.4 GHz	26 MHz	Japan	Up to 10 mW
5.2 GHz	200 MHz	Available in U.S. and Europe for HIPERLAN only	50 or 250 mW
5.8 GHz	125 MHz	North America	Up to 1W
24 GHz	259 MHz	North America	Up to 25 mW
60 GHz	5 GHz	North America now and hopefully Europe and Japan soon	500 mW
> 300 GHz	Theoretically infinite but for practical use < 50 MHz	Worldwide	Limited by eye safety rules

HP's Involvement

The combination of desired propagation, technology cost, and regulatory issues decides for any given application what frequencies to use. For each frequency range and application, a whole set of technologies are required. These go from the basic device technology, through packaging and system integration, to protocols and networking standards, and finally applications. HP is involved at all levels of this hierarchy over a wide range of frequencies, as the other wireless communications articles in this issue demonstrate.

Article 2 describes the applications and most widely accepted standards for infrared communications. The standards provide interoperability between devices for mobile professionals and consumers. The IrDA standards provide short-range, walk-up, point-and-shoot-type communications. Infrared provides a very low-cost implementation and worldwide freedom from regulation.

RF technology trade-offs for wireless communications is the subject of **Article 3**. The article concentrates on the frequency range from 900 MHz to 5 GHz. This frequency range has the most activity presently for local and wide area data networks. The article describes different cost and performance trade-offs, and the effects of the continually increasing performance and scale of integration in silicon technologies.

* Type certification is a process by which the United States Federal Communication Commission (FCC) approves a product for sale but does not test each unit sold.

As the carrier frequency becomes higher, silicon alone cannot provide sufficient performance. One solution to this problem is a multitechnology chipset for 12-GHz direct broadcast satellite (DBS) receivers, which is described in **Article 6**. The delivery of video via a direct broadcast satellite has had the fastest initial growth rate of any consumer electronics product in history. HP has played a significant role in this success by providing very high-performance circuits at consumer prices.

An extremely advanced technology is described in **Article 4**, which describes a 0.1- μm MODFET (modulation doped FET) for use in high-speed wireless communications. This technology provides transistors with such tremendous performance that applications such as 60-GHz wireless LANs and 70-GHz collision avoidance radar become feasible. In addition, the technology can be used at 12 GHz, in which case the devices provide lower noise and higher power efficiency for DBS systems. This article includes a discussion of packaging issues as well, no simple matter for such high frequencies.

Article 5 takes a similar tack of using a very advanced technology (enhancement-mode PHEMT*) to provide remarkable performance in a commonly used frequency range. In this case, the frequency is the 850-MHz cellular telephone band, and the performance benefit is output power (two watts of RF power from a single IC operating from a 3V power supply) and excellent efficiency (50%).

Conclusion

The incredible growth of wireless communications is bound to continue as consumers demand the convenience of untethered mobile access. The articles mentioned above are only a sampling of the work in wireless communications going on at HP. HP is involved in nearly every wireless communications market supplying everything from discrete devices, integrated circuits, and packaging to complete communication modules, networking, and application software. This breadth and depth of involvement positions HP to take full advantage of this rapidly growing market.

* PHEMT = pseudomorphic high-electron-mobility transistor.

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