# Get Ready for a Wireless World

Wireless communication is poised to become one of the world's major growth industries during the next decade, and physicists with a good understanding of electromagnetic waves will have an edge in finding rewarding opportunities in this burgeoning field. Today, virtually every telecommunications and computer company is preparing for the advent of the wireless world. Silicon foundries now turn out chips with built-in wireless capabilities, and many original equipment manufacturers design these chips into new products that they hope will give them a share of the anticipated wireless bonanza.


The exponential growth of cellular telephones in the past decade shows how rapidly a new technology can win acceptance when it is convenient and offers unique benefits. More than 50 million Americans have bought cell phones, and although the growth rate has slowed, millions of new customers sign on every year.

Wireless communication offers the user powerful benefits: It is easy to use, and it can be used almost anywhere. Convenience will spark wireless's growth in the computer market just as it has with cell phones. The computer market, in turn, will spin off a host of new wireless devices for consumers. Business applications, such as wireless credit-card transactions, are already in use, and applications once only dreamt of will become a reality in the next two decades. The two-way wrist radio, introduced in the Dick Tracy comic strip in the 1950s, has been far surpassed by the digital personal-communications service (PCS) phone of today.

The next stage beyond the cell phone is wireless data communication. Digital PCS phones already have a limited data-communication capability. Portable and desktop computers are being equipped with infrared or radio links to other computers and to peripheral equipment such as printers and image projectors. Infrared is fine for short-distance, one-to-one connections (see *The Industrial Physicist*, 6/98, pp. 17-18). Radio-frequency wireless systems, however, can transmit data faster and farther than infrared systems and can provide multiple and simultaneous connections.

The federal government set the stage for the wireless business boom when it opened up the radio-frequency spectrum for general commercial use. The need for an increased bandwidth for cellular telephones provided the driving force behind the government's action. Indeed, the economic imperative is so strong that governments worldwide have agreed to make certain radio frequencies available for commercial or public use. They have formalized their actions through the International Telecommunications Union (ITU), which sets standards and protocols for telecommunications.

Wireless local area networks (LANs) that use radio waves to send data at Ethernet rates (10 Mbps) are available today. So are extended-area wireless networks that can operate over distances up to 40 km. Universities across the United States are setting up wireless campuses that allow students and faculty to log into the school computer network and the Internet from a laptop or handheld computer anywhere on campus—classroom, cafeteria, laboratory, or even a shady spot on the lawn. A company with offices scattered throughout one or more buildings can connect all its employees with a wireless communication system. In industry, management can maintain direct links to manufacturing operations with a wireless system.

The potential for wireless applications seems almost endless:

- Today's business office has an underpinning of cables and wires for connecting computers and telecommunications equipment. These cables could disappear from offices built in the future, which may require wires only for electricity. In addition, companies moving their operations will not have to run cable through their new premises.
- Wireless communication systems will be extended to equipment on the manufacturing floor. Cable-free computer connections to equipment will allow more efficient and higher-quality production.
- The construction industry now uses wireless extensively for voice communications. In the future, wireless will obsolete paper blueprints as engineers check specifications using a portable computer linked by radio to the computer-assisted design (CAD) system in their offices. The National Institute of Standards and Technology (NIST) is building a construction-automation test bed where wireless systems will measure the exact alignment of construction components using global positioning system (GPS) satellites and on-site instruments.
- In science and technology research, convenience will motivate the move to wireless connections between computers, instruments, and other equipment. When the shift to wireless begins, companies whose products lack wireless connections will find

themselves losing market share. Developing wireless connectivity for R&D equipment, however, seems unlikely to interest the major players in wireless. This leaves the market wide open for innovative individuals and companies already familiar with the needs of researchers.

Major chip manufacturers, including Texas Instruments, IBM, Lucent, Motorola, and Hewlett-Packard, have been building wireless capabilities into the next generation of digital signal processors (DSPs) and microprocessors. DSP chips play a key role in equipment used to send and receive wireless data. Faster DSP chips that were recently introduced enable vendors to design products that can simultaneously handle voice and data transmissions.

IBM and Intel, along with about 20 telecommunications companies and wireless-product vendors, have formed a special interest group called Bluetooth to create a specification and chipsets (specific combinations of chips) for universal short-range radio communication between devices. As envisioned, the Bluetooth "radio-on-a-chip" will be able to transmit up to 10 m at 700 to 900 kbps, which is fast enough for video, voice, and data. Likely applications for Bluetooth initially include cell phones, portable computers, personal digital assistants, digital cameras, computer peripherals, and LAN servers. A group of Bluetooth devices could be used to create an ad hoc wireless LAN. Even household appliances and devices in cars may come equipped with the wireless chipsets.

## Public-use radio bands

Dozens of new companies have installed wireless LAN systems that operate on public radio frequencies, which, unlike cell phones, do not use frequencies that require licensing by the Federal Communications Commission (FCC).

The FCC has set aside a portion of the radio spectrum, called the industrial, medical, and scientific (IMS) bands, for unlicensed use. Some restraints exist, such as a maximum of 1 W of transmission power, but anyone can broadcast on these bands. The FCC also has allocated a limited portion (300 MHz) of the radio spectrum for unlicensed use by community groups, schools, libraries, and hospitals, as well as by businesses and individuals. This public band, known both as the unlicensed National Information Infrastructure (U-NII) and the SUPERNet (shared unlicensed personal radio network), allows users to operate a wireless network that covers up to 15 km.

A technique called spread spectrum, or frequency hopping, allows the transmission of an almost unlimited number of messages without interference over the IMS and U-NII bands. The technique, which the military has used routinely for decades, consists of putting data into packets and transmitting

each packet over a different frequency. Each packet occupies the frequency for only an instant, which allows sending thousands of packets almost simultaneously.

The receiver detects packets intended for it and puts them together in the right order. An error-correction code tells the receiver when it has received corrupted packets, and it signals the transmitter to resend that data. Also, a sophisticated technique called forward error correction greatly increases the probability of all packets arriving correctly. Because spread spectrum is in its early commercialization stage, opportunities appear plentiful for physicists to apply their knowledge and mathematical skills to further improving this technique.

## Wireless networks

In the computer and telecommunications industries, wireless networks offer a major growth area. Lucent Technologies (Murray Hill, NJ), for instance, purchased Hewlett-Packard's multipoint wireless business to position itself as a major wireless broadband-equipment supplier to service providers. Lucent's WaveLAN, according to surveys, has captured about 40% of the market for wireless LANs in the education, manufacturing, and business markets.

In most cases, wireless capability is simply added to existing hardwired LANs. The cost of installing a wireless access node on a network starts at about $1,000, and adding a wireless card to a computer or other device costs $300 or more. Companies offering wireless LAN products include BreezeCOM (Carlsbad, CA), Netwave Technologies (Pleasanton, CA), Proxim (Mountain View, CA), Symbol Technologies (Holtsville, NY), and WebGear (San Jose, CA).

The University of New Hampshire has set up the Interoperability Laboratory Wireless Consortium, which offers testing services to vendors of computer networks, both wired and wireless. The laboratory determines whether wireless products comply with the IEEE 802.11 standard for interoperability.

Computer maker Sun Microsystems (Mountain View, CA) has teamed with Harris Semiconductor (Melbourne, FL) to demonstrate a next-generation wireless network capable of transmitting data and video to mobile and desktop computers at 11 Mbps. The wireless network uses a direct-sequence spread-spectrum technology, which Harris developed for military radios, and a radio-signal modulation technique known as MOK. Funding for the demonstration system comes in part from NIST's Advanced Technology Program.

Campuses, neighborhoods, and even entire cities can be made part of a wireless network. Major telecommunications companies such as AT&T and several new compa-


nies are installing "fixed wireless" networks in cities to transmit voice and data. AT&T is planning to use its wireless network to deliver voice and data from its global network to local destinations. Home Wireless Networks (Atlanta, GA) has proposed using wireless units to add multiple telephone connections to homes.

Metricom (Los Gatos, CA) offers wireless Internet access to customers in San Francisco, Seattle, and Washington, D.C., using small transmitters installed on utility poles. WinStar Communications (New York, NY) is operating a trial wireless network in Washington, D.C., that carries voice, data, and video.

## Other innovations

Receiving satellite signals is now commonplace. However, sending signals to a satellite still requires a relatively powerful transmitter. A system developed and marketed by Hughes Network Systems, called DirecPC, offers an interim solution. The DirecPC system enables a personal computer to receive data at high speed directly from a satellite, but the computer uses an ordinary telephone link to send data. Several companies market two-way satellite terminals that can be linked to an office LAN.

Direct links to satellites will become readily available with the advent of commercial systems in low Earth orbit (below 2,000 km). The first systems, such as Motorola's Iridium, are intended to pick up signals from mobile digital phones, but they also will carry some data traffic from portable computers. Iridium plans to begin commercial operations this fall, and the completed system will have 66 satellites.

Satellites intended primarily for handling data traffic are in the design stage. Some companies, such as Motorola and Teledisc, plan to use satellites in low Earth orbit. Others aim higher. Hughes Communications, for example, plans to put 20 satellites into medium earth orbit at 10,000 km and 16 satellites into a geosynchronous orbit at 36,000 km for its Spaceways system. Hughes is also building 10 satellites for ICO Global Communications' medium Earth orbit system, intended primarily for voice communication.

Antenna design offers a promising area for new breakthroughs, particularly for small,

portable devices. Antennas in mobile phones require constant improvement as the phones themselves shrink more and more. Improved antennas are also needed for direct satellite links. Multiple antennas can increase channel capacity, and the addition of loops and small elements can facilitate tuning an antenna to specific frequencies.

And some new antenna designs are in the offing. Fractal Antenna Systems (Fort Lauderdale, FL), for instance, is using repeated patterns that look like fractals to develop a "micropatch" antenna the size of a 35-mm slide. The fractal antenna design was pioneered by Nathan Cohen, director of science and engineering at Boston University's Metropolitan College, who also serves as Fractal Antenna's chief technical officer.

Another area of innovation comes from attempts to combine computer and telecommunications standards. The initial outcome of these efforts is a smorgasbord of competing proposals, each with its own acronym: FDMA, TDMA, CDMA, GSM, PCS, AMPS, CDPD. Fortunately, efforts under way should consolidate wireless specifications so that any wireless device of the future can communicate with any other device or network. The Wireless Application Protocol (WAP) Forum is developing a globally applicable set of protocols for delivering Internet and computer network data to wireless devices. The WAP specifications in part use software for handheld devices developed by Unwired Planet (Redwood City, CA), a company that joined with Nokia, Ericsson, and Motorola to found WAP Forum. The Forum is receiving strong industry support worldwide.

Wireless products—other than mobile phones—are coming into general use. Many gas stations use satellite wireless systems for credit card confirmations, and many restaurants and cocktail lounges use wireless portable terminals for taking orders. Wireless computer peripherals—modems, mice, keyboards, and printers—are available from an increasing number of companies.

Recently introduced products include a wireless superfloppy 120-MB drive, wireless whiteboards for conference rooms, and wireless pay phones for remote or rural areas. Johnson Controls (Plymouth, MI) is developing a car rearview mirror with a wireless transceiver that will monitor your tires, automatically pay for gas and road tolls, store reminder messages, call for roadside help, and provide GPS navigation and Internet access. In the home, marketers foresee wireless control of appliances becoming the next major trend.

Most manufacturers and vendors inevitably will concentrate on adding wireless connections to existing products. The more interesting and much more profitable approach asks: What new and wonderful wireless products can we devise?