Wireless networking using so-called 802.11 protocols is growing by leaps and bounds, mostly in spectrum shared with hams. How can we best use this "Wi-Fi" technology and are we better off using it as hams, under Part 97 of the FCC rules, or as unlicensed "regular people" under Part 15? The answers may surprise you.

Wi-Fi for Hams
Part 1: Part 97 or Part 15?

BY RON OLEXA,* KA3JIJ

If you're like me, over the past year you've been seeing more and more about Wi-Fi, 802.11, wireless hotspots, and the like. Like me, too, you may be wondering how this technology can be put to use, and if there are any amateur uses for this consumer technology. Like wired computer networks, wireless offers multi-megabit speeds and (lately) reasonable prices. The 802.11b standard operates in and around 2.4 GHz, under Part 15 of the FCC rules. However, some of the available channels happen to fall within the amateur band and therefore may be used under Part 97 rules. In this article I will explain what 802.11b is, explore the rules under which it operates, and show some of the ways you can put it to use.

What is 802.11?

802.11 is a wireless networking standard administered by the IEEE (Institute of Electrical and Electronic Engineers) that currently includes the 802.11a, 802.11b, and 802.11g specifications. An industry group known as the Wi-Fi (Wireless Fidelity) Alliance certifies its members' equipment as conforming to the 802.11a and b standards and allows compliant hardware to be marked "Wi-Fi." The Wi-Fi seal of approval tries to ensure compatibility among thousands of devices made by hundreds of vendors. In early October 2002, the group modified the Wi-Fi mark to indicate both a and b standards by noting 2.4 or 5 GHz band compatibility. Because of this guarantee of compatibility, creating a simple home wireless network is now as easy as installing a Wi-Fi certified 802.11 client card in each computer. These devices operate in the U.S. under Part 15 of the FCC Rules, so no license is needed.

802.11 is an extension of wired Ethernet, bringing the same principles to wireless communication, and as such the system doesn't care about the kinds of data that pass over it. It's primarily used for TCP/IP, but can also handle other forms of networking traffic, such as AppleTalk or PC file-sharing standards.

Computers and other devices operating Windows or Mac OS, and many flavors of Unix and Linux, may communicate over Wi-Fi using equipment from a variety of vendors. The Wi-Fi radio is typically a PC or PCMCIA card, although USB adapters and other forms (including PDA versions) are also available. Smaller devices that fit into internal

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A Wi-Fi antenna installation in Los Angeles. Note that the antenna is aimed downward to focus signals on the usage area and to minimize interference outside the area. If you look very closely at the far left of the photo (just to the right of the white vent pipe), you'll see a second Wi-Fi antenna, about 60 feet away from the first. Use of directional antennas and different channels allows multiple installations to operate virtually on top of each other without interference. (Photo by the author)

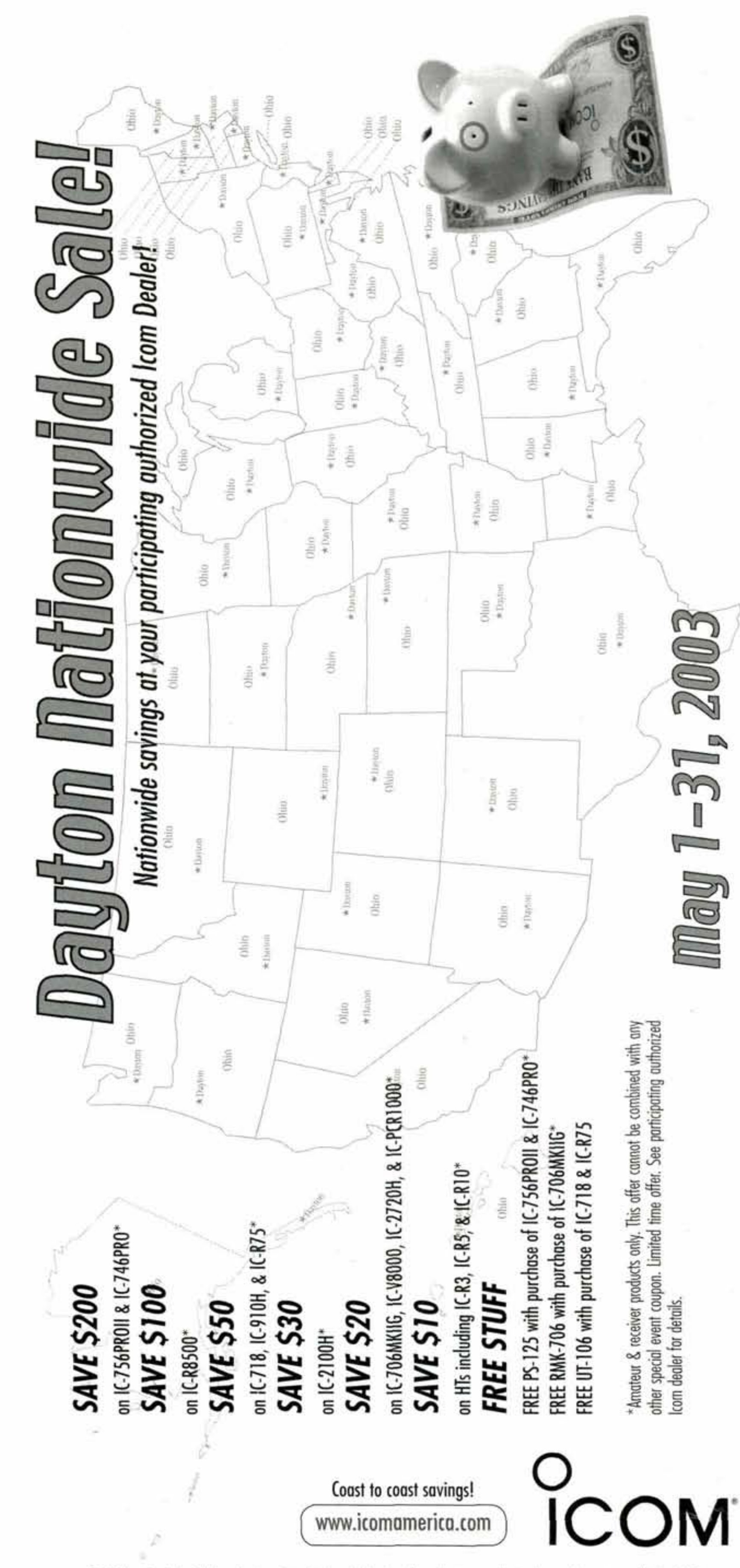
Secure Digital and Compact Flash card slots started appearing in late 2002.

The 802.11b specification allows for the wireless transmission of approximately 11 Mbps of raw data on the 2.4 GHz band. Links can span from a few hundred feet indoors to a few miles outdoors. (The 802.11a specification can handle 54 Mbps on the 5.6 GHz band, but typically at shorter distances. A relatively new standard, 802.11g, combines the 54 Mbps data rate of 802.11a with the 2.4 GHz frequency of 802.11b. The distance that can be covered for any of these versions depends, as with any radio, on RF power and path loss.)

Each Wi-Fi radio can operate in Infrastructure mode, where one Wi-Fi device acts like a hub or router for many computers, or in Ad-Hoc mode, where the Client card in each computer is a peer of all others, and the client cards communicate among themselves directly. Ad Hoc operation allows the computers on the improvised network to "talk" to each other, but not much more. Adding an *Access Point,* which acts as a base station that controls the client cards, and placing the cards in "infrastructure" mode, adds the ability to do more complex networking tasks such as network access control and sharing an Internet connection. A typical WLAN (Wireless Local Area Network) installation uses one or more Wireless Access Points, which are dedicated stand-alone radios with better antennas and an Ethernet port plus a client device for each computer on the WLAN network. Best of all, the prices for this hardware have dropped to the point where client cards can be purchased for under $50. Bridges and Access Points are now under $100.

The 802.11b standard is backwards compatible to earlier specifications, known as 802.11, allowing speeds of 1, 2, 5.5, and 11 Mbps on the same transmitters. If the signal or path is poor, the radios automatically reduce the link speed to make it more robust. Multiple 802.11b access points can operate in the same location by using different channels. The specification defines 14 channels, which are staggered at 5 MHz intervals, from 2.4000 to 2.4835 GHz. Only channels 1 through 11 are legal in the U.S., and only channels 1, 6, and 11 have no overlap among them.

By the way, 802.11a uses 12 non-overlapping channels in the 5.6 GHz UNII unlicensed spectrum—eight in the low part of the band for indoor use and four in the upper for outdoor use. 802.11a's range is generally shorter, but it can often transmit at higher



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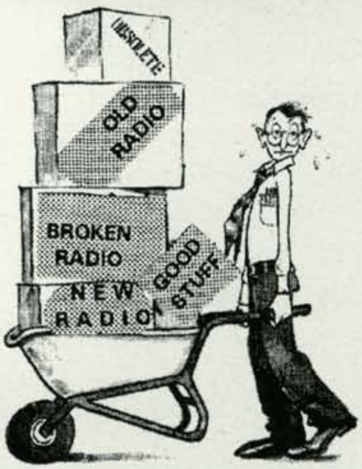

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speeds than 802.11b for a given path.

Currently, 802.11b is the only standard deployed for public short-range networks, such as those found at airports, hotels, conference centers, and coffee shops and restaurants. Several companies currently offer paid hourly, session-based, or unlimited monthly access via their deployed networks around the U.S. and internationally.

802.11b products are now plentiful and cheap, and should become a boon to amateur experimentation with high bandwidth digital systems. With 11 Mbps of throughput available, many interesting communications opportunities are possible under Part 15 and Part 97 operation. 802.11b products are a great way to extend a data or Internet connection to a site by building a dedicated point-to-point link, or to build a point to multipoint Digital Base Station, which could provide a high-speed data connection shared by a number of fixed and mobile users. The remainder of this article will focus on the operation of 802.11b products in the 2.4 GHz band. If sufficient interest exists, future articles could also discuss operation at 5.6 GHz.

Available Hardware and Operating Modes

802.11x hardware consists of three subsets: *Access points,* which are the equivalent of base stations; *client cards,* which are the equivalent of computer NIC cards; and *bridges,* which can link network segments together. Client cards can communicate with each other directly (in Ad-hoc mode) or with an access point (in Infrastructure mode). Bridges are specialized devices which can be used together as point-to-point links, or with an access point as part of a point-to-multipoint link. The majority of the available equipment comes from vendors Proxim, Cisco, D-link, and Linksys.

Many newer Access Points also contain other data network management and control functions. It is now common to find an Access Point that includes a router, NAT (Network Address Translation), MAC (Medium Access Control) Address filtering, and a DHCP server. These functions are critical for developing any data network, including a wireless one.

In a typical situation the local network has one "pipe" going to the Wide Area Network (WAN), usually to the Internet. Most ISPs (Internet Service Providers) expect only a single computer to use the connection, so only one IP address per connection is provided. If our wireless network has multiple computers, each one needs a unique IP address to communicate. You could buy multiple connections or IP addresses (one for each computer) from your ISP, or you could just share a single connection. In this situation the access point (through its routing capability) is assigned the single IP address provided by the ISP. NAT functionality in the Access Point's router then maps this single IP address on the WAN side to multiple Private IP addresses (one for each of your computers) on the LAN side, allowing the WAN connection to be shared.

To handle the computers on your LAN, the Access Point uses DHCP to automatically assign a "private" IP address to each computer as it logs onto the network. Each network interface device (such as a NIC or Wi-Fi card) in a data network has a unique identifier, known as a MAC address. This is sent as part of the 802.11 handshake when a computer establishes a connection to an Access Point. The MAC address is what is mapped to an IP address in the router. MAC Address filtering can be used to block unauthorized users from gaining access to your wireless network by allowing only a preprogrammed list of MAC addresses to be granted access.

Having these functions within the Access Point avoids the need for additional equipment to perform these functions. When I built my first 802.11b system five years ago, it consisted of a Lucent Access Point, a Cisco router, and a dedicated Linux computer to handle DHCP, NAT, firewall functions, and access control. The cost of that system was over $15,000. Today you can buy an Access Point that provides the same functions for under $100 retail!

Most wireless access points and bridges are based upon the same chipset used in the Client cards. Primarily envisioned for use in portable devices, and designed to accommodate their limited battery power source, most chip sets deliver only a fraction of the 1 watt power level authorized by the FCC. In fact, most units deliver between 15 dBm (30 mw) and 23 dBm (250 mw) of output power. Also, the lower power chipsets seem to exhibit about a 6 dB reduction in receiver sensitivity as compared to the higher cost devices. If RF performance is a consideration, shop for your equipment carefully. This is not normally an area of concern. As we shall see, the utilization of high-gain antennas can achieve significant coverage distances from these low powers. If more coverage is needed, high-power access points and bridges are available, as are high-power bi-directional linear amplifiers designed specifically for use with 802.11 hardware.

FCC Rules for Part 15 and Part 97 Operation

As delivered, 802.11 products conform to FCC Part 15 rules, which limit both the devices' RF output power and EIRP. The most stringent restrictions are placed on omnidirectional operations, since those result in the highest overall interference contribution to the surrounding area. In the case of omni operation, the EIRP is limited to 1 watt. If a directional antenna is used, the allowable EIRP jumps to 4 watts. If a fixed point-to-point link is implemented, Part 15.297 allows legal operation as long as the power level of the 1 watt TX is reduced by 1 dB for each 3 dB of antenna gain above 6 dBi. Thus, a link maximized under Part 15 using a 30 dBi gain parabolic reflector would require the TX output power to be reduced by 8 dB, calculated as follows: (30 dBi – 6 dBi)/3. This results in 158 watts EIRP being achieved legally under the Part 15 rules.

The restrictions of Part 15 are not as limiting as some may believe. Given the EIRP limits, a point-to-point link of tens of miles is certainly possible. If, on the other hand, you're a ham and you would like to have wide-area multipoint coverage, Part 97 rules (with their relaxed power constraints) could make modified 802.11 ideal for an area-wide high-speed data network. However, as I will discuss later, in many cases the limiting variable in any deployed network will be capacity, not coverage, so covering an area with multiple low-power Access Points could be a better solution than trying to use a single more powerful device to cover the same area.

Another benefit of Part 15 operation is that the Wired Equivalent Privacy (WEP) function can be enabled. All Wi-Fi certified equipment has this feature. Because information is transmitted over the air, there is an opportunity for someone to monitor that data with another receiver. In order to provide some degree of security to the data, WEP was included in the 802.11 standard. WEP requires a common key to be enabled in the access point and any client that wishes to use it. By enabling WEP you can both secure the system to only trusted users with whom you've shared the key, and provide some level of protection to the data that the user is communicating. WEP cannot be utilized under Part 97 rules because of the prohibition on encrypted communications.

A final benefit of Part 15 operation is that it has no commercial content re-

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strictions. A Part 15 compliant network may be connected to the Internet, and users may interact and behave in the same manner as they would on any other Internet connection.

There are numerous considerations for Part 97 operation. Only certain 802.11b channels fall completely within the amateur allocation at 2.4 GHz. As a wideband spread-spectrum emission, the main power is contained in a 22 MHz wide window. However, the power spectrum doesn't fall to –50 dBc until twice that bandwidth. This may be important, depending upon the Out of Band Emission limits placed on spread-spectrum operations under Part 97. Since I'm not a lawyer, I'll leave the answer to this question to those who have more experience in this subject matter. Still, the best-case interpretation means that channels 1 through 5 may legally be used under Part 97. The worst-case interpretation still allows channels 2, 3, and 4 to be used while assuring that no out-of-band emissions are generated by the operator. In either case it would be prudent to avoid using channel 1, due to the possibility of causing interference to AO-40 satellite operation.

The next consideration for use of these devices under Part 97 relates to the fact that 802.11b devices are spread-spectrum devices. Part 97.311 governs SS emissions, specifically limiting power output to 100 watts, and for output powers greater than 1 watt, specifies that automatic power control (APC) must be used.

Unmodified 802.11b radios do not have a power output greater than 1 watt, so as long as we limit ourselves to antenna gain, compliance with 97.311 is trivial. While Wi-Fi devices do track the S/N ratio and other parameters used for data rate fallback (but not APC), the methods used do not exactly comply with the method stated in Part 97.311d. Implementing APC in a Wi-Fi device is probably beyond the capability of most amateurs, but clearly needs to be examined if we are to take advantage of the higher power levels we are authorized to use.

Finally, remember that use under Part 97 must comply with *all* of Part 97, including station identification, no encrypted transmissions, no commercial uses, and controlled use. Station ID is the easy part. All 802.11 devices have a Service Set Identity, or SSID, which is broadcast by the Access Point to identify itself, and received by client devices where it is used to find the network they belong to. Because SSID is constantly sent as part of the overhead data stream, setting your callsign as the SSID should suffice as station identification.

You must also assure that non-amateurs cannot gain access to the network. Keep in mind that this is Part 15 consumer technology. Any 802.11 client device will be able to see any Access Point on the air and can try to log onto it. Access control can be accomplished using MAC filtering. This feature is available in some Access Points, and allows you to limit service to known MAC addresses. To use it you would load the MAC addresses of your amateur users into the Access Point.

Probably the most onerous of the Part 97 rules relates to the no commercial content provisions of Part 97. Based on these restrictions, it would be impossible to legally connect your Part 97 compliant network to the Internet, due to the amount of commercial content and pop-up ads that appear, even when you yourself are not using the site for commercial purposes. Even e-mail can contain automatically inserted commercial messages over which the sender has no control.

I'm sure there are other Part 97 issues that will need to be addressed in order to legally use the available equipment. Apparently other amateurs have realized this, too. While researching this article, I discovered that the ARRL is supporting a project called Hinternet, for Ham Internet. Its initial focus is on the utilization of 802.11 products under Part 97 rules. They are currently working on legal and technical issues associated with Part 97 use of 802.11. Their web page is <http://www.arrl.org/hsmm/>. Hopefully by the time this article is published this group will have made some headway on the legal questions as well as set forth some technical standards that will assure peaceful coexistence with the numerous Part 15 devices already in service.

Therefore, while Part 97 use is feasible and can provide extensive coverage from a single site, it is fraught with restrictions that significantly limit the appeal of doing so. Without the ability to provide Internet access, Part 97 use will be limited to allowing amateurs to network their computers together to do file sharing and private messaging between them.

Let's Build a Wi-Fi Network

In Part II of this article we'll look at all the considerations that go into designing and building a Wi-Fi network, whether it's for "regular" Part 15 use or amateur Part 97 use. We'll examine 2.4 GHz propagation, path-loss considerations, and options for various setups. Until then, think about how you would use your Wi-Fi network and whether Part 97 or Part 15 will best serve your needs.■

Part I of KA3JIJ's article showed us that hams using high-speed wireless "Wi-Fi" networking in shared amateur spectrum may sometimes benefit from higher power levels allowed by Part 97, but may be better off at other times sticking with the looser content standards of Part 15. In his conclusion, Ron shows us how to build these networks for either type of use.

Wi-Fi For Hams
Part II: Building a Wi-Fi Network

BY RON OLEXA,* KA3JIJ

In part one of this article we discussed the basics of high-speed wireless networking (Wi-Fi) on bands shared by both hams and unlicensed Part 15 users. We also discussed the pros and cons of using one of these networks under Part 97 (as ham stations) vs. Part 15. Here in part two (of the article, not the FCC rules) we'll look at building a Wi-Fi network and the different considerations of how that network would be built for a Part 15 setup vs. Part 97. The first thing we need to do is understand the nature of propagation on 2.4 GHz.

2.4 GHz Propagation Characteristics

Radio-signal propagation can be divided into free space, reflection, diffraction, and scattering mechanisms. For point-to-point link analysis, a free-space propagation model can be used as long as the first fresnel zone is free of obstacles. Fresnel zone is the area around the visual line-of-sight into which radio waves spread out after they leave the antenna. If this area is not clear, reflections and multi-path will occur, leading to a reduction in signal strength at the receiver. If there are fresnel-zone obstructions, a line-of-sight propagation model should be used.

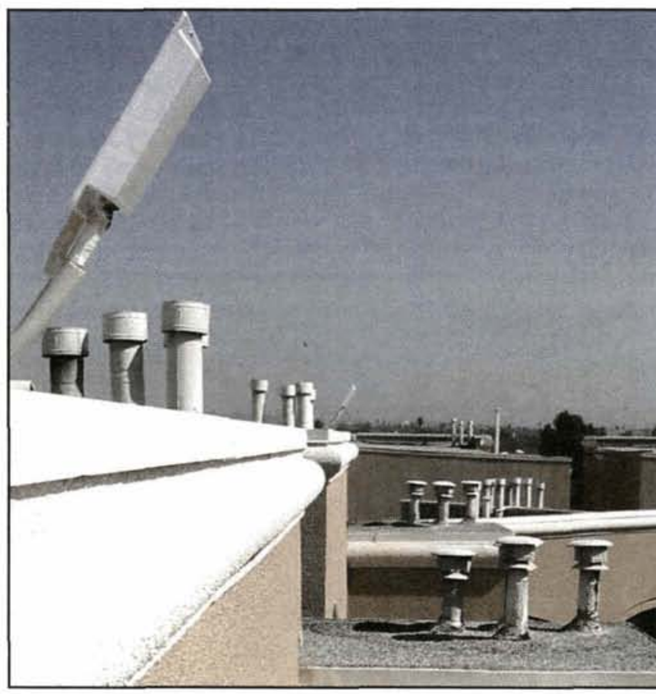
To accurately predict the propagation of a 2.4 GHz signal you need to know the gain and loss of each part of the link system. While equipment specifications are easy enough to find, the path loss can be tricky. There are programs that can be used to accurately predict path loss, but my advice is to estimate the loss using the graph in fig. 1 and the equation below, then put together a good system and see what happens. The link budget formula (which is actually simpler than it looks) is as follows:

$$L\,[\mathrm{dB}] = P_{tx}\,[\mathrm{dBm}] + G_{tx}\,[\mathrm{dBi}] - P_{rx}\,[\mathrm{dBm}] + G_{rx}\,[\mathrm{dBi}] - M\,[\mathrm{dB}]$$

where L is the link budget in dB, Ptx is transmit power, Prx is receiver sensitivity, Gtx and Grx are antenna gains on the transmit side and receive side respectively, and M is fading margin. All values are expressed in dB for ease of calculations. Using conservative power levels and antenna gains to design a simple point-to-point link yields the following:

$$L = 17\ \mathrm{dBm} + 15\ \mathrm{dBi} - (-84\ \mathrm{dBm}) + 15\ \mathrm{dBi} - 10\ \mathrm{dB} = 121\ \mathrm{dB}$$

This link could easily be assembled and operated under Part 15 rules, providing you use compliant external antennas and equipment. Looking at the free-space line of fig. 1, we



A directional antenna installation. Note the horizontal mounting angle, known as "down tilt." Down tilt is used to center the main lobe of the antenna on the area to be served, rather than on the horizon. It is used to improve signal strength in the desired service area and reduce interference to other areas, an important consideration, since over 15 different access points serve this community. (Photos by the author)

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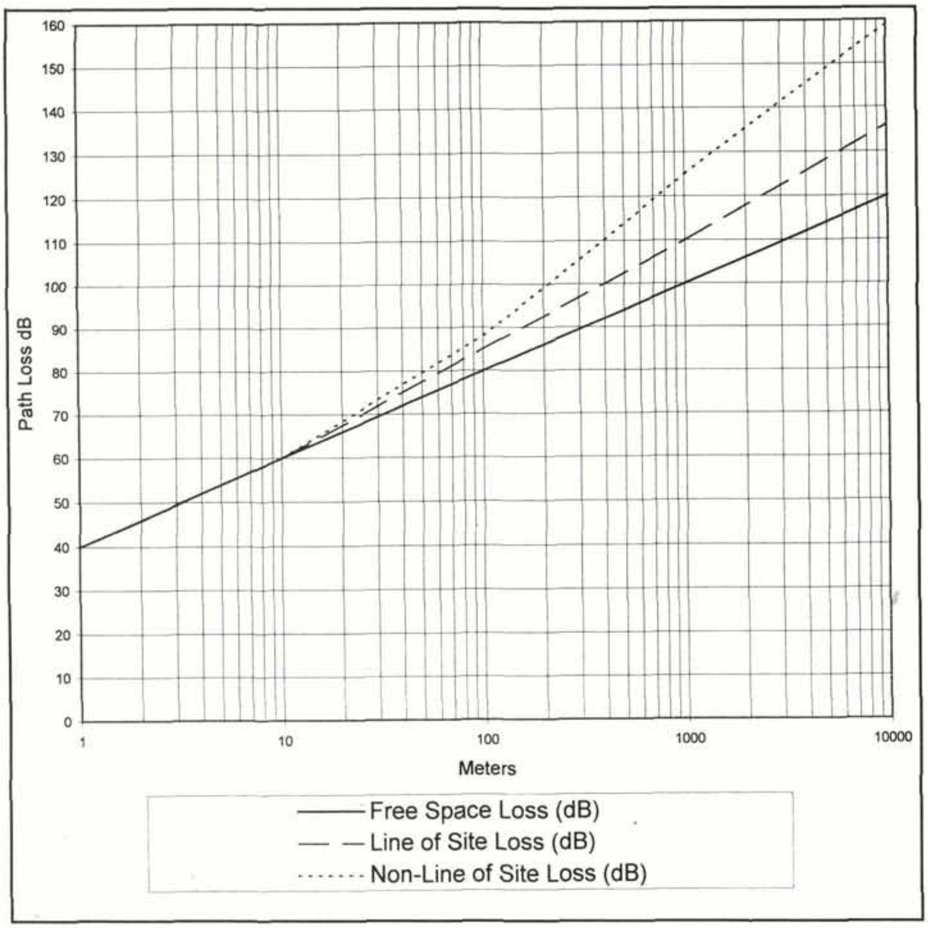

Fig. 1– Estimated link distances for a given path loss. The free-space line is an acceptable estimate for a link where both antennas are visible to each other and there are no nearby obstructions. The line-of-sight (LOS) curve is used where there is optical LOS, but there is an object in the fresnel zone. NLOS assumes that there are buildings and trees within 50 feet of the transmitter and that the receiver is at street level within this clutter.

An omnidirectional antenna installation. This omni antenna has 15.1 dBi of gain and is designed with a main lobe down tilt of 3 degrees. The antennas in the photos, as well as many others, can be purchased at <http://www.natcommgroup.com/index.php>.

can see that 121 dB allows for a link of over 10 kilometers! You can see from the graph that free space offers a huge advantage in terms of link distance, but the reality is that most of us live in an urban or suburban environment where free-space links are impossible to achieve. Thus, a more realistic result for the real world would be to use the curves shown for line of sight (LOS) or non-LOS. The line-of-sight curve assumes optical line of sight with *obstructions in the fresnel zone*. The covered distance of the 121 dB path drops to about 2.5 km under these conditions. The non-line-of-sight curve assumes no major obstructions (such as hills or other dense obstacles), only some trees and buildings, but even that adds 25 dB or more attenuation to the line-of-sight path loss.

While our 121 dB link budget would result in a non-line-of-sight link distance of only about 500 meters, remember that we can use much better antennas than in our conservative assumptions. The same point-to-point link, with 30 dBi antennas at each end, could easily span a few miles, all while remaining within Part 15 rules!

To assist in evaluating your system coverage I suggest getting a copy of Netstumbler from <http://www.netstumbler.com>. Netstumbler is a freeware program that turns your 802.11-enabled computer into a tool for *measuring signal strength and interference* and identifying any 802.11 signals in an area. It can even be used in conjunction with a GPS unit to generate coverage maps!

Speaking of knowing all the losses in the system, one which should not be forgotten is feedline loss, which can be significant at these frequencies. Even really good cable such as LMR-400 coax exhibits 6.8 dB of loss per hundred feet here, and an improperly assembled connector could exhibit over 3 dB of loss. Keep the feedline run as short as possible. In fact, the best bet is to put the 802.11 *equipment in a weatherproof* box and mount it as close to the antenna as possible. If you are using an access point or bridge, all you need to provide it is DC power and an Ethernet cable, both of which can be run 300 feet without a problem.

Project Concept: A Wide-Area Data Network

Using the point-to-multipoint capabilities of 802.11 allows for the construction of an IP-based network with the capability of connecting users over a wide area.

When designing a wireless data network, the **4 C**s must be considered: Coverage, Capacity, Carrier to Interference Ratio (C/I), and Cost. Let's take a look at how these factors interact. In

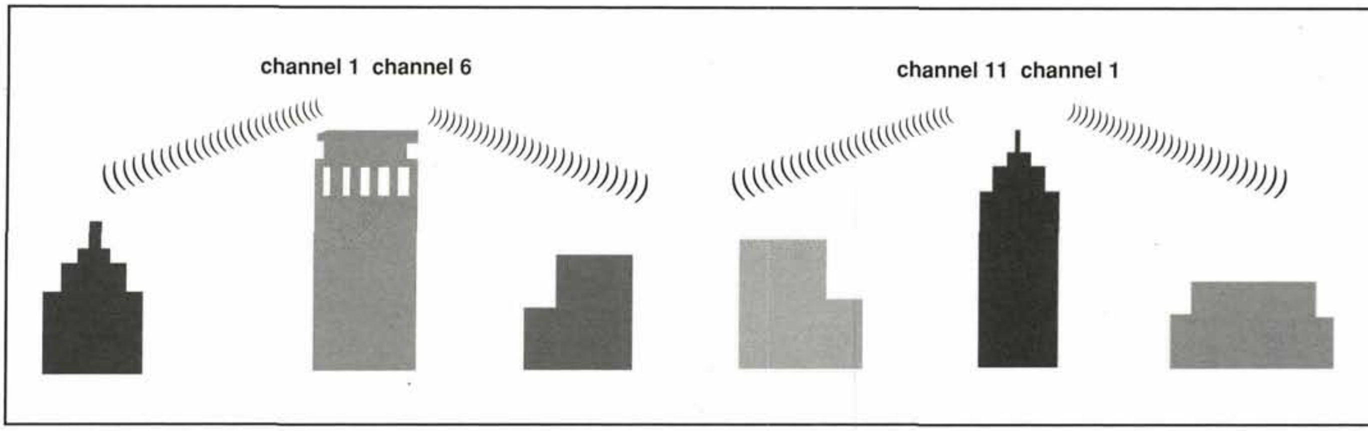

Fig. 2–Reuse of channels in a system. Both physical separation and antenna aperture can be used to provide interference protection. In this case Channel 1 can be reused at both sites because of both physical separation and the directional antennas. The covered area can be increased many times over by continuing to reuse the channels at additional sites with separation intervals sufficient to avoid co-channel interference.

this example I'll use a college campus that is 1.5 km long and 1/2 km wide, with a mix of two-story to eight-story buildings. The users will operate standard client cards without external antennas. Thus, we will assume 0 dBi gain for these antennas.

The first design will be Part 15 compliant using omni antennas. The access point selected has a power output of 100 milliwatts (20 dBm) and a receive sensitivity of –84 dBm. The access points will be mounted as close to the antennas as possible to minimize feedline loss to 1 dB. This configuration is compliant with Part 15 rules as long as it does not generate more than 1 watt EIRP, meaning we can use an 11 dBi gain omni antenna. Using the link budget calculation yields an acceptable path loss of 104 dBm. Applying this figure to the NLOS graph in fig. 1 shows that each access point can cover about a 300 meter radius; thus, two access points could cover most of the campus, while three would assure coverage over the entire area. Since there are three non-overlapping channels (1, 6, and 11), each site can be assigned a unique channel to avoid inter-site interference. As I mentioned earlier, there is a possibility of Channel 1 interfering with AO-40 operation, so it would be best to deploy this network on channels 2, 6, and 11 or 2, 7, and 11. This clears AO-40 interference at the expense of adding some adjacent channel interference in the network, but the interference most likely will be inconsequential.

From a cost standpoint, each of the access-point locations would cost about $300, assuming $100 for the access point itself, $150 for the antenna and cable, and $50 for a weather-

proof enclosure. Thus, for this example a $900 system would cover the campus extremely well and offer the users up to 33 Mbps of available bandwidth.

What happens if we use directional antennas? Well, we can increase the power to 4 watts EIRP under Part 15 rules. For simplicity, I'll use 180-degree directional antennas with 17 dBi of gain. This yields an acceptable path loss of 110 dB. The NLOS graph shows that you can expect coverage of about 400 meters. Using two sites, each 400 meters inside the campus, allows us to cover the area with only two sites. However, because of the directionality of the antennas each site needs two access points and antenna systems. With four access points there are insufficient channels for each one to have a unique channel. In this case channel reuse must be deployed. Channel reuse is simply coordinating the use of limited spectrum to allow the intended signal (the *C* in C/I) in an area to be greater than the unwanted signal (the *I* in C/I) by a certain margin. This is the concept behind modern telecommunications systems such as cellular and PCS. The operators of those systems repeatedly reuse limited channels using physical separation and antenna patterns to provide C/I levels sufficient to allow near-interference-free operation over large service areas. Think of it as repeater coordination on a much smaller scale. Since directional antennas are used, you can take advantage of both antenna pattern and physical site separation in planning the reuse of channels. A possible reuse plan for this example is shown in fig. 2.

The cost and capacity of this network is higher since four access points and antennas are needed. While the cost increases to $1200, the available bandwidth also rises to 44 Mbps.

Either of these designs will work and both are Part 15 compliant, meaning anyone could legally use the system, and it could be connected to the internet. The selection of one over the other has more to do with real-world availability of suitable antenna locations, access to an internet connection, and the usage characteristics of the users, which will dictate the amount of capacity you need to build.

But what can be done under Part 97 rules? Basically, we lose all the power limitations, so coverage can be dramatically increased. The campus could be covered with a single site located mid-campus. This would require the system to cover a radius of 750 meters. The NLOS path loss will be about 120 dB. This can easily be covered using a 17 dBi gain omni antenna and a 1 watt bi-directional amplifier. One and 2 watt amplifiers are commercially available for about $500 each. Because this design limits the transmit power to 1 watt, it can be legally operated under Part 97 without implementing automatic power control.

The downsides of this configuration are capacity, interference, access control, and loss of internet connectivity. With only a single access point, the campus wireless network only has an 11 Mbps capacity, while the costs are nearly identical to our 33 Mbps design. Moreover, this system may be accessed only by licensed amateurs, so appropriate access control mechanisms must be implemented at additional expense. Another issue to be considered is channelization. Only one non-overlapping channel is available, so no localized reuse is possible. The next site will need to have enough physical separation to assure interference-free operation of both; thus there will be gaps in coverage. In addition, high-power operation could become a source of interference to Part 15 users in the service area. (*Legally speaking, Part 15 users must put up with all interference from licensed users. But the reality is that there are a lot more of them than there are of us, so if for no reason other than good community relations, it's best to do what we can to minimize interference to other users.—ed.*) Worst of all, while the Part 15 designs could provide internet access, this Part 97 design would be precluded from doing so unless all internet commercial content could be filtered out before it got to this network.

Roll Your Own

The author has provided an Excel® spreadsheet file that is posted on our website (link from our July highlights page) to help readers make the necessary calculations for setting up individual systems. It is an Excel® representation of a COST 231 HATA propagation model, which is routinely used for NLOS propagation analysis in commercial RF planning tools. The big difference between Ron's model and the commercial version is that Ron's assumes flat earth, while the commercial products use actual terrain data to calculate a path profile. Please note that this is only a spreadsheet file and you must already have Microsoft Excel® or other spreadsheet software that reads Excel® files on your computer. *—W2VU*

Conclusion

As you have seen in the previous exercise, 802.11 is extremely flexible, provides many options for designing coverage and capacity into an area, and has the ability to provide considerable area coverage under both Part 15 and Part 97 rules. The determination of how to implement a network will ultimately be driven by the environment to be covered, the availability of suitable transmitter sites, and the needs of the users. There are already many individuals and companies who have used 802.11 to provide internet access in everything from coffee houses and apartment complexes to entire communities, and they have done so using the equipment under Part 15 rules.

Also, almost every week brings a press release about a new 802.11 product. Many of these products seem to focus on combining RF components and antenna technology in ever more creative ways. This results in many new products with the ability to extend 802.11 over greater and greater distances, while still remaining compliant with Part 15 rules. In the weeks that I've been writing this article a start-up company named Vivato has announced an 802.11 product with a smart antenna. The smart antenna allows a single antenna array to form multiple individual antenna beams, each treated as a point-to-point link. These beams are steered in real time to each user as necessary. Obviously, with the higher EIRP power limits associated with point-to-point links, this technology should be able to serve users over significant distances. Of course, with complexity comes cost: The product carries a price tag of over $10,000. However, to cover an entire community from a single site that price may be a bargain.

The proliferation of 802.11b equipment, combined with the public and commercial interest in 802.11b, makes this technology ripe for adoption by the amateur community. There are many interesting uses for this technology under both the Part 15 and Part 97 rules, and the limitations are not as severe as generally imagined. While propagation at 2.4 GHz is closer to a light beam than a radio wave, antennas can pack huge amounts of gain into a very small space. Equipment is extremely inexpensive and readily available for nearly every computer. Link design is simple enough, using easy calculations and a graph, but don't let an unfavorable number stop you. Try the link and see what happens. You might be surprised!

I encourage every amateur to experiment with this readily available and inexpensive consumer commodity. I would enjoy hearing from you with questions or comments, or just to share your stories. ■