digital connection

BY DON ROTOLO,* N2IRZ

A Cheap and Easy High-Speed Data Connection

Welcome to the "Digital Connection"! In this new column my goal is to bring you a variety of topics related to radio, computers, and the internet, with an emphasis on practical how-to-do-it information. This is an expansion of my previous "Computers & Internet" column in *CQ*, adding radio into the mix. We've also upgraded from quarterly to semi-monthly, appearing in every even-numbered month.

In my opinion, there's nothing more exciting about amateur radio than trying new operating modes and methods. This column will introduce new tools and techniques, and sometimes re-examine old ones, to give you everything you need to get into something different. If there's some topic you'd like to see covered here, drop me a note and let me know.

Building a Fast Data Link

For this first column we'll be looking at some practical information on using modified commercial wireless networking gear for amateur radio. We've all been hearing about wireless networking equipment for creating a wireless Local Area Network (LAN) in your home. This uses a standard known as 802.11b. It should come as no surprise that adapting this equipment to amateur use is fairly easy, and it works well, too.

The advantage over traditional packet radio technology is huge. Not only can you get data rates in the megabits-per-second range, but the equipment is laughably inexpensive. This makes for some very inexpensive, high-performance links. The disadvantages include the extremely low transmitter power and the need for a computer of some kind.

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Uncle Charlie and the Law

Before we get started, there's the small matter of FCC Rules & Regulations. 802.11b networking transceivers are sold with the understanding that the user shall not modify them in any way, including using any antenna not specifically designed for that equipment. Doing so invalidates their Part 15 type acceptance, making it illegal to use them. However, we will be operating our equipment under **Part 97** of the FCC rules, so using modified 802.11b transceivers appears to be legal, as long as all Part 97 rules are followed, including station identification, encryption, and others.

The bottom line here is, although I think the use of these modified devices is legal, I'm not a lawyer or legal expert. Since it will be *your* license on the line if anything is amiss, if you're uncomfortable with my interpretation, then I strongly advise you to seek an expert for an opinion *before* you start transmitting. *(But please don't ask the FCC to give you a ruling. Some questions are best left unasked—ed.)*

802.11b

The design goal was to create a radio-based data link to span a distance of about one-half mile, with data rates in the Megabit per second range. The RF path is essentially line of sight, but with some trees and buildings in the way. The idea was to gain enough experience in building this relatively

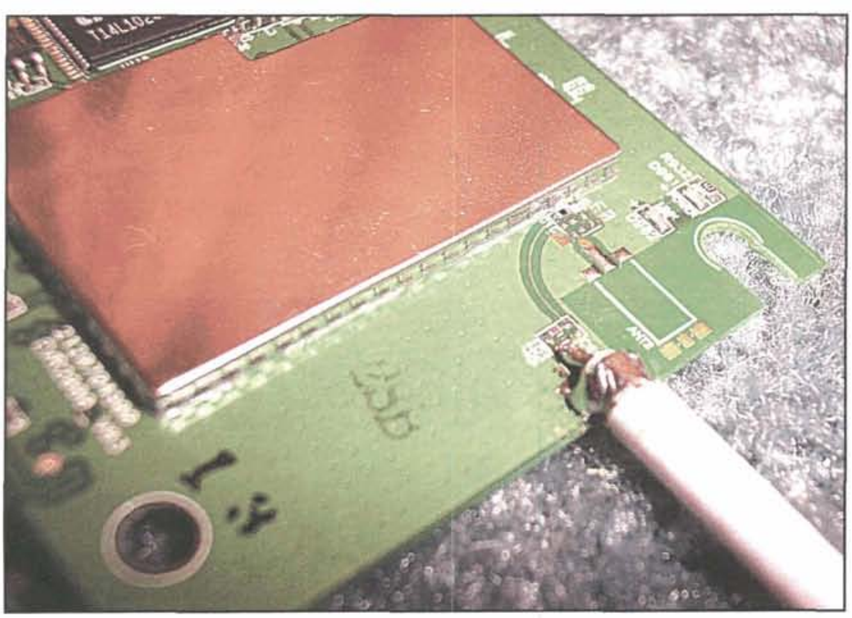

Fig. 1– A close-up view of the Linksys network card's antenna-connection point. Here you see the RG-58 cable that I soldered onto the board after unsoldering the original internal antenna connection.

short-hop link to be able to build longer links some time in the future using 802.11b networking gear. I learned a lot during this process, and that is what I will share with you here.

802.11b equipment is named after the IEEE standard describing the protocol and frequency standards for these 2.4 GHz wireless network adapters. You might see 802.11**a** equipment, which is for the 5.7 GHz band. Much like 802.11b, only some of the channels fall within the amateur 13 cm allocation. Note that a new standard is just about to enter the market, 802.11**g**, which uses the modulation techniques of 802.11a on the 2.4 GHz frequency band. For now, my advice is to stick with the 2.4 GHz 802.11b equipment; it's less expensive and a little easier to work with.

At first I was trying to accomplish all this without having to buy anything at all. For some reason that didn't work, so I went to Best Buy and bought the cheapest 802.11b networking card I could find. Instead of getting an internal card, I decided on a USB interface. I bought a Linksys Wireless USB Network Adapter, Model WUSB11, version 2.6, for about $90. Note that there are choices other than USB for the computer interface; just select the one which works best for you.

Configuration

Installation and configuration are simple. Just pop in the CD-ROM and install the software, then connect the adapter to the USB port, and in a few minutes you're nearly ready. For peer-to-peer networking (direct computer-to-computer communication), as opposed to a central hub or router, you should use the "Ad-Hoc" mode. If you use the "Infrastructure" mode, you must have a wireless hub or router at the other end, which might be an option for some sites. In this case, I wanted to communicate directly with another network card, so I went with the Ad-Hoc mode.

Next select a channel from 1 to 6 only, because only these lie entirely within the amateur 2.4 GHz band. Channels 7 and above have at least a portion outside the amateur allocation and should not be used under Part 97. Be sure to set the Encryption mode to Off or Disabled. Finally, set your station Identifier or SSID to your callsign, which I believe should be sufficient for FCC ID purposes.

My partner in all this was a neighbor who runs a medium-size communications technology company and has lots of toys, such as 802.11b-equipped laptops, to play with. He helped me test and debug our short-hop link.

After configuring both ends, we tried to establish a link with both computers in the same room. It worked perfectly the first time, and I was amazed at how easy it was. Informal testing showed that we had a range of only a hundred feet or so before the link quality (as shown by the configuration utility) started to degrade. Our next task was to get some high-gain antennas.

Antenna Connection

Before we discuss the antennas, we need to look at the modifications I had to make to the network adapter so I could connect an external antenna. Note that some 802.11b network adapters are equipped with connectors for an external antenna, but most—like the one I bought—are not. After ruminating on the topic for a few days, I worked up my courage and opened up my brand-new network adapter, breaking the "warranty void if broken" label in the process.

A single screw (in a recess under one of the rubber feet) and a few clips held the adapter together. I went slowly and carefully, using my trusty Swiss Army knife, and nothing broke in the process. The PC board came out easily, but the antenna was still encased in its housing. A few moments with the knife and some broken plastic later (it was glued), the antenna revealed itself as well. It turns out the antenna is a folded 1/2 wave, constructed from 1/32 inch FR4, and there's a 1/2-wave "ground plane" strip on the other side. For a sense of scale, the whole antenna board is 52 mm long.

Anyway, the best part was that the antenna was connected to the main board with a tiny piece of coax! I carefully unsoldered the coax from the board, making sure I didn't also desolder the very tiny SMT (surface mount technology) capacitor, about the size of a grain of salt. I connected a slightly longer length of Teflon® RG-58 coax (fig. 1) which terminated in a mini-UHF connector. I used a mini-UHF because it was handy, and I had the matching female end as well. I suppose there would be better choices for 2.4 GHz. Something small, such as an MCX, or even a BNC, would probably be better. Thus, with a careful touch of a soldering iron my Part 15 device was converted to Part 97 operation.

Antennas

Now let's talk about antennas. Based on our experiments, I guessed that I would need about 100 times the gain, which is 20 dB, to span a half mile. It was just a guess, not a calculation, and helped me limit my antenna search to ones with at least 10 dBi gain. (Two 10 dBi antennas—one at each end—provide a "system gain" of 20 dBi.) At least it was a place to start.

On the internet I searched Google for "802.11b antenna," and the first site that came up was the wireless networking site run by Greg Rehm, KD7RCG, at <http://www.turnpoint.net/wireless/index.html>. There are links to a few homebuilt 2.4 GHz antennas, one even designed by Greg himself. My favorites are the "Pringle's potato chip" Yagi and Greg's "Nalley Beef Stew" horn. I felt that either should provide the gain I was looking for, and the beef stew horn seemed to be the better of the two, both in terms of performance and ease of assembly. I also visited two commercial sites, Down East Microwave <http://www.downeastmicrowave.com/>, which sells a 17.5 dBi loop Yagi for $99 assembled, and Resources Unlimited <http://www.resunltd4u.com>, which has a 24 dBi parabolic grid for $129. Both sites sell other antennas as well.

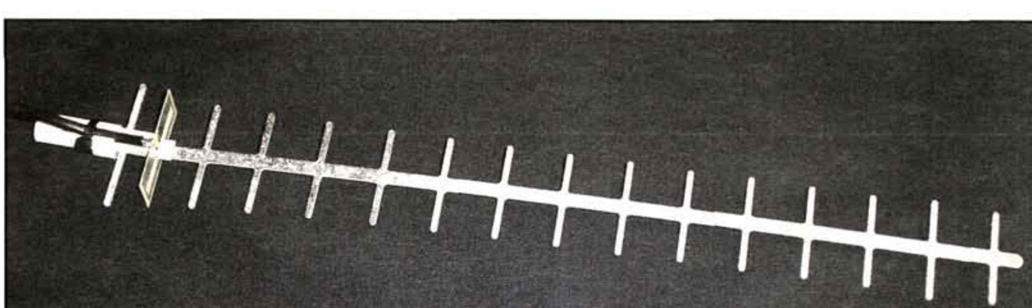

Fig. 2– The Aironet WLAN antenna. This is a simple 16-element Yagi with a PC-board driven element, sporting 13.5 dBi gain. It is stamped from a single piece of 1/16 inch aluminum sheet. Refer to the text and Table I for construction details.

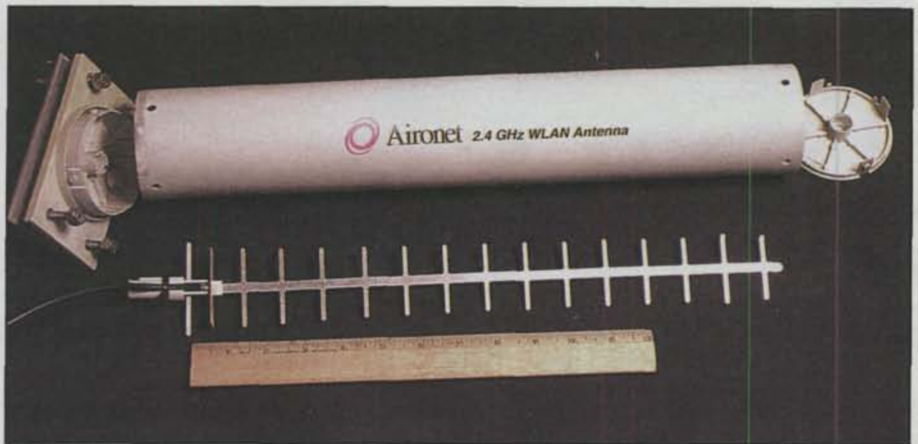

Fig. 3– The Aironet antenna and its plastic-tube radome. If you build one at home, you can use regular plastic pipe instead. A mounting plate is at the rear.

Director	Width overall	Distance
1	2 1/8	3/4
2	2 1/16	1 3/4
3	1 31/32	2 13/16
4	1 15/16	3 15/16
5	1 7/8	5
6	1 7/8	6 1/16
7	1 27/32	7 1/8
8	1 27/32	8 3/16
9	1 25/32	9 1/4
10	1 13/16	10 5/16
11	1 25/32	11 3/8
12	1 25/32	12 7/16
13	1 15/16	13 1/2
14	1 25/32	14 9/16

Table I– Director dimensions and positioning (all dimensions in inches). See text for driven element (DE) and reflector dimensions. The distances are measured from the front of the DE to the rear of the element. Director 1 is closest to the DE; director 14 is farthest.

In retrospect, I at least should have built one of the homebrew antennas. Maybe I will someday. I was spared the need, however: Out of the blue, a friend of a friend contacted me, having bought some gear from me last year at a hamfest. I had some more stuff I knew he would find useful for a project, and it turned out that he happened to have a nice 2.4 GHz Yagi he was willing to trade. After a few days I was the proud owner of a used commercial 2.4 GHz Yagi designed just for 802.11b gear and rated at a healthy 13.5 dBi.

Of course, I then did what every good ham does with a new piece of equipment, before even testing it to see if it would work: I took it apart. What came out is shown in fig. 2. Since those homebrew antennas are well documented on the web, I'll document the commercial antenna here, and readers can then make or buy the antenna they prefer.

The Aironet Antenna

The Aironet WLAN antenna, model AIR-ANT1949, is designed for use with Cisco equipment. Details on the antenna can be found at <http://www.cisco.com/>; search on Aironet Antenna. It is a compact unit housed in a plastic radome. It comes equipped with about three feet of RG-58U, terminated with a reverse-polarity TNC connector.

The reverse-polarity connector—a male TNC connector body with a female contact pin inside—is the opposite of what you would normally be able to buy. Manufacturers use these uncommon connectors to help ensure the antenna is not connected to equipment for which it is not intended, as specified by the FCC's Part 15 rules. However, you can buy these reverse-polarity connectors from many on-line connector vendors, such as The RF Connection <http://www.therfc.com> or Cable Experts <http://www.cablexperts.com>. Also remember that modifying an antenna invalidates your permission to use it with any 802.11b equipment under Part 15. If you buy or build one and use it *exclusively* under Part 97, as I did, then there shouldn't be a problem.

Opening up the radome revealed a very simple 16-element Yagi antenna made from a single piece of 1/16 inch aluminum sheet and a small piece of PC board. There are 14 directors, each 1/8 inch wide from front to back, on a 1/4 inch wide boom. See Table I for the director dimensions. The reflector is also 1/8 inch wide from front to back, 2 1/2 inch wide, and positioned 9/16 inch from the front of the driven element. Overall, the antenna is about 16 inches long and 2.5 inches wide at its widest. It was originally mounted inside a plastic tube, as shown in fig. 3, but you can also use a piece of 3 inch plastic pipe. On the original, slots in the end caps kept the antenna centered, which you can also do, or use plastic disks instead. End caps are still a good idea, to keep insects out.

If you were manufacturing thousands of these antennas, then creating a tool to stamp them out would be worth it. For the rest of us, a few hours with a nibbling

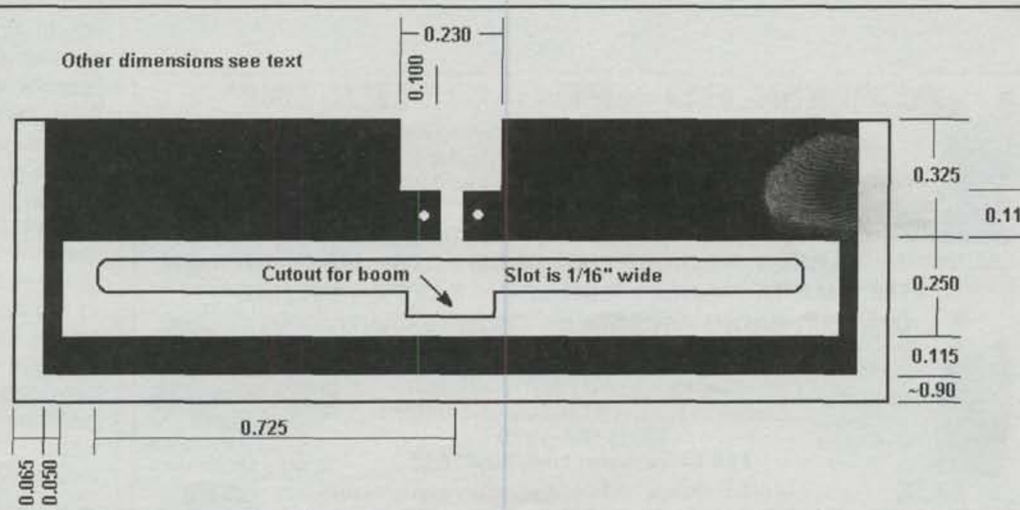

Fig. 4– Etching dimensions of the driven element. This is fabricated from single-sided 1/32 inch thick ceramic PC-board material. The coaxial feedline center conductor is soldered into one of the holes near the center, the shield into the other hole.

tool should take care of it. If you have access to a larger arbor press, you might make a punch and die set for cutting out the space between elements, sort of like a giant nibbling tool. Using copper instead of aluminum would allow an antenna to be soldered together out of individual strips. You could also use a band saw or similar to cut one out of sheet aluminum. If you made a full-size pattern on the computer and cut the antenna out by hand, I'd guess it would take an evening's work. Add another evening etching the PC board driven element and assembling it into an antenna. Two evenings' work seems like a reasonable investment for such an antenna. Note that the Pringle's and Beef Stew antennas might take half that time.

Fig. 4 shows the etching dimensions of the driven element (DE) as best I can measure with a micrometer and magnifying glass. The DE is made from a piece of cream-colored ceramic-like PC board material (perhaps Rogers RT/duroid®) 1/32 inch thick. It is exactly 2 inches wide and 0.780 inch high. There is a long 1/16 inch slot machined into the element, used to allow the DE to be slid into position past the reflector and onto the solid boom, between the reflector and first director. Once in position, there is another slot, 1/4" × 1/16", in which the boom rests. A 1/16 inch thick piece of plastic helps position and lock in the DE relative to the reflector, and also serves to support the coaxial feedline. It seems to me that one could use ordinary glass-epoxy material, or perhaps some microwave-type Teflon®, but this probably will affect the gain and performance somewhat. I imagine that the ceramic material would be difficult to cut, especially for the slot in the middle.

The feedline is soldered into the driven element as shown in fig. 5. It should not matter which point is used for the center conductor and which is used for the shield. In the photo you can also see the piece of plastic used for positioning, and imagine how the metal boom fits into the slot behind the plastic piece.

Fig. 5– Close-up of the driven element (DE). Note the soldered feedline connections, and the small plastic wedge which helps position the DE relative to the boom.

The Results

To sum up, after buying the least expensive wireless LAN adapter I could find, I configured it and got the link working at a short distance. Some simple experiments told me what kind of distance to expect, and I modified the LAN adapter to accommodate an external antenna by soldering a new piece of coax to the RF output point (Remember, this makes the adapter illegal for Part 15 use.). After lucking into an antenna that should work, I changed the connector to match our LAN adapters. Antenna aiming took some time and coordination, but the link ended up working just fine. If I had had to buy everything new, it still wouldn't have cost $500 for both ends.

I hope that this information will help you when you assemble your own high-speed data link. You might want to set up something to remotely operate your HF or VHF digital station from a laptop; multi-op contest stations might use these links for their logging networks; or you might want to actually communicate with a fellow ham keyboard-to-keyboard. The network adapters are very inexpensive, antennas can be built or bought, and distances of a dozen miles line of sight shouldn't pose any significant challenges. Just remember that feedline losses at 2.4 GHz can be huge, high-gain antennas have narrow beamwidths, and don't be tempted to use these techniques outside of amateur radio.

Next time, we'll review some the many ways we can send data over radio, with an emphasis on HF modes. In the months that follow, we'll take a closer look at some of these modes, with some practical advice on how you can start using them. If you have any questions, comments, or thoughts on what I should cover in future columns, please write. I'd love to hear from you.

73, Don, N2IRZ