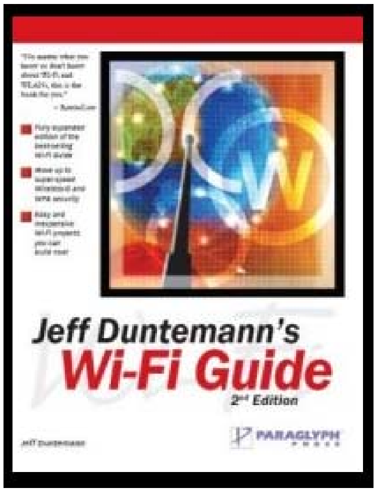

Jeff Duntemann's Tetra-Brik Wi-Fi Antenna How-To

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For more on Wi-Fi antennas, don't miss
Jeff Duntemann's Wi-Fi Guide, 2nd Edition

Introduction

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A lot more has been said than written about the legendary Pringle's Can Wi-Fi antenna, and a lot more people have talked glowingly about them without ever actually *using* one. Look closely, and you'll see that you have to add various things to it to make it work even so-so. Unless you have a can with a foil lining (not all Pringle's cans that I've seen do) and unless you can make good electrical contact to that foil lining (not a slam-dunk, trust me!) the can won't act as a waveguide antenna and thus won't throw your signal very far or bring in anything from a distance.

Don't obsess on the Pringle's solution. There's an easier kitchen-trash antenna to be had: The Tetra Brik Soup Box. Even as recently as mid-2002 these were uncommon in the United States, though they have been around for years in Europe. Now, however, Swanson's Chicken Broth in a Tetra Brik can be found in almost any major supermarket. In most health food supermarkets you can also find non-dairy milk substitutes (rice milk, soy milk, oat milk, etc.) in 32-oz Tetra Brik containers.

In this brief Web-based how-to I won't go into gruesome detail on the physics of waveguide antennas. I spend a lot of time on that in my book, and if you're curious about how it all works, please pick up a copy. Be aware, however, that you're building a rectangular waveguide antenna. The calculations are somewhat different than for circular waveguide antennas, like coffee can, spaghetti can, or (yes) Pringle's can antennas.

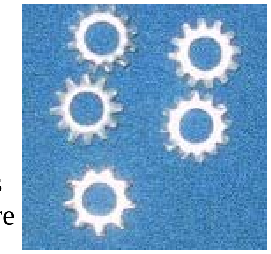
What You'll Need and What You're In For

The process of making a Tetra Brik antenna involves some knife work, a little—very little!—soldering, and (horrors!) some calculator math. Use a *sharp* knife or single-edged razor blade. A dull knife will mostly just deform the cardboard and put you in danger of getting yourself sliced up. Whatever you use, be careful.

The necessary materials are these:

1. A Tetra Brik of a suitable size. More on this below.
2. About 2 inches of #12 or #14 copper wire. This is just a scrap, and it's the gauge of wire commonly used in house wiring. If there's a construction site nearby, look in the dirt or in the site dumpster for scraps.
3. A silver-plated type N male coaxial connector, chassis (that is, 4-hole) mount. More on this below.

4. Four round-head machine screws, size 4-40, 1/2" long.
5. Four 4-40 next nuts for the above screws.
6. Eight "spiny" lockwashers (see photo at right) of a suitable size for the above screws. These, by the way, are *very* important! I'll explain why later on.
7. (Optional) A handle or bracket of some kind. What this turns out to be depends on how you intend to use the antenna. More on this below.



You'll need these tools:

1. A sharp knife or single-edged razor blade. A round needle file with a sharp point ground on its tip is also useful for making screw holes in the cardboard Brik.
2. A small soldering iron, and a scrap of electrical solder. (Don't use acid-core metalworking solder!) You don't need much.
3. A small screwdriver and nut driver for the size of the hex nuts that you use. The nuts are usually 1/4" in diameter.
4. If you intend to make a metal bracket or handle, you'll need a drill of some kind, to drill holes for the N connector and four mounting screws. The handle is optional; some people (in keeping with the kitchen-trash nature of the project) just use duct tape.

If you're still up for it, let's get to work.

Step 1. Get Yourself a Brik!

Above are three common products packaged in Tetra Brik containers. All of the Briks that I've seen in stores are of a suitable size for Wi-Fi antennas, but that may not always be the case in the future, so be prepared to do some measuring. The Swanson 1 quart (32 oz) soup boxes are the ones I've had most experience with. They are 65 X 95 X 165 millimeters. The Tetra Brik container (as opposed to the soup) is a European product, hence the metric measurements. Since I first wrote this tutorial, I've begun seeing one-quart Briks that are a little bit smaller in cross-section but a little bit taller, and measure in at 58 X 90 X 195 mm. I think this new size is an Americanization of the package, as its English measurements are 2 1/4" X 3 1/2" X 7 5/8". This is not different enough to cause a problem; however, anything more than about 50% larger than the Briks shown here may not be suitable at the 2.4 GHz Wi-Fi frequencies.

At right I show the logo at the bottom of the carton. Look for it.

Make the soup for lunch (I recommend adding some Egg-n-Onion Matzo!) and you're there.

The outside surface of Tetra Brik containers is slick and waxy-feeling, and doesn't take pen or pencil markings very well. Use a fine-point permanent marker like a Sharpie to put lines on the Brik for cutting or hole-poking.

Step 2. Cut the End Off and Clean It Up

Take a *sharp* knife or single-edged razor blade and cut off the top of the Tetra Brik as cleanly as you can. Tip: cut about an eighth of an inch down from the top of the box. For the cleanest cut, draw good straight lines in Sharpie marker on the brik where you intend to cut, and follow the lines with the knife or razor blade.

Discard the cut-off end (you won't need it, except perhaps for practice in poking or drilling screw holes) and clean the inside of the Brik well with soap and water. Most soup has garlic and/or onion powder in it, and the last thing you want is an antenna that smells like bad Italian cooking. Besides, the worse it smells, the more likely it is that your dog will haul it off into a corner and shred it for you.

Step 3. Measure the Brik and Calculate the Feed Point Dimension

I've seen (and used) two suitable sizes of Tetra Brik container in American supermarkets, and I suspect that as they become more popular in the US, even more sizes will become available. *The size of the Brik is critical to calculating the correct feed point.* What works for one size will work less well (or perhaps not at all) for a different size. You must measure the Brik and calculate a feed point dimension for that particular Brik.

There are basically three calculations that must be done: 1) The *free space wavelength* for the frequency of the Wi-Fi channel that we're using; 2) the *cutoff wavelength* for the Tetra Brik that we've chosen; and 3) the *guide wavelength* for the Tetra Brik that we've chosen. The guide wavelength calculation depends on the first two calculations, so they must be done in order as explained below. Note that the calculations are best done using metric units, because the speed of light is very close to 300,000,000 meters per second.

The free space wavelength depends *only* on the microwave frequency at which Wi-Fi operates. For Wi-Fi channel 6, the frequency is 2.437 GHz, which is the same as 2437 MHz. Free-space wavelength can easily be calculated by dividing the speed of light in millions of meters per second by the frequency, in millions of cycles (Hertz) per second. Because both values are numbers of millions, the "millions" cancels out, and you can use a formula like this to calculate the free-space wavelength in meters:

300

2437

This yields .1231 meters, or 12.31 centimeters. That's your free space wavelength. Channel 6 is the center of the Wi-Fi band in the US. If you calculate your antenna for Channel 6 it should actually work fairly well all across the band. On the other hand, if you want to calculate a value for one of the two ends of the band, use the frequencies of 2412 MHz for Channel 1, or 2462 MHz for Channel 11.

The second calculation is even easier: The cutoff wavelength is twice the width of the Brik's long face. (*Not* the Brik's length!) For the Swanson's Brik, that's 95 mm X 2, or 190 mm, which is 19 cm. "Cutoff wavelength" is just that: The wavelength beyond which the antenna will not work effectively. This isn't an issue for Wi-Fi, which has a wavelength of 12.5 cm at its longest. The value, however, must be plugged into the next calculation.

The final calculation is for the Brik's guide wavelength value. This is a little more involved, and is a function of the frequency and the geometry of the waveguide. The formula doesn't render well using any graphics tools I have, so I'll express it in Pascal:

```
GuideWavelenth = 1 /
SQRT(SQR(1/FreeSpaceWavelength)-SQR(1/CutoffWavelength));
```

Express all values in *meters*, not centimeters or millimeters. In other words, rather than use 12.31 centimeters for free space wavelength, type it into your calculator as .1231 meters. Ditto cutoff wavelength. The result value will also be in meters.

Here's an example for practice. Plug the values into the equation to see if you come out with the same answer!

- Channel 6 free space wavelength = .1231 m.
- Cutoff wavelength for 95 mm wide Brik = 2 X .095 m = .190 m
- Guide wavelength (from formula above) = .1616 m.

With the calculated guide wavelength figure in hand, divide it by four to yield the feed point offset from the bottom of the Brik:

- Feed point offset = .1616 / 4 = .040 m.

That's the crucial value for the next step.

Step 4. Mark the Feed Point and Make the Hole

The feed point is positioned along a line down the center of the *front* face of the Brik. There is a seam down the center of the back face which will make mounting the N connector difficult. That's why you must use the front face. Unless you're paranoid about the final appearance of the antenna (and hey, it's made out of kitchen trash, right?) I recommend drawing a line down the length of the front face, at the center, as shown in the photo.

Measure your feed point offset value from the bottom of the Brik along the center line of the front face. In the photo at left, I stuck a white self-adhesive address label to the Brik so that the mark

indicating the feed point would not be lost amidst the details of that vegetable medley, heh.

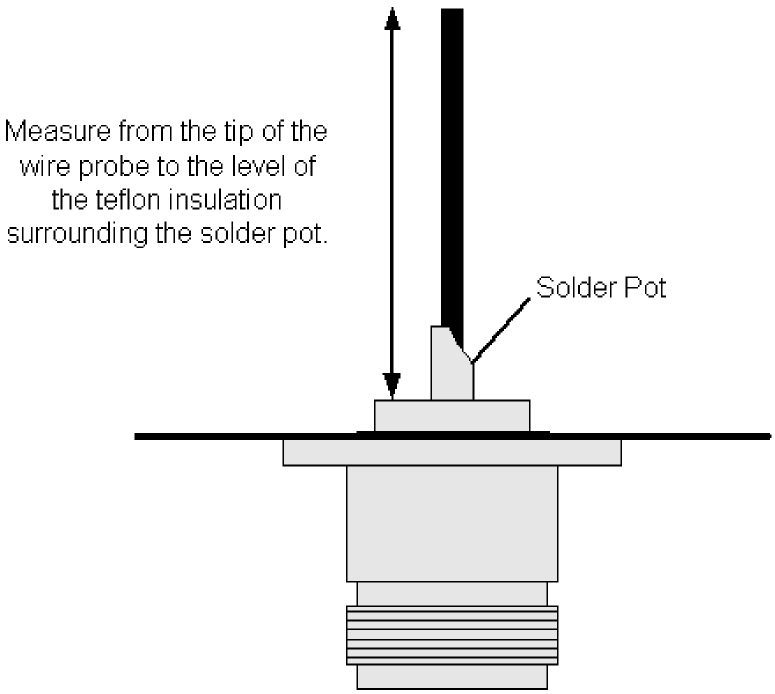
Next, draw a circle centered on the feed point spot, 5/8" in diameter. This is the diameter of the coaxial N connector flange that must pass through the wall of the Brik. Using a very sharp knife or razor blade, carefully cut out the 5/8" circle completely and discard the round piece.

At this point, set the Brik aside. We need to make the probe assembly.

Step 5. Make the Probe Assembly

The probe consists of a male N coaxial connector with a short length of #12 or #14 copper wire soldered into its "solder pot." At left is a photo of a pair of silver-plated N connectors, which I purchased from [Fleeman, Anderson, & Bird]. Nickel-plated N connectors can be had for less, but they may not be "microwave-friendly" due to lossy insulation material. Go for silver. Be suspicious of anything with yellow or non-white insulation around the solder pot. Some older and cheaper N connectors use phenolic insulation, which is lossy at microwave frequencies.

Find a piece of #12 copper wire about 2" long. #14 will do, but it's thinner and bends more easily. #12 is a common size in residential electrical wiring, and you can find scraps lying around almost any construction site. Remove any insulation. Straighten the piece of wire as completely as you can. Solder the wire into the N connector's solder pot, which is the little copper-colored protrusion pointing upward in the right hand photo above.Make sure that the wire is perpendicular to the connector's flange. If it solders crooked, re-melt the solder and straighten it.



The touchiest measurement in the whole Tetra Brik antenna project is the length of the wire in the probe assembly. The length is the free-space wavelength divided by four. For Channel 6, that would be 123.1 millimeters divided by 4, or 30.77 mm. Now, the idea here is to do your best. Admittedly, measuring a fraction of a millimeter is a dicey business, and although the closer you come, the more sensitive your antenna will be on Channel 6.

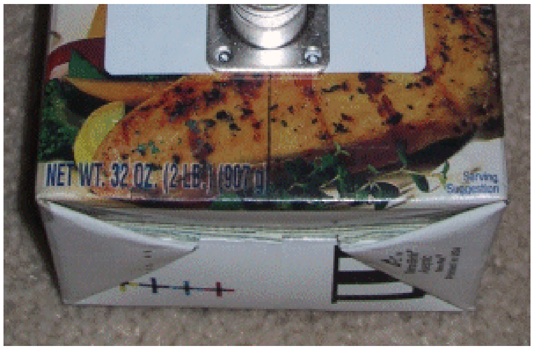
When you're talking accuracy to the millimeter, the question of where to measure *from* is significant. One end, obviously, is the tip of the wire probe. If you cut it unevenly, file it with a small file so that it's reasonably rounded and flat on the end. The other end of the measurement is to the level of the white Teflon insulation that surrounds the solder pot of the N connector. That's key: *You're measuring from the probe tip to the point where the solder pot emerges from the coaxial structure of the connector.*

It's best to measure it a millimeter or so on the long side, and then carefully file the tip to bring it down to the final desired length. But once you've got it to the correct length, the probe assembly is done.

Step 6. Mount the Probe to the Brik

Place the probe point-down on the Brik, with the point passing through the 5/8" hole you cut in the front face of the Brik. Center the N connector body on the line you drew on the Brik. Take a marker and mark the four mounting holes onto the Brik, as shown at left. Placing a mailing label on the Brik (as I show here) helps to make the marked points more visible.

The holes you need to poke through the Brik for the four mounting screws are

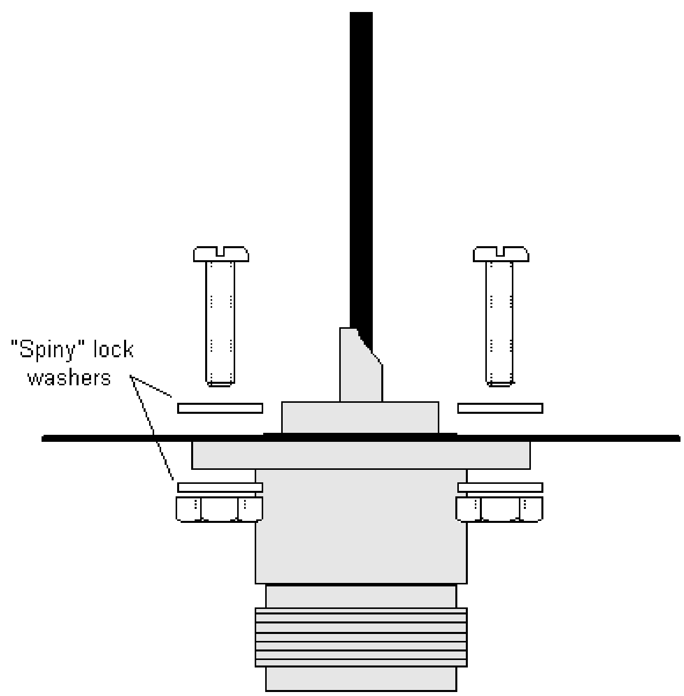


small, about 7/64". An awl will work, and some jackknives have something trekkers call a drill, which is really a type of awl. I use a round needle file with a sharp point ground on the tip. If it's sharp it will do the job. Using a needle file allows you to make a crisp, clean hole by poking the file through the cardboard and then filing the holes to a diameter that will pass the mounting screws.

You can also use a hand drill or Dremel tool with a 7/64" bit. Drilling cardboard is trickier than it sounds; experiment on the discarded top of the Brik if you're not experienced in drilling flimsy materials. Tip: Insert a length of 2" X 2" pine lumber into the Brik so that you're drilling through the cardboard into the wood, The wood will support the Brik and make for cleaner holes.

After drilling or poking the four mounting holes, take a razor blade and trim away any cardboard protruding from the holes into the Brik. You want the holes to be as smooth as possible so that the screw heads will lay flat against the plastic/foil liner, and not against cardboard gouged out of the outer layers.

This next step is probably the trickiest part of the project, aside from measuring the probe length. The trick lies in the way the Brik is made, and how the N connector body must have good, four-point electrical contact to the Brik's inner foil layer. The Brik is a three-layer construct: A cardboard box contains a thin foil inner lining, which in turn is coated with a thin plastic film to keep the Brik's contents from attacking the foil liner. The four screws that mount the probe assembly to the Brik *must* contact the foil. This is *not* easy!



The way I found works best is to use eight spiny lock washers. As shown in the technical drawing at right, the lock washers go under the heads of the four mounting screws, as well as under the hex nuts on the other side of the N connector's square flange. When you tighten down the hex nuts, use a nut driver and push them hard. You must tighten the hex nuts sufficiently hard so that they force the lock washer spines through the thin plastic film covering the foil, allowing the washers to make electrical contact with the foil. *For the Brik antenna to work well, the Brik's foil liner must contact the N connector body!*

Test it with an ohmmeter after tightening the four hex nuts: Touch the N connector body with one probe, and force the tip of the other probe through the plastic film layer to contact the foil liner. If you don't get solid continuity, you're not done. Tighten the hex nuts a little more and test for continuity again. If necessary, *carefully* abrade away the

plastic film over the four mounting holes with the finest sandpaper you can find. Don't sand too hard or you'll destroy the foil underneath, which means you'll have to have some more soup for lunch and start from scratch with a new Brik! (Note: Make sure your test probes are
sharp enough at their tips to pierce the plastic film layer to the foil
beneath. If necessary, file or bench-grind at least one one needle-sharp.)

Step 7. Attach the Brik to a Handle Or a Bracket

An antenna like this needs to be mounted to be useful. What sort of thing you mount it to depends on how you intend to use it. It can be used as a "bandwidth expander" to bring a Wi-Fi marginal connection up to full bit rate. I detail how this situation occurred to me in my book in Chapter 15. I was getting only 1 Mbps (if I could connect at all) from my living room coffee table, because my metal-filled kitchen lay on a long path between the coffee table and my wireless access point. Using a simple soup-box antenna on a home-made stand, I was able to point the antenna toward the access point and immediately bring the connection up to full speed. Precision aiming was not required.

The bracket is nothing more than a scrap of aluminum bent in a vise and drilled for the 5/8" body of the N connector and the four 1/8" mounting holes. The bracket in turn is bolted to a scrap aluminum heat sink, which provides nothing more than ballast to keep it upright.

Another obvious support would be a camera tripod. The hole in the bottom of the bracket shown in the photo at left has a 1/4" diameter hole, to match the 1/4-20 thread stud standard on most inexpensive tripods.

The antenna can also be used for warscanning—that is, for standing in one place, perhaps on a hill ot atop a tall building—and manually scanning the vicinity for accesspoints using NetStumbler. I've used a photo tripod as a support for warscanning on occasion, but I also created a sort of "pistol grip" handle for Wi-Fi antennas so that I can aim them by hand. The pistol grip antenna is more portable without a tripod, though it's a little trickier to aim steadily enough to allow your stumbling utility to pick out the really faint ones. The pistol grip is shown in the photo below:

As a matter of habit, I only mount my home-brew Wi-Fi antennas by the N connector. This allows me to use any bracket or handle for any antenna, and I can mix'n'match as needed. (I haven't yet made an antenna so massive or heavy that it can't be mounted by its N connector...but that day will come.) This also allows you to make as few holes in the Brik as possible, which is good. The more screw heads and holes in the Brik, the more signal scattering will occur inside the Brik, and the higher your noise level will be.

At left is the same handle mounted to the Brik antenna I've just described. Using a handle with a Wi-Fi waveguide antenna (like this one) takes a steady hand and some patience. The longer the waveguide, the fussier the aiming of the antenna is, and this is about as long a waveguide antenna as you can usefully aim by hand.

As an example of a waveguide antenna that's a little too long, see the picture at lower right. The can is steel, and contained a bottle of Malibu spiced rum. I was able to use it effectively when it was mounted to a camera tripod, but trying to warscan by holding it in my hand failed completely.

I cover the use of tin cans and the calculations that go with them at great detail in my book. The rum can antenna would work better if it were shortened by three or four inches. Any waveguide antenna, furthermore, works better with a flared metal horn at the "mouth," but that's a lot of fussy metalwork and I

won't go into the calculations in this simple how-to. For more about horns used with Brik antennas, see this site. A full-fledged general-use Javascript horn designer can be found here. If you're good with a tinsnips and a (heavy-duty) soldering iron, you can make an excellent waveguide antenna horn with copper roof flashing.

Done! Now, how good an antenna *is* it?

My testing shows that it's way better than a Pringle's can, but not quite as good as a Hunt's Spaghetti Sauce can. (I explain in considerable detail how to build the Hunt's cantenna in Chapter 15 of my book.) Much depends on how good an electrical connection you can manage between the Brik's foil lining and the body of the N connector. If the antenna doesn't appear to perform for you, that's the first thing you should check. Use an ohmmeter with two probes with good sharp points, and test electrical continuity between the body of the N connector and the foil lining of the Brik. If you don't get a kick to zero ohms, tighten the screws with the spiny lockwashers. Keep in mind that it's the lockwasher spines that pierce the insulating transparent plastic film and allow connection to the inner layer of aluminum foil. Without that connection, you don't have a waveguide antenna, and your results will be down in the trash somewhere.

Also check that you measured the probe wire correctly and that it's as close as possible to the calculated length. At microwave frequencies, an eighth of an inch *counts*.

Software, Sources, and References

Wardriving Software:

- NetStumbler.com, for the NetStumbler and MiniStumbler utilities.
- Aerosol, a simple wardriving utility for Windows that supports some USB client adapters, including Linksys WUSB11. Good device support, fairly minimal feature set. Requires a protocol driver like WinPCap.
- Kismet is probably the most commonly used wardriving utility for Linux. It works in monitor mode and can detect APs whether or not their broadcast beacons are operating.
- AirTraf, a curses-based (i.e., text mode) wardriving utility for Linux. A CD-bootable version for Windows users is promised; this will boot into Linux without affecting the underlying system. Not available yet.
- DStumbler is part of BSD-Airtools, and is a curses-based wardriving utility for BSD Unix.
- MacStumbler is similarly the leading utility for the Mac. OS/X only, and so far requires AirPort wireless hardware.
- KisMac is a wardriving utility for Mac OS/X that works in monitor mode (like Kismet, its only relationship thereto) and can detect APs that have their beacons disabled.
- PocketWarrior for PocketPC supports Prism-based clients cards on the PocketPC platform. Theoretically works with any NDIS 5.1-compatible Prism driver, but it's always best to check the list of supported cards.
- WarLinux, a CD-bootable version of Linux created specifically for wireless auditing. I haven't used it yet but it's a promising idea: Configure Linux with all the machinery already in place for wireless network auditing.

- Warglue is a suite of console (text-mode) utilities for converting among the three major wardriving logfile formats: NS1, (NetStumbler) Kismet, and Wiscan. Warglue also contains a utility for knocking out defective GPS coordinates from a logfile.

Several other pertinent utilities exist (see the list at wardriving.com) but the ones listed above are the main ones.

Pigtails & N Connectors:

- My personal favorite source for wardriving hardware (antennas and connectors, primarily) is Fleeman, Anderson, and Bird. They sell goods related to Wi-Fi generally, but have paid special attention to the sorts of things wardrivers use. Their omnidirectional mag-mount antenna beats anything I myself have ever tried, including Pringle's and various tin-can antennas. They also sell every conceivable type of pigtail, silver-plated coaxial connectors, and microwave-capable coaxial cable.

Books on Antenna Theory:

- *The ARRL UHF/Microwave Experimenter's Manual*, The American Radio Relay League, 5th printing, 2000. A steal for $20. This is where I learned most of my microwave antenna theory, and is the place to go if you want more details on how these things actually work.

Other Tetra Brik Tinkerers on the Web:

- 802.11b Horn Antenna Designer -- Good English translation of a French language site. Nice JavaScript horn calculator.
- Reseau Citoyen: Boite de Lait -- In French. Brush up on your BabelFish!
- Cardboard Horn -- A little sparse, but shows how to build a Brik into a larger cardboard-box horn for more gain. Nice!

Postscript: Version of 6/29/2006

Some (but only a little) of the material in this how-to is adapted from the latest edition of my book, *Jeff Duntemann's Wi-Fi Guide*. ISBN 1-932111-88-3 $34.99. If you found this how-to useful, please consider buying the book. It covers Wi-Fi antenna theory and construction in detail, along with pigtails, coax losses, link budgets, and a lot of other need-to-know material for extending the range of stock Wi-Fi gear.