MICROWAVELENGTHS

Intro/Antennas

W1GHZ at the workbench

Tom Williams, WA1MBA, has decided to retire from writing Microwavelengths and has asked me to fill in. A short bit of background: I have been licensed since 1962, as WV2ZZF, WA2ZZF, N1BWT and finally W1GHZ. Although I hold an Advanced class license (it took a long time to pass 13 wpm, so I'm keeping it), I have never made a contact below 50 MHz. Professionally, I do computer hardware design; microwaves is only a hobby, though I did work as a microwave engineer for several years.

Tom has done a great job of providing an introduction to microwaves, covering a broad topic in each column. If there are any topics he has missed, please let me know and we will try to address them. Otherwise, we will look at some of them in more detail, concentrating on practical examples, starting with antennas. With the limited space of two pages per column, these won't always cover all possibilities—what is important is up to my discretion, or lack thereof.

By practical examples, I mean things that a ham can do. When I was getting started in VHF, there was a magazine, the *VHFer*, published by Loren Parks, K7AAD. Under the title was the slogan "Learn by doing." When you take a course or read about something, you start to understand it, but you really learn when you actually do it. So we will try to include these practical examples.

Antennas

When asked why I like microwaves, my usual answer is that the antennas are big enough to be interesting—how many HF antennas are 25 wavelengths in diameter? My interest in antennas began when I finished my first 10 GHz transverter in 1993. Before this, we had been using Gunnplexer transceivers and simple horn antennas, having fun on wideband FM. I thought the transverter, operating SSB or CW, could use a dish antenna to increase DX possibilities. Since parabolic dish antennas have been around for years, there must surely be a clear explanation in *The ARRL Handbook*.

Well, it turned out to be much more complicated. There was enough information by W2IMU in the *ARRL VHF/UHF Experimenters Manual*[1] for me to put the dish together with a feed and get it on the air (*the most important part*) for the 10 GHz contest, but I didn't really feel I understood anything. I spent the next winter reading about antennas, including some professional antenna books where you can drown in math, and started to figure out some of it. Then I made some antennas, figured out how to measure antenna gain at 10 GHz, and made measurements to see if I'd gotten any of it right.

Since it took me a lot of effort to begin to understand microwave antennas, and others would probably have the same problem, I began writing what I had learned, in an attempt to make it more understandable for the amateur. This started as a paper for a Microwave Update conference, became a series of articles in *QEX*, and grew into an on-line antenna book as I read and learned more: the *W1GHZ Microwave Antenna Book—Online* at **www.w1ghz.org**. Unlike a paper book or magazine column, an online book can be continuously updated, improved, even corrected as needed. So, if you feel a need for more than we cover in a column, please go to my Web page.

Antenna Gain

One sunny afternoon, I was on top of Mt Wachusett in Massachusetts running some 10 GHz tests with WA1MBA, about 30 miles away. The path is line-of-sight, and Tom observed that my signal was 70 dB above the noise, a signal report much more useful than an S-meter reading (this report meant that my signal was received with 10 million times more power than the noise). I observed that our combined antenna gains totaled about 67 dB. If we had been using only dipole antennas, we would have struggled on CW. Antenna gain makes a real difference for microwaves.

What is antenna gain? Unlike an amplifier, an antenna does not increase the power of the signal—antennas cannot create energy! Instead, it concentrates some of the energy in a desired direction. The gain is the increase in radiated power in a given direction, compared with an antenna that radiates energy equally in all directions. This theoretical antenna that radiates equally in all directions is called an *isotropic* antenna, and the gain is referred to as *dBi*, gain over isotropic. Occasionally, gain will be given as *dBd*, gain over a dipole. Gain in dBi is 2.14 dB higher than gain in dBd. Advertising gains with no reference are usually bogus.

Gain of an antenna is primarily proportional to size—more gain requires a bigger antenna. The size that matters is the *aperture*, the effective electrical capture area of the antenna. Some antennas, like the Yagi-Uda beam, have an aperture larger than the physical cross-section, but horns and dishes are simple: the physical opening is the aperture. The larger the aperture, the narrower the beamwidth, so that more of the energy is concentrated in the desired direction, yielding more gain.

Horn Antennas

We are going to start out with horn antennas. Not only are they simple and easy to build, they work—a horn antenna almost always works as predicted, so we may use them with confidence. A horn alone is a good antenna, providing medium to high gain, up to perhaps 25 dBi. For higher gains, a horn can be a good feed for a parabolic dish. As a practical example, we will build a small 10 GHz horn, which is an ideal feedhorn for the ubiquitous DSS TV dish. Next month we will discuss dish antennas, with the feedhorn and DSS dish as our practical example.

A horn antenna starts out as a waveguide transmission line—an open-ended transmission line will radiate quite well, with a modest amount of gain, but the aperture area is quite small, only the cross-sectional area of the waveguide, with dimensions less than a wavelength. For higher gain, a larger aperture is needed, so the waveguide simply flares out to a larger aperture, like the horns in Figure 1. A horn for circular

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Figure 1—Horn antennas for microwave bands from 2.3 GHz to 24 GHz.

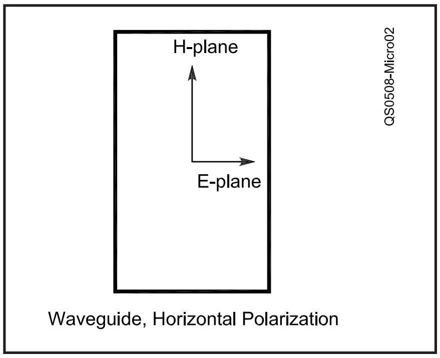

Figure 2—Orientation of E-plane and H-plane in waveguide.

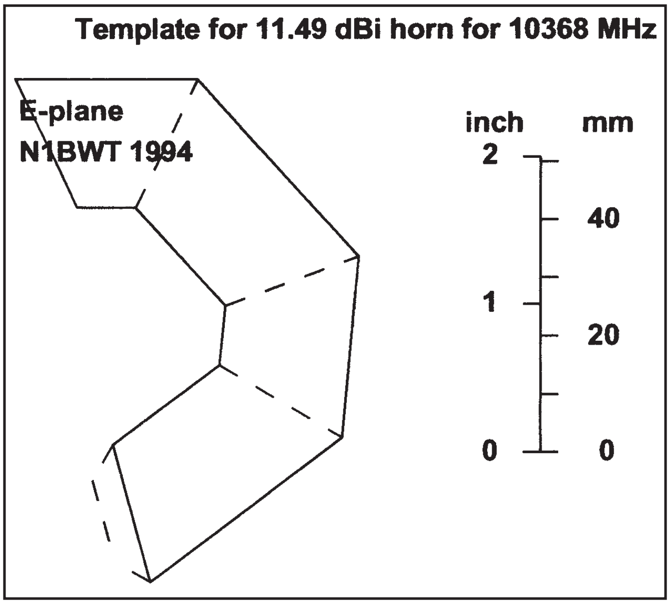

Figure 3—Template for 10 GHz feedhorn for DSS dish.

Figure 4—Using the template to cut out the horn.

Figure 5—Bending the horn along the fold lines.

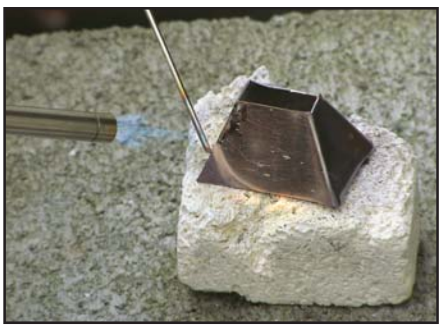

Figure 6—Soldering the open seam closed.

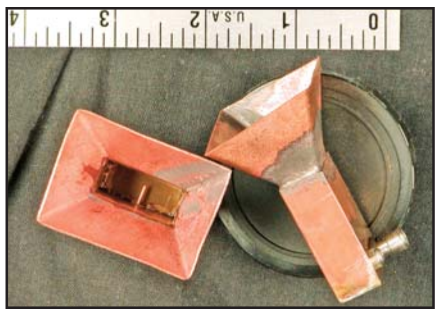

Figure 7—Finished feedhorns. The probe for the transition from waveguide to coax will be discussed in a future column.

waveguide looks just like a funnel.

Rectangular horns, also called pyramidal horns, are more common than circular. They have the advantage of providing more control over the radiation pattern, since the aspect ratio of the aperture is not fixed. The aperture might be narrow in one dimension, providing a broad beam, and large in the other dimension, making the beam narrower. Kraus[2] gives the following approximations for the 3 dB beamwidth in degrees:

$$\text{Eplane} = \frac{56}{Ae_{\lambda}} \text{ degrees} \qquad \text{[Eq 1]}$$

and

$$\text{Hplane} = \frac{67}{Ah_{\lambda}} \text{ degrees} \qquad \text{[Eq 2]}$$

where Ae_{λ} is the aperture dimension in wavelengths in the E-plane and Ah_{λ} is the aperture dimension in wavelengths in the H-plane. The E-plane and H-plane orientation is sketched in Figure 2. We often refer to the orientation of the E-plane as the polarization of the antenna.

Kraus also gives an approximate formula for the gain of a horn:

$$G \cong 10 \cdot \log_{10}\left(4.5 \cdot Ae\lambda \cdot Ah\lambda\right) \text{dbd} \qquad \text{[Eq 3]}$$

where gain is in dB over a dipole; add 2.14 dB for dBi. Note that the gain is proportional to the aperture *area*, since the two aperture dimensions are multiplied together.

The length of the horn provides impedance matching, from the transmission-line impedance in the waveguide to the impedance of free space, 377 Ω. A very long horn will have low VSWR but wastes metal and can become mechanically unwieldy. An "optimum" horn[3] is one that provides maximum gain per unit of metal area. My microwave antenna program, *HDL_ANT* (available on my Web site), will calculate an optimum horn for any frequency or calculate the gain of any arbitrary horn. It provides the option of drawing a template for horn fabrication, like the one shown in Figure 3.

The template is of a feedhorn for a DSS dish at 10 GHz, based on design graphs by G3RPE.[4] The horn aperture dimensions are 41 mm in the H-plane and 31.2 mm in the E-plane, and the axial length, from the end of the waveguide to the aperture plane, is 20 mm. The DSS dishes are ideal antennas for 10 GHz, and are readily available, but you can't buy a good feedhorn. Instead, we shall show how easy it is to make one.

The first step is to make a few copies of the template, adjusting the copier if possible so the inch scale is accurate. Then we tape one to some flashing copper or hobby brass, fold it up, and solder it together. Start by cutting out the template and folding it up to make a paper horn, to see how it goes together.

Take another copy of the template and cut around it leaving some margin. Tape this to a piece of copper and cut out the outside lines of the template with tinsnips, as shown in Figure 4. Then fold the copper along the lines; if you don't have a bending brake, just clamp each line in a vise, bend, and tap with a hammer to make a sharp seam, as shown in Figure 5. Remove the paper and tape, give it a final bend to get the final edges together, and solder the final seam. I like to use silver-braze with a torch, Figure 6, but ordinary solder and a big soldering iron works fine.

After it cools off, the copper is very soft and can be given a final bending to match WR-90 waveguide. Then solder it to the waveguide, file the inside of the joint smooth, and you have a feedhorn. Not only is it better than anything you can buy, it is something you can be proud of. If you want to polish it up and make it pretty, go ahead. Mine (Figure 7) is usually weathered—I'd rather use it than show it off.

In the next column, we will continue to learn by doing, using this horn as a feed for a DSS dish. If you aren't ready for 10 GHz yet, the same techniques apply at lower frequencies, with bigger but less critical dimensions.

Notes

[1]pp 9-26 to 9-43.

[2]John Kraus, W8JK, *Antennas*, New York: McGraw Hill, 1956.

[3]D. E. Cozzens, "Tables Ease Horn Design," *Microwaves*, Mar 1966, pp 37-39.

[4]D. Evans, G3RPE, "Pyramidal horn feeds for paraboloidal dishes," *Radio Communications*, Mar 1975. Also in: M. W. Dixon, G3FPR, *Microwave Handbook, Vol 3*, RSGB, 1992, p 18.85.