Sectoral Horn Antennas for Microwave Beacons

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Microwave beacons are really useful for monitoring propagation or just for reassurance that your gear is still operating. For rovers, they also provide an accurate heading and frequency. I monitor a 10 GHz beacon constantly so I am ready for any possible contacts.

Most beacons use omnidirectional antennas such as waveguide slot antennas to provide coverage in all directions. These antennas are omnidirectional, within a few dB, in the azimuth plane but have a narrower elevation pattern. The combination provides modest gain, typically 10 or 12 dB, around the azimuth.

The NEWS Group supports several beacons in New England. Recently, the 10 GHz beacon site on Mt. Washington, NH, FN44ig, was lost when the building housing it was removed. This beacon had excellent coverage and is a real loss. As a replacement site, Eric, KV1J, proposed a mountain in northwestern Maine to which he has access.

Since this location, FN44rq, is farther east than Mt. Washington, there is very little activity to the north and east. I suggested that we might consider a wide directional antenna that could mainly cover the parts of New England to the south and west where almost all activity occurs. In Figure 1, we can see that a 3 dB bandwidth of about 90° will cover most of the activity in New England. A second proposed 10 GHz beacon location on Cape Cod, in FN41, could also cover New England with a similar pattern, favoring the southern part of the region plus the New York, New Jersey, and Philadelphia metropolitan areas, without wasting power toward the ocean.

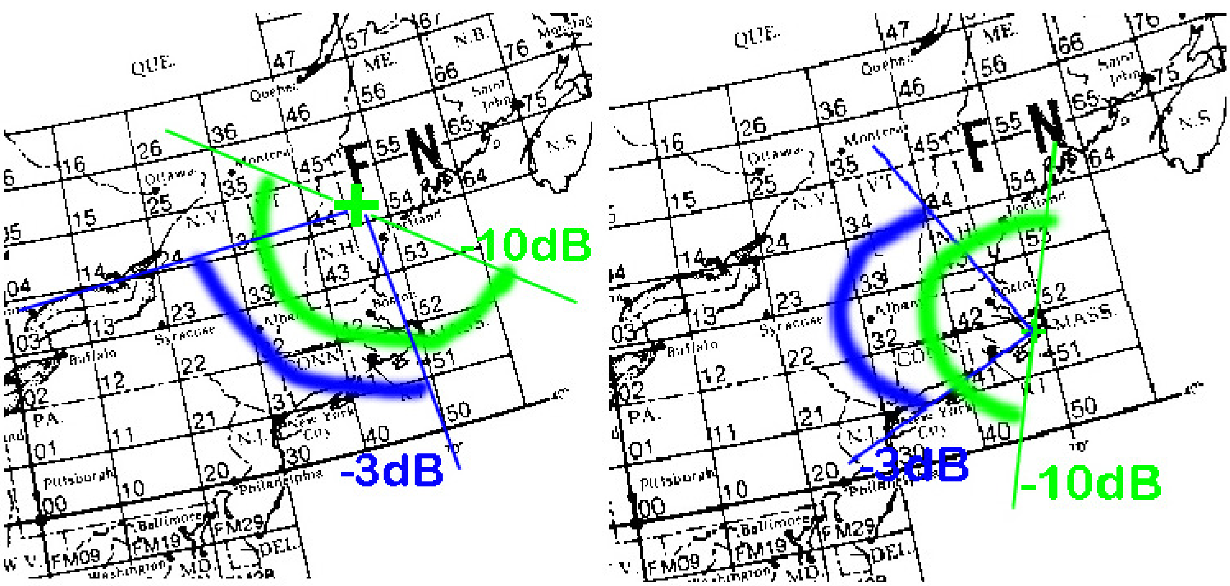

Figure 1 – An antenna pattern about 90° wide provides good coverage of New England from beacon locations in FN44, left, and FN41, right.

Sectoral Horn Antennas

The wide directional antenna I had in mind is a sectoral horn antenna, shaped to provide a wide azimuth pattern and a narrower elevation pattern. Kraus[1] gives these approximations for rectangular horn beamwidth, where A is the aperture dimension in wavelengths:

$$E_{plane} = \frac{56}{A_{e\lambda}} \text{ degrees}$$

$$H_{plane} = \frac{67}{A_{h\lambda}} \text{ degrees}$$

For horizontal polarization, the Eplane is azimuth and the Hplane is elevation. A 90° Eplane beamwidth needs as aperture width A_e of about 0.6λ. The Hplane aperture height can be as large as is convenient, to reduce the elevation beamwidth and reduce gain. Note that the beamwidth is inversely proportional to aperture size, so that a tall, narrow horn has a wide beamwidth and narrow vertical pattern. The flare length of a horn should be longer than the largest aperture dimension for a clean pattern.

To make a narrow and tall horn for 10 GHz, it seemed easier to machine one at the local makerspace, TheFoundryVT, than to fold and solder sheet metal as one might for a more conventional pyramidal horn. I fiddled some numbers to fit the aluminum stock available online in reasonable quantities and settled on a horn with $A_e = 0.544\lambda$, $A_h = 3.33\lambda$, and flare length of 3.33λ, to be machined in two halves from ¾ x4 inch aluminum bar.

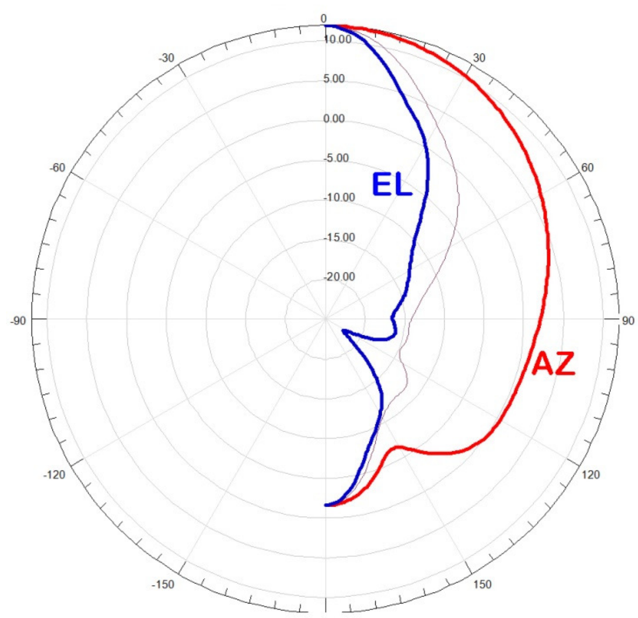

Figure 2 – Radiation patterns for a 10 GHz Sectoral Horn antenna

Simulations of these horn dimensions show a gain of about 12 dBi, with a -3dB beamwidth of 86° and a -10dB beamwidth of 180°. The elevation beamwidth is about 24 degrees, wide enough to fill in areas below the mountain and high enough for short rainscatter. An antenna pattern plot in Figure 2 shows a smooth azimuth pattern with no holes, so there is some signal available even for stations in unexpected directions, even off the back.

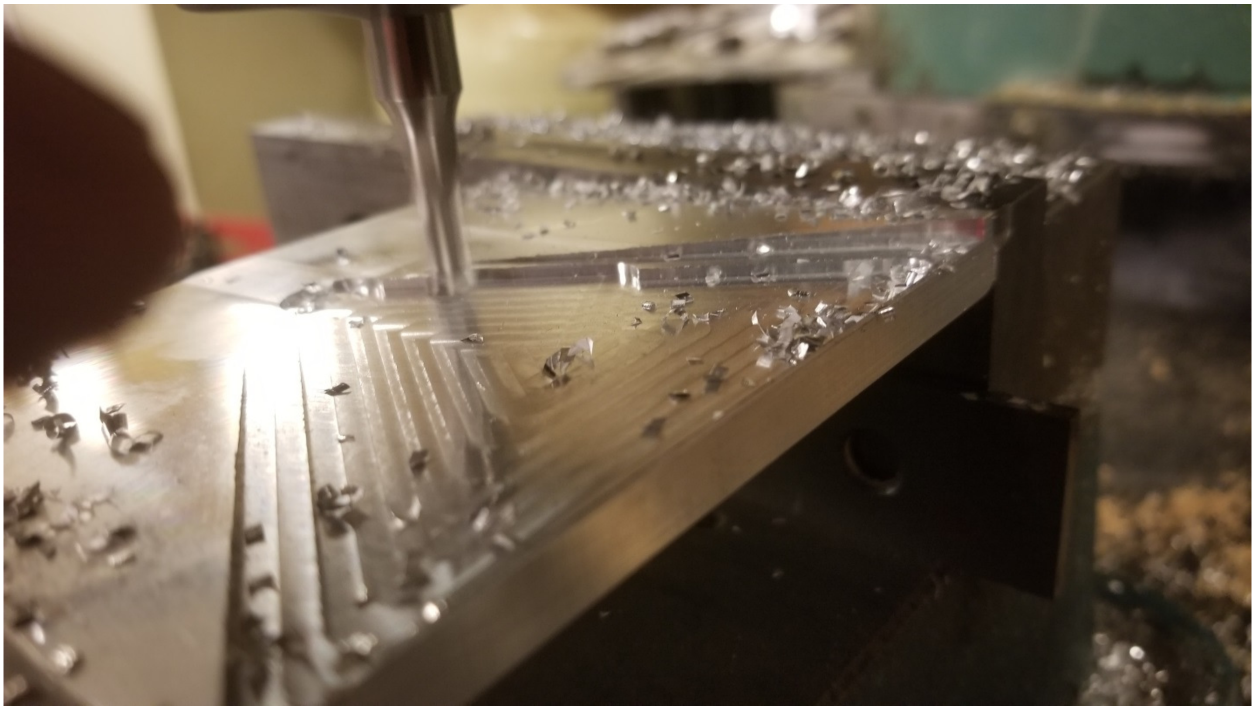

Figure 3 – Sectoral Horn half for 10 GHz being machined by CNC mill.

Figure 3 shows one half of a horn being machined. The horn has a compound flare: 2° in the Eplane is made by setting the stock on angle blocks while the wide Hplane flare is cut by the CNC milling machine. Then the WR-90 waveguide walls are cut square to the stock. A lot of metal is being removed, so milling time is about 1.5 hours. Two halves are screwed together to complete the horn – since they are made with the same CNC program, alignment is pretty good. Two finished horns are shown in Figure 4, one with WR-90 waveguide input and the other with an integral coax transition.

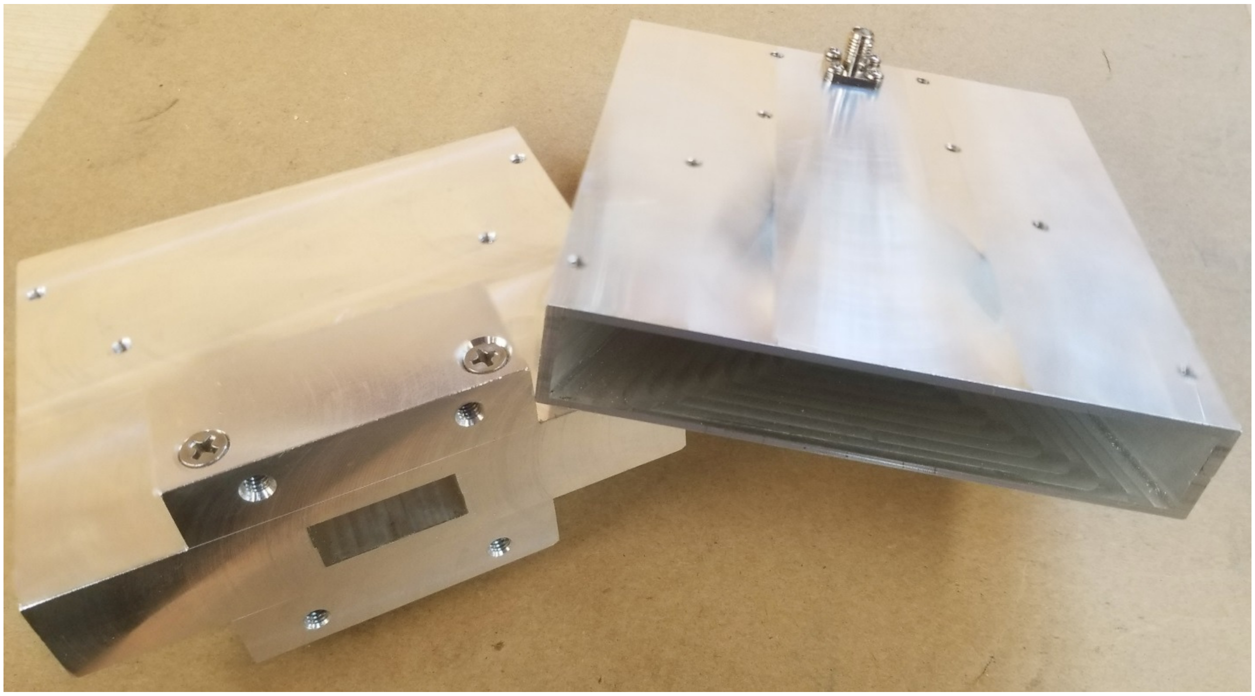

Figure 4 – Sectoral Horns for 10 GHz with WR-90 Waveguide input, left, and integral coax transition, right.

24 and 47 GHz

A threat to the amateur 47 GHz allocation several years ago led to an effort to put some 47 GHz beacons on the air. Tom, WA1MBA, started an effort to build some 47 GHz quadruplers to provide the beacon signals. He recently unveiled the results at the November 2022 NEWS meeting and will have them available at Microwave Update 2023.

Tom asked me if I could make a waveguide slot antenna for 47 GHz. NO! The slots would be too narrow (~0.012" wide) and too critical – beyond my skills. I mentioned my prototype sectoral horn for 10 GHz and suggested something similar would work for 47 GHz. I made a sketch and a CAD model for a smaller version of the 10 GHz horn for WR-19 waveguide, also requiring angle machining. While reviewing it prior to machining, I realized that the E-plane aperture dimension was close to the E-plane dimension of WR-28 waveguide, which some hams use on 47 GHz since it is more available. A horn with the same E-plane dimension at both ends would not require angle machining, so I changed the design to WR-28 waveguide with an E-plane aperture of 0.140 inches, about 0.56λ. The H-plane dimension was chosen to fit in 2 inch wide aluminum bar stock, about 7λ. Figure 5 shows the simulated radiation pattern at 47.1 GHz: about 14.5 dBi gain with a -3dB azimuth beamwidth of 82° and a -10dB beamwidth of 170°. The elevation pattern is narrow with lots of unimportant sidelobes.

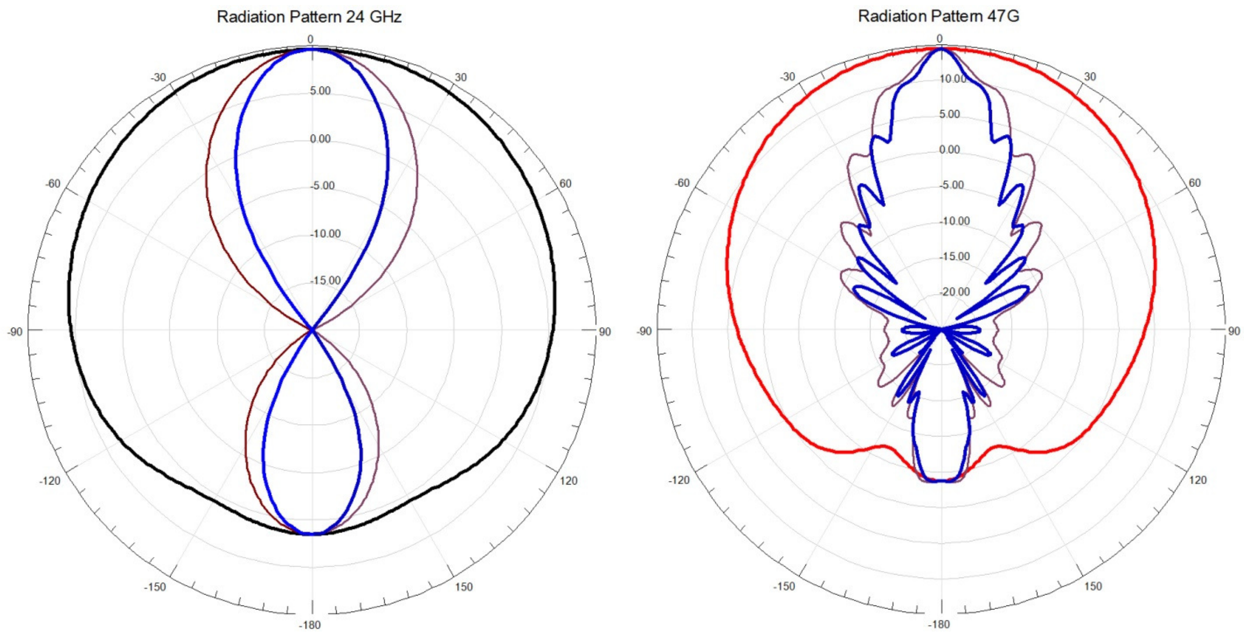

Figure 5 – Radiation patterns for WR-28 sectoral horn at 24 GHz and 47 GHz

I discussed the change to WR-28 with Tom, and he agreed, since he had chosen WR-22 waveguide for the quadruplers – only a small mismatch for either WR-28 (21 dB return loss) or WR-19. It also occurred to us that WR-28 waveguide also works at 24 GHz (hams can ignore official waveguide frequency ranges within reason), so this could be a dual-band horn. Another simulation yielded the 24 GHz radiation pattern shown in Figure 5 – lower gain of about 9.6 dBi, since the H-plane aperture is only about 3.7λ at the lower frequency. The azimuth radiation pattern is even more broad, since the Eplane aperture is only 0.28λ, with a -3dB beamwidth of 142° and a -10dB beamwidth of 360° – the gain never drops below the -10dB level.

With simpler machining and much less metal being removed, the CNC milling time for each half is reduced to under 20 minutes. My first prototype, shown on the left in Figure 6, used a rectangular waveguide flange pattern compatible with WR-28, WR-22, and WR-19. When I showed it Tom, he said that he used the circular flange pattern, preferred for instrumentation, compatible with all three waveguide sizes. This required thicker aluminum stock to accommodate the circular flange pattern, shown on the right in Figure 6. In the middle is a horn showing the aperture. I also made one with hole patterns for both the rectangular and circular flanges after breaking a tiny center drill ruining a hole.

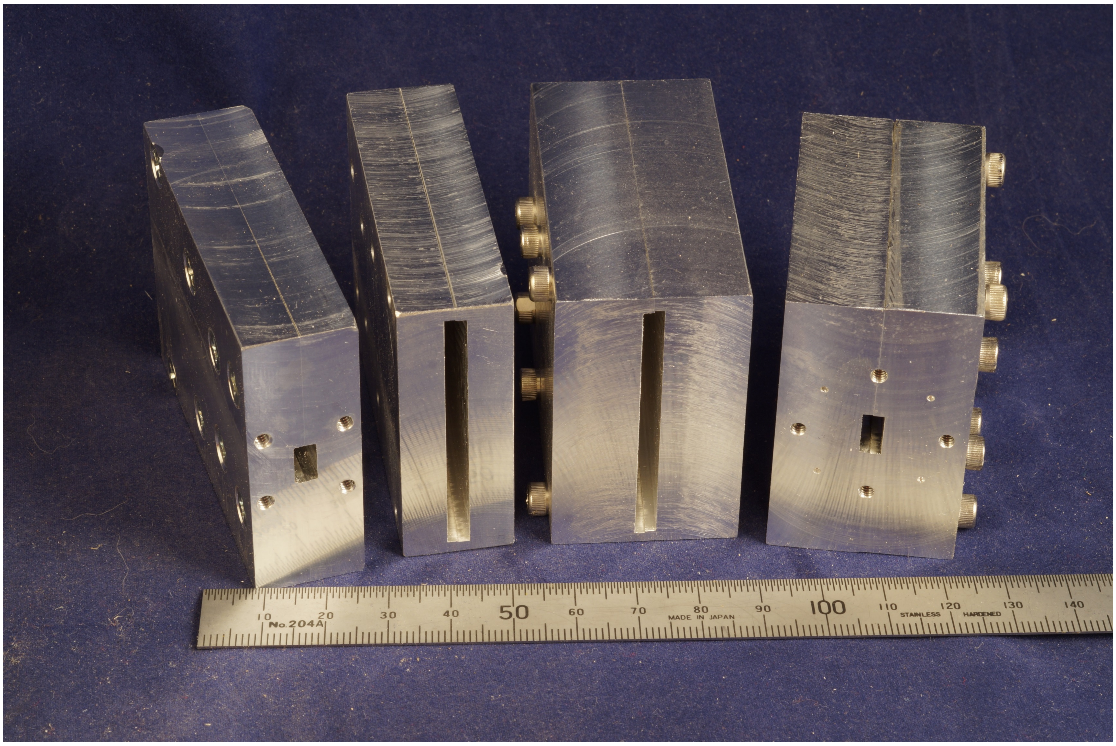

Figure 6 – Sectoral horns for 24 & 47 GHz with WR-28 waveguide input

Lower Frequencies

Sectoral horn antennas for lower frequencies would not be so narrow, so easier fabrication techniques would be possible, like soldering thin metal or PC board stock. I've been considering one for 3.4 GHz using foil-coated 2-inch thick Styrofoam (transparent to RF), leaving the aperture end uncovered.

The E-plane aperture dimension of a sectoral horn can be chosen for the desired coverage – it doesn't have to be as broad – and the H-plane aperture dimension can be as large as is convenient to provide gain. The flare length should be longer than the larger aperture for a clean pattern.

Summary

The sectoral horn antenna can provide broad coverage in a desired direction with reasonable gain. Dimensions are not critical, so they may be built with a variety of techniques. They are tall and thin so could be mounted on the side of a tower or mast – for a rover operation, several could be stacked side-by-side on a mast for multiple bands with easy antenna aiming.

If vertical polarization is required, simply reverse the aperture dimensions and mount the horn horizontally.

Note: 1. J. Kraus, *Antennas, Second Edition*, McGraw Hill, 1988.