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A New Figure of Merit for Antennas, the Gain-Volume Ratio, and its Application to the Folded Horn

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Abstract

We consider here a new figure of merit for antennas, the gain-volume ratio, which may be used to characterize antenna performance. We apply this to the folded horn, and to other antennas in its class. On this basis, the folded horn has a 4 dB advantage over its closest competitor, a standard gain horn.

I. Introduction

The folded horn [1,2] was developed with the idea of minimizing antenna size, while retaining moderate gain. We develop here the gain-volume ratio as a figure of merit to characterize how well that goal was realized. This figure of merit is quite general, and can be applied to other antennas.

We begin by defining the gain-volume ratio. We then compare the gain-volume ratio of the folded horn to similar antennas in its class.

II. Gain-Volume Ratio

We can define a gain-volume ratio (GVR = η_V) as

$$\eta_V = \frac{G}{V_\lambda} \tag{1}$$

where G is the antenna gain, and V_λ is its volume in cubic wavelengths at the frequency of interest. Note that all three quantities in the above equation are functions of frequency. Since gain is normally expressed in decibels, we can express η_V in terms of decibels using simple arithmetic,

$$\eta_{V,dB} = G_{dB} - V_{\lambda,dB} \tag{2}$$

where $V_{\lambda,\mathrm{dB}} = 10 \log_{10} V_\lambda$.

Note that instead of gain, one might prefer to use realized gain in the above formulas. Recall that realized gain is just the gain reduced by impedance mismatch. In other words, realized gain is normalized to the power *available* to the antenna, instead of the power *accepted* by the antenna. This is expressed as [3, Appendix B]

$$G_r(\omega) = G(\omega)\left[1 - |S_{11}|^2\right] \tag{3}$$

Note that "realized gain" is the preferred terminology in place of "effective gain," which was used in [3, Appendix B]. If we replace gain with realized gain in the above figures of merit, we simply add an extra subscript r to the earlier formulas to generate the realized gain-volume ratio,

$$\eta_{V,r} = \frac{G_r}{V_\lambda} \tag{4}$$

$$\eta_{V,r,dB} = G_{r,dB} - V_{\lambda,dB} \tag{5}$$

Realized gain is often a more useful measure of antenna performance than gain, because it includes the effect of impedance mismatch. It is also a simpler quantity to measure at an antenna range, because a measurement of the S_{11} of the antenna under test is not required. For well-matched antennas, the two versions of gain are very close.

III. Antenna Comparisons

We compare here the gain-volume ratios of the folded horn to those of other antennas operating at 3 GHz. According to [1,2], the realized gain of the FH-1E was 10 dB at 3 GHz. Photos of the folded horn are shown in Figure 1, and a scale drawing is shown in Figure 2.

We compare our results for the FH-1E to three other antennas, which are shown in Figure 3. These include the ETS Lindgren (EMCO) model 3115 double ridged waveguide (1-18 GHz), the A.H. Systems model SAS-582 standard gain horn (2.6-3.95 GHz), and the Farr Research model IRA-3M (0.25 – 20 GHz). We compare their gains at 3 GHz and all their physical dimensions in Table 1.

Using the data of Table 1, we calculated the gain-to-volume ratio, η_V, of all four antennas in Table 2. We observe a 4 dB advantage in the folded horn over its closest competitor, the A.H. Systems standard gain horn.

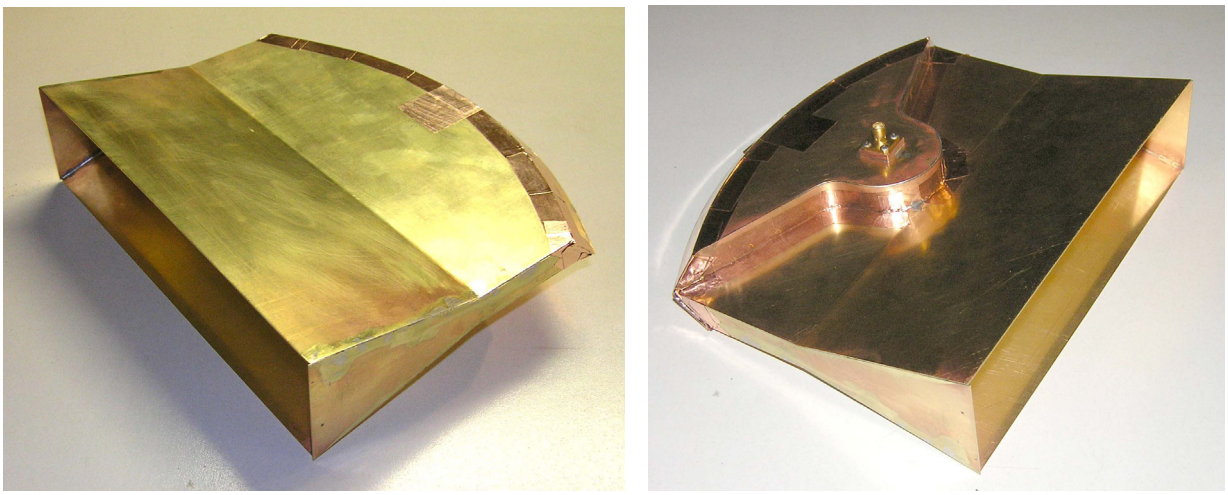

Figure 1. Photos of the top and bottom of the folded horn.

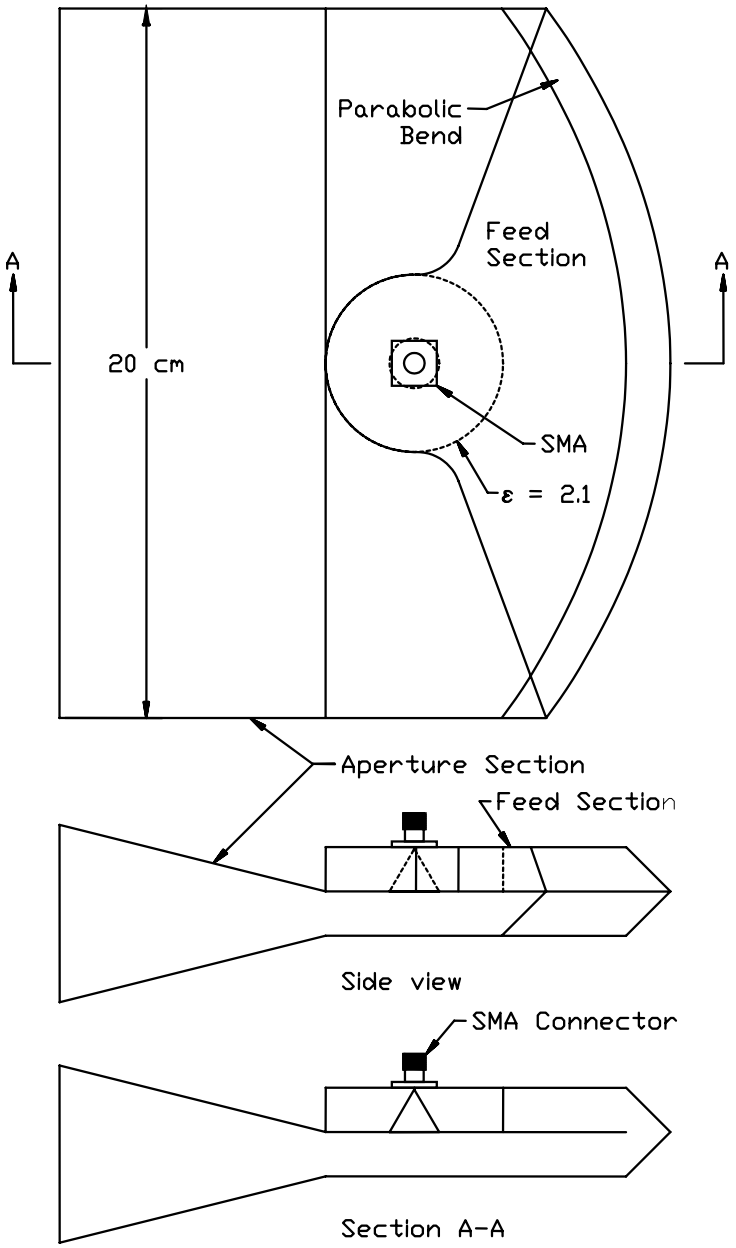

Figure 2. Sketches of the folded horn.

Figure 3. The ETS Lindgren (EMCO) model 3115 double-ridged horn (left), the A.H. Systems model SAS-582 standard gain horn (middle), and the Farr Research model IRA-3M (right).

Table 1. Antenna Comparison in Terms of Gain and Volume

Antenna	Gain at 3 GHz (dBi)	Aperture Size (cm)	Length (cm)	Volume (cubic λ at 3 GHz)
Farr Research FH-1E	10	20 X 5	17.2	1.7
ETS Lindgren (EMCO) 3115 double ridged	9	24.4 X 15.9	27.9	10.8
A.H. Systems SAS-582 standard gain horn	15	20 X 15.2	45.0	13.7
Farr Research IRA-3M	15	49 cm diam.	30.0	56.6

Table 2. Antenna Comparison in terms of Gain-Volume Ratio

Antenna	Gain at 3 GHz (dBi)	Volume (dB at 3 GHz)	$\eta_{V,dB}$ (dB at 3 GHz)
Farr Research FH-1E	10	2.3	+7.7
ETS Lindgren (EMCO) 3115 double ridged	9	10.3	–1.3
A.H. Systems SAS-582 standard gain horn	15	11.4	+3.6
Farr Research IRA-3M	15	17.5	–2.5

IV. Concluding Remarks

We have investigated a new figure of merit, the gain-volume ratio, which is useful when comparing the gain and size of various antennas. We have compared the folded horn to three other antennas, and have found the folded horn to have a 4 dB advantage over its closest competitor, a standard gain horn.

References

1. E. G. Farr, L. H. Bowen, C. E. Baum, and W. D. Prather, "The Folded Horn Antenna," *IEEE Trans. Antennas and Propagation*, Vol. 55, No. 11, November 2007, pp. 3341-3344.

2. E. G. Farr, L. H. Bowen, C. E. Baum, and W. D. Prather, "The Folded Horn Antenna," Sensor and Simulation Note 520, December 2006.

3. L. M. Atchley, E. G. Farr, *et al*, Characterization of a Time Domain Antenna Range, Sensor and Simulation Note 475, June, 2003.

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