Controlling the Gain of Wide Band Open Quad Ridge Antennas

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***Abstract*—We present a methodology to precisely control the gain of an open quad-ridge horn (OQRH) without impacting the input match over the wide band frequency of operation characteristic of this type of horns.**

***Index Terms*—Open Quad-Ridge Horn, Gain Control, Wide Band Feed.**

I. Introduction

The broad bandwidth characteristics of dual and quad-ridge horns have been studied since the early 1960's [1] initially boasting an impressive 7:1 fractional bandwidth and 3:1 input VSWR using a closed dual-ridge horn with a matching lens to achieve high gain. In the late 1980's we find a very compact ($\lambda/4$ aperture) open quad-ridge horn with a 3:1 fractional bandwidth (3.5:1 VSWR) [2]. Full wave analysis studies were developed to analyze the potential of half open dual-ridge horns used as prime feeds of parabolic reflectors [3]-[4]. Those launcher section modifications of dual-ridge horn designs achieved 18:1 fractional bandwidth (4:1 VSWR) for EMC applications [5], and a novel open boundary quad-ridge [6] with a 9:1 fraction bandwidth (3:1 VSWR) broke the bandwidth limitations imposed to enclosed quad-ridge horns. This was followed by a super-open boundary quad-ridge horn [7] with a 25:1 fractional bandwidth, albeit a 4:1 VSWR. This paved the way for 15:1 fractional bandwidth (2.5:1 VSWR) [8]. More recently, dual-ridge and quad-ridge horn antennas have been extending into the millimeter and sub-millimeter wavelengths [9]-[10]; all of this attestting the ultra wide band characteristics of this versatile geometry.

The dual-ridge and quad-ridge horn antennas typically have 12 to 14 dB of antenna gain. While the main effort has been to achieve the largest fractional bandwidth possible, few attempts have been made to increase the antenna gain, lenses [11].

Presenting in this paper is a method suitable to control the gain of open quad-ridge horns. We also present actual measurements of a newly developed open quad-ridge horn developed to verify this design approach.

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II. Gain Control

For a closed horn, increasing the gain typically involves increasing the horn length, this also applies to enclosed dual and quad-ridge horns. For open quad-ridge horns, (OQRH), the main objective is to increase the effective aperture of the horn without changing its input match characteristics. This is equivalent to applying a scaling factor, β, to the open quad-ridge section of the horn, while maintaining the launching section invariant (Figure 1). Since there are several quad-ridge profile design possibilities, i.e., Type A: exponentials, Type B: hyperbolic, etc, a suitable parameter (or set of parameters) needs to be identified that, after this transformation, can be traced back to an overall equivalent β scale factor of the aperture of the horn.

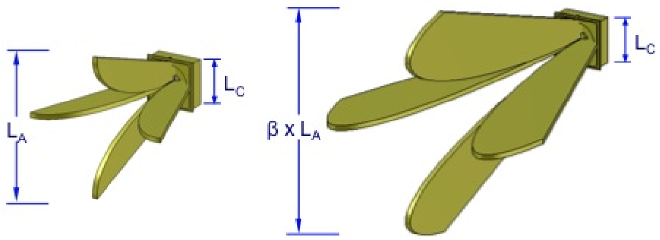

Fig. 1. Scaling of a Open Boundary QRH (OQRH) Type-A profile while maintaining the launching section invariant.

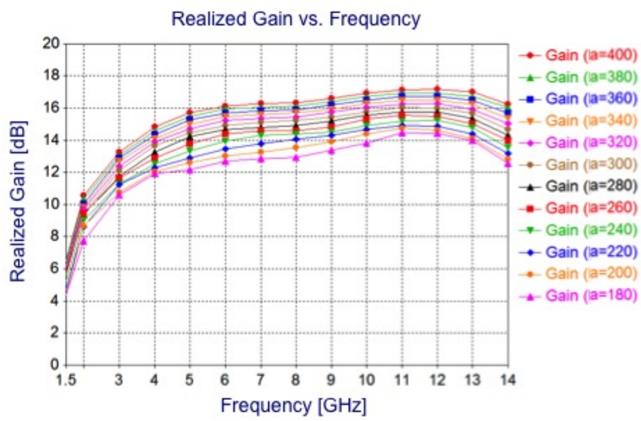

Fig. 2. Gain as a function of frequency for OQRH Type-A profile for different values of scaling parameter (arbitrary units)

Figure 2 shows the calculated antenna gain as a function of frequency for a OQRH Type-A profile, with a 9:1 fractional bandwidth, for different values of an index parameter a. The aperture scaling parameter β is a function not necessary linear of the parameter a used in the figure. The figure shows that very fine gain control can be achieved over the antenna gain expanding from 12 dB to 17 dB. The obvious question is: "What about the input match?" Figure 3 shows the input

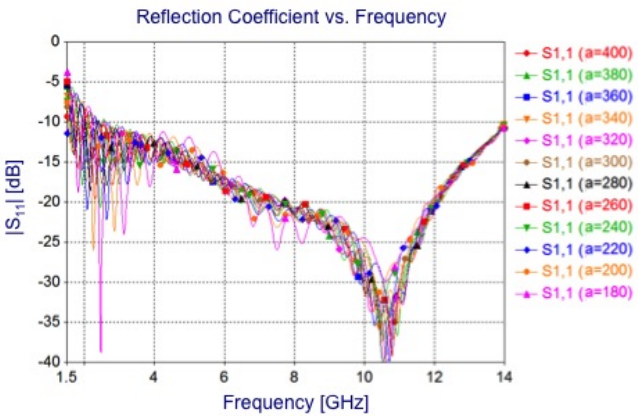

Fig. 3. Input reflection coefficient as a function of frequency for OQRH Type-A profile for different values of scaling parameter (arbitrary units)

reflection coefficient as a function of frequency for this set of scaling parameter values, indicating that a good input match is maintained over the frequency band for all the aperture scale variations. This approach can also be applied for other types of quad-ridge profiles, (i.e., hyperbolic (Type-B)), as shown in Figure 4 below.

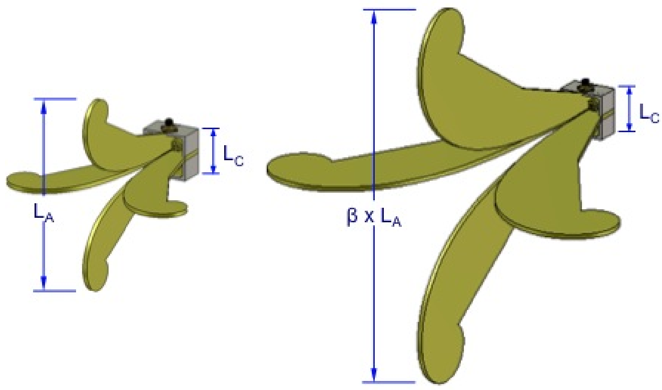

Fig. 4. Scaling of a OQRH Type-B while maintaining the launching section invariant.

For OQRH Type-B profiles the calculated realized gain vs. frequency variations as a function of a index parameter CC is shown in Figure 5, indicating that over 4 dB of antenna gain control can be achieved. As mentioned earlier, The aperture scaling parameter β is a function not necessary linear of the indexing parameter CC used in the OQRH Type-B profile designs. Likewise, Figure 6 shows the calculated input match for this OQRH Type-B profile resulting in an input match better than -10 dB over a 9:1 fractional bandwidth.

III. Antenna Realization and Measurements

As a proof of concept, an OQRH Type-B profile design was fabricated (Figure 7), for which we a scaling parameter $CC = 72$, (in previous Figure 5) was selected, providing an appropriate size envelope for our application. The measured input reflection coefficient as a function of frequency is shown

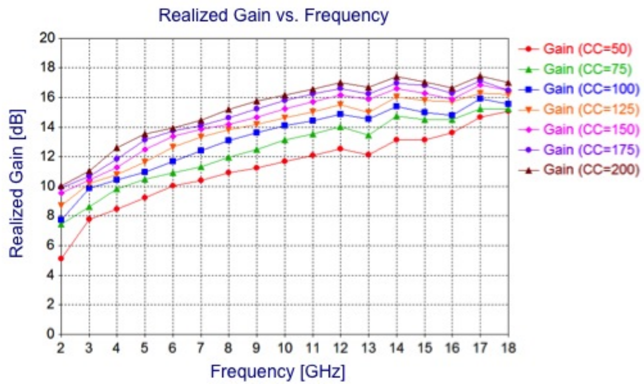

Fig. 5. Gain as a function of frequency for OQRH Type-B profile for different values of scaling parameter (arbitrary units)

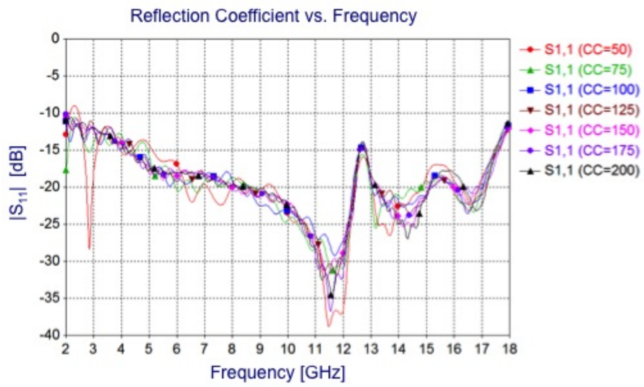

Fig. 6. Calculated input reflection coefficient as a function of frequency for OQRH Type-B profile for different values of scaling parameter (arbitrary units)

in Figure 8. The input match is better than -12 dB from 2 to 18 GHz and it is similar to what is predicted in Figure 6, although with a less marked resonance response between 12 GHz and 13 GHz.

Fig. 7. Manufactured OQRH Type-B design (CC=72).

Figure 9, shows the realized antenna gain, with a linear response from 2 to 18 GHz, starting with an initial value of 8 dB and a peak value of 17 dB at the high end of the band.

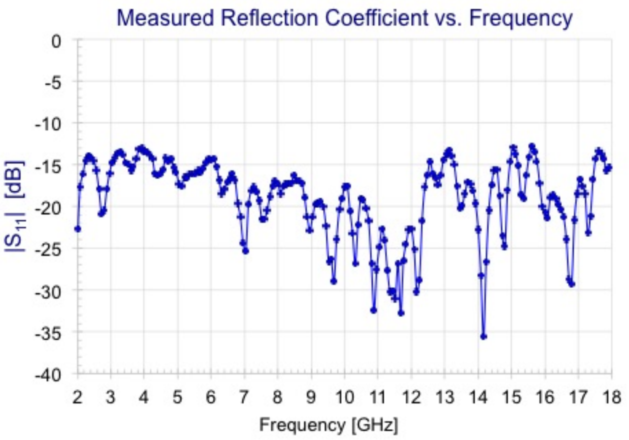

Fig. 8. Measured Input reflection coefficient as a function of frequency for manufactured OQRH Type-B profile.

The calculated gain is also indicated in the figure as a dashed line and follows very closely the actual measured data.

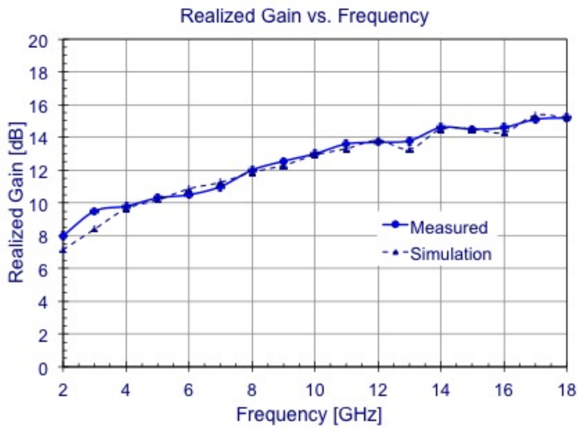

Fig. 9. Comparison between measured and simulated realized gain as a function of frequency for manufactured OQRH Type-B profile. The dashed line corresponds to the simulated response.

IV. Conclusion

This paper presents a method to achieve fine control of the antenna gain of open quad-ridge horns without impacting the the original input match of the horn. This approach was applied in simulations to two different OQRH geometry profiles; followed by selecting, fabricating and testing of an OQRH design based on this methodology. The results demonstrate a very good agreement between simulated data and actual measurements.

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