New broadband EMC double-ridge guide horn antenna

Broadband antennas, due to the large frequency bands required by standards, are the work horse of electromagnetic compatibility testing. Traditionally the antenna parameter of interest to the EMC engineer was the antenna factor. The advent of higher frequency testing has brought the development of a new double-ridge guide horn design.

By Vicente Rodriguez

Radiated immunity or susceptibility and radiated emissions are the two main types of radiated EMC measurements. Antennas are used in radiated EMC testing to sense and generate fields. International and national standards have defined the test distance, the antenna to be used, and the location of the equipment [1].

For years the EMC engineer paid little attention to the pattern of the antenna being used. The engineer would have an idea of the direction of the main beam and would point the antenna to the equipment under test (EUT) so that this fell under the main beam. Originally most standards called for the use of half-wavelength dipoles for frequencies 80 MHz and higher and for short dipoles for frequencies below 80 MHz. However, to reduce test time, broadband antennas such as biconical dipoles and log periodic dipole arrays began to be accepted.

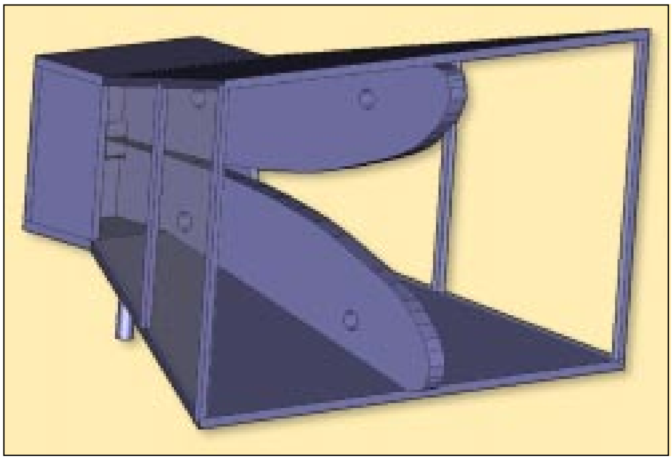

Figure 1. The original model of the new DRGH.

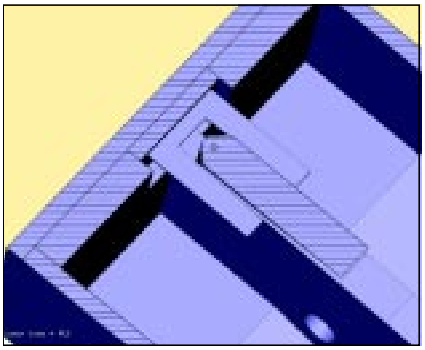

Figure 2. The feed cavity of the new DRGH for EMC applications.

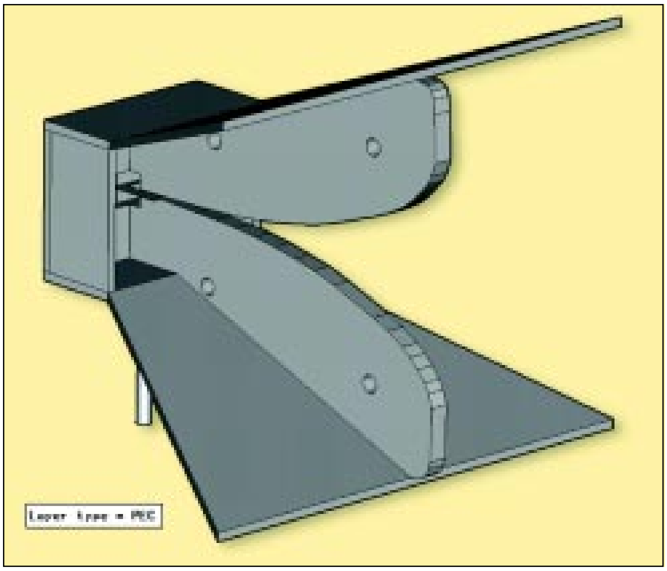

Figure 3. The final geometry of the new DRGH for EMC testing.

Figure 4. One of the three prototypes of the new antenna.

The use of broadband antennas reduced the test time because the technician did not have to stop the test and adjust or change the dipole antenna for the next short band of frequencies. As the use of broadband antennas extended, standards were changed to allow for the use of broadband antennas as long as the measurements performed with these antennas could be related to the half-wave dipole. Other standards went further and defined which broadband antennas must be used. The latest version of the Military Standard Mil-Std 461E stated the use of broadband DRGH as the antenna of choice for frequencies above 200 MHz [2].

One of the antennas required by this military standard was a DRGH for the 1 GHz to 18 GHz range. This broadband horn has been an accepted antenna in EMC for more than 40 years. In February 2003, a paper was published [3] that showed the numerical analysis of a traditional 1 to 18 GHz DRGH commonly used in EMC measurements. The authors pointed out deficiencies in the pattern that in their view rendered the antennas' use in EMC applications as questionable.

These revelations were not a surprise to most users, especially those using the antenna for susceptibility. In susceptibility or immunity testing the antenna must generate a uniform field over a given vertical plane. These users knew of the problems for the traditional 1 to 18 GHz antenna to effectively illuminate the uniformity plane.

An improved design of the 1-18 GHz DRGH maintains a single radiation lobe for the entire frequency range. As in the February 2003 paper, the entire horn was modeled, including the coaxial feed in Microwave Studio. The geometry used in the numerical model was then exported to Solidworks. A mechanical model was then generated, and prototypes of the antenna were manufactured and tested and the results compared with the model predictions. The improvement was based on applying different ideas to the horn and making sure that the propagation of higher order modes was suppressed.

Numerical analysis

The antenna is modeled as a perfect electrical conductor (PEC)

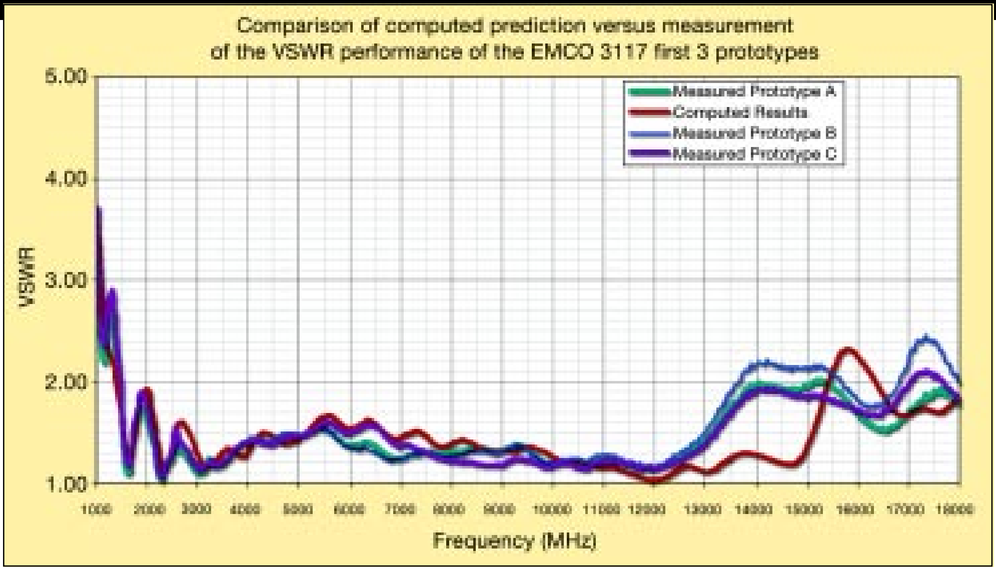

Figure 5. The predicted VSWR compared with the 3 prototype antennas.

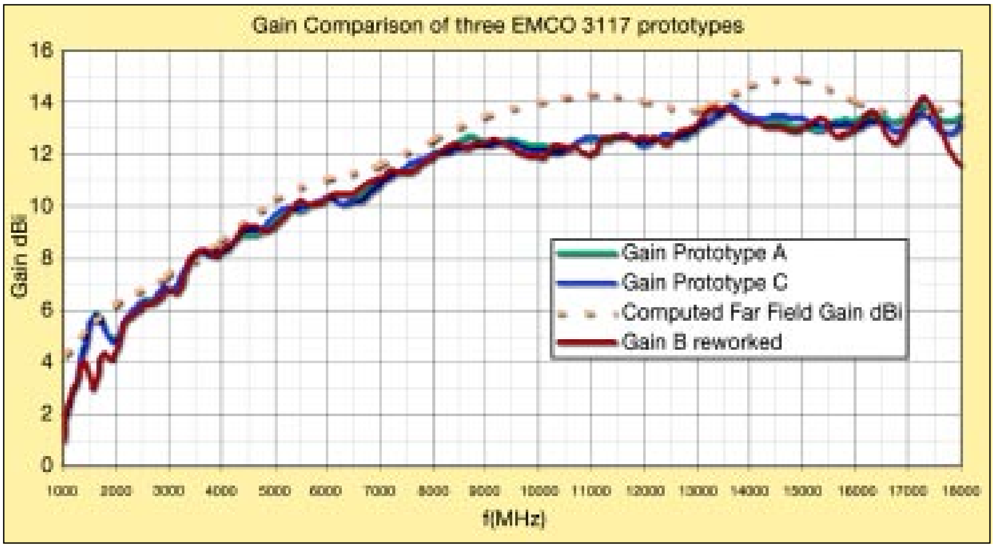

Figure 6. Comparison of directive gain between prototypes and prediction.

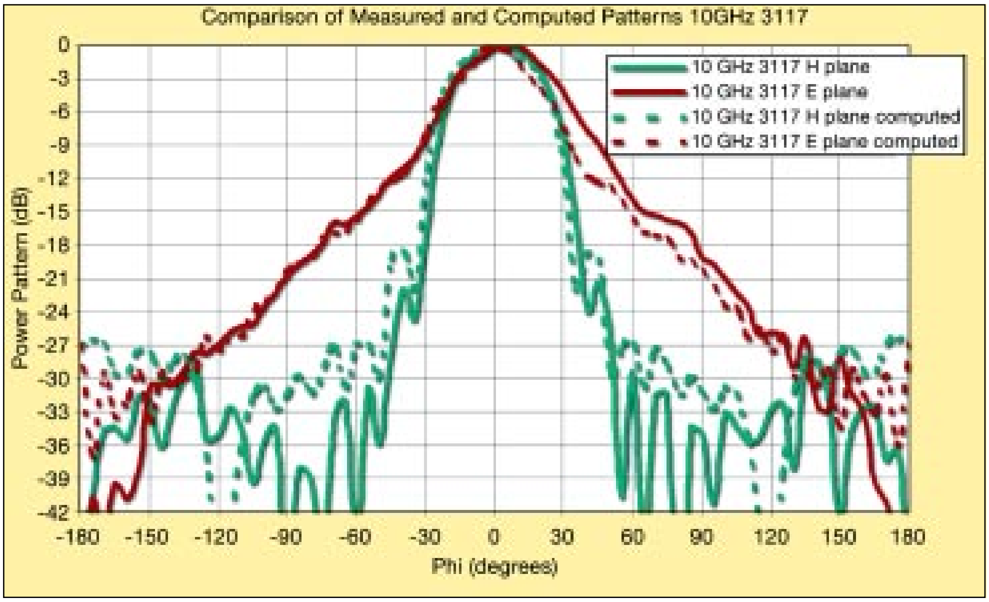

Figure 7. Radiation pattern at the two principal planes at 10GHz. computed and measured.

structure fed by a coaxial line with 50 Ohm impedance. Because of the realistic feed, only a single plane of symmetry can be used in analyzing the antenna. A perfect magnetic conductor (PMC) symmetry plane is used so that it is only needed to solve half of the geometry. Figure 1 shows the geometry generated in the numerical model.

The starting point of the design was to model the traditional DRGH design as it was done in the 2003 paper. From this analysis several modifications were adopted. The first modification to the new antenna was to reduce the size to push to higher frequencies the split pattern problem. Additionally the feed cavity was redesigned. Figure 2 shows the new feed cavity showing a structure designed to suppress higher order modes. Also, the curvature of the ridges was changed to achieve better matching at the aperture of the horn.

The results from the analysis showed that the side-bars were increasing the gain at the low frequencies. Furthermore, a study of the fields in the antenna showed that the dielectric supports for these bars were having a detrimental effect on the main beam at the higher end of the range. The final design was implemented without any sides. Mechanically, no additional support was needed for the top and bottom plates. Figure 3 shows the final geometry.

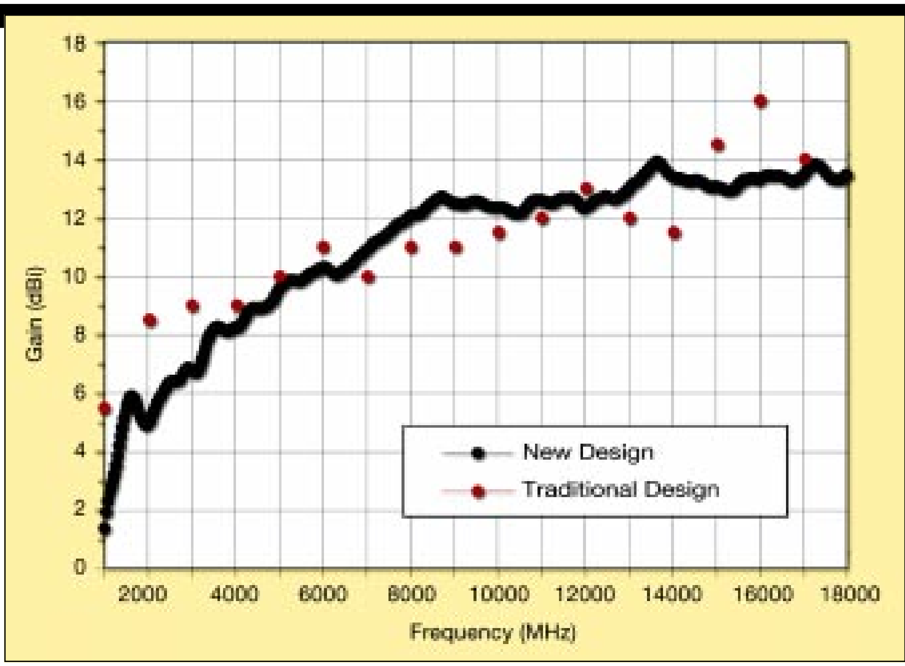

Figure 8. Comparison of traditional and new design

Radiation pattern is the key issue on the new design. It has a superior pattern behavior than the traditional horn.

Numerical results and measurements

The results from the numerical model that were important to the design goals were studied in detail. These parameters of importance were: the directivity or directive gain, the VSWR, and the radiation pattern quality. The desired objective was to get an antenna with similar performance to the traditional design but with better pattern behavior. The design shown in Figure 3 was exported to Solidworks. Using Solidworks, the mechanical engineer designed a way to manufacture the antenna. Once the mechanical design was finalized, three prototypes were manufactured. Figure 4 shows one of the three prototypes.

The VSWR, gain and pattern of the prototypes were measured. Figure 5 shows the VSWR of the model compared to the three prototypes.

The results show good correlation between model and measurement only at frequencies below 13 GHz. Above 13 GHz, a deviation exists—probably due to not having enough unknowns at the higher end. Due to memory constraints on the model, 15 cells per wavelength were the maximum allowed at the highest frequency of interest.

The gain was measured following the SAE ARP-958-C [4]. Figure 6 shows the comparison between measurement and prediction.

Again a good correlation exists between model and actual measurement. The higher gain of the prediction can be explained by the losses in the aluminum body of the antenna and also effects due to small gaps between the parts that make up the antenna.

The radiation pattern was computed at frequencies every 1 GHz between 1 and 18 GHz. Additional frequency steps were computed at 18.5 and 19 GHz and every 0.25 GHz between 16 GHz and 18 GHz. Full three-dimensional patterns were measured in an anechoic chamber. Figure 7 shows the two principal planes of the pattern at 10 GHz both computed and measured.

Figure7 shows good agreement between the predicted pattern and the measured results with the exception of a slight shift in the pattern. But it is less than 5 degrees.

Comparison with traditional DRGH antenna

As can be seen from Figure 8, the gain from 1 GHz to 3 GHz is much lower for the new when compared with the traditional design. However, one must recall that at those frequencies it is still possible to find good power to price ratios for amplifiers. Additionally, note that from 8 GHz to 18 GHz, the gain for the new design is fairly flat with no more than 2 dB of variation. This frequency range is where the advantages of the new over the traditional design are clearly seen.

It is true that the traditional design appears to have a higher gain from 15 to 16.5 GHz, but this result is due to a narrow beam such that the antenna is unable to illuminate the entire EUT. At 18 GHz the notch in the traditional design pattern causes the gain to drop about 6 dB below the new design gain.

While it is understood that amplifier power is an issue for EMC engineers, it must be pointed out that this antenna has the ability to generate fairly uniform field planes throughout the required frequency range. Also, unlike the traditional design and since a wider beam is obtained at 1 GHz, it is possible to bring the antenna closer to the EUT and still illuminate the entire object with the required field. This is potentially useful in smaller anechoic chamber dimensions such as 3 meters.

Radiation pattern is the key issue on the new design. It has a superior pattern behavior than the traditional horn. Overall, the EMC engineer must realize the advantage of having a good pattern behavior for the whole band even if the tradeoff is lower gain for 12 percent of the operational band of the antenna. Additionally the better pattern behavior makes the antenna suitable for applications other than EMC. The traditional design

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Vicente Rodríguez-Pereyra attended the University of Mississippi where he obtained his B.S.E.E., MSEE and Ph.D. with an emphasis on electromagnetic theory. In June 2000 Rodriguez joined EMC Test Systems (now ETS-Lindgren) as an RF and electromagnetics engineer.

Rodriguez's interests are numerical methods in electromagnetics especially when applied to antenna design and analysis. Since his association with ETS-Lindgren, Rodriguez's interest has spread to the use of these numerical techniques in designing EMC and RF/MW absorber. Rodriguez is the author of more than 20 publications including journal and conference papers as well as book chapters. He holds a patent for hybrid absorber design and has a patent pending for a new dual-ridge horn antenna design for EMC applications. Rodriguez is a member of the IEEE and several of its technical societies including the MTT and the EMC societies.

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pattern behavior was not suitable for the antenna to be used as a source for reflectors or in anechoic chambers for antenna pattern measurement. The new design's more constant pattern makes the horn suitable for these other applications.

Conclusions

The results both measured and predicted show that the new design is comparable in gain and antenna factor (AF) to the traditional horn. The lack of side structures has decreased the low-end gain when compared with the traditional design. Also the open sides have caused the beamwidth to be larger at the low end than the traditional design. However for most of the 1 to 18 GHz band, the performance is similar and the better pattern behavior has translated into a more stable gain and AF for the high end of operation.

Even more important is that the new design has a better pattern. The main beam does not split into four separate lobes at any frequency of operation. The result is an antenna that is better suited than the traditional design for EMC and other applications. RFD

References

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