A BROADBAND DOUBLE RIDGE GUIDE HORN WITH IMPROVED RADIATION PATTERN

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Abstract.- Broadband antennas are the workhorse of EMC testing and Antenna Pattern Measurement. The large frequency band allows testing of equipment without interruptions to change antennas. Until recently the main antenna parameter of interest to the EMC engineer was the antenna factor (AF). EMC engineers were not interested in antenna patterns, most antennas were assumed to have a directive pattern with a smooth main lobe. As testing at higher frequencies has become important, attention to the radiation pattern has become a key issue. Recently a double ridge guide horn (DRGH) design has been found to have a very poor pattern for about half of the band it covers. This traditional design has been accepted in the EMC community as a standard antenna. In the paper a new design of DRGH is introduced which maintains a single lobe radiation pattern over the entire band and is comparable in gain and AF with the traditional design.

Key words: EMC, Antennas, time domain methods.

I. Introduction

There are two main types of radiated EMC measurements; Radiated Immunity or Susceptibility and Radiated Emissions. Antennas are used in radiated EMC testing to sense and generate fields. International and national standards define the test distance, antenna to be used and location of the equipment [1]. For years the EMC engineer paid little attention to the pattern of the antenna being used. The EMC 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 80MHz and higher and for short dipoles for frequencies below 80MHz. However, in order to reduce test time broadband antennas such a bi-conical dipoles and log periodic dipole arrays began to be accepted. The use of broadband antennas reduced the test time since 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 200MHz [2].

One of the antennas required by [2] was a DRGH for the 1GHz to 18GHz range. This broadband horn has been an accepted antenna in EMC for over 40years. On February 2003 a paper appeared [3] that showed the numerical analysis of a traditional 1-18GHz DRGH commonly used in EMC measurements. The authors pointed out deficiencies in the pattern that in their view rendered the antenna use in EMC applications as questionable.

These revelations in [3] 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 1-18GHz antenna to effectively illuminate the 1.5m by 1.5m uniformity plane. Figure 1 shows the measured pattern of the traditional design at 16GHz showing the main beam broken into 5 smaller lobes.

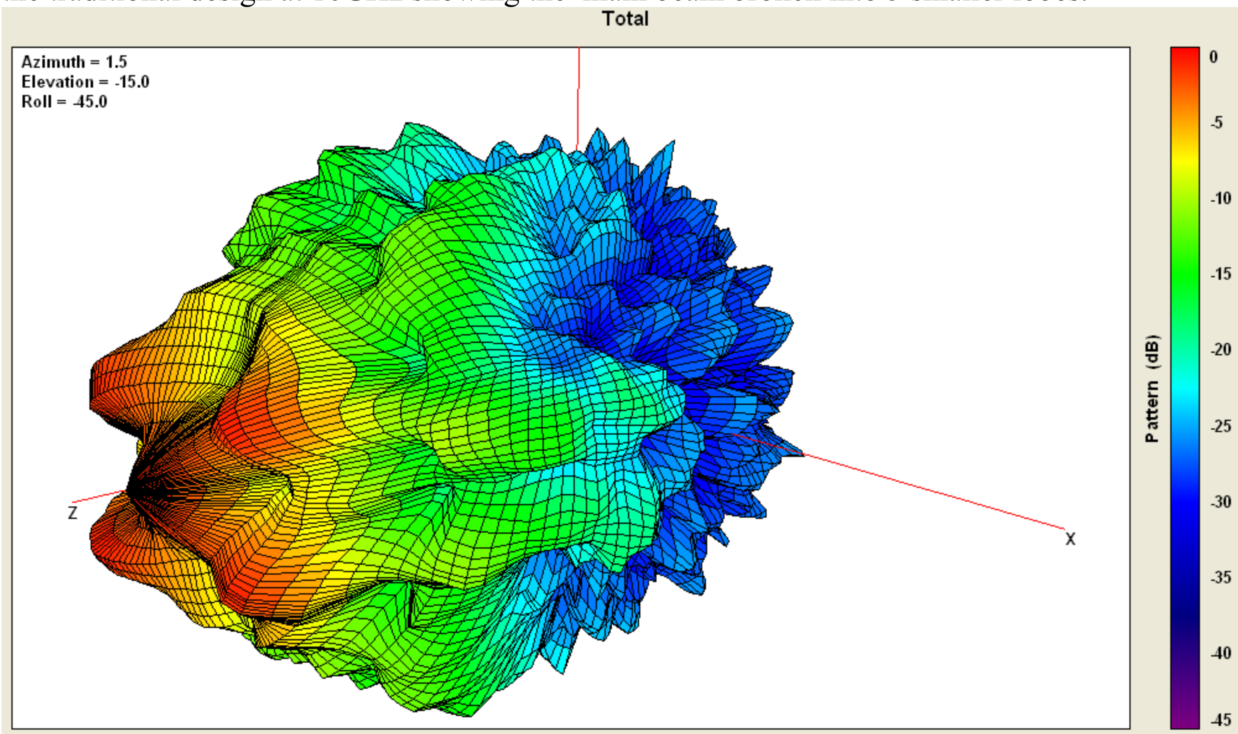

Figure 1. The 3D measured pattern of the traditional Double-ridged guide horn.

This paper presents an improved design of the 1-18GHz DRGH. The new antenna maintains a single radiation lobe for the entire frequency range. As in reference [3] the entire horn was modeled, including the coaxial feed. Additionally, 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.

A time domain method was chosen for the analysis. CST Microwave Studio was the commercial solver chosen to design the new antenna.

II. Numerical Analysis

The antenna is modeled as a PEC structure fed by a coaxial line with 50 ohm impedance.
A PMC symmetry plane is used so that it is only needed to solve half of the geometry. Figure 2 shows the geometry generated in the numerical model.

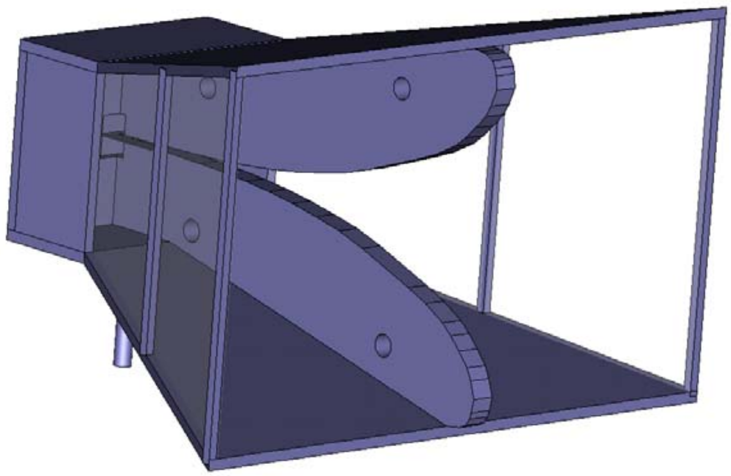

Figure 2. The original model of the new DRGH.

The starting point of the design was to model the traditional DRGH design as it was done in [3]. From this analysis several modifications were adopted. First the new antenna was reduced in size to push to higher frequencies the split pattern problem. Additionally the feed cavity was redesigned. Figure 3 shows the new feed cavity showing a structure design to suppress higher order modes. Also the curvature of the ridges was changed to achieve better matching at the aperture of the horn.

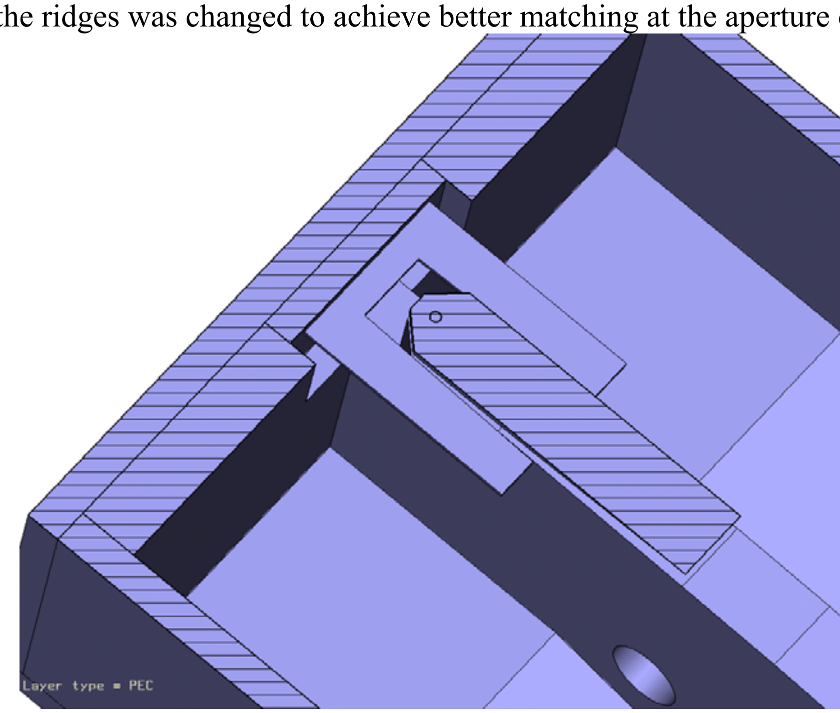

Figure 3. The feed cavity of the new DRGH for EMC applications.

The results from the analysis showed that the side-bars were increasing the gain at the low frequencies as reported in [3]. Additionally, it was found 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 4 shows the final geometry being analyzed.

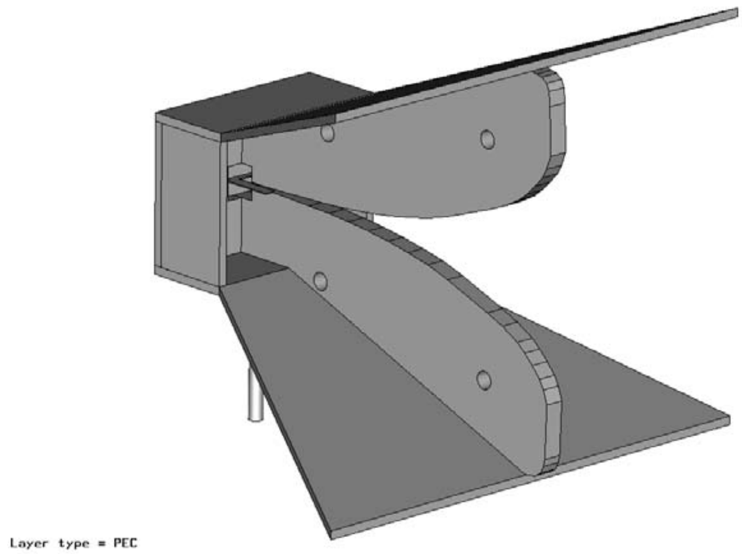

Figure 4. The final geometry of the new DRGH for EMC testing.

III. **Numerical Results and Measurements**.

The results from the numerical model that were of interest to the design goals were the directivity or directive gain (which is related to the AF), the VSWR and the radiation pattern quality. The objective was to get an antenna with similar performance to the traditional design but with better pattern behavior.

Once the numerical model design was finalized three prototypes were manufactured. Figure 5 shows one of the 3 prototypes.

Figure 5. One of the three prototypes of the new antenna.

The VSWR, gain and pattern of the prototypes were measured. Figure 6 shows the VSWR of the model compared to the 3 prototypes.

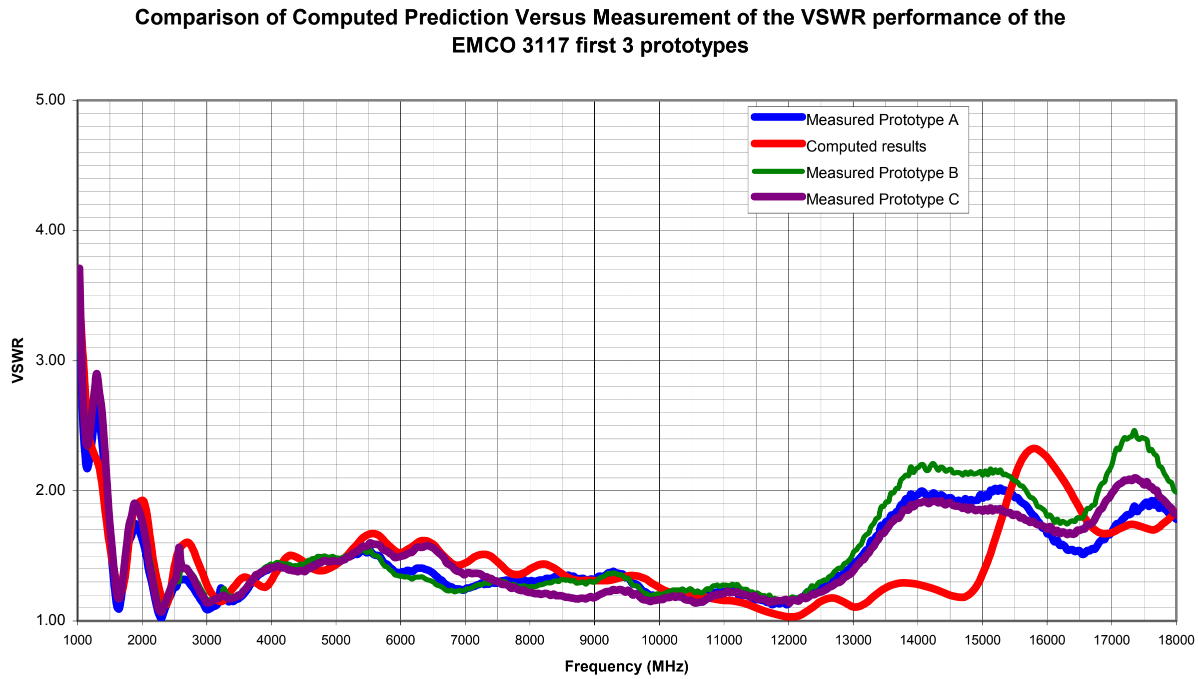

Figure 6. The predicted VSWR compared with the 3 prototype antennas.

The results show very good correlation between model and measurement only at frequencies above 13GHz there is a deviation. This is probably due to not having enough unknowns at the higher end. Due to memory constrains on the model 10 cells per wavelength was the maximum allowed at the highest frequency of interest.

The Gain was measured following the SAE ARP-958-C [4]. Figure 7 shows the comparison between measurement and prediction.

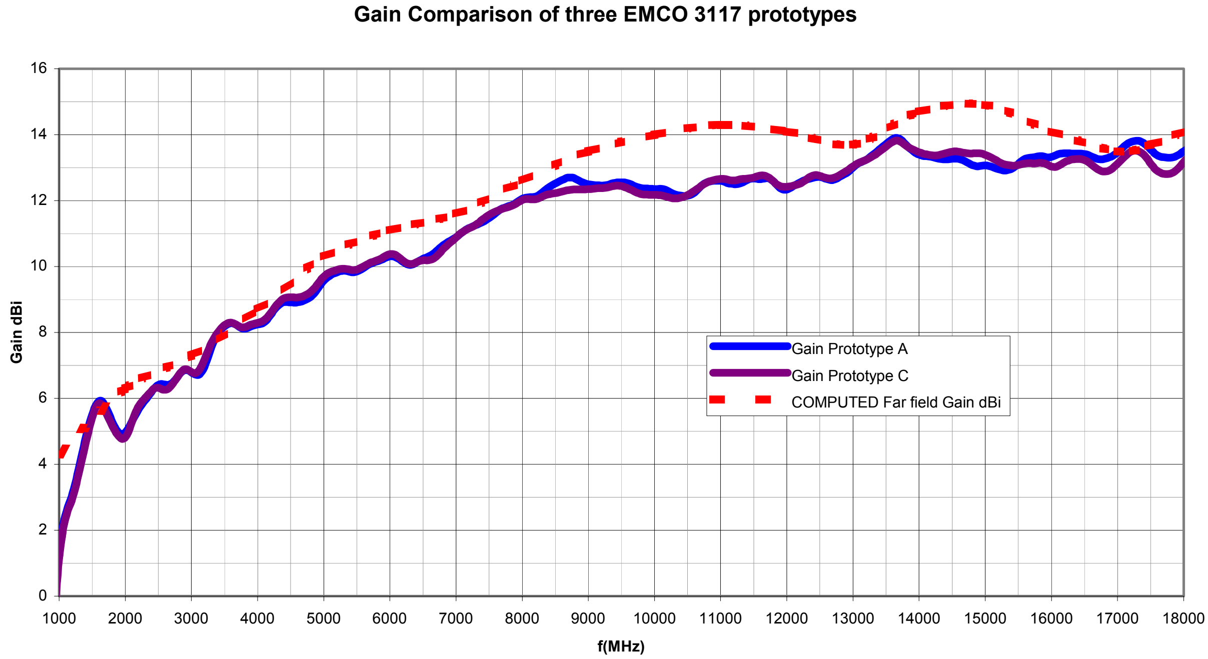

Figure 7. Comparison of directive gain between prototypes and prediction.

Again there is a very good correlation 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 additionally the directivity value provided by the modeling software package was a far field value, while the antenna was measured at 1m distance following the SAE ARP 958 procedure, so some near field gain compression is expected.

The radiation pattern was computed at frequencies every 1GHz between 1 and 18GHz. Additional frequency steps were computed at 18.5 and 19GHz and every .25GHz between 16GHz and 18GHz. Full three-dimensional patterns were measured in an anechoic chamber. Figure 8 shows the two principal planes of the pattern at 10GHz both computed and measured.

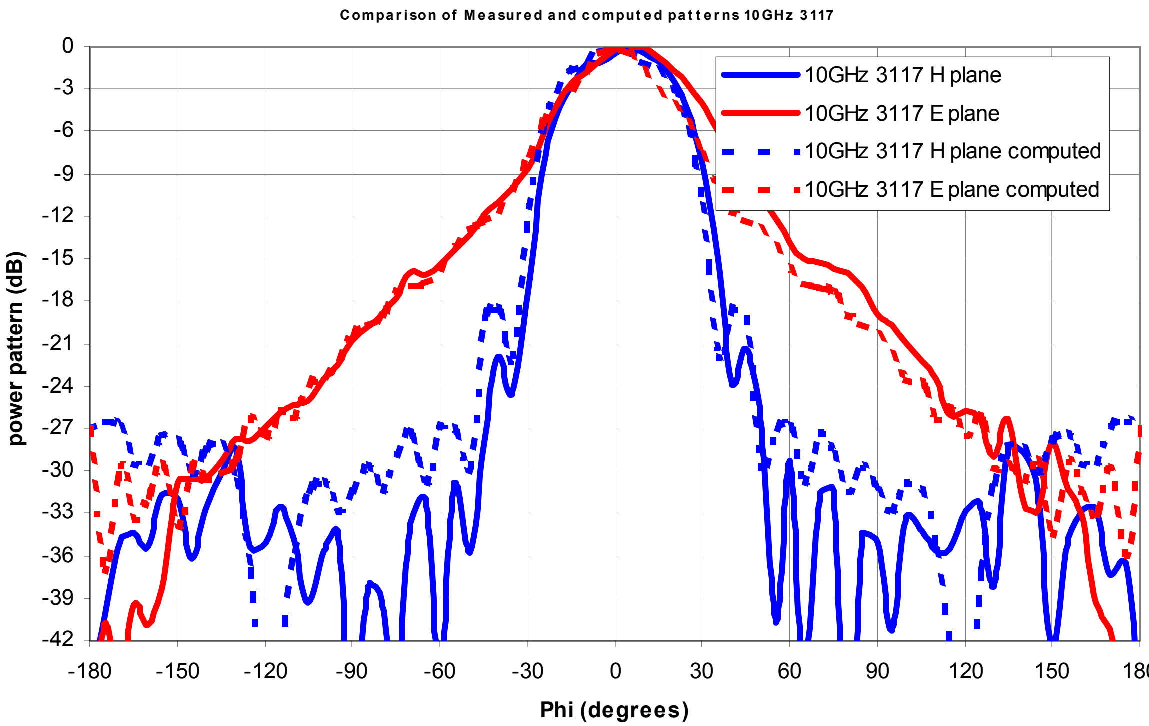

Figure 8. Radiation pattern at the two principal planes at 10GHz. computed and measured.

Figure 8 shows very good agreement between the predicted pattern and the measured results there is a slight shift in the pattern but it is smaller than 5degrees.

Figures 9, 10 and 11 show 3d patterns computed and measured at 16,17 and18GHz, although at 17GHz incipient lobes at 45º appear they never materialized in to four separate beams. Further analysis of the data shows a 1dB ripple maximum in the front end of the main beam.

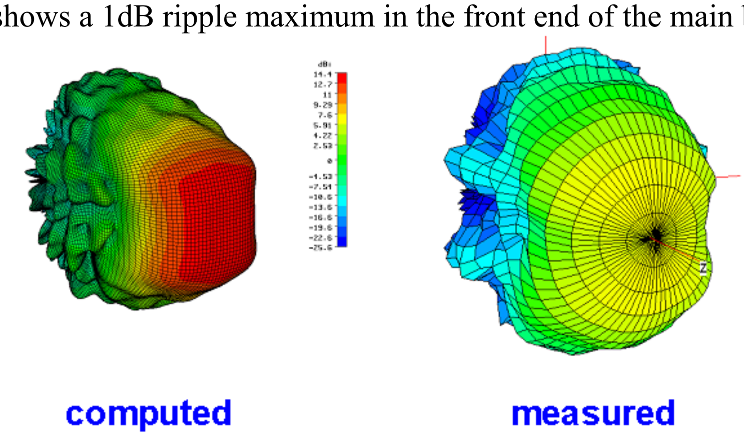

Figure 9. 3D radiation pattern at 16GHz.

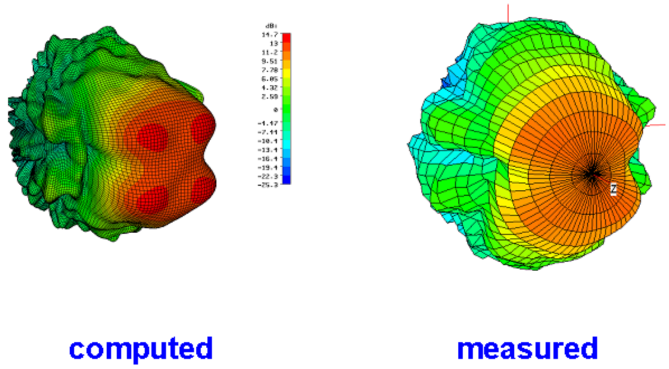

Figure 10. 3D radiation pattern at 17GHz.

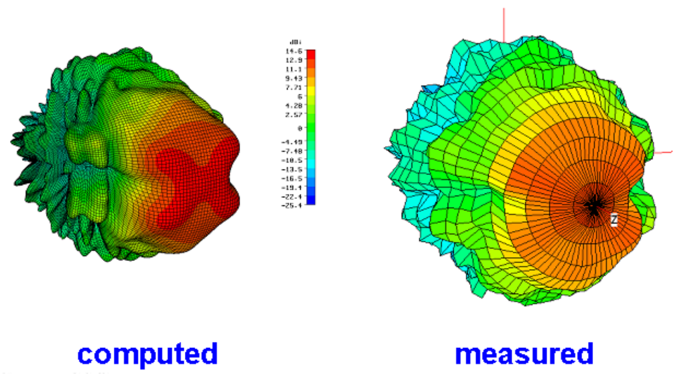

Figure 11. 3D radiation pattern at 18GHz.

Figures 9 to 11 suggest very good correlation between the numerical results and the prototype whose pattern was measured. Further numerical analysis was performed to analyze the possibility of shaping the top and bottom plates for aesthetic and practical reasons. The model in figure 12 showed that there was no mayor effect from extending the top and bottom plates.

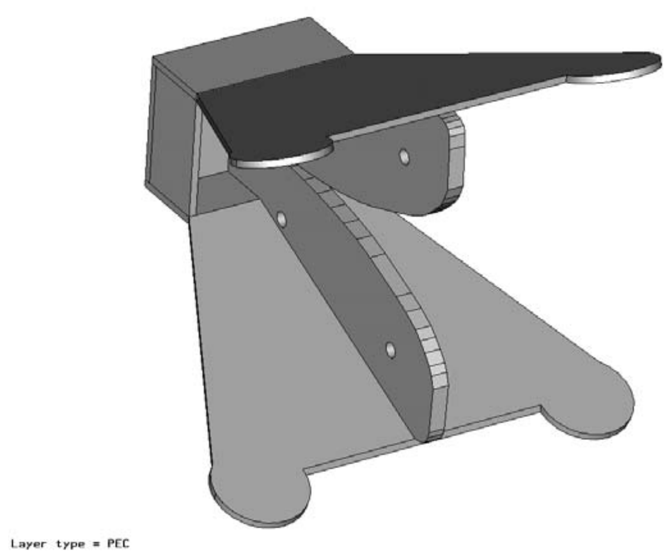

Figure 12. Additional model showing the extended corners.

Extending the corners allowed for the horn to be stored facing down. A common practice in EMC laboratories Figure 13 shows the horn stored in this fashion.

Figure 13. The new horn in showing the extended top and bottom that allows for storing it facing down.

IV. Comparison with traditional DRGH antenna

As it can be seen from figure 14 the gain from 1GHz to 3GHz is much lower for the new design than for the traditional. 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 8GHz to 18GHz the gain for the new design is fairly flat with no more than 2dB of variation. That is the range where the advantages of the new design over the traditional are clearly seen.

It is true that the traditional appears to have higher gain from 15 to 16.5GHz, but that corresponds to such a narrow beam that the antenna is useless when it comes to illuminate the equipment under test (EUT). at 18GHz the notch in the traditional design pattern causes the gain to drop about 6dB below the new design gain values.

While it is understood that amplifier power is an issue for EMC engineers. It must be pointed to them the ability of this antenna to generate fairly uniform field planes throughout the frequency range of the antenna. Also, since a wider beam is obtained at 1GHz it is possible to bring the antenna closer to the EUT and still illuminate the entire object with the required field.

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 cost is lower gain for 12% of the operational band of the antenna. Figure 15 shows the measured pattern for the new horn design at 16GHz, it is clear that a smoother an nicer pattern is radiated by the new horn than by the traditional design

V. 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 beam-width to be larger at the low end than

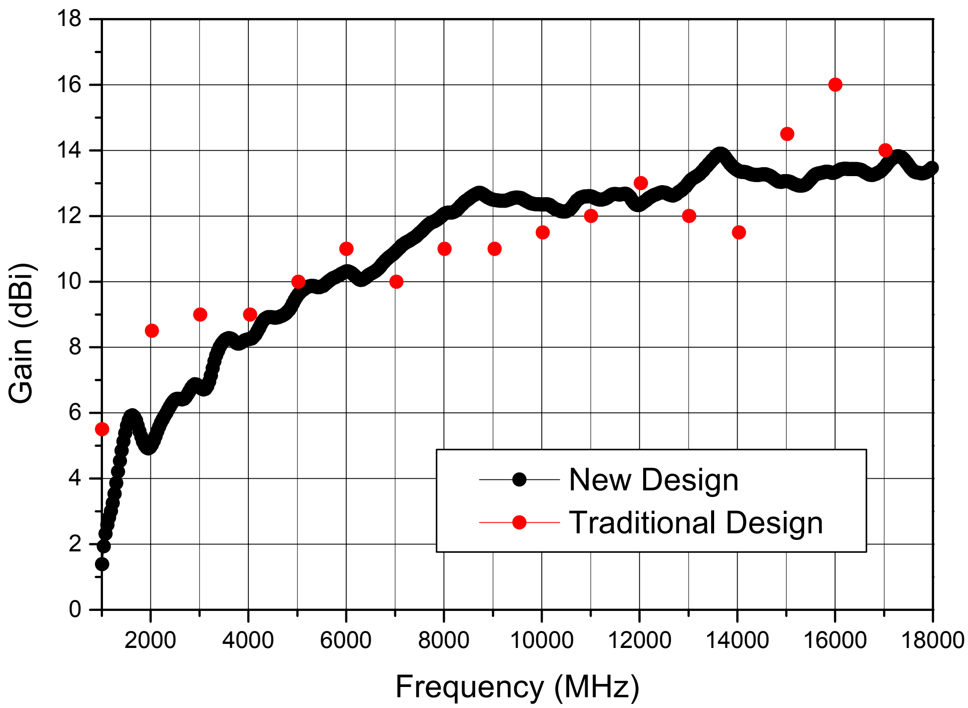

Figure 14. comparison of traditional and new design

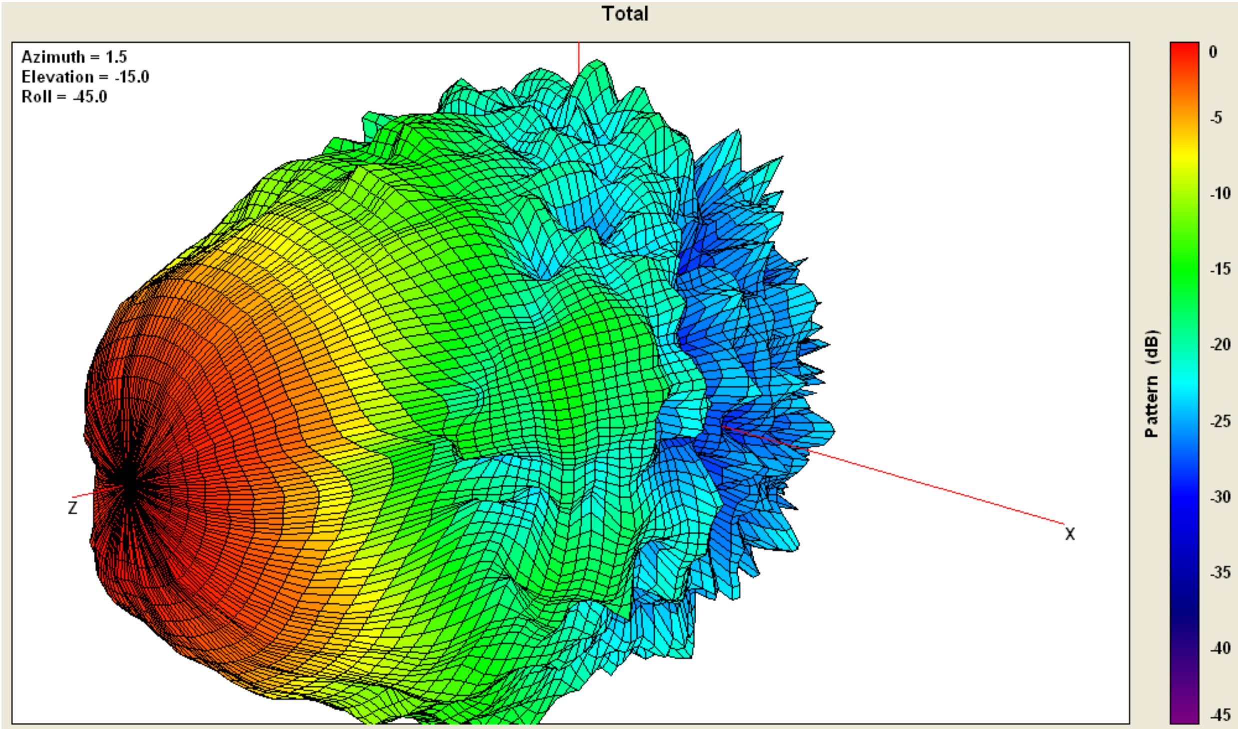

Figure 15. Measured radiation pattern of the new horn design at 16GHz.

the traditional design. However for most of the 1 to 18GHz band the performance is similar and the better pattern behavior has translated in to 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 in to four separate lobes at any frequency of operation. The result is an antenna that is better suited than the traditional design for EMC applications.

VI. **References**

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Vicente Rodríguez-Pereyra. Attended the University of Mississippi where he obtained his B.S.E.E. in 1994. During the fall of 1994 he joined the Department of Electrical Engineering at the University of Mississippi as a research assistant. He was involved in projects regarding reduction of cross-talk in high speed digital circuits as part of an Army Research Office grant and on the use of the Finite Difference Time Domain technique in antenna analysis. During this period he completed his Master of Science and Doctorate in the area of Engineering Science with emphasis on Electromagnetic Theory in 1996 and 1999, respectively. On August 1999 Dr. Rodríguez joined the department of Electrical Engineering and Computer Science at Texas A&M University-Kingsville (Formerly Texas A&I University) as a Visiting Assistant Professor. In June 2000 Dr. Rodríguez left the academic world when he joined EMC Test Systems (now ETS-Lindgren) as an RF and Electromagnetics engineer. During this time he was involved in the anechoic design of several chambers, including rectangular and taper antenna pattern measurement chambers. He was also the principal RF engineer for the anechoic chamber at the Brazilian Institute for Space Research (INPE) the largest chamber in Latin America and the only fully automotive EMC and Satellite testing chamber. In September 2004 Dr. Rodríguez took over the position of Senior Principal Antenna Design Engineer, placing him in charge of the development of new antennas for different applications and on improving the existing antenna line. Among the antennas developed by Dr. Rodriguez are new broadband double ridge guide horns with single lobe pattern and high field generator horns for the automotive industry.

Dr. Rodríguez's interests are Numerical Methods in Electromagnetics and specially when applied to antenna design and analysis, since his association with ETS-Lindgren Dr. Rodríguez's interest has spread to the use of these numerical techniques is designing EMC and RF/MW absorber. Dr. Rodríguez is the author of more than twenty publications including journal and conference papers as well as book chapters. Dr. Rodriguez holds a patent for hybrid absorber design additionally he has a patent pending for a new dual ridge horn antenna design for EMC applications. Dr. Rodríguez is a member of the IEEE and several of its technical societies including the MTT and the EMC societies. Dr. Rodríguez is an active member of the Applied Computational Electromagnetic Society (ACES). He is an Associate Editor of the ACES Journal and chair of the member communications committee of ACES. Dr. Rodriguez has served as a reviewer for the ACES Journal and for the Journal of Electromagnetic Waves and Applications. He has co-chaired a session during the 2003 ACES symposium and workshops during the 2002 and 2004 IEEE, EMC annual symposiums. Dr. Rodríguez is a Full member of the Sigma Xi Scientific Research Society and of the Eta Kappa Nu Honor Society.