Using a Non-Physical Absorber Termination for the Analysis of RCS Pylons Using a Higher Order Basis Function Method Of Moments

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***Abstract*— Low back-scattering pylons are a typical feature of RCS measurement ranges [1], these can achieve levels between -25 and -45 dBsm [2]. The measurement of the RCS level from a pylon is a difficult task. The Measurement requires adding a low RCS target to hide the top edge of the pylon. In this paper a numerical technique is explored to estimate the RCS of a pylon using a high order basis function method of moments technique (HOBF-MoM). The paper explores a technique to hide the top and bottom features of the pylon using a non-physical lossy material to get the RCS from the main pylon structure. The effects of the structure on the RCS of standardized targets like spheres is also explored.**

***Index Terms*—RCS measurements, Numerical Techniques.**

I. Introduction

To measure RCS, special structures have been created to support the target under test (TUT). Some of these structures are based on having a low dielectric property, close to air, such as expanded polystyrene (EPS) columns [3]. In reference [3], Baggett and Thomas discuss some of the drawbacks of the foam column as a support. The foam columns have a limited weight that they can support while maintaining a permittivity that is close to air. As higher density foams are used to support higher loads, the permittivity of the expanded polystyrene increases. In reference [3] it was shown that the RCS of the Styrofoam column increased from -40dBsm (dB related to a square meter) at 2 GHz to levels in the -21dBsm at the upper end of the K band. The column measured by Baggett and Thomas could support TUTs of up to 22.68 kg (50 Lbs.). RCS metallic pylons can support much higher loads, A look at [4] shows that some models can support up to 1364 kg (3000 lbs.). Hess describes in [2] that the typical pylon has the cross section of two intersecting circles that describe an ogive. The length to width ratio is used to describe the geometry of the typical ogive used in RCS pylons. In [4] typical ratios of 4 to 1 are mentioned, but it is not uncommon to see a higher ratio of 6:1 and even higher. There is a limit to the ratios that can be physically achieved. The limit is driven by mechanical concerns. Additionally, the TUT needs to be rotated, to present different aspects to the incoming wave. This rotation requires a rotator at the top of the pylon and the ogive width is limited to allow for mechanical systems that allow for the rotation of the TUT of for cabling to control the rotating mechanical system. Hess goes on to describe in [2] that the Pylons are measured using ultra low RCS terminations such as the so-called NASA Almond described in [5].

When performing RCS measurements indoors, the most common approach is the compact range [6]. Recently Rodriguez et al. used a HOBF-MoM approach to analyze a compact range [7]. In reference [7] the typical field distribution in a compact range is presented. The same numerical technique is used to compute the mono-static RCS of a pylon. In this paper a pylon with a 8:1 ratio is analyzed. The first step it to check the validity of the results provided by the numerical method. To check the method, the RCS of a standard perfect electric conducting (PEC) sphere is computed using the technique. This allows for establishing the largest sized patch that can be used to describe the curved structure and get accurate solutions. After the numerical method has been validated, the truncation of the structure is done to reduce the physical size of the problem. The termination of the top and bottom of the pylon using lossy ogives is explored. The results for the monostatic RCS are shown. Finally, the results for the RCS of a PEC sphere on top of the pylon are presented.

II. The Pylon Model and MoM validation

A. PEC Sphere

While the Higher-Order Basis Function MoM code allows for quadrilateral patches of up to 2λ, when doing RCS of curved surfaces the maximum patch size has to be reduced to ensure that the meshed geometry comes close to the actual geometry being analyzed. A series of analyses and convergence studies have shown that 0.3λ is sufficient to provide a good computational result. While this is short of the upper limit of the method, that allows for patches up to 2λ, it is better than the traditional 0.1 to 0.05λ used in MoM with traditional basis functions. A PEC sphere with a 60 cm diameter is analyzed using the HOBF-MoM technique. Figure 1. shows the computed RCS of the 60 cm diameter sphere compared to the Raleigh and Mie series results. The results match very well and prove that the method can provide the right solution for the RCS of a curved object when the quadrilateral patches are set to a maximum of 0.3λ.

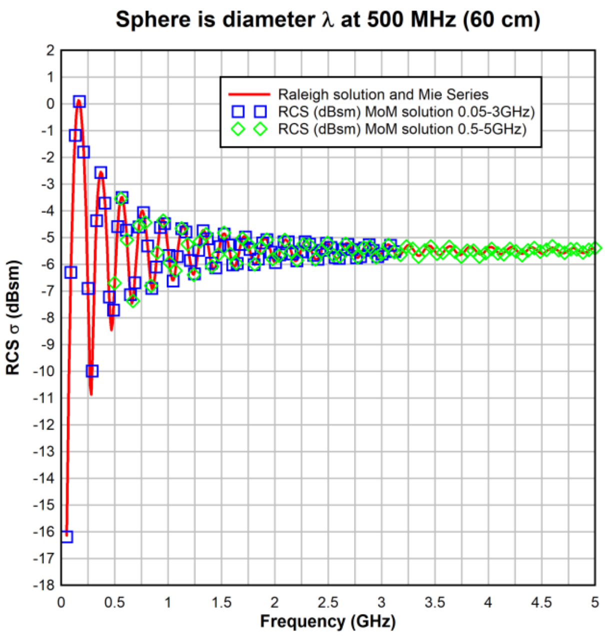

Fig. 1. RCS of a 60 cm diameter sphere versus frequency

B. Truncantion and termination of the pylon model

To model the pylon rather than modeling the entire structure, only the section of the structure that is in the QZ and its proximity needs to be analyzed. Figure 2 shows the results for one of the analyses performed by Rodriguez et al. [7]. A pylon and the QZ have been superimposed onto the field distribution in the range. The scale is in $dB_{v/m}$ related to the highest field in the 2D slice. The highest level corresponds to the field inside the circular corrugated aperture horn. As it can be seen in Fig. 2 the lower part of the Pylon is hidden form the incoming wave by the absorber fence around the feed horn.

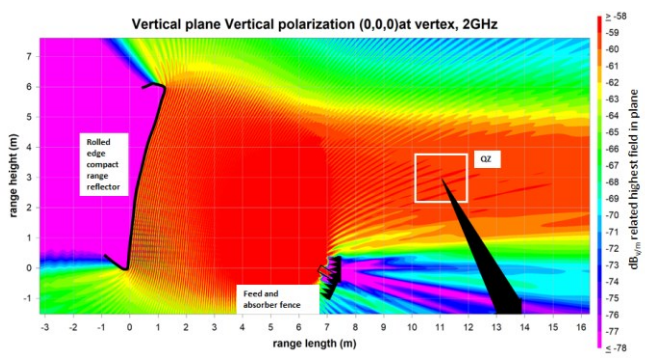

Fig. 2. Field distribution in a compact range showing the QZ and a pylon superimposed.

Figure 2 shows that only a small section of the pylon is in the QZ. And about half of its length is illuminated with fields that are over 10 dB lower magnitude than the fields at the QZ. Thus, it is not necessary to model the entire length of the pylon, but only a smaller section. To terminate the truncated pylon, the method reported by Hess in [2] is used. Hess mentions about a low RCS termination, like the NASA Almond, described in [5]. In the present paper an ogive is used as the termination. While Woo et al. reported a metallic ogive RCS in [5], in the present paper an ogive of a non-physical material is used. The fictitious material is such that

$$\begin{aligned} \varepsilon_r &= 1 + j10 \\ \mu_r &= 1 + j10 \end{aligned} \tag{1}$$

Choosing these material permittivity and permeability properties, the wave impedance will be the same as the surrounding vacuum, and the material will be lossy. The overall pylon is an 8:1 ratio ogive that is a total of 5 m in vertical height. The angle of the leading edge is about 25 degrees with respect to the vertical. The simulation will model only a 3 m vertical section of the pylon (roughly the section that will be in the main illumination from the compact range). The lossy ogives on the top and bottom of the pylon section have twice the ratio as the pylon, thus 16:1. The top edge termination is 24 times the length of the upper cross section of the pylon and 12 times the width and height. The bottom lossy ogive is 6 times the length and 3 times the width and height. Figure 3 shows the modeled section of the pylon with the lossy ogive terminations.

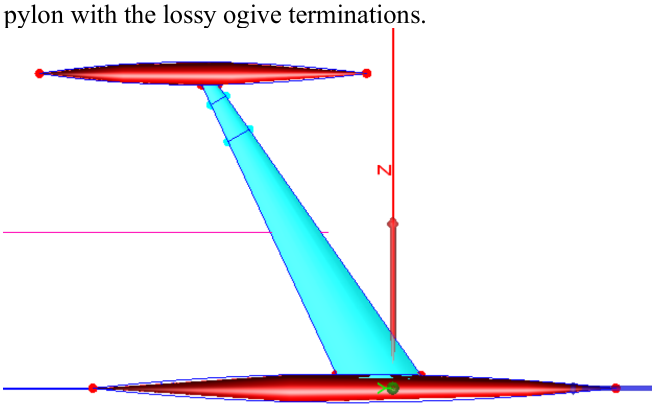

Fig. 3. The PEC pylon section with the lossy ogive terminations.

In the next section of the paper the results of the RCS of the lossy ogives, the pylon with the terminations, and the full 5m pylon are analyzed to validate the results and the overall methodology. Using symmetry, it is possible to model this 3m pylon section up to 3 GHz, with less than 10,000 unknowns. The Unknowns being surface magnetic and electric currents at any media interface.

III. Numerical Results

A. *Numerical results for the pylon RCS*

The first step of the model is to check that the RCS of the lossy ogives is low enough to help with the computation of the model. Figure 4 shows all the numerical results for the pylon analysis. Based on the angle of the front or leading edge of the pylon, a theoretical result for a wedge that exhibits that similar angle can be done. The theoretical results for a 28.5-degree wedge for both polarizations of the field are shown on Fig 4. The results. for the pylon RCS should not exceed this theoretical limit. Figure 4 shows that RCS of the lossy ogives is the in the -65dBsm to -80dBsm for most of the frequency range. This is effectively a "noise-level" to our simulation results. The monostatic RCS of the pylon section is computed from 500 MHz to 3 GHz. Both polarizations are computed, and the results plotted on Fig. 4. The results show that the VV polarization case improves from -27 dBsm at 500 MHz to between -40 and -50 dBsm up to 3 GHz. For the HH polarization case, the levels improve from -45dBsm at 500 MHz to better than -60 dBsm for frequencies above 1.5 GHz. Each polarization is computed for a total of 31 frequency points. The HH case required 78,860 unknowns to be solved. the computation of the 31 frequency points took 9.27 hours on a 16-core processor with 1 Quadro GV100 Graphic Processing Unit (GPU), The VV case required 98913 unknowns to be solved and it took 11.8 hours to solve.

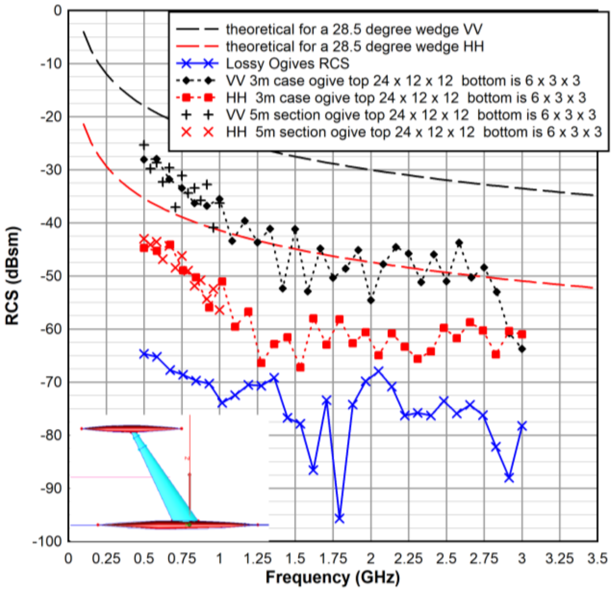

Fig. 4. Numerical results for the monostatic RCS for the lossy ogives, the terminated 3m and 5 m pylon sections, and the theoretical wedge RCS

To verify that the truncation of the pylon does not have a detrimental effect on the calculation, the full 5 m long pylon is also modeled. Because this 5 m long section is electrically larger, it is modeled only up to 1 GHz. The mesh is different than the one used in the main simulation where the quadrilateral patches were set at $0.3\lambda_{3GHz}$ (that is, where λ is the wavelength at 3 GHz). For the full pylon the quadrilateral patches were set at $0.15\lambda_{1GHz}$ (where λ in this case is the wavelength at 1 GHz). This makes for slightly different meshes and changes slightly the accuracy of the model. Despite this difference, the results for the longer pylon show the similar levels and trend as for the 3m section. The full pylon length simulations required 40,590 unknowns for the HH case, a total of 13 frequencies were solved in 1.73 hours. The VV case required 75,846 unknowns and it solved 13 frequencies in 3.8 hours

The results show that this approach can provide estimates of the RCS of pylons used in RCS measurements and that the truncation if done properly does not have a detrimental effect on the RCS results.

B. *Numerical resutls for a 30 cm sphere on the pylon*

As a final validation for the method, a 30 cm PEC sphere is placed on top of the 3m pylon section. The RCS of the entire structure is computed and compared with the Mie series solution. Figure 5 shows that for the HH case there RCS of the sphere on the pylon closely follows the Mie series solution. While for the VV case there is a difference although the results are similar amplitude. This is expected since it was shown in Fig. 4 that the VV response was higher than the HH response for the pylon.

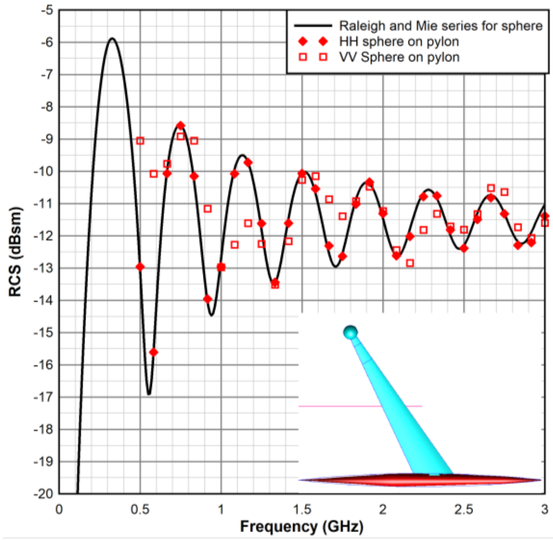

Fig. 5. Monostatic RCS of the pylon with a 30 cm diameter sphere on top.

Figure 6 shows the difference between the Mie series solution for the sphere and the sphere on the pylon for the VV case. The dBsm results are changed to linear units. The absolute value of the difference between the RCS for the Mie series solution and the numerical computed results for the sphere on the pylon is calculated at each frequency point. The difference between the results is then changed back to dB and is plotted in Fig. 6. The resulting values are fitted to a line to observe the trend of the difference.

The results show a significant difference between the Mie series solution and the results for the sphere on the pylon for the VV case. With differences in the order of 0.01585 m^2 at 500 MHz, However, the difference becomes smaller as the frequency increases to levels in the 0.002512 m^2.

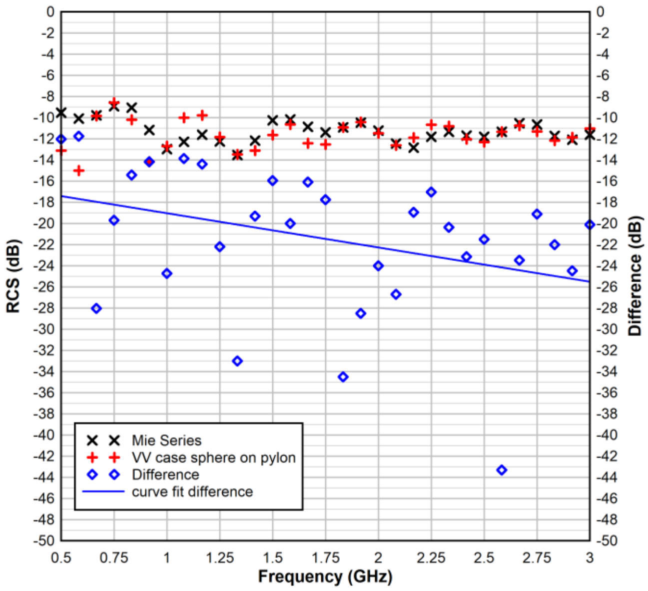

Fig. 6. Difference between the Mie series solution and the computed sphere on the pylon.

IV. Conclusion

The author has shown a method for truncating a pylon to be able to model it and to obtain the RCS of said pylon. A methodology for treating the truncation has been introduced which reduce the effects of the ends of the pylon on the RCS. This has been demonstrated by modeling different lengths of the same pylon geometry. Finally, a sphere has been placed on the pylon and the RCS computed to show that it follows the expected RCS with errors that are smaller than -18dB and decrease as the frequency increases despite the electrically increased size of the pylon geometry.

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