EMF Backscattered from an S-Shaped Inlet Cavity Calculated by Spectral Rays Tracking Method (part 2)

Elias A. Rachid

High School of Engineering of Beirut (ESIB) - Saint Joseph University (USJ), Campus des Sciences et Technologies
B.P.11-0514 Beirut, Lebanon
Email: elias.rachid@fi.usj.edu.lb

Abstract

In this paper, an original method for propagation modeling within waveguides, cavities, or structures with dielectric or conducting curved interfaces is presented and validated especially for S-bend inlet. This method is based on the discretization of the plane wave spectrum of the source fields, truncated by the guide or cavity aperture (without any approximation, neither far field nor asymptotic). The obtained results are validated by comparison with well-known solutions.

1. Introduction

The EM backscattered from an S-Shaped inlet cavity is analyzed generally using different techniques such: integral equation method, hybrid combination of asymptotic high frequency and modal methods, and the geometrical optics ray method. A new ray tube launching and tracking method based in discretized Plane-Wave Spectrum (PWS) of source field is proposed. Fields at any observation point are expressed as a discrete sum of all contributions from ray tubes tracked backward within the propagation environment, each ray tube representing a sample of the source PWS. We have already applied this method with high accuracy in the context of multiple reflections and refraction in dielectric lens antenna analysis, open cavity and waveguide analysis (rectangular circular and dielectric) [1-3]. Compared to the Shooting and Bouncing Ray (SBR) method [4] and the Generalized Ray Expansion GRE method [5] the SRT can be more efficiency of the SBR and similar to the GRE not in the spatial domain but in the spectral domain. We propose here to demonstrate its potential in the context of S-Shaped inlet cavity analysis and compare the obtained results with the solutions and measured values figured in [6]. The formulation of the method was explained very clearly in [1, 2].

2. Principle of the method

To find the field at an observation point M, we sweep the directions of arrival to that point with ray tubes launched backwards from M. In a multi-reflecting and/or refracting environment, it is possible to track a ray launched from M through successive local refractions and reflections. For a given ``tube" of directions of arrival, the ray path is found and saved after this backward launching step. When the four rays' tube reaches the source plane, the directions of the rays, projected on the transverse plane of the wave vectors space, define a transverse differential surface in the spectral domain. With the knowledge of both this spectral surface and the aperture distribution PWS, we calculate the field associated to the ray tube. This field is then transformed along the ray path previously saved, following the usual Geometrical Optics rules: in multi-reflecting and/or refracting environments, propagation of the field along a ray tube not only changes the phase of the field, but also its amplitude and direction, through reflection and transmission operators, and through phase front transformations at curved interfaces.

3. Numerical results and validation

Figure 1 shows the two inlet geometries. The inlets are rectangular of the same planar dimensions and perfectly conducting and will be analyzed in 3D at 10 GHz with all propagating modes in the waveguide sections (6 modes). Figure 2 shows the backscatter vs. aspect angle (θ) for the inlets of figure 1 using SRT method and the Asymptotic Modal (AM). The results agree quite well. The maximum Normalized Absolute Error (NAE) between the two methods is small than 3% for the straight inlet and 5% for the S-bend inlet. More applications of the SRT compared to the Asymptotic Modal for another S-form give accurate results. Figure 3 shows the level of the NAE for the E-field obtained by the RST method and the reference modes (6 modes) for a Straight inlet planar with perfect conductor waveguide, length=15 λ and aperture=3 λ, the source is a unit plane wave with incident angle θ equal to 0°, 10°, 20°, 30° and 45°. We can conclude that, near the aperture the NAE takes the value of about 5% in some points near the aperture and it is small than 2% for the other points because the SRT method takes into account the evanescent modes and the results are compared to the 6 propagating modes only. The SRT method is applied to an S-shaped inlet for making the termination not directly visible alters the backscattered pattern; the obtained results superpose with those calculated for the modes and the NAE still small than 2% for this type of inlet. The SRT method is applied and accurate to a small aperture waveguide and cavities in the order of have wavelength aperture and 3 waveguide length. Error is depending to the reflection number (N_{max}) and the values of sampling rate taken into account for the cavities. To obtain the convergence, N_{max} change from an application to another ($50< N_{max}<200$), it can be choosing about 200 (z=250 λ) for the perfect conducting waveguides and 50 for the same waveguides with loss or for the dielectric waveguide. Finally, the choice of the sampling rate ($n_{step} = 5$ number of samples by length wave) with fixed step is an enough number to be use in general and to obtain the convergence for any application using the SRT method.

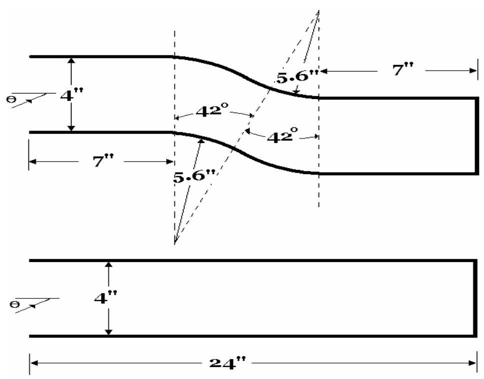

Fig. 1- Straight and S-bend inlet planar geometries

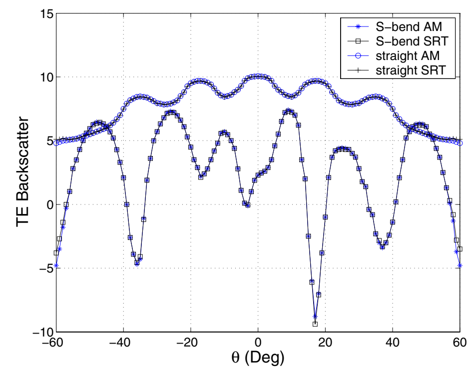

Fig. 2- TE Backscatter vs. aspect angle for S-bend and Straight inlets at 10 GHz

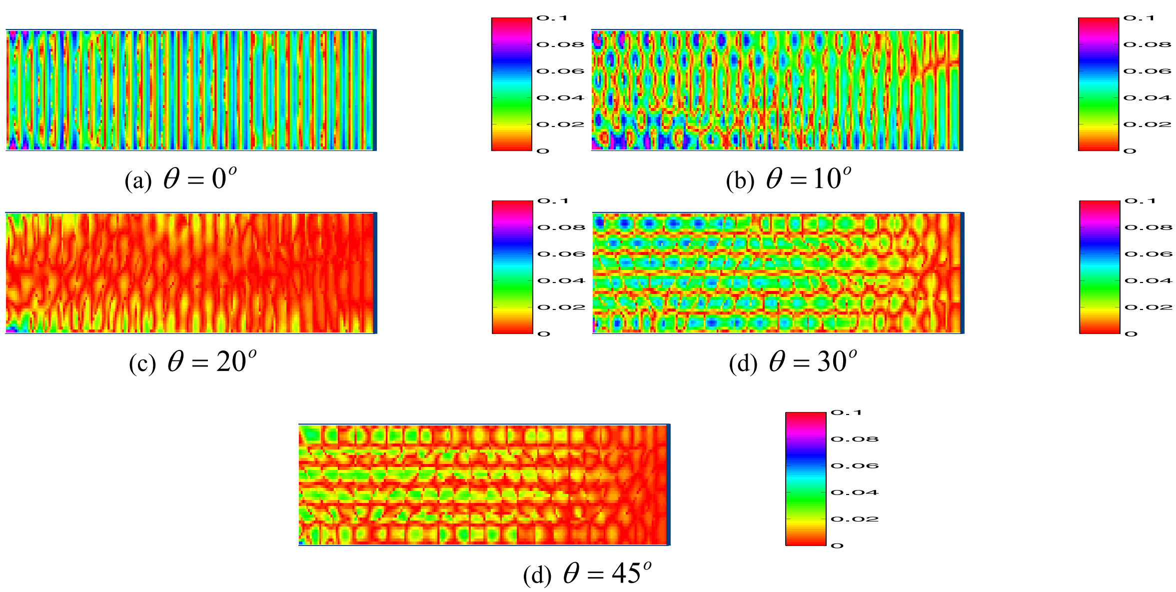

Fig 3- Level of the Normalized Absolute Error for the E-field obtained by the RST method and the reference modes for a Straight inlet planar with perfect conductor waveguide, length=15 λ and aperture=3 λ, the source is a unit plane wave with incident angle θ equal to 0°, 10°, 20°, 30° and 45°.

4. Conclusion

In this paper, the SRT method applied to the S-bend give a high accuracy compared to the Asymptotic Modal solution. This method can be used to provide reference solutions, in order to validate asymptotic methods such as Gaussian beam launching. The SRT method represents an interesting alternative to existing methods when fields have to be known at a limited number of predefined observation points; only one 2D summation per observation point is needed.

5. References

1. I.A. Ehtezazi and C. Letrou, "A spectral domain ray tracing method for quasi-optical device modelling", *Antennas Propagat. Soc. Int. Symp. Dig , pp.1086-1089, 1998.*

2. E. Rachid and C. Letrou, "A spectral domain ray: An Alternative method for devices modeling*", 27th General Assembly of Radio Science {URSI.}, no 1827, August 2002, The Netherland.*

3. E. Rachid, and C. . Letrou, Spectral Ray Tracking: An Alternative Method for Guided Propagation Modeling, *EIT2006, 6th conference, Michigan, USA, May 2006.*

4. H. Ling, R. Chou, and S.W. Lee, "Shooting *and bouncing rays: calculating the RCS of an arbitrarily shaped cavity," IEEE Trans Antennas Propagat*, *Vol.37), 194-205, Feb. 1989.*

5. P.H. Pathak, R.J. Burholder, R.C. Chou, and G. Crabtree, "A generalized ray expansion method for analyzing the EM scattering by open-ended waveguide cavities*," Antennas Propagat. Soc. Int. Symp. Dig. , pp.840-843. 1989.*

6. R.J. Burkholder , C.W. Chuang and P.H. Pathak, "*Electromagnetic Fields Backscattered from an S-Shaped Inlet Cavity with an Absorber Coating on its Inner Walls" Final report No 715723-2, Ohio State University, USA, July 1987.*