

Modified Edge Representation Computer Code
for Diffraction Analysis of Slot Antennas with Finite Ground Plane

Masanori KOSUGI, Tetsu SHIJO and Makoto ANDO
Dept. of Electrical and Electronic Eng. Tokyo Institute of Technology
2-12-1, O-okayama, Meguro-ku, Tokyo, 152-8552, Japan
shijo@antenna.ee.titech.ac.jp

1. Introduction

Slot antennas are usually designed assuming an infinite ground plane. However, actual slots are often cut on a finite ground plane and the design/analysis should take the perturbation due to diffraction into account. Most ground planes are much larger than the wavelength and EM analysis for the whole structure including the finite ground plane as the boundary value problems is computationally too heavy. It is not effective in that the dimension ratio between the antenna and the ground plane is usually very large and that the antenna excitation is well approximated by the assumption of an infinite ground plane. Figure 1 shows a linear slot array on the waveguide as an example. In calculating diffracted waves from large but finite planes with arbitrary shape for a given sources, high frequency (HF) approximations are advantageous. Unfortunately, antenna designers are often not too familiar with HF methods and try to use an excessively large ground planes in experiments to realize desirable agreement between measurements and design. The modified edge representation (MER)[1] is a high frequency approximation which expresses the edge diffraction as contributions from the equivalent edge currents (EEC). MER explicitly defines EECs in terms of sin/cos functions at every point on the periphery of the arbitrary ground plane including straight/curved edges and corners. The RB/SB and caustic singularities in standard ray theories can be eliminated for practical purposes without the use of Fresnel functions. So, MER can easily be implemented in codes for ground plane scattering. The purpose of this paper is to develop a general purpose program[3] for calculating the edge diffraction from a finite ground plane by MER. Key features of the program based upon MER are reported and calculated values for the slot arrays are compared to measurements and the improved agreements are confirmed.

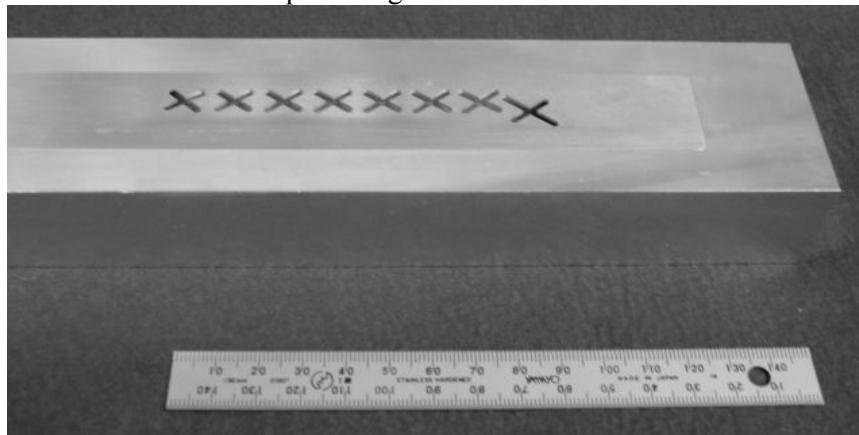
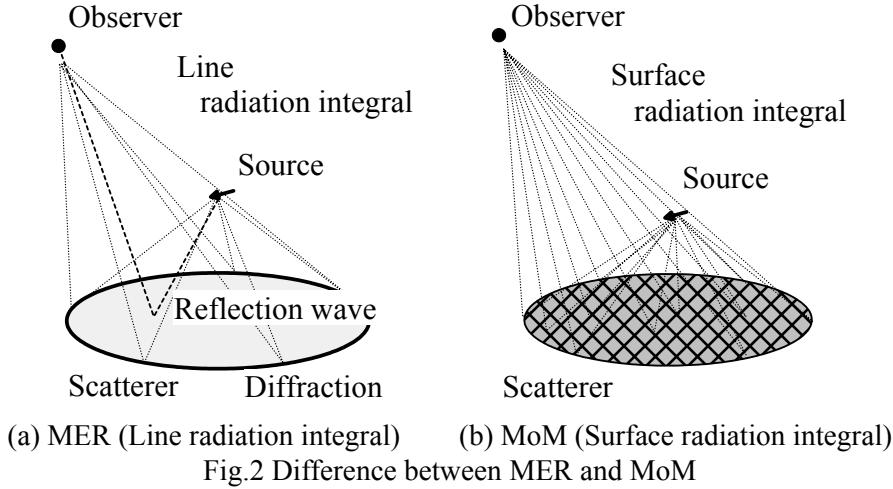


Fig.1 Cross slot array antenna with finite ground plane
(Infinite ground is assumed in designing slots)

2. Modified edge representation

MER is an extension or an embodiment of EEC based upon the geometrical theory of diffraction (GTD). GTD borrows the field in canonical problems with the local resemblance to the original one and predicts the diffraction as the sum of contributions from only the points satisfying the diffraction law or Fermat's principle for diffraction. At every point on the periphery, MER replaces the actual edge by the modified edge satisfying Fermat's principle; the equivalent edge currents (EEC) are defined by classical GTD, which suffers from RB/SB singularities. The overall diffraction from the finite ground plane is given in term of line radiation integrals of EECs defined completely over the

periphery. In the exact sense of boundary value problems, the diffraction is given in terms of surface radiation integrals of currents induced not only along the periphery but also all over the scatterer; this results in a large size integral equation to be solved for the whole surface current over the ground plane by MoM, etc. MER is advantageous in calculating diffracted waves from large but finite flat planes with arbitrary shape. These concepts are compared and sketched in Fig.2.



3. General purpose program

The general purpose program for diffraction analysis is demonstrated. A target user is an antenna engineer who is not familiar with diffraction analysis. A parameter input interface is prepared by a graphical user interface (GUI) as shown in Fig.3. The user inputs the design frequency, the observer information (position and polarization), the source information (position, direction and excitation), and the finite ground plane information (coordinates of the vertices of polygon approximation of the ground plane). The program outputs the desired component of the radiation pattern of the total (GO + diffracted) field in the specified observation plane. The arbitrary source, electric/magnetic current, is approximated by the sum of multiple small electric/magnetic dipoles with different complex excitation coefficients; longer sources, arrays and complicated slots/wires can be treated, provided the electric/magnetic current distribution is available. In most of cases, the current distributions designed on the assumption of infinite ground plane are the good approximations for them.

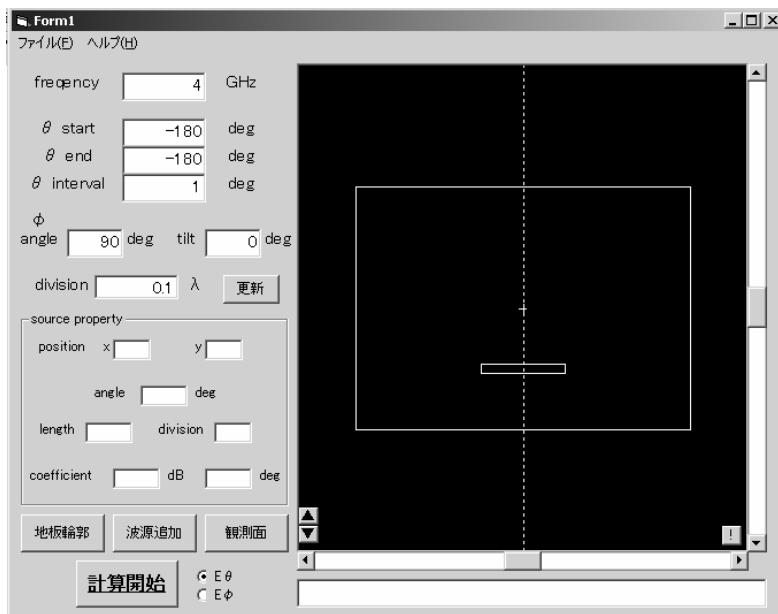


Fig.3 Parameter input interface prepared by graphical user interface (GUI)

Figure 4 illustrates the unique modeling of the rectangular ground plate in MER. For the observer ($\theta = 30^\circ, \phi = 45^\circ$) in (a), four diffraction points fall on the edges of the plate for which modified edges coincide with the original ones (marked by \circlearrowright). For the observer ($\theta = 60^\circ, \phi = 45^\circ$) in (b), on the other hand, two of the diffraction points fall just on the corners. In MER, the segments falling on the corner are also treated as the edge similar to other ones and does not need special treatment; the user does not have to be aware of the movement of the diffraction points. This is a diffraction-beginner friendly feature of the program.

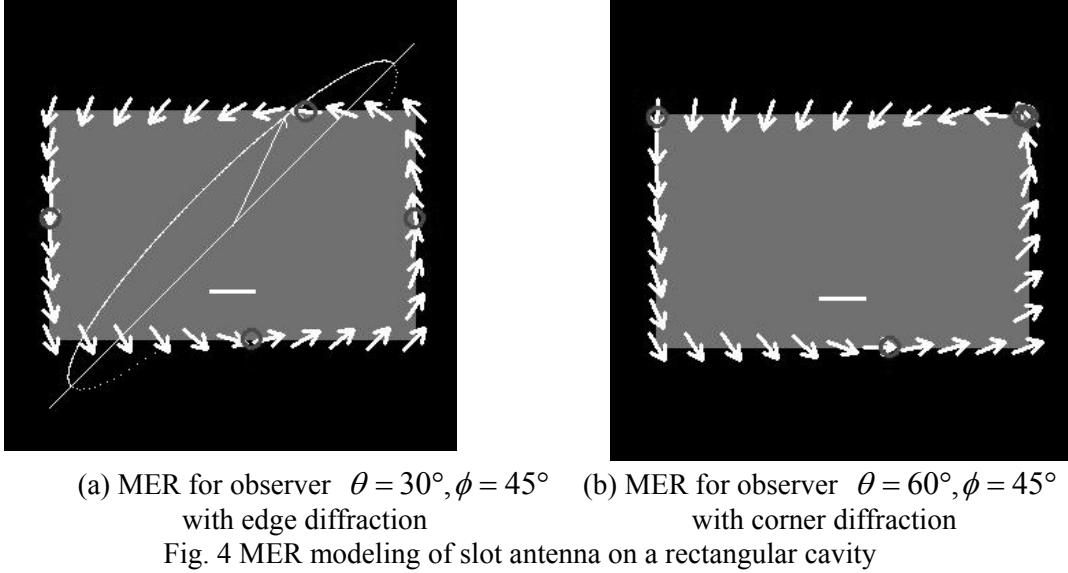


Fig. 4 MER modeling of slot antenna on a rectangular cavity

4. Numerical examples and comparison with measurements

Radiation patterns predicted by this program are shown and are compared with measurements for a cavity slot antenna and a cross slot array antenna. Figure 5 shows the analysis model and the radiation pattern for a cavity backed slot antenna with rectangular ground plane. In Fig.5(b), the dashed line is the approximation assuming the infinite ground plane. The solid line is the output of the proposed code by MER while the dotted line expresses the experiments. Even in its boresight ($\theta = 0$ degree), the perturbation due to diffraction is serious the infinite ground plane approximation is inaccurate. On the other hand, the prediction by this program is accurate for the full 360 deg region.

As another example, a linear cross slot array[2] in Fig.6(a) is analyzed by this program. This antenna consists of eight crossing slot arrays and is designed to radiate a circular polarized beam in a tilted direction of 50 degrees at 11.85 GHz. MoM-FEM hybrid analysis was conducted to obtain the fields in the crossed slots in detail as shown in Fig.6(b). About 70 magnetic current dipoles are used to describe one crossed slot. Furthermore the GTD wedge diffraction coefficients are used in the front region ($-90^\circ < \theta < 90^\circ$) in EECs in MER, though edge diffraction coefficients are used elsewhere empirically. Figure 6(c) presents the radiation pattern calculated for an infinite ground plane and for a finite ground plane by this general purpose program and measured. In the region near the main beam, numerical result assuming the infinite ground plane show good agreement with this program. This antenna is a high gain antenna and has relatively small edge perturbation. Although the influence of the edge diffraction is very weak, numerical result by this program reasonably predict the measurements in the full angular region.

5. Conclusion

The general purpose program for calculating the edge diffraction from the finite and flat ground plane by MER was developed. Calculated values are compared with experimental values for the cavity backed slot antenna and the crossed slot array antenna and the improvement due to inclusion of diffraction was checked. MER adopts only classical GTD edge/wedge diffraction coefficients, but MER can eliminate the singularities at SB/RB and caustic in numerical line integration.

Extensions to the curved ground plane are left for future study.

References

- [1] M. Ando, "Radiation Pattern Analysis of Reflector Antenna," Electronics and Communications in Japan, part 1, vol.68, no.4, pp93-102, 1985.
- [2] T. Hirano, J. Hirokawa, and M. Ando, "Design of a Waveguide Crossed Slot Linear Array with a Matching Element By the Method of Moments Using Numerical-Eigenmode Basis Functions," TECHNICAL REPORT OF IEICE, AP2003-52, pp.67-72, July 2003. (in Japanese)
- [3] M. Kosugi, M. Ando, "Radiation pattern analysis program for an antenna over a finite ground plane based upon the modified edge representation," IEICE Technical Report, 2004.

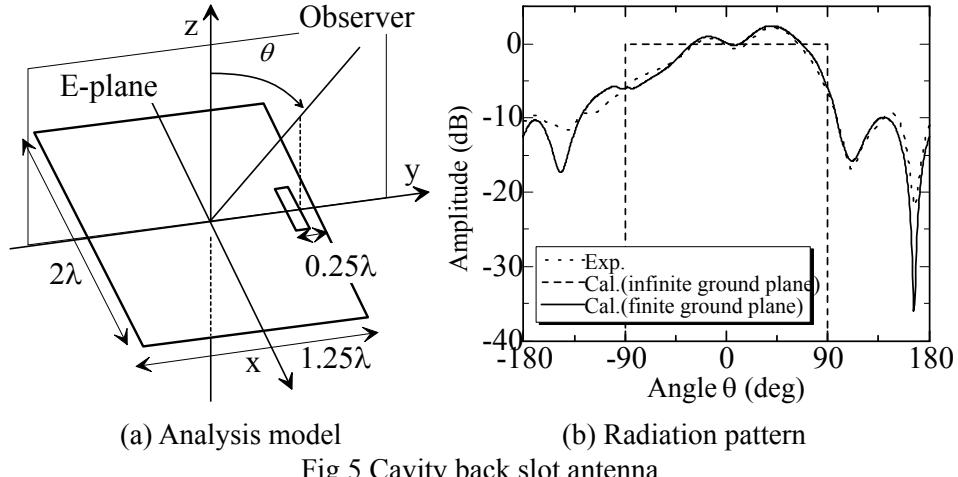


Fig.5 Cavity back slot antenna

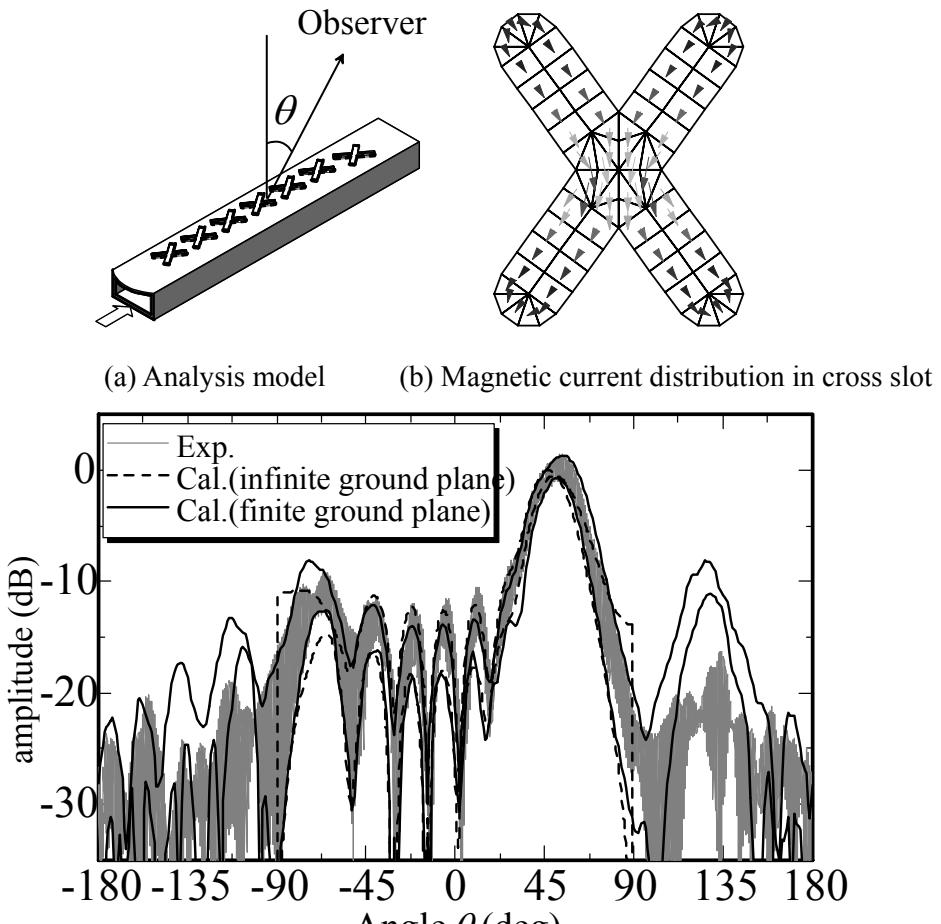


Fig.6 Cross slot array antenna