Study of the Scattering from Cavities

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Abstract

In this paper, the scattering of several cavities is studied by using the Connection Scheme[1] for cavity problems. As a result, we found that when the aperture size is small enough, the key factor that affects on cavity scattering is the shape of the fringe area of the cavity aperture, while the effect of its interior shape can be ignored. When the aperture size becomes large, the effects of the interior shape become more and more important, even for the case that only one dimension of the aperture becomes large while another dimension is small enough.

1. INTRODUCTION

The cavity scattering is a very general phenomenon. It includes the scattering from a plane inlet, the scattering from a missile silo, and that from the cracks and gaps mounted on the surfaces of all kinds of objects. The typical numerical methods for cavity scattering problems are Finite Element Method[2], Finite Difference of Time Domain[3], as well as Connection Scheme based on integral equations and equivalent principle, and so on. In real world, some cavities are very complex in shapes while others are simple, for instance the long and bended cavities and the narrow and straight cavities. For the case that a cavity is very long in depth, the computation complexity becomes very large, while the whole cavity is taken into account. So can we just take one part of the cavity into account and ignore its other parts? In this paper, the Connection Scheme is employed for calculating the scattered fields from several cavities. As a result, we found that when the cavity aperture is small enough, the primary factor that affects on the cavity scattering is the shape of the fringe area of the cavity aperture, while the effect by its interior shape, for instance the depth, can be ignored. Based on this characteristic, the computation complexity for solving the scattering from a thin-long cavity can be reduced drastically. But when the aperture size becomes larger and larger, the effect from the interior shape becomes more and more important, even for the case that only one dimension of the aperture becomes larger and another dimension keeps an enough small size. It suggested that the analysis of scattering from crack or gape is not always so simple, viz. just considering it as a narrow groove. The inner part behind the crack should also be taken into account.

2. SIMPLY DISCRIPTION OF CAVITY CONNECTION SCHEME

Cavity Connection Scheme (CS) is an integral equation algorithm for 3 dimensional cavity scattering problem designed by Tai-Mo Wang and Ling Hao in 1991[1]. Its main

idea is to dissect a long cavity into several small sections. Commonly, every section has two open sides, viz. two apertures. In each section the magnetic integral equation is employed to construct the relationship, viz. the admittance matrix between the magnetic field and the magnetic current on its two apertures. On the apertures shared by two adjoined sections, the field and current continuity is used to "connect" these two sections into one new section, simultaneously, the admittance matrix of the new section is obtained by merging the admittance matrices of the two original sections. Employing this scheme recursively, all sections are "connected" into one section, viz. the cavity, and at the same time, the admittance matrix that relates the magnetic field and magnetic current on the cavity apertures is obtained. Here if the cavity has a shorted end, one of its apertures is considered to be zero in size. The outer space may be thought as another section of the cavity. But it has source. Hence employing MFIE to this special section, one obtains the relationship among the magnetic field, the incident magnetic field and the equivalent magnetic current on the aperture of this section. Then "connecting" this section with the cavity via the field and current continuities on their adjoined part-the cavity aperture, we can solve out the magnetic currents on the aperture.

3. NUMERICAL ANALYSIS VIA THE CONNECTION SCHEME

The first example is a rectangular cavity with the aperture size of $0.48\times0.32\lambda^2$. It is mounted on an infinite plane. Its depth d is a variable. See figure 1. Figure 2 shows its $\theta\theta$, $\phi\phi$, and x polarized RCS, for the cases of $d=3.2\lambda$ and 10λ, respectively. We can see that although their depths are different, their RCS results are the same. In applying Connection Scheme, these two cavities are divided into 8, and 20 sections, respectively. The angle between the scattering direction and axis z is 40°.

The second example is a bended cavity having the same aperture shape with the first example. See figure 3. It consists of two sections. The upper section is a rectangular cavity with the depth of d a variable, while the lower part is an offset slant cavity with the height of $h=0.9\lambda$ and the slant angle of $\theta=30^\circ$. Figure 4 shows its $\phi\phi$ polarized RCS. For comparison, the results of the rectangular cavity in the first example with the depth of $d=10\lambda$ are also shown here. From this figure we can see that when $d\geq0.5\lambda$, the results of the bended cavity are the same as that of the rectangular cavity.

From these two examples, we can conclude that when the aperture size is small enough, the dominating factor that affects the cavity scattering is the shape of the fringe area of the cavity aperture. Hence the computation complexity of solving the scattering from a thin-long cavity can be reduced drastically by just replacing it with a narrow cavity (about 0.5λ) having the same aperture shape.

Is this conclusion suited for the large aperture cavities? The answers from the third example are negative. The third example is a rectangular trough. See figure 5. Its aperture size is $0.2\times16.25\lambda^2$. The depth $d=0.425\lambda$, 0.85λ, and 1.75λ. Figure 6 shows its $\phi\phi$ polarized RCS. The result for the case of $d=0.85\lambda$ agrees well with that from [1]. From this figure, we can conclude that when the size of the aperture becomes large, the effect of the interior part of the cavity becomes more and more important, even for the case that the size of one dimension remains small enough. Figure 7 shows its $\theta\theta$ polarized RCS. In this figure, the results of the three cases are the same. Because the aperture size along axis y is only 0.2λ, a very small number, the only guide wave model propagating in the trough is TE01 model. But TE01 model hasn't contribution to the θ

polarized far field on the XoZ plane. Thus the only part that has contribution to the θ polarized far field on the XoZ plane is the diffraction effect of the fringe.

4. CONCLUSION

From the numerical study of the scattering by several cavities, we had found that when the aperture size is small enough, the key factor that affects on cavity scattering is the shape of the fringe area of the cavity aperture, while the effect of its interior shape can be ignored. This will drastically reduce the computation complexity for solving the scattering from the thin-long cavity. But when the aperture size becomes large, the effects of the interior shape become more and more important, even for the case that only one dimension of the aperture becomes large while another dimension is small enough.

REFERENCE

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[2] J. M. Jin, The Finite Element Method in Electromagnetics, New York, Wiley, 1993.

[3] Tse-Tong Chia, Robert J. Burkholder, Robert Lee, "The Application of FDTD inHybrid Methods for Cavity Scattering Analysis", IEEE Transactions on Antennas and Propagation, Vol. 43, No. 10, October, 1995.

FIGURES

Figure 1. A rectangular cavity.

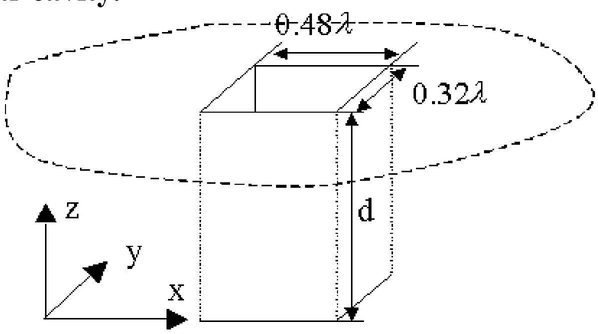
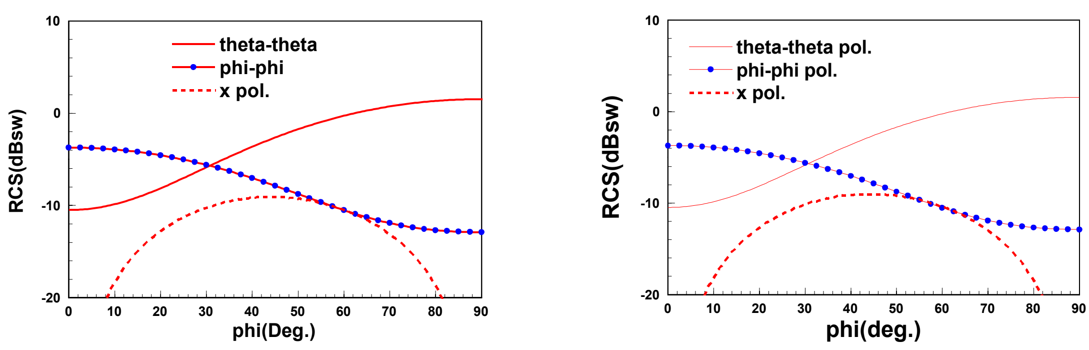


Figure 2. RCS of the cavity demonstrated in figure 1. (a) $d = 3.2\lambda$**, (b)** $d = 10\lambda$**.**



(a) (b)

Figure 3. A bended Cavity.

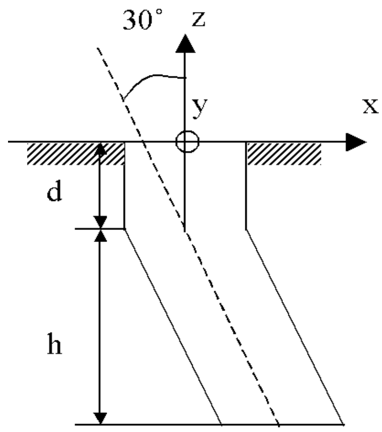


Figure 4. Phi-phi polarized RCS of the bended cavity.

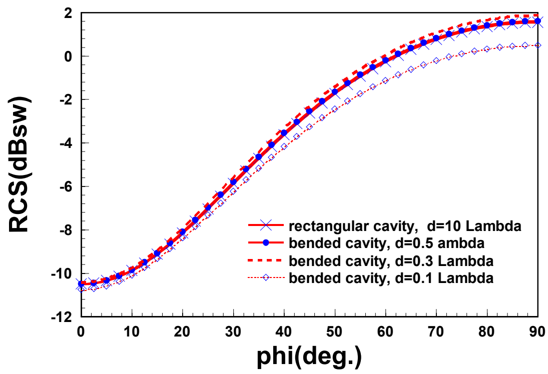


Figure 5. A trough.

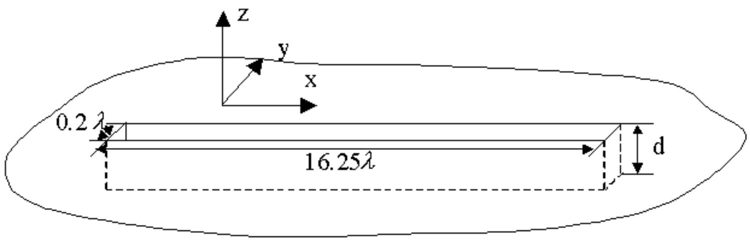


Figure 6. RCS of the trough. (a) phi-phi polarized, (b)theta-theta polarized.