Artificial Magnetic Conductor and Its Application

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Abstract-**In this paper, the reflection phase diagram along with frequency changes of artificial magnetic wall (AMC) is studied and we can determine the frequency band at which the AMC can be achieved. The concept of virtual electric/magnetic walls which are formed by combining perfect electric conducting parallel plates and perfect magnetic conducting parallel plates is cited. In practice, the perfect magnetic wall can be replaced with an artificial magnetic conductor surface. The implement of the Quasi-TEM waveguide with uniplanar compact electromagnetic band gap (UC-EBG) structure is simulated. The field distribution in the waveguide is presented with two simulation methods in HFSS which verifies the existence of the VMW. The phenomena in connection with AMC and resonance are also discussed.**

Index Terms-Artificial magnetic wall (AMC), virtual magnetic/electric Walls (VMWs/VEWs) , quasi-TEM waveguide, resonance phenomena.

I. INTRODUCTION

The perfect electric conductor (PEC) surface is well known that fully reflects incident waves with reflection phase of 180 while the perfect magnetic conductor (PMC) introduces a zero degree phase shift. But perfect magnetic conductor doesn't exist in nature. We use artificial magnetic conductors (AMC) instead of the perfect magnetic conductor [1]. The AMC is an equivalent magnetic conductor with a limited bandwidth and it works as an ideal equivalent magnetic conductor just at a fixed frequency. Recently, there has been a growing in realization of artificial magnetic conductors through the use of periodic surfaces [2]. In practice, the reflection phase of AMC surface cross zero at just only one frequency point (for one resonant mode) because of the resonant nature of such an AMC structure. The useful bandwidth of an AMC is in general within the range of +90 degree to -90 degree on either side of the central frequency [3].

One application of AMC surface can be seen in development of quasi-TEM waveguide in which phase velocity is equal to the speed of light in free space and field distribution becomes uniform in the center of the waveguide at a specific frequency point [4]. Another application of AMC surface is to construct a TEM waveguide by replacing the side PEC surfaces in conventional rectangular waveguide with the virtual magnetic Walls (VMWs) [5]. Two important advantages are observed, namely, a loss reduction since there are no metallic side walls, and also, an easy way to integrate or create rectangular waveguide in planar circuit. The field distribution in a cross section of the waveguide was simulated.

II.TEM WAVEGUIDES BASED ON VE/MWS

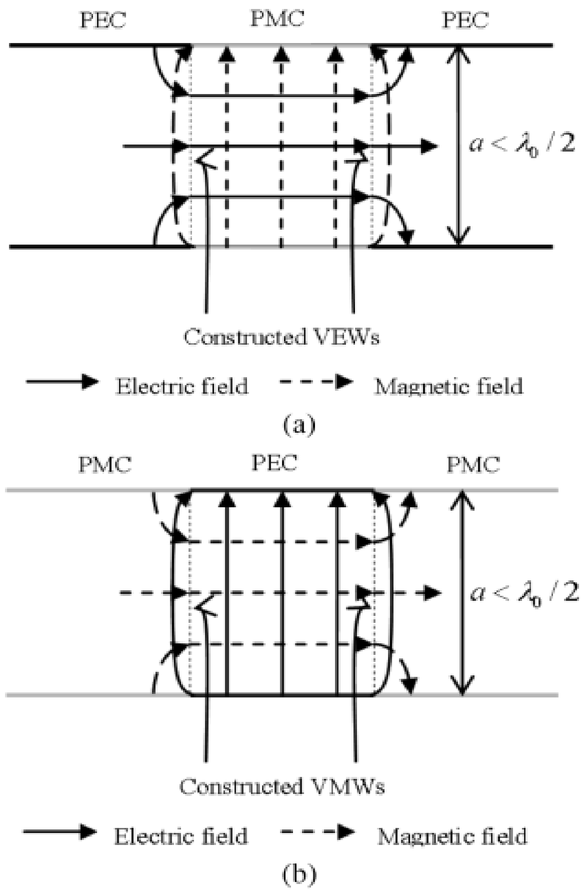


Fig.1. Field distributions of TEM modes and VE/MWs (a) TEM mode wave-guide based on VEWs. (b) TEM mode waveguide based on VMWs.

The virtual magnetic/electric Walls (VMWs/VEWs) can be used to construct TEM waveguides as shown in Fig. 1. In Fig. 1(a), a PMC parallel plate waveguide is connected to two PEC parallel plate waveguides at both sides. In this case, two vertical VEWs are formed at the PEC/PMC interfaces. Only the TEM mode with E-fields parallel to the plates can be supported in the PMC parallel plate waveguide when the distance of the two parallel plates is smaller than a half of wave-length. The electromagnetic fields are confined in the center region bounded by the two side VEWs. Different from the real electrical conductor, the VEW allows the fields to penetrate into the PEC parallel plate waveguide region. However, the fields will decay very quickly when it passes through the VEW. Fig. 1(b) shows a complementary TEM waveguide based on VMWs. It shares the same properties as that in Fig. 1(a) except that the electric and magnetic fields are interchanged.

III. REFLECTION PHSE OF AMC

As all we know, the frequency selective surface (FSS) is a periodic structure which shows a band-pass or band-stop characteristics at a fixed frequency [6]. This frequency is a point where the structure resonance occurs. The AMC is also a frequency selective surface but different from it which has a ground plane on the back of the periodic structure. The principle of AMC operation is based on the resonance of cavities formed between the periodic array and the ground plane. The AMC has a limited bandwidth because of the nature of resonance and its characteristics vary in the bandwidth.

A uniplanar compact electromagnetic band gap (UC-EBG) st ructures, first presented by Itoh's group [7], is used as AMC su rfaces. The UC-EBG surface is fabricated on a conductor-base d Duroid substrate (Duroid 6010) with dielectric constant of 10 .2 and thickness of 25 mil. As in Fig. 2, the unit cell design of t he EBG surface with d=180mil,b=162mil,h=45mil,g=s=18mil i s showed.

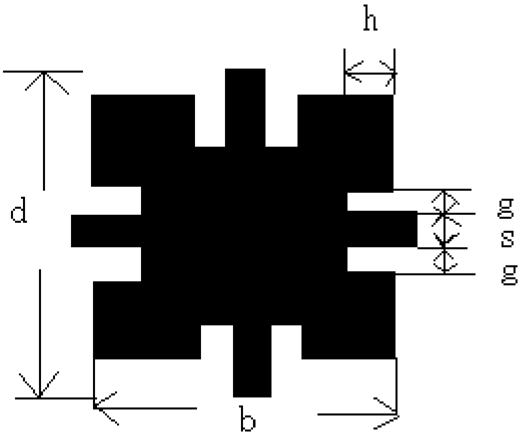
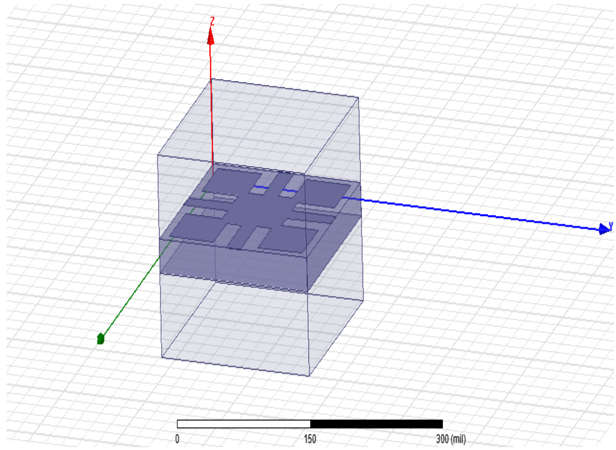
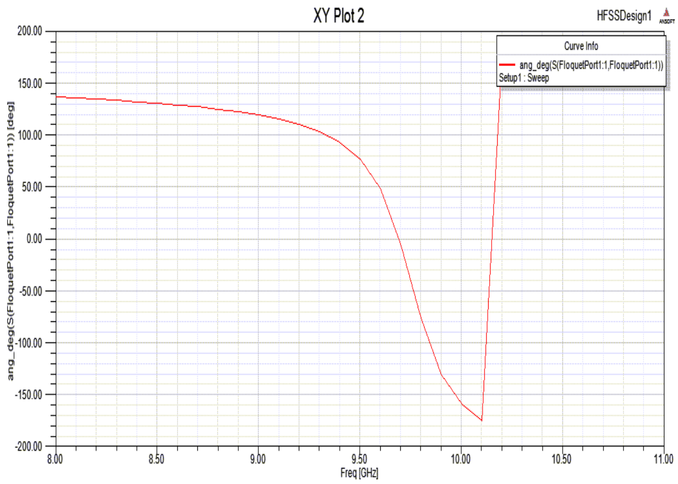


Fig. 2 A unit cell of the PBG lattice

The full-wave finite-element-based simulation package Ansoft-HFSS [8] is applied to obtain the reflection phase characteristics of the AMC structure in figure 3 and 4. Two methods were used to achieve the results we want. In figure 3(a), two pairs of master-slave boundaries of assumed the scan angles difference was placed at the front and back boundaries and the left and the right boundaries of the unit cell along the x-direction and the y-direction. The Floquet excitations were added to both the upper and the lower surfaces. The result is showed in figure 3 (b). As in figure3 (b), the reflection phase changes along with the change of frequency and crosses the 0 degree (for one resonant mode) at the frequency of 9.66GHz. The useful bandwidth is 9.3~9.9GHz in which the reflection phase is within the range of +90 degree to -90 degree. In general, we have achieved the artificial magnetic conductor in this bandwidth.



(a)

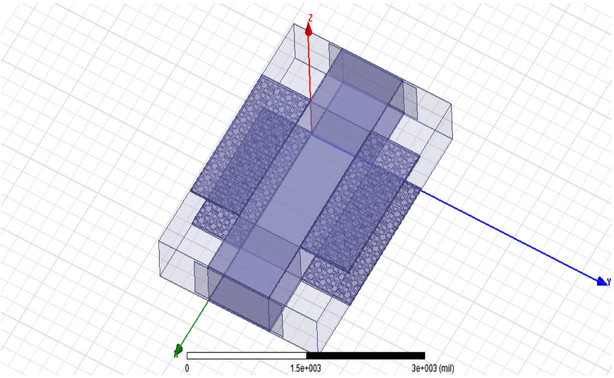


(b)

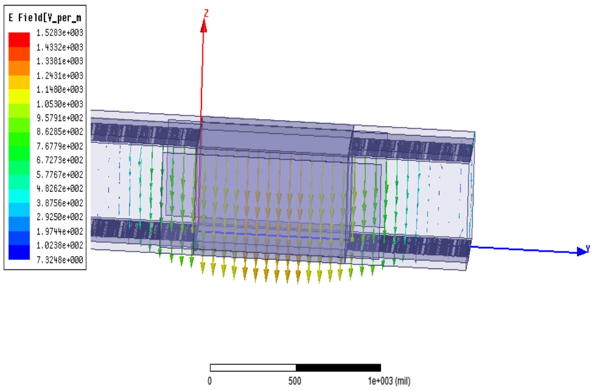
Fig.3 Floquet method of reflection phase (a) The model of UC-PBG in HFSS (b) The result of the reflection phase with the frequency

IV. FIELD DISTRIBUTIONS OF THE TEM WAVEGUIDE BASED ON AMC TECHNIQUE

In order to prove the existence of the virtual magnetic wall, the full-wave finite-element-based simulation package Ansoft-HFSS is applied while the existence of the virtual electric wall has been proved in another paper. The waveguide consists of two parallel PCB with four pairs of periodic on both sides. The length of the PCB is about 10 times the length of UC-PBG used above. A standard rectangular waveguide whose sidewalls are removed with the length of 900mil and width of 400 mil is in the middle of the model .Two standard rectangular waveguides with the same parameters are placed at the front and back boundaries in order to eliminate the impact of discontinuities. The whole model is covered by air box whose four walls are set to radiation boundary condition. The part we are interested in is the field distribution between the two parallel PCB. One must be pointed out that the distance between the two parallel must be less than half of a wavelength in the frequency band we are interested in. The whole model is presented in figure 4 (a).



(a)



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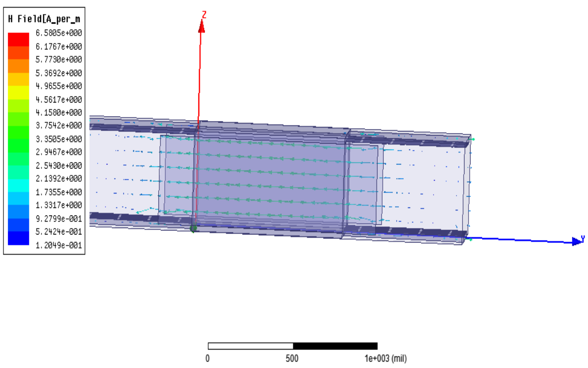
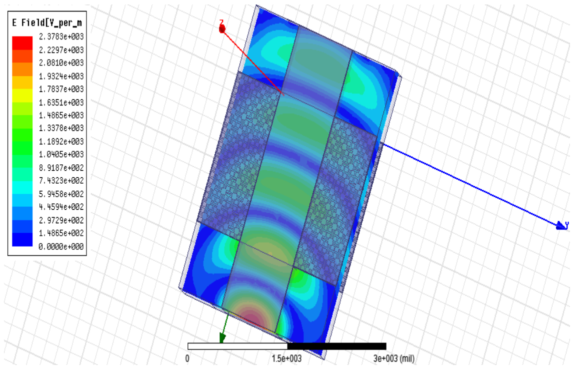


(c)



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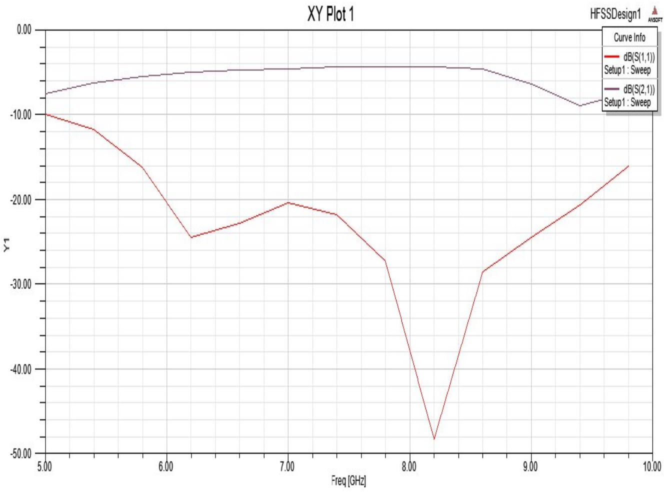
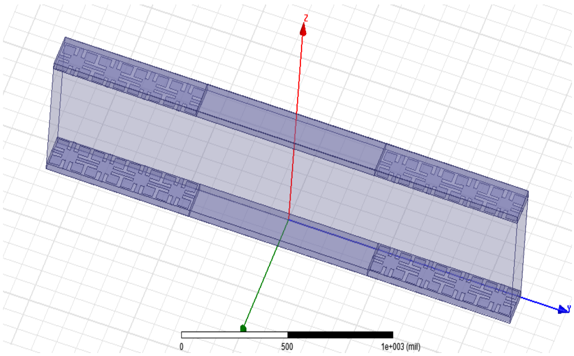


(e)

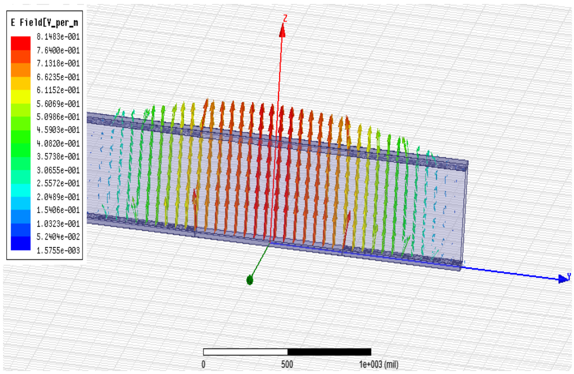
Figure 4 Calculation of the VMWs with the Driven mode (a) The model of the Quasi-TEM waveguide in AMC technology (b) Electric field distribution on the middle cross section (c) Magnetic field distribution on the middle cross section (d) The magnitude of the electric field distribution throughout the model (e) Magnitude of S(1,1) and S(2,1) in dB

Figure 4 (b) and (c) show the electric and magnetic distributions in the middle of cross section of the model. The solution frequency is 8GHz. The field distributions are close to that of figure 1 (b).The field almost keeps uniform in the entire center region of the waveguide and decrease very quickly outside the VMWs. The characteristics of the field distribution indicate that two VMWs exist on both sides of the waveguide. The magnitude of the electric is also showed in figure 5(d). We can easily find that the magnitude of electric decrease very quickly outside the VMWs. All of these can prove the existence of the VMWs. Figure 4 (e) shows the magnitude of S(1,1) and S(2,1) in dB. Most of the energy is transmitted to the port 2 in a large band which is probably between 6.8GHz and 8.6GHz. This frequency band doesn't fall within the resonance frequency band which can prove that the Quasi-TEM with UC-PBG structure doesn't depend on the resonance phenomenon and has a wider bandwidth.

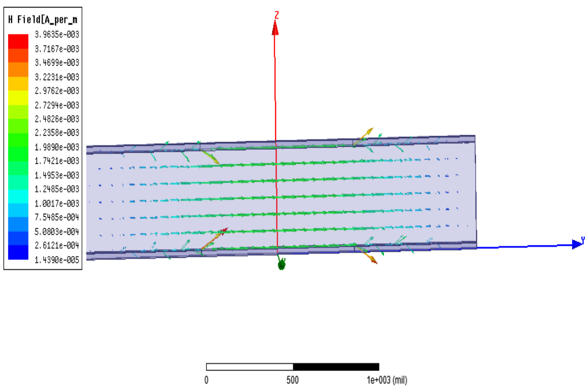
The Eigen mode method in HFSS is also applied to achieve the virtual magnetic wall. The structure of the waveguide is similar to the above but with only one periodic. The parameters of the waveguide is the same to the Driven mode. Figure 6 (a) shows the model of the Quasi-TEM waveguide based on AMC technology. A pair of master-slave boundaries of assumed phase difference was placed at the front and back boundaries of the unit cell along the longitudinal axis (x-direction) to compute a corresponding frequency of the eigen value. The electric and magnetic distributions in the cross section of one cell of 30 degree phase difference in the master-slave boundaries are showed in figure 6 (b) and (c) which are similar to the distributions of the Driven mode. The corresponding frequency is 8.2GHz which is very close to that of the Driven mode.



(a)



(b)



(c)

Figure 6 Calculation of the VMWs with the Eigen mode (a) The model of the Quasi-TEM waveguide in AMC technology with only one periodic (b) Electric field distribution on the middle cross section (c) Magnetic field distribution on the middle cross section

V. CONCLUSION

In this paper, two methods of implementing the phase reflection diagram were presented. We can easily determine the frequency band at which the AMC can be achieved. The implementation of the AMC is concerning to the resonance phenomenon. The existence of the VMW was also proved with two kinds of simulation methods in HFSS. In both methods, the Quasi-TEM waveguide was also achieved because of the VMWs. The field distributions in the cross section were simulated. The different frequency points between the AMC which is the resonance point in general and the Quasi-TEM waveguide with the VMWs show that the realization of the Quasi-TEM is not based on the traditional resonance theory and have a wider bandwidth.

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