ANALYSIS OF THE EFFECT OF EBG SIDEWALLS IN PARALLEL PLATE SLOT ANTENNAS

José-Manuel Fernández, Manuel Sierra-Castañer

Universidad Politécnica de Madrid. E.T.S.I. de Telecomunicación. 28040 Madrid.
Tel. 34-91-5495700. Fax. 34-91-5432002. E-mail. jmfdez@gr.ssr.upm.es

Abstract: *In this work we analyse the effect of EBG sidewalls in parallel plate slot antennas. Electromagnetic BandGap (EBG) structures present some interesting properties that may overcome some of the problems of conventional technologies. Recently, several EBG structures have been proposed and demonstrated to be useful in enhancing performances of microwave circuits or antennas. We use these novel structures to realize a perfect magnetic conductor (PMC) surface artificially. The results of the effect using PMC in comparison with perfect electric conductor (PEC) in the sidewalls of the parallel plate slot antennas is presented as examples of application. Using PMC sidewalls in this kind of antennas, relatively uniform field distributions are improved, so it allows to increase the directivity getting to enhance the efficiency of these antennas.*

1. Introduction

The Electromagnetic bandgap (EBG) structures are novel periodic structures that, by generating a bandgap, can properly control the propagation of electromagnetic waves. These structures can be one, two or three dimensional periodic structures and they have been investigated for their versatility in controlling the propagation of electromagnetic waves in one, two or three dimensions. EBG technology presents some interesting properties that may overcome some of the problems of conventional technologies. In particular, recently, several EBG structures have been proposed and demonstrated to be useful in enhancing performances of microwave circuits or antennas. For example, the problem of the non-uniform field distributions in a parallel plate waveguide with perfect electric conductor (PEC) sidewalls can be prevent using perfect magnetic conductor (PMC) sidewalls. To date, PMC surfaces are receiving more and more attention since they offer advantages that cannot be accomplished by utilizing traditional PEC. In contrast to the realisation of a PEC, which is not difficult in practical situations, the realisation of a PMC remains a difficult task. The difficulty stems from the fact that no suitable material has been found which can be used as a PMC. Hence, the analysis and design of a PMC is important. One possibility to design an artificial PMC is to use periodic structures [1].

The purpose of this work is twofold: first, to provide further knowledge on the functioning of artificial PMCs by designing and analysing them, and second, to present the practical applications of PMC sidewalls in parallel plate slot antennas. The aim is to uniform the field distributions using PMC sidewalls in comparison with the PEC ones in a parallel plate waveguide and in parallel plate slot antennas.

For the design of the artificial PMC based on [1,2,3], where Itoh present the possibility to create a PMC surface with a novel 2D uniplanar EBG structure, we are going to analyse an array of closely spaced patches.

These planar periodic EBG structures are particularly attractive and have been intensively investigated due to their advantage of being simple, low cost and can easily fabricated using any standard planar process without the need for vias, which are necessary for other types of EBG structure. With the aim to check the ideas exposed before, 3D electromagnetic simulations based on Finite Integral Time Domain (FITD) have been achieved with the software CST Microwave Studio v. 4.0.

As a practical example, EBG sidewalls acting as PMC are going to be analysed in parallel plate slot antennas as described in [4,5]. A most uniformity of the field distributions allow us to increase the directivity, getting to enhance the efficiency of these kind of antennas. These pratical applications will allow us to validate the simulation results.

3. Design of the PMC with EBG

The main difference in electrical property between a perfect electric conductor (PEC) and perfect magnetic conductor (PMC) can be observed by measuring the reflection coefficient. The magnitude of the reflection coefficient for both cases is equal to 1, while the phase differs by 180°. Alternatively, the conducting surface acts as an open circuit in the case of a PMC, and conversely as a short circuit in the case of a PEC. One way to present these short and open conditions is by using a periodic pattern. Each element of the periodic pattern provides an equivalent L and C parallel connection, which changes the surface impedance. At frequencies where the periodic loading presents an open circuit condition, a PMC surface is created. The basic idea here is the introduction of a periodic network of LC elements to shorten the wavelength of the propagation wave. PMC surfaces show interesting properties.

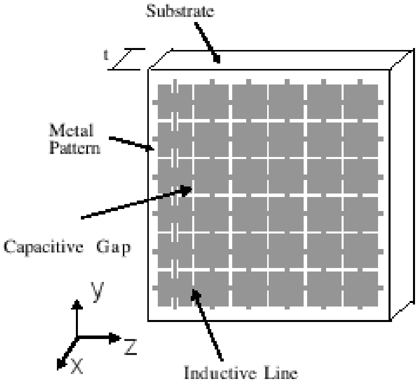


Fig. 1: EBG 2D uniplanar structure acting as PMC

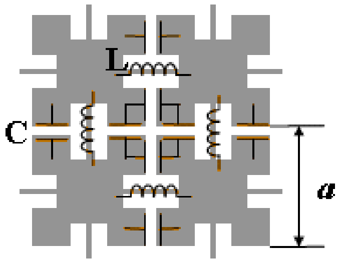
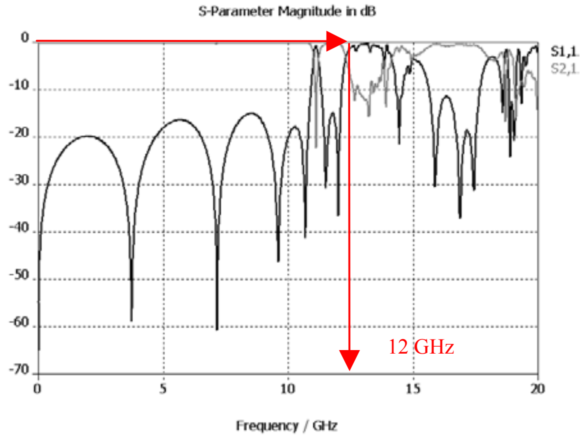


Fig. 2: Equivalent circuit scheme of the EBG periodic structure

In this work, a 2D uniplanar EBG structure is employed to realize the PMC surface [1,2,3]. To understand the performance of the planar PMC structures, it is suitable to investigate as a test structure a periodic array of closely EBG 2D uniplanar patch as shown in Fig. 1.



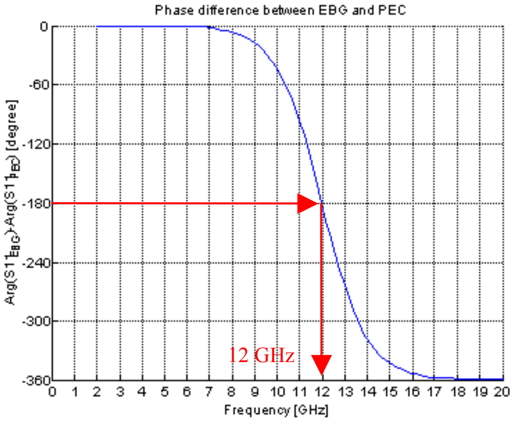


Fig. 3: Simulated S-parameters of a normally incident plane wave on the 2D uniplanar EBG surface

Fig. 4: Simulated phase difference of the reflection coefficient between EBG and PEC surfaces

As can be seen in Fig. 3, especially from 11.75 to 12.25 GHz, it corresponds to the frequency range where the EBG sidewalls behave like PMC surfaces. In Fig. 4, the optimum operating point is at 12 GHz, where a 180° phase difference in reflection coefficient between PMC and PEC surfaces occurs around it.

2. Analysis of Parallel Plate Waveguide

The prototype of the waveguide that we analysed is a rectangular parallel plate waveguide of 330mm x 318mm with sidewalls, between that we had a foam dielectric of 7.5mm height. The operating frequency of this waveguide is 12 GHz. The ideal functioning of the waveguide only propagate a TEM mode (or quasi TEM). An array of probes excite the parallel plate waveguide to generate a TEM mode. A common characteristic to the propagation of this kind of mode is his degradation at the same time as we move away from the feed point, that cause non-uniform field distributions in the waveguide with PEC sidewalls.

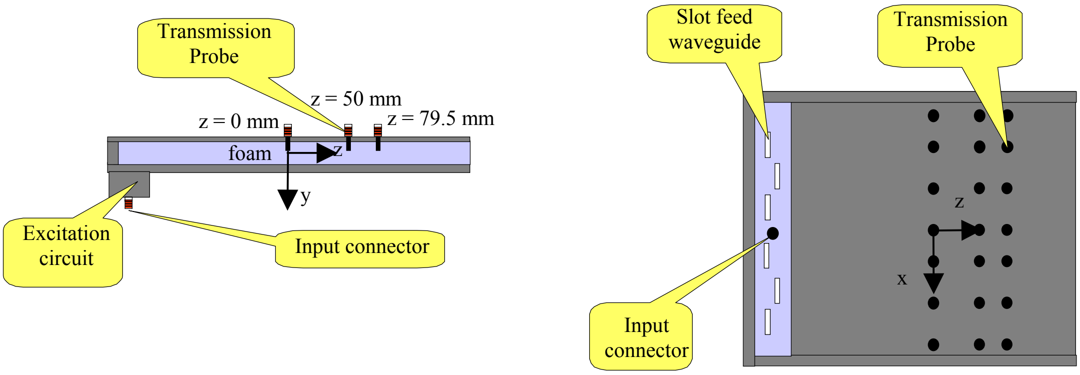


Fig. 5: Scheme of the parallel plate waveguide

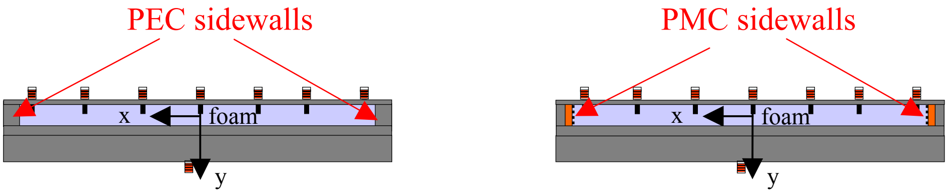


Fig. 6: Scheme of the profile parallel plate waveguide with PEC and PMC sidewalls

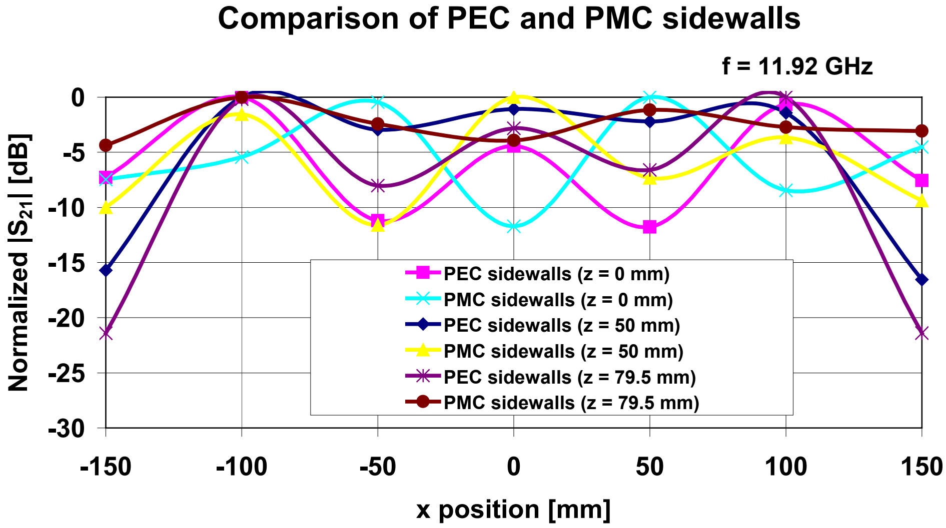


Fig. 7: Comparison of the measured transmission coefficients in the parallel plate waveguide with PEC and PMC sidewalls

As can be seen in Fig. 7 , the PMC sidewalls waveguide has a relatively uniform field distribution compared to the standard waveguide with PEC sidewalls. The ripples that can be seen in the results are due to that the TEM wave has been generated with an array of slot in the feed waveguide.

4. Practical Application

The proposed 2D uniplanar EBG structure acting as PMC is applied in parallel plate slot antennas shown in Fig. 8 and Fig. 9 [4,5], which operating frequency is 12 GHz.

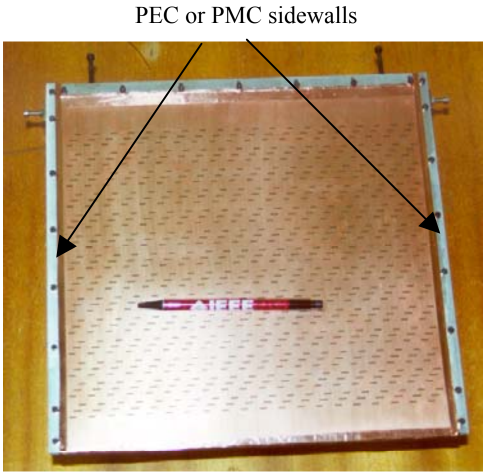


Fig. 8: Parallel plate slot antenna with linear polarization excited by rectangular waveguide

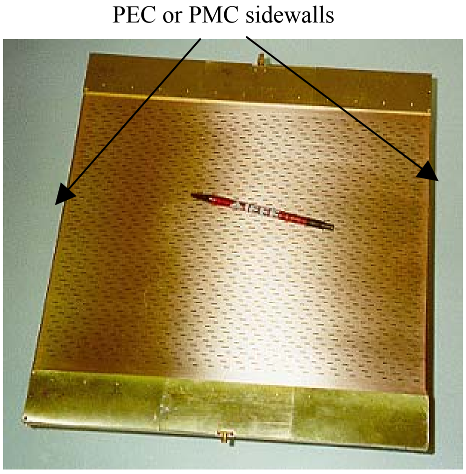


Fig. 9: Parallel plate slot antenna with linear polarization excited by microstrip circuit

5. Conclusion

The simulation and experimental analysis effect using EBG sidewalls acting as PMC in a parallel plate waveguide and in parallel plate slot antennas have been presented. The simulation and the experimental results show that a fairly uniform field distribution along the transverse direction of the parallel plate waveguide with PMC sidewalls has been obtained. These results demonstrate the feasibility of applying PMC sidewalls to improve the characteristics of parallel plate slot antennas. A most uniformity of the field distributions allow us to increase the directivity, getting to enhance the efficiency of these kind of antennas. These pratical applications will allow us to validate the simulation results. The analysis results of the effect between the PEC and PMC sidewalls in prototypes of parallel plate waveguide and parallel plate slot antennas will be compared with the simulation results and presented in JINA'04.

Acknowledgment

The authors would like to thank CST (Computer Simulation Technology GmbH) the license for the use of the software CST Microwave Studio v. 5.0, utilized for the simulations that have been achieved in this work.

REFERENCES

[1] K.-P. Ma ,K. Hirose, F.-R. Yang, Y. Quian and T. Itoh, "Realization of magnetic conducting surface using novel photonic bandgap structure", IEE Electronic Letters, Vol. 34, N° 21, pp.2041-2042, October 1998.

[2] C.C. Chang, Y. Qian and T. Itoh, "Analysis and Applications of Uniplanar Compact Photonic BandGap Structures", Progress in Electromagnetics Research, PIER 41, pp.211-235, 2003.

[3] Y.Zhang, J. von Hagen, M. Younis, C. Fischer and W. Wiesbeck, "Planar Artificial Magnetic Conductors and Patch Antennas", IEEE Transactions on Antennas and Propagation, Vol. 51, N° 10, pp.2704-2712, October 2003.

[4] M. Sierra Castañer, "Contribución a las Técnicas de Diseño y Análisis de Antenas de Ranuras sobre Placas Paralelas ", Tesis Doctoral, Universidad Politécnica de Madrid, Febrero 1999.