Analysis by FDTD Method of a Microstrip Antenna with PBG Considering the Substrate Thickness Variation

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Abstract

This work is supposed to contribute to the development of researches in the area of Patch Antenna. The general purpose involves a Microstrip antenna on Photonic Band Gap structure. The use of this structure implies in the reduction of the troublesome surface waves that plague the performance of these antennas and complicate its theoretical modeling. The FDTD approach is used because of its versatility to study the reflection, refraction and diffraction phenomena. For such problem, an absorbing boundary condition must be introduced at the outer lattice boundary to simulate the extension of the lattice to infinity. In this case, it is very important to avoid parasitic reflections and due this the UPML is used. Here, an efficient code using parallel processing is applied.

1. INTRODUCTION

Basically, the PBG structures are made of dielectric materials (or metals) distributed periodically inside of an evolving region [1-2]. When this region are submitted to the electromagnetic waves propagation, a remarkable characteristic, due to the periodicity of the material, is the existence of frequency bands where the electromagnetic waves are reflected to and do not propagate in their inner. A substrate characterized by these properties is of fundamental importance in the solution of the surface wave problem that plagues the performance of the Microstrip antennas [3-4].

The term surface wave is associated to the flow of energy that is confined to a region next to a surface. These waves are present in Microstrip antennas due to the form and to the material used in their compositions. The waves excited in the process of radiation of these antennas are radiated more efficiently into the structure than the air side. This is due to the fact of the substrate dielectric constant to be greater than the unit. Thus, the substrate works as a storage device of propagating modes on the ground plane of the antenna. If the interface between two media is perfectly plane, these waves will not contribute to the radiation process. However, the antenna edges, in this case, diffract or scatter the waves that reach there, giving origin to end-fire lobules. This effect is known as edge effect. Further more, if a system is formed by multiple antennas (array), all sharing the same substrate and ground plane, the currents that will come up, due to the conducting properties of the ground plane,

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may cause coupling of fields, which reduce even more the efficiency of the antenna [5].

In this work, another model is proposed, for the conventional microstrip antenna initially published in [6] and analyzed in [7]. The aims of this work are: a) to identify; b) to analyze; and c) to reduce the surface wave problem. For this, the Microstrip patch is symmetrically positioned at the center of a substrate, which is composed of a PBG structure. This study is feasible through the FDTD method, implemented by the technique of ABCs UPML [8]. The use of the parallel processing is also evidenced, because of the difficulties with data storage in memory, and due to the processing time for this kind of implementation [9-11].

2. MICROSTRIP ANTENNA MODEL WITH PBG

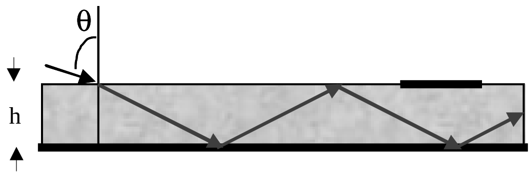

Fig. 1. Surface wave ilustration inside of a Microstrip antenna.

An analytical description about the surface wave propagation can be found in [12]. From this work, one can conclude that it is possible to reduce the effects of these surface waves in the case of a Microstrip antenna. This will be achieved, in this work, by using the photonic band gap theory. Thus, in Fig. 2 it is illustrated a new configuration of a Microstrip antenna. The conventional antenna has been analyzed in others papers, as referred in [13].

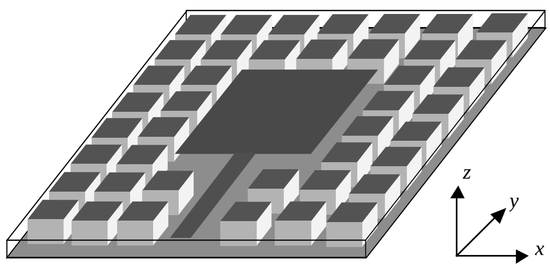

Fig. 2. Microstrip antenna with PBG structure.

The aim of this new configuration is to reduce the surface wave problems at the resonant frequencies. The mechanism responsible for the surface waves generation can be explained by the ray optics. As these waves have their origin related to the reflections that occur on the ground plane and on the substrate-air interface (see Fig.1), it is then more suitable to use a periodic structure which avoids the propagation of these waves. To do so, dielectric blocks are attached as showed in Fig.2. These blocks were simulated using a material of relative permittivity ε_r=10.2 while the rest of the substrate is maintained by ε_r=2.2.

3. NUMERIC TREATMENT

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In order to obtain the following results (Figs. 3-8), the conventional antenna thickness presented in [6] was increased. As it is known, the increase of the substrate thickness evidences the surface waves problem. Consequently, this will affect the antenna performance in the radiation frequencies.

In this work, as well as in [6], the patch has dimensions of 12.45mm x 16.00mm, and the feedline width is of 2.46mm. The substrate thickness has an initial value of 0.794mm. In the discretization of the structures considered here, Δx=0.3891mm, Δy=0.4000mm and Δz=0.1588mm were considered. Thus, the rectangular patch was defined by a mesh of points of 32Δx by 40Δy, while the feedline has the dimensions of 6Δx by 20Δy. In order to maintain the Courant condition, the time discretization was done in such way that Δt=0.441ps. For the excitation source of the antenna it was considered a Gaussian pulse, whose bandwidth is of 30 GHz, with duration of T = 16.0 ns and a delay of 3.0T. In all the cases analyzed, 8000 time iterations were necessary to obtain the steady state. For the analysed model, the elements introduced in the antenna structure are cylinders, where their transversal sections are squares with dimensions of 8Δx by 8Δy, spaced by four cells. As it is noticed in Fig 2, the patch is maintained in the center of the structure, distanced by 4Δx from the blocks along the x-direction and by 6Δy along the y-direction. For the feedline, the dielectric blocks were distanced by 5Δx of its sides. The UPML was simulated with ten layers and its parameters are the same described in [8].

The increment of the substrate thickness was done starting from the original value of 5Δz. Thus, the simulations were done with the addition of one cell until the double of the initial substrate thickness (10Δz), both for the reference antenna as for the model proposed with PBG (Fig.2).

In Figures. 3-6 is shown the return loss as a function of frequency for two situations that are: a) a Microstrip antenna with a homogeneous substrate (continue line) and b) the same antenna using a substrate with a PBG structure (line with markers). For Figures 3-6, h (Figure 1) was considered equal to 5; 6; 9; and 10Δz, respectively. The effects due to these modifications are evidenced in the antenna bandwidth, as can be seen in these figures. It is also important to notice that this result is a situation among those that were obtained for various values of the substrate thickness (Figures 3-6). From these figures one can see, when the substrate is thicker, the different behaviors of these antennas.

The FDTD method is currently the most powerful tool of analysis in the identification of surface waves in planar structures. These waves were identified, for the first time, by using this method, in [14]. However, although simple, no work was found in literature, up to now, that showed the reduction of these waves by means of analysis of the spatial distribution of electromagnetic fields.

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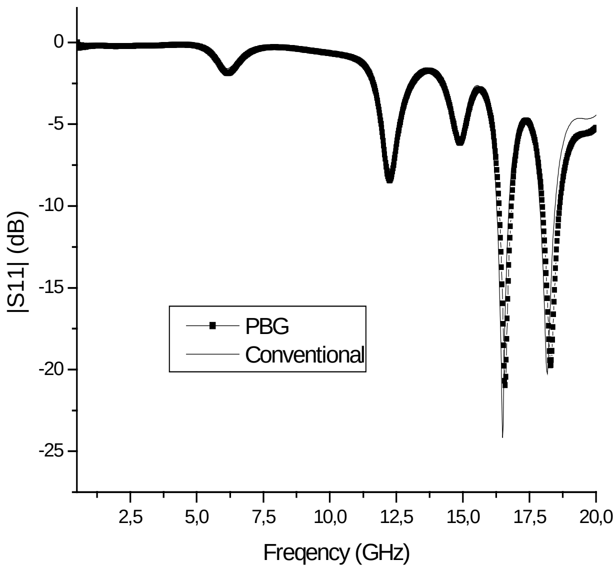

Fig.3. Comparison between the return loss of the new structure and that of reference, considering h = 5Δz (see Fig.1).

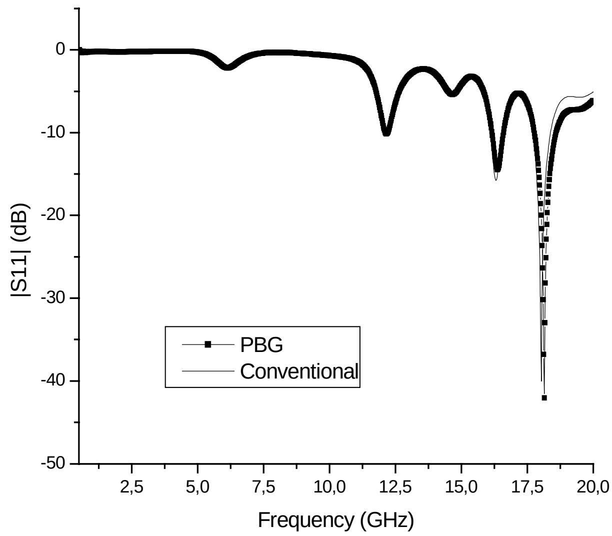

Fig.4. Comparison between the return loss of the new structure and that of reference, considering h = 6Δz (see Fig.1).

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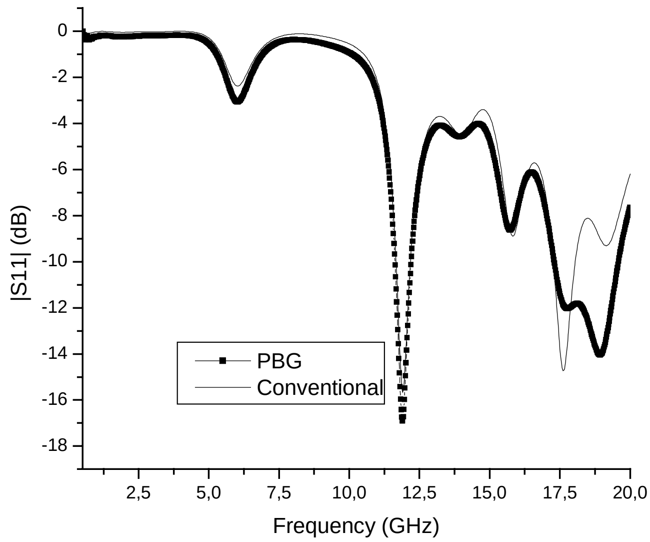

Fig.5. Comparison between the return loss of the new structure and that of reference, considering h = 9Δ z (see Fig.1).

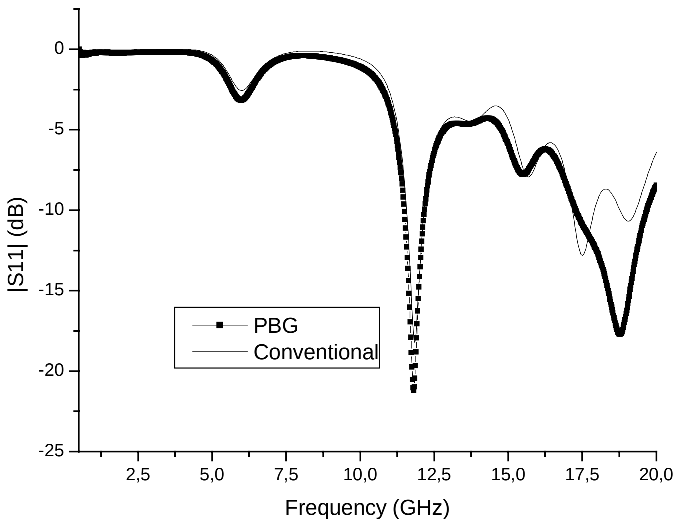

Fig.6. Comparison between the return loss of the new structure and that of reference, considering h = 10Δz (see Fig.1).

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Figure 7 shows an instantaneous of the intensity of the E_z electric field component, one cell above the ground plane, for the conventional antenna. This instantaneous was computed after 500 time steps. It mean that the waves leave the patch and continue to propagate in the substrate (as indicated by the arrow). These waves are the surface waves.

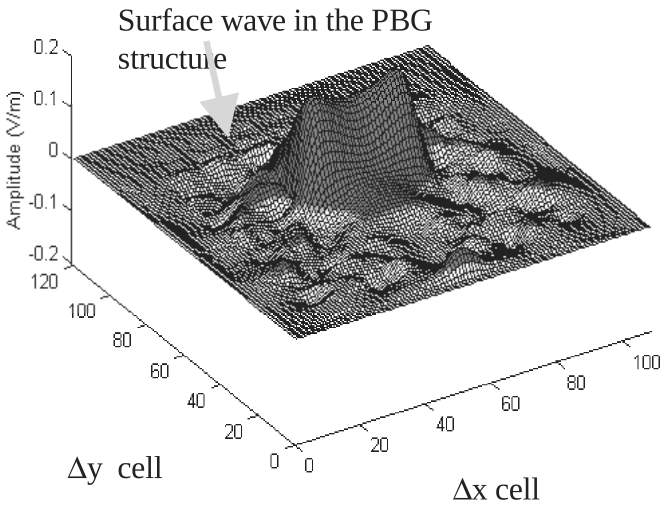

Fig.7. Distribution of the intensity of the E_z electric field component, one cell above the ground plane of the conventional antenna, after 500 time steps.

Figure 8 shows an instantaneous, after 500 time steps, for the intensity of the E_z electric field component, one cell above the ground plane of the antenna proposed in Fig. 2. It is noticed, in Figure 8, that the surface waves (as indicated by the arrow) leave the antenna path and continue their propagation in the substrate. In this case, the level of the intensity of the E_z electric field component is lower than that verified in Figure 7. This can be explained by the fact that the frequencies of the substrate modes fall within the forbidden band, the excited substrate modes will exponentially decay, hence reducing the energy lost into the substrate and increasing the energy coupled to the radiated field. It is important to emphasize that the effect of the periodic structure depends on the wavelength, on the lattice constant, on the blocks dimensions and on the permittivity of the media involved.

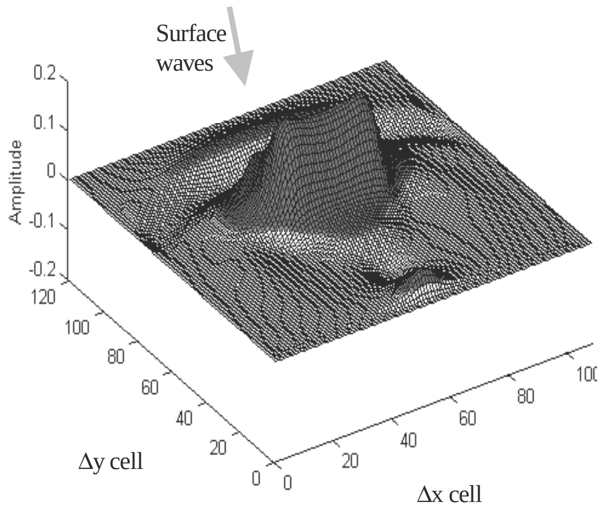

Fig.8. Distribution of the intensity of the E_z electric field component, one cell above the ground plane of the antenna proposed (Fig.2), after 500 time steps.

4. CONCLUSION

The results here obtained as well as the future works proposed have as background the finite difference time domain – FDTD method. This method was implemented through the UPML techniques. This method has limitations in use, such as long processing time and great computational memory. These problems can be overcome through the use of parallel processing. In this work, it was used eight PC machines configured as Beowulf cluster, MPI library, 1.5 GHz AMD Athlon processors, 1.5 GB DDR RAM on each machine, and 100Mbits network interface.

One of the main objectives of this work was the identification of surface waves. These waves, excited in the process of radiation of these antennas, are radiated more efficiently into the structure than the air side. In relation to Microstrip antennas, these waves are reinforced by the substrate that works as a confiner means of these waves. Thus, the electric and magnetic fields can be calculated and observed. Consequently, the control over the intensities of these fields can be done through visualization techniques, which depend only of the projected structure where they propagate. For this reason, the use of this method is very appropriate in the demands of the required analyses.

The response in the resonance frequencies, obtained in the project presented as model of a Microstrip has the character of the proposal of this work by use of a numerical analysis. However, a better analysis on the control of the surface waves can still be made. The results show that the dimensions of the blocks, the lattice constant and the value of the permissivity used in PBG material have a strong influence about the bandwidth of the analyzed antenna. Besides, the border effects on the radiation parttern can be observed, in the case of simulation

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of a finite antenna.

This project can be much more defined starting from the determination of the periodic structure dispersion diagram to be used. What can be done through the finite difference frequency domain method (FD-FD method).

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