A Novel Approach to Design of Electromagnetic Band Gap as a Microwave Filter

Amir Saman Nooramin, Mohammad Radfar, Samira Zali Asl, Javad Moshfegh, Mahmoud Shahabadi

Faculty of Electrical and Computer Engineering, University of Tehran, Iran

Asnamin7@yahoo.com, m.radfar@ece.ut.ac.ir

Abstract_*In this paper; we introduce a novel two dimensional (2D) triangular Electromagnetic Band Gaps (EBG) design. Our procedure is based on the general properties of periodic structures and continues with examining the effect of changing the size and different aspect of parameters using HFSS 10 (High Frequency Structure Simulator). In the next step, we fabricate three different structures and in respect to measurement methods, we test them precisely and compare them with simulation results. After that, in regard to various results of preceding experiments, we achieve versatile rules which lead us to a novel design.*

Keywords: Photonic crystal, Band gap, Periodic structure, HFSS.

1 Introduction

Periodic electromagnetic media generally shows band gaps, ranges of frequency in which incident electromagnetic wave cannot propagate through the media.

These band gaps are generated if the whole incidence power reflects from the crystal and it occurs when all reflected waves from different layers of structure are in-phase to each other.

So, the periodicity length should be in the same scale of propagating wave in that medium.

EBGs require that the electric field lines run along thin veins: thus, the rods are best studied for E parallel to rods, and the holes are best studied for E running around the holes.

So, Corresponding to the polarizations of incident wave, there are two basic topologies for such these structures, rods with high relative permittivity εr surrounded by a medium with low εr, or holes with low εr in a medium with high εr.

Base on the application, it is essential for the structure to have the periodicity in all directions of incident wave.

2 Structure

The structure is assembled by stacking layer by layer dielectric rods while the center-to-center distance is 'a' (Period of the structure). Starting at any reference rod the neighboring rod is shifted '0.5a' parallel to it (in the triangular shape). The structure has seven periods in length and four periods in width.

Basic lattice structure is fabricated with the following parameters. The radius of the rods is 3 millimeters. The height of the rods is 100 millimeters. The relative permittivity of the material (Plexiglass) is 3.1 [F/m]. The 'a' parameter is 18 millimeters.

- Structure A: It consists of the aforesaid topology. Two holder plates keep the rods in desired position.

- Structure B: This one is quite the same as structure A but eight plates are added. Each plate is drilled in the same pattern of the rods, in addition to extra holes drilled similarly by '0.5a' shifting in width. The rods are fitted on their holes in the parallel plates which have equal distance from each other.

- Structure C: it is the same as the structure B with 17 plates.(Figure 1)

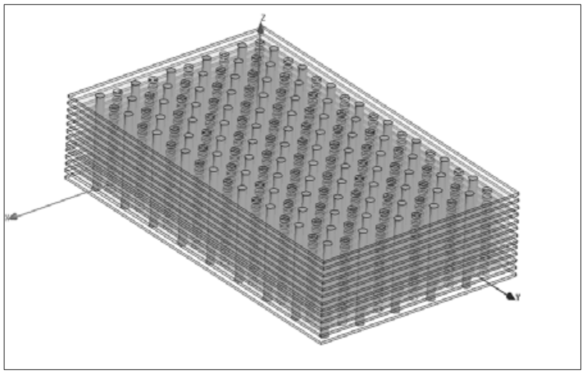

Figure 1- Structure C

3 Measurement method

Studying measurement method is so important because the will be monitored it this level.

In the simplest method, it is possible to use two horn antennas facing each other and measure fields in both with and without structure. The subtraction of them will be the effect of the structure, but there is a defection in calibration. According to figure2 and 3, the structure may be operating like a lens; therefore additional radiation will disturb the calibration.

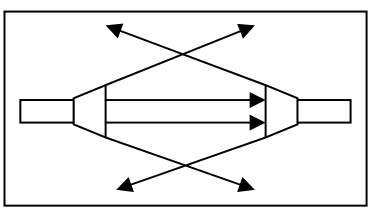

Figure 2- Normally the beam diverges

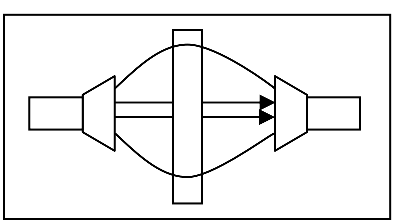

Figure 3- The structure acts as a lens

Far field measuring will decrease this defection and will be a good approach to achieve to reliable results.

Using waveguides is another solution to decrease this phenomenon, but it is necessary to build the wave guide in the same dimension of the crystal which is involved in fabrication difficulties.

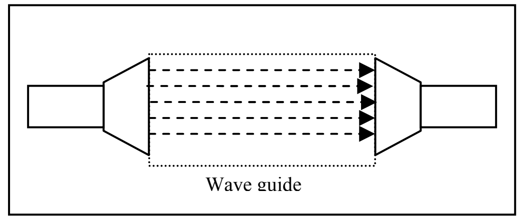

Figure 4- Using wave guide improves the accuracy

Another useful approach is to use two lenses, consequently the microwaves converge (Figure5) between these two lenses, plane wave is transmitted with Gaussian distribution, and it is good enough for the experiment.

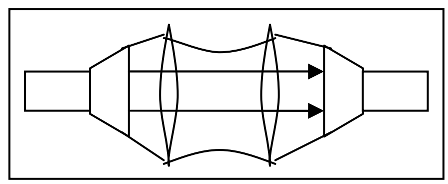

Figure 5- The waves converge by means of using two lenses

It is hard to produce such lenses that work well in this range of frequency.

Instead of lenses, it is also possible to use two dishes for reflecting waves.

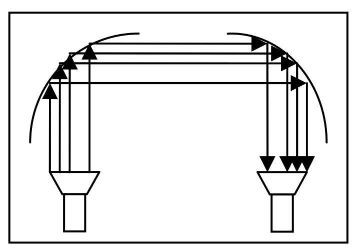

Figure 6- Two dished paralleled the waves

Because of straight propagation of wave, calibration will be more precise.

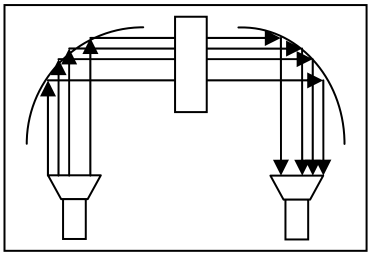

Figure 7- The structure do not disturb calibration

Measuring the fields in many places in respect to scattering pattern is a new proposed method (Figure8). It involves in designing a controlled machine which can measure fields in many positions and reports both positions and related fields.

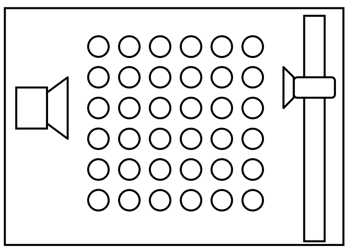

Figure 8- the fields are measured in many positions with portable antenna

It is noticeable that all the measurement in this paper is based on the first method. Standard gain horn antennas (9.7×6Cm) were used to transmit and receive the EM radiation. Surrounding of the test setup was covered with absorbers to build an anechoic chamber. The setup was calibrated for power measurement of the EM wave transmitted between the antennas. The structure was placed in the beam path of the EM transmitted from the source antenna.

In this setup'd' stands for the distance between two horn antenna .which were connected to spectrum analyzer.

4 Designs, Simulations and Fabrications

In the process of studying the effects of different parameters on EBG, the following facts are used. For the vertical components of the electric field, the cylindrical structures provide us a deep band gap. Consequently, such structures are proposed to have rectangular topology at first.

To reach a significant band gap, the period should be approximately equal to the wavelength. In order to set middle frequency of the band gap, f_C, to 11 GHz, 27 millimeters is selected for the initial value of 'a'.

Experimental relationship between the radius of rods, R, and 'a' is $R \approx 0.2a$. This inspires 5.4mm initially for 'R'. Increasing the relative permittivity decreases the above equation's coefficient.

The results do not show the acceptable deep band gap. As we know increase of the average relative permittivity of the structure deepens the band gap. To do this, 'R' can be increased. But it only widens the band gap with no influence on the depth of it. So the number of the rods must be increased in a way that the period remains constant. Therefore f_C does not change. The proposed structure (structure A) is demonstrated in figure8.

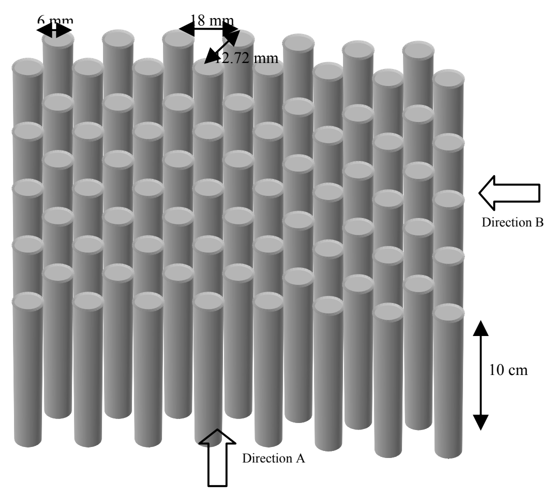

Figure 9- The proposed structure A and the used directions

Using the structure with the following properties ends in the lower frequency that what was not desirable. So both 'a' and 'R' were decreased. Among the available sizes for 'R' in plexiglass, the 3 millimeters must be selected. In the procedure of finding appropriate value for 'a' some experimental rules have been achieved:

- In the fixed average relative permittivity, the periodicity length only changes f_C.
- The number of periods changes the width and depth of the band gap a lot, so the more number of periods, the deeper band gap.
- The increase of structure's width reduces f_C.

According to above, the best value for 'a' is found 18 mm. This structure has been simulated by HFSS for five periods in length. The results are illustrated in figure10.

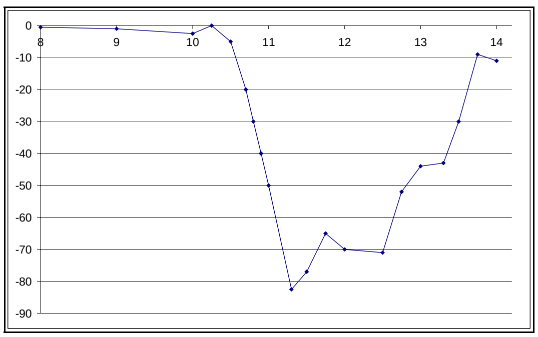

Figure 10-The simulation result, structure A, direction A

The fabricated structure initially is similar to structure A with four periods in direction A and seven periods in direction B.

The measurement results for this one is depicted in figure11 (direction A) and figure11 (direction B).

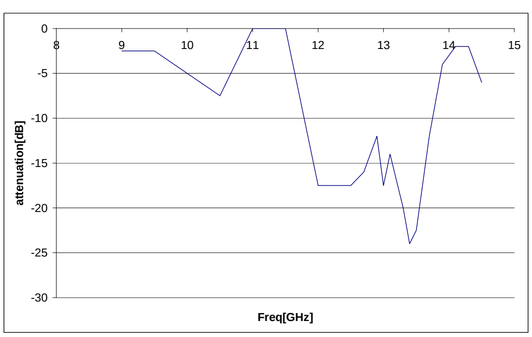

Figure 11- Measurement result, structure A, direction A, d = 13 cm

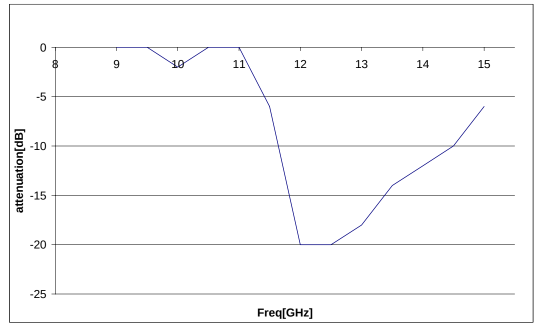

Figure 12- Measurement result, structure A, direction B, d=20 cm

As it is obvious, this structure has a good behavior for vertical electric fields but it is not good enough for horizontal one, so structure B is suggested.

For the horizontal component of the electric field, the hole topology provides us a deep band gap and 10 extra planes is added to make structure B. But because of many simulation problems which is caused by huge structure, it is impossible to analyze it with available computers.

Experimental results are shown in vertical mode for direction A in figure13 and for horizontal mode in figure14.

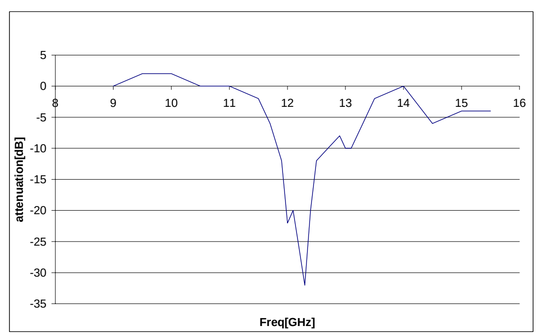

Figure 13- The experimental result, structure B, direction A, vertical mode, d = 15 cm

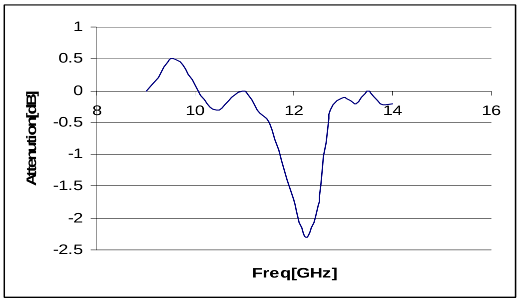

Figure 14- The experimental result, structure B, direction A, horizontal mode

As depicted in figure13, it is obvious that f_C has decreased. Due to the increase of the averaged relative permittivity for vertical field, the potential energy increases. So it decreases f_C.

As we are faced with the shallow band gap for the horizontal electrical field, it is necessary to increase the number of plates just like what has been done in structure C.

Because of the same simulation problem, the results are only experimental. They are demonstrated in figure14 for direction A with vertical electric fields and in figure 16 for horizontal electric field and the same direction. It is necessary to mention that measurements are done by a Agilent HP8510C network analyzer.

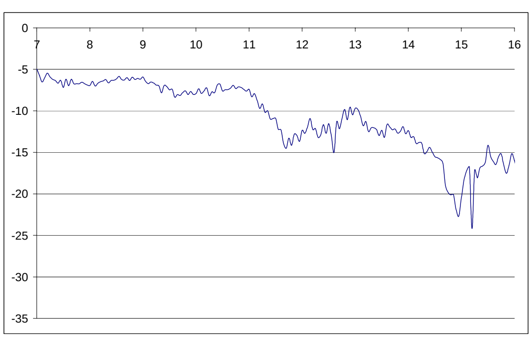

Figure 15- The experimental result, structure C, direction A, vertical mode

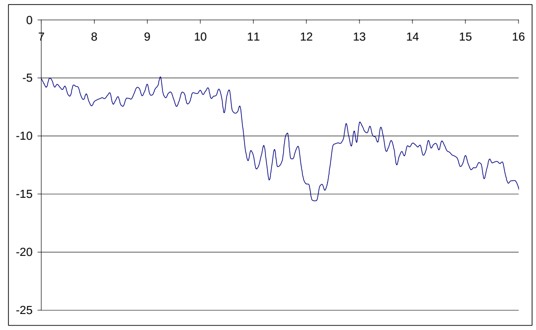

Figure 16- The experimental result, structure C, direction A, horizontal mode

As it seems obvious in figure15, decrease in effective area of rods which faces to incident wave, reduces of rods' effect to make the band gap. So it will be shallower.

Figure16 indicates that increasing in the number of holes affects the depth of band gap because of increasing the effect of holes.

Therefore, for cases in which the device should reflect both TE and TM polarizations, structure C can trade off between both kinds, although structure A is just perfect for vertical mode .

In addition to studying 2-dimensions, structure C has another periodicity in the third dimension. Because of periodic slabs, it may have a band gap. Obviously forbidden range of frequencies depends on the distance between these slabs such as structure C has band gap about 150 GHz because of having periodicity about twenty millimeter.

5 Conclusion

In this paper, we introduced a new structure which includes parallel plates. This structure can ease the fabrication process and also shows desire behavior to incident wave.

Moreover, it has proper capability to trade off between different wave modes.

In addition to scaling property of crystal, which adapts it for every application, we introduced another application for the fabricated structure.

6 Future works

It will be so precisely, if it is possible to measure waves in last proposed method of measuring, which is under investigation.

Also in order to study every structure before fabrication, it seems to be necessary to analyze every lattice with computer program. It prevents from building unsuccessful structures and decrease expenditure of the project. This is also certificates experimental result.

A new structure is proposed in figure17.

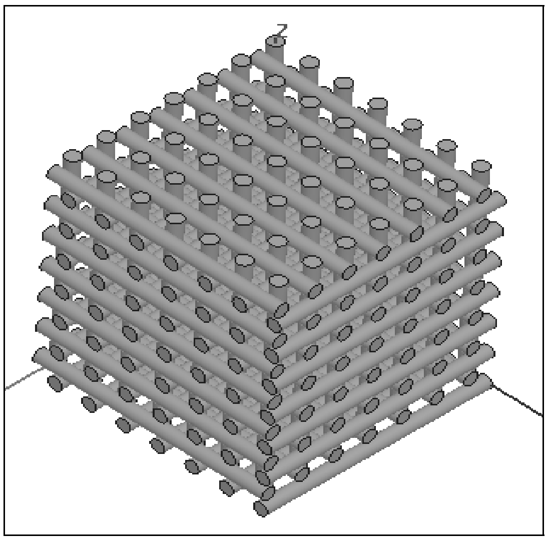

Figure 17- New proposed structure

According to process results, the rods are more efficient than the holes. So the following structure is design base on this fact, for having better band gap. We have started to investigate on this lattice to examine fabrication challenges.

7 Acknowledgement

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