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Fractalized Meander Line EBG based Microstrip Patch Slot Antenna

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ABSTRACT

There have been many investigations in the past regarding the design of multi- band antennas. A multiband antenna is the one in which the same antenna can be operated at different frequencies. There have been many approaches towards the design of the multiband antenna like stacked patches, parasitic patches, use of slots, shaping i.e., the use of notches, reactive loading, slot loaded patches etc. The use of slots is an easier approach towards the design of multiband an- tenna as there is a well defined theoretical approach towards the design of the slot antennas. These slots can be cut either in the patch or in the ground plane as needed for the application. Higher gain is an important requirement for an antenna and use of Electromagnetic Band-Gap structures(EBG) is one of the promising technique to achieve this.

The present thesis work focuses on the design of multiband antenna as well as novel Electromagnetic Band-Gap structures and their integration for enhance- ment of the gain of the antenna at desired frequencies of operation. The multi- band antenna is designed by cutting slots in the ground plane and the Uniplanar EBG is employed for the gain enhancement.

The Fractalized Meander Line EBG based Microstrip Patch Slot Antenna oper- ates in the 6-7 GHz (Extended C-Band) and has a fractional bandwidth of 13% , and it maintains the radiation characteristics in the desired band with gain rang- ing from 5.5 to 7 dB. The Meander Line EBG based Multiband Antenna operates in the WLAN and WiMAX bands at frequencies 2.4, 3.6, 5.2 GHz respectively having gain 3.5 , 4.2 and 6.19 dB

1 Introduction

1.1 Microstrip Patch Antennas (MPA)

The Microstrip Patch Antenna(MPA) basically consists of a dielectric substrate sandwiched between two metallic plates on both the sides. These metallic plates consist of the radiating patch on one side (top) and the ground plane on the other side. The schematic diagram of the MPA is indicated in fig. 1.1 [2],[32].

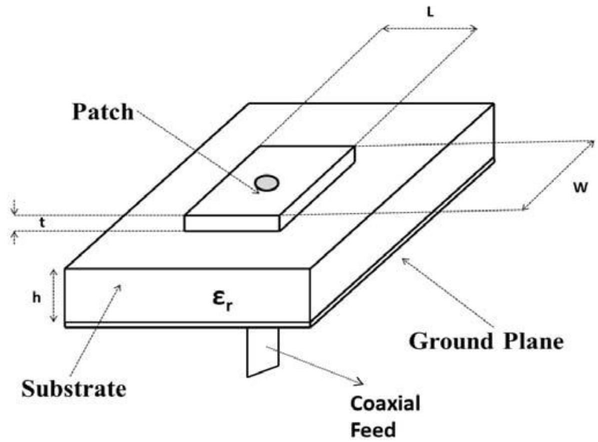

Figure 1.1: Microstrip Patch Antenna

The Patch as well as the ground plane is usually made up of conducting material like copper.The patch element as well as feed line is usually made over the sub- strate by removing undesirable copper cladding. The patch can be made of any shape, but for the ease of analysis usually the patch is made square, rectangular, circular, triangular, and elliptical or any other known geometrical shapes. The parameters of the MPA are L, W, h, t. Generally L lies in the range 0.33330 λ0 < L < 0.5λ0, where λ0 denotes the free space wavelength. The metallic patch is chosen to be very thin such that t <<< λ0, where t denotes the thickness of the metallic patch. The height of the dielectric substrate h lies in the range
0.003λ0 < h < 0.05λ0. Usually the relative electrical permittivity of the substrate generally has a value lying between 2.2 < er < 12.

The MPA can be fed by many techniques like microstrip line feed, coaxial feed, aperture coupling, proximity coupling. There are many techniques available for the analysis of the MPA like Transmission line model, Cavity model where the mathematical modeling of the first method is discussed in the next section.

Microstrip antennas are used as integrated antennas in wireless devices such as mobile phones, and also employed in Satellite communications. The Mi- crostrip Patch Antenna (MPA) finds immense applications [17] in mobile and satellite communication, Global Positioning System, Radio Frequency Identifi- cation(RFID), WiMax, RADAR, Rectenna, telemedicine applications, etc. The advantages of MPA are low weight, low profile, both linear and circular polariza- tion, easy feeding. The main disadvantage of MPA is its low bandwidth [17]

1.2 Electromagnetic Band Gap (EBG) structures

Electromagnetic Band Gap structures are defined as artificial periodic (or some- times non-periodic) objects that inhibits the propagation of electromagnetic sur- face waves in a specified band of frequency for all incident angles and all polar- ization states [3],[42].

EBG structures are simply the specific arrangement of the dielectric substrates and the metallic conductors arranged periodically in a peculiar fashion. They can be realized as 3D Volumetric structures, 2D planar surfaces, and 1D transmission lines [23]. The types of the EBG based on the above classification along with the examples are given by table 1.1.

Table 1.2: Types of EBG structures

Type	Examples
3D volumetric structures	woodpile structure and multi-layer metallic tripod array
2D planar surfaces	a mushroom-like surface and uni-planar design
1D transmission lines	microstrip line with periodic holes on the ground plane

The 2D structures are the mushroom structures and the uniplanar EBG structures. The diagram of the two structures is given in fig. 1.2.

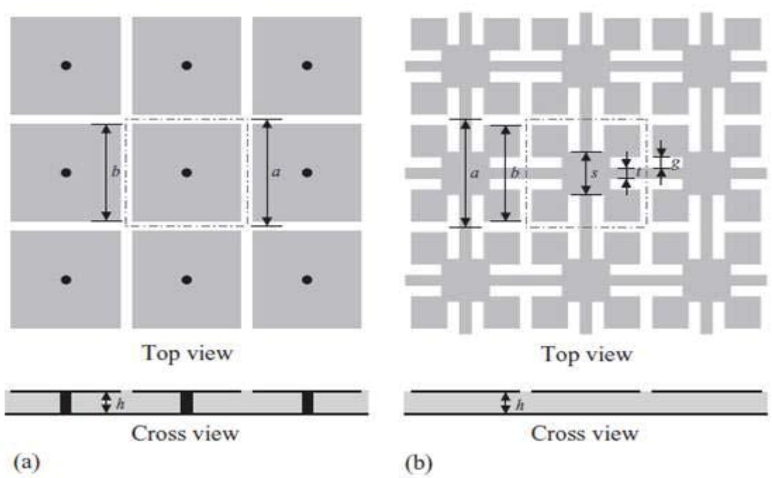

Figure 1.2: 2D EBG structures: (a) Mushroom structure (b) Uniplanar EBG

Structure

The mushroom structure consists of metallic patches and the vias connecting the ground plane and the metallic patches. Whereas the uniplanar EBG consists of the metallic patches only and the structure doesn't includes connecting vias. The entire EBG structure is placed in the same plane as the antenna hence the name Uniplanar EBG.

The Mushroom structures operate in the lower frequency range whereas the Uni- planar EBG operates in the higher frequency range (for the same unit cell size). The lower frequency operation stems from the fact that the Mushroom EBG has vias which acts as inductances, thus lowering down the frequency range. But the fabrication complexity of the Uniplanar EBG is much higher. The Uniplanar EBG on the other side is much easier to design and fabricate.

Since the Uniplanar EBG operates at a higher frequency range, we must work out on the methods to modify the basic design as in fig. 1.2, in order to operate the EBG in the lower frequency range.

The two known principles for lowering down the operating frequencies of the Uniplanar EBG's are [6]:-

• In order to achieve compactness of the Uniplanar EBG structure, the equiv- alent capacitance and inductance has to be increased somehow in the basic Uniplanar design.

• To widen the bandwidth of the Uniplanar EBG BandGap, the value of the inductance is to be increased.

1.2.1 Fractalized Meander Line Uniplanar EBG

The Uniplanar EBG is designed on FR-4 (Flame Retardant-4) substrate having dielectric constant er = 4.3 and electrical conductivity (loss tangent) tanb = 0.025 and thermal conductivity = 0.3 W/k/m. The unit cell of the designed EBG structure is depicted in fig. 3.1. The unit cell of the EBG structure differs from the basic Uniplanar EBG, where in the entire EBG structure is fractalized having first iteration only. Also the connecting lines are replaced by the meandered lines. The Unit cell size is 15mm (which is also called its periodicity). The parameters used in the design are tabulated in the table 3.1.

An array of size 5 x 5 elements is used to simulate the EBG structure as depicted in fig. 3.2. The height of the FR-4 substrate is taken as h = 1.5mm. On the other side of the EBG array, the ground plane is used. The discrete port is used for exciting the EBG structure, which are placed diagonally in the design. The advantage of placing the discrete port diagonally is that such an arrangement is ensuring the calculation of maximum surface wave suppression. The copper cladding of 0.018mm is considered in the design.

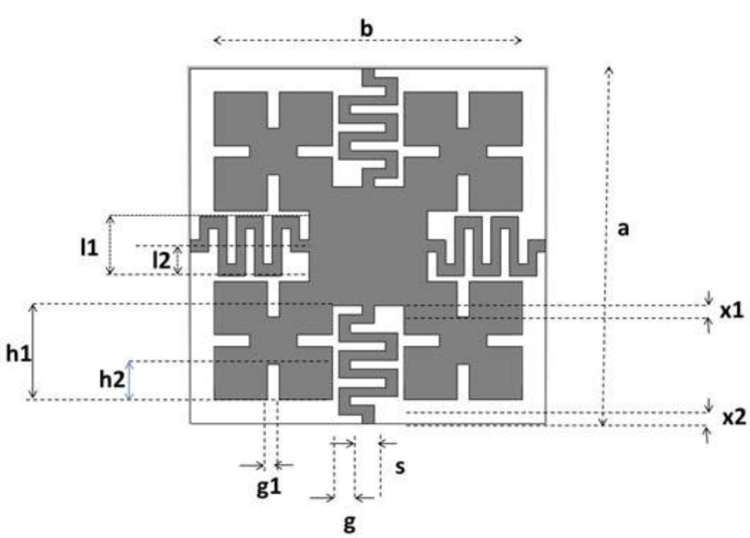

Figure 1.2.1: Unit Cell: EBG design 1

Table 1.2: List of parameters for EBG design 1

Parameter	Value(mm)
a	15
b	13
l1	1.5
l2	2.5
x1	0.384
x2	0.392
g	1
g1	0.5
h1	4
h2	3
s	1

The fractalized EBG structure is employed, which introduces the additional ca- pacitances in the EBG structure thereby lowering down the frequency of oper- ation and hence the same unit cell can have Band Gap in the lower frequency range.By introducing the meanders shape to the line, increases the value of the inductances associated with the line. This increased inductances also lead to the lowering down of the BandGap of the EBG structure.

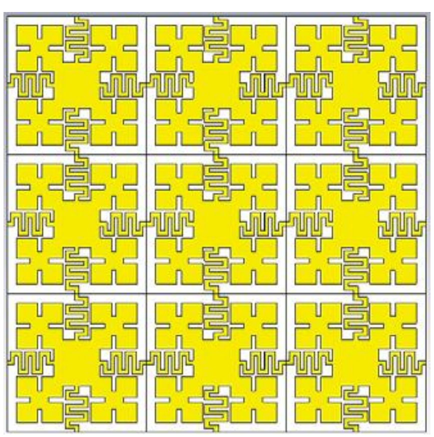

Figure 1.2.1: EBG Array

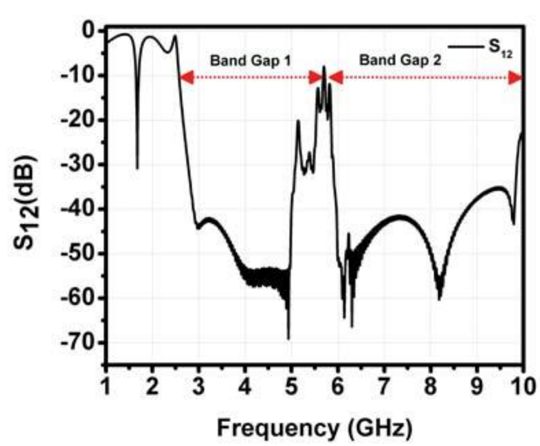

Figure 1 . 2 . 2 : EBG Band Gap diagram

2 Fractalized Meander Line EBG based Microstrip Patch Slot Antenna

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2.1 Description of the Antenna combined with the EBG

The Microstrip Teeth-Like Patch Slot Antenna is shown in the fig. 4.7 and the same with the EBG structure embedded is given by the fig. 4.6. The patch is surrounded by the Fractalized Meandered Line Uniplanar EBG. In order to compare the antenna gain with and without the EBG structure, the antenna size is kept same i.e., $W_s \times L_s = 105 \times 75mm^2$.

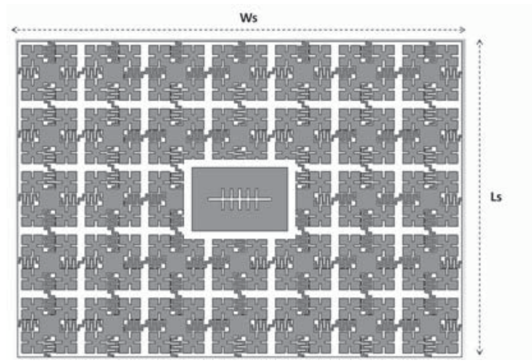

Figure 2.1: Antenna with the EBG

Figure 2.2: Antenna without EBG

2.2 Results and discussions

Fig. 4.8 show the gain variation of the Microstrip patch antenna with the teeth like slots with and without the integration of the EBG structure. As clearly indicated, the gain of the antenna in the 6-7 GHz band is enhanced considerably. The surface wave suppression is clearly indicated by the fig. 4.9 and 4.10, where the former shows the surface wave propagation noticed outside the band gap of the Electromagnetic BandGap structure, whereas the latter shows the surface wave suppression obtained inside the band gap of the Electromagnetic BandGap structure. The fig. 4.11 shows the farfield pattern of the antenna with the EBG.

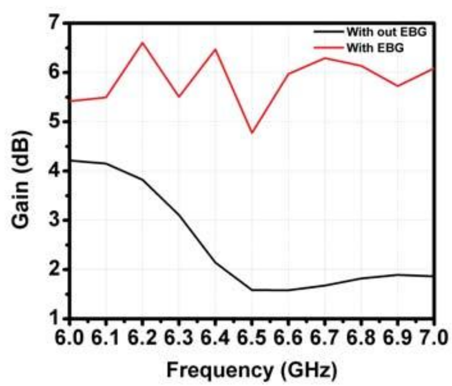

Figure 2.2.1: Gain comparison between the antennas

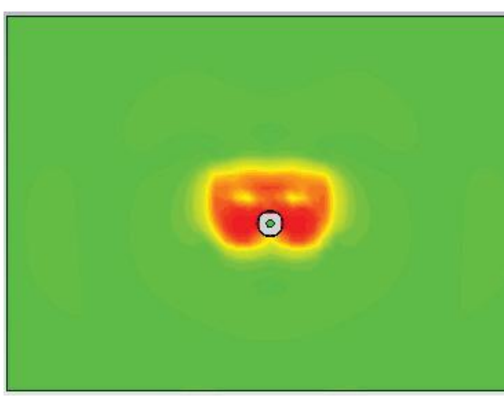

Figure 2.2.2: Surface waves in the ab- sence of the EBG at 6.459 GHz

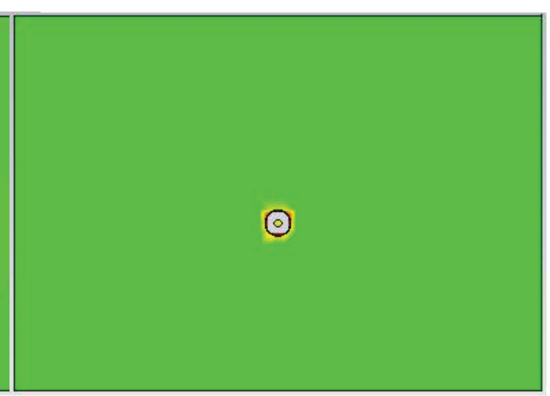

Figure 2.2.3: Surface waves in the presence of the EBG at 6.459 GHz

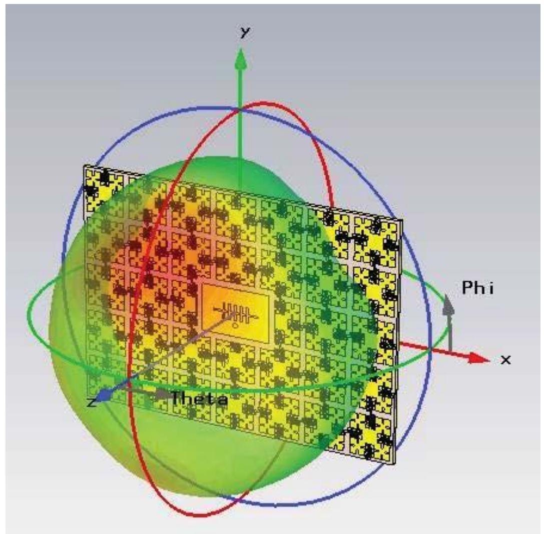

Figure 2.2.4: Farfield at the center frequency 6.497 GHz

2.3 Measurement and results

The antenna was fabricated using LPKF PCB prototyping machine and the S_{11} parameters were measured using Agilent Vector Network analyzer (VNA). The Top view of the fabricated antenna is shown in fig. 4.12. The comparison between measured and simulated S_{11} parameters is shown by fig. 4.13. The measured and simulated results shows striking similarities as expected.

Figure 2.3.1: Fabricated antenna: Top View

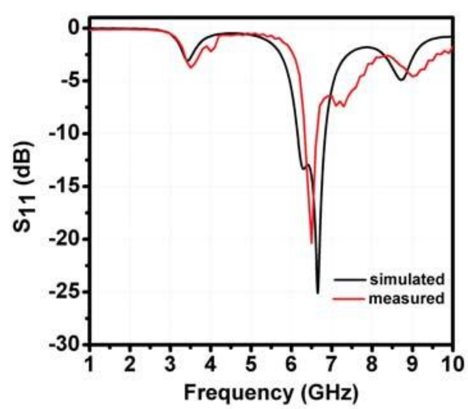

Figure 2.3.2: Comparison of S_{11} of the measured and simulated antenna

2.4 Conclusion

The Fractalized Meander Line EBG based Microstrip Patch Slot Antenna is fab- ricated which operates in the 6-7 GHz (Extended C-Band) and has fractional bandwidth of 13% , and it maintains the radiation characteristics in the de- sired band with gain ranging from 5.5 to 7 dB. The integration of the EBG has enhanced the gain by 2 dB. The antenna has applications in the Satellite and Defence fields.

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