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Design and Analysis of Micro Strip Patch Antenna

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***Abstract*—Micro strip patch antennas became very popular because of planer profile, ease of analysis and fabrication, compatibility with integrated circuit technology & their attractive radiation characteristics. But also some drawbacks of low efficiency, narrow bandwidth and surface wave losses. To improve surface wave losses uses Electro Magnetic Band Gap structures, for improving efficiency & bandwidth do proper impedance matching. We design and simulate the new EBG structures operating at 2.4GHz resonant frequency.**

Keywords-Gain,Micro srip antenna,improve surface wave losses

I. INTRODUCTION

Micro strip antenna is most common small sized antenna in which a metal patch is deposited on dielectric material. Micro strip patch antennas have been an attractive choice in mobile and radio wireless communication. They have advantages such as low profile, low cost and robust. However, at the same time they have disadvantages of low efficiency, narrow bandwidth and surface wave losses. Recently, considerable research effort in the electromagnetic band gap (EBG) structure for antenna application to suppress the surface wave losses and improve the radiation performance of the antenna [1].

When source signal is applied at metal ground plane & patch, the EM waves will be radiated. The radiation will not be perfect as there are some losses due to dielectric material. We have to minimize these losses. To minimize these losses we will insert EBG structures with Micro strip Patch Antenna.

We take 3 layers of same dielectric material (FR_4 epoxy) and make air cavities of different radius & at different positions. we vary the radius and distance of air cavities and see the effects on insertion loss at 2.4GHZ.

II. OBJECTIVE

The objective of this project is to design and simulate the new EBG structure operating at 2.4GHz frequency and study the performance of the rectangular micro strip antenna with and without EBG structure. So that we can suppress the surface waves, through which improve the gain and directivity of micro strip antenna.

III. MICRO STRIP ANTENNA

At 1953, micro strip antenna was proposed by G.A. Deschamps. By the early 1980s basic micro strip antenna elements and arrays were fairly well established in terms of design and modeling. micro strip antenna antennas also known as printed antennas. The micro strip antenna offers low-profile, conformable to planar and non-planar surfaces, simple and inexpensive to fabricate using modern printed-circuit technology, mechanically robust when mounted on rigid surfaces and very versatile in terms of resonant frequency, polarization, patterns and impedance. Major disadvantages of micro strip antenna are their low efficiency, low power, poor polarization purity, poor scan performance, very narrow frequency bandwidth and existence of surface waves [2, 3, 4].

Micro strip patch antenna is consisting a radiating patch on one side of dielectric substrate and a ground plane at another side. A simplest configuration of micro strip antenna is shown below:

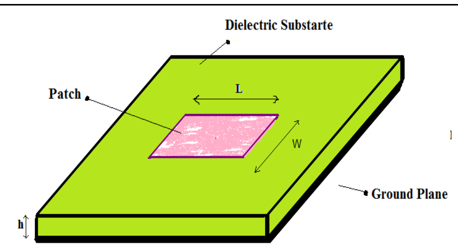

Fig-1micro strip antenna

Conductor of length L and width W on a dielectric substrate with permittivity ε_r, thickness or height of the dielectric being h. The length for the patch depends on the height, width of the dielectric substrate. The rectangular patch antenna is designed so as it can operate at the resonant frequency. The frequency of operation of the patch antenna of Figure 2.1 is determined by the length L.

The center frequency will be approximately given by

$$f_c \approx \frac{c}{2L\sqrt{\varepsilon_r}} = \frac{1}{2L\sqrt{\varepsilon_0 \varepsilon_r \mu_0}}$$

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The above equation says that the patch antenna should have a length equal to one half of a wavelength within the dielectric (substrate) medium. The patch can be various shapes for example square, rectangular, circular, triangular and any other configurations.

IV. IMPORTANT PARAMETERS OF ANTENNA

When an antenna is designed the engineer has a specific band in mind. It could be fairly narrow such as the CB band (440 KHz) or relatively broad like the 2-meter band (4000 KHz). Knowing full well that an antenna, for the purpose of this discussion, can only be resonant at one particular frequency, the center of the particular bandwidth becomes the target design frequency. For example, the CB band starts at 26.965MHz and is 440 KHz wide. So, 1/2 of the bandwidth added to the low frequency places the center frequency at 27.185MHz.For any given antenna length, the two primary starting points for design involves frequency and impedance; frequency as determined by the transmitter/receiver design and impedance as required by the equipment's circuitry. With the antenna resonating at the center frequency, the impedance falling into the acceptable tolerances of the radios circuitry and the availability of a suitable ground plane it is likely that the SWR will be at or near 1.1:1 at that particular frequency. That reading would indicate that the antenna is absorbing nearly all of the energy that is coming from the transmitter. Nonetheless, even if you achieve a 1.1:1 SWR at the target center frequency that doesn't mean that the antenna will be marketable for there is the problem of bandwidth .

V. TRANSMISSION LINE MODEL

This model represents the micro strip antenna by two slots of width W and height h separated by a transmission line of length L. The micro strip is essentially a non-homogeneous line of two dielectrics, typically the substrate and air.

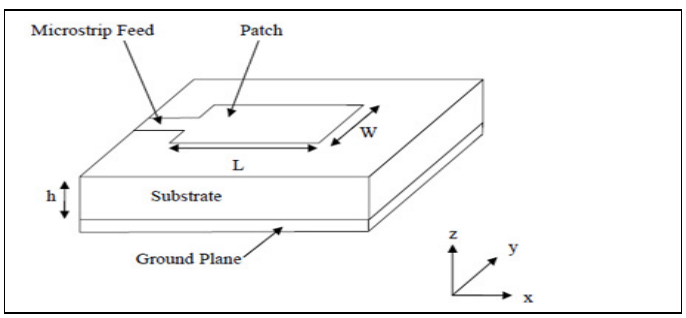


Fig-2 (a) Micro strip Patch Antenna

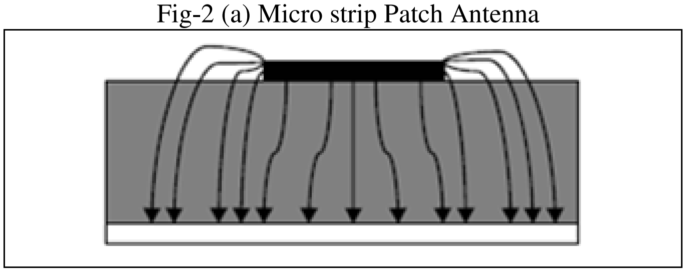


Fig-2 (b) Electric Field Lines

Hence, as seen from Figure(a),(b), most of the electric field lines reside in the substrate and parts of some lines in air. As a result, this transmission line cannot support pure transverse electric-magnetic (TEM) mode of transmission, since the phase velocities would be different in the air and the substrate. Instead, the dominant mode of propagation would be the quasi-TEM mode. Hence, an effective dielectric constant (ε_{reff}) must be obtained in order to account for the fringing and the wave propagation in the line. The value of ε_{reff} is slightly less then$\varepsilon_r$because the fringing fields around the periphery of the patch are not confined in the dielectric substrate but are also spread in the air as shown in Figure.

Where ε_{reff} = Effective dielectric constant

ε_r = Dielectric constant of substrate

h = Height of dielectric substrate

W = Width of the patch

Procedure of designing MS antenna

The procedure for designing a rectangular micro strip patch antenna is explained in following steps:

Step 1: Calculation of the Width (W):

The width of the Micro strip patch antenna is given as:

$$W = \frac{c}{2f_o\sqrt{\frac{(\varepsilon_r+1)}{2}}}$$

Substituting c = 3.00e+008 m/s, ($3*10^{-8}$ m/sec)

ε_r= 4.4 and fo= 2.4 GHz, we get:

W = 0.038036 m = 38 mm

Step 2: Calculation of Effective dielectric constant (ε_{reff}):

The effective dielectric constant is

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{W}\right]^{-\frac{1}{2}}$$

Substituting εr = 4.4, W = 38 mm and h = 4.8 mm we get:

ε_{reff} =3.7716

Step 3: Calculation of the Effective length ($Leff$):

The effective length is:

$$L_{eff} = \frac{c}{2f_o\sqrt{\varepsilon_{reff}}}$$

Substituting ε_{reff}= 3.7716, c = 3.00e+008 m/s and fo= 2.4 GHz we get:

L_{eff}= 0.03218mm=32.18mm

Step 4: Calculation of the length extension (ΔL):

The length extension is:

$$\Delta L = 0.412h\frac{(\varepsilon_{reff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{reff}-0.258)\left(\frac{W}{h}+0.8\right)}$$

Substituting ε_{reff} = 3.7716, W = 38 mm and h = 4.8 mm we get:

ΔL = 2.1520 mm

Step 5: Calculation of actual length of patch (L):

The actual length is obtained by:

$$L = L_{eff} - 2\Delta L$$

Substituting L_{eff} = 22.6043 mm and ΔL = 2.5310 mm we get:

L = 27.87mm=28mm

VI. WHAT IS EBG?

EBG stands for Electromagnetic Band Gap Substrate. Electromagnetic band gap structures are defined as artificial periodic or sometimes non-periodic objects or say that dielectric materials and metallic conductors that prevent the propagation of electromagnetic waves in a specified band of frequency for all incident angles and all polarization states [5].

At present time, there is a need of smaller and broad bandwidth antennas .This can be achieved by fabrication of antenna on thick piece of high permittivity substrate. The main disadvantage is that, the unwanted substrate modes begin to form and propagate towards the edges of the substrate, which have a deadly effect on the antenna radiation pattern.

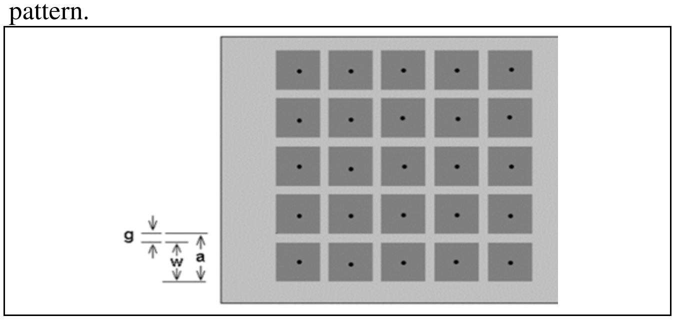
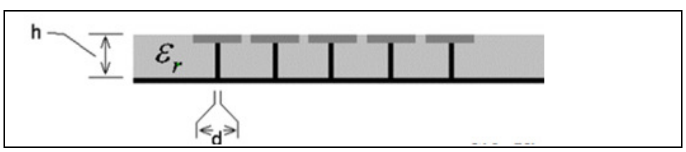


Fig-3 (a) Electromagnetic bandgap structure -Top View



(b)-3 Cross section of EBG-Side View

EBG can be categorized into three groups according to their geometric configuration:-

a. Three-dimensional volumetric structures.

b. Two-dimensional planar surfaces.

c. One-dimensional transmission lines.

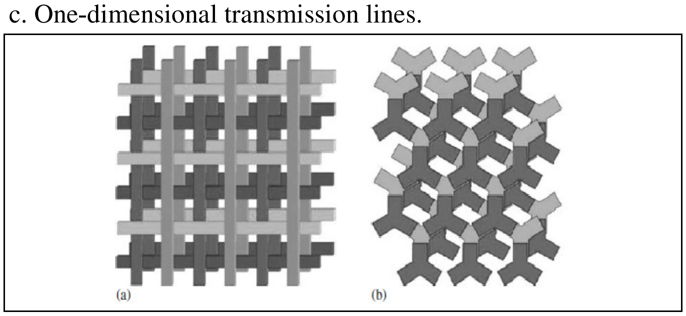


Fig- 4 Three dimensional EBG structures:

(a) a woodpile dielectric structures

(b) a multi-layer metallic tripod array.

Figure shows two representative 3-D EBG structures: a woodpile structure consisting of square dielectric bars and a multi-layer metallic tripod array.

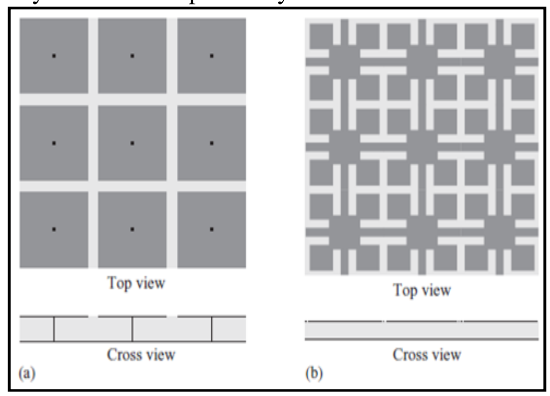


Fig-5 (a) A mushroom-like surface

(b) A uni-planar surface

Figure shows two representative 2-D EBG structures: a mushroom-like surface and a uni-planar design.

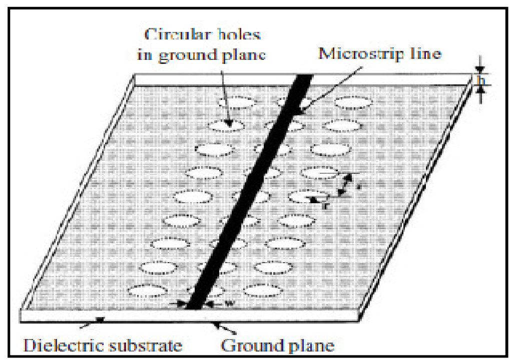


Fig-6 One dimensional EBG surfaces

We will discuss only on the 2-D EBG surfaces, which have the advantages of low profile, light weight, and low fabrication cost, and are widely considered in antenna engineering.

c. EBG structures can be classified into different categories according to their EM properties:

The first category of EBG structures focuses on inhibition of electromagnetic wave propagation. The electromagnetic wave can be either a plane wave with a specific incident angle and polarization or a surface wave bounded to a ground plane. Most of the three-dimensional EBG structures, such as the periodic array of dielectric rods, fall into this category. Some two-dimensional surfaces can also be put into this category when the surface waves are prohibited.

a. The second category of EBG structures emphasizes the reflection phase property. Usually two-dimensional surfaces with a very thin profile are being considered in this category.

VII. EBG WITH MICROSTRIP PATCH ANTENNA

The below figure is of micro strip antenna which shows that the electromagnetic waves are trapped in the substrate; these trapped electromagnetic energy leads to the development of surface waves and due to this gain and efficiency of the antenna decreased [6].

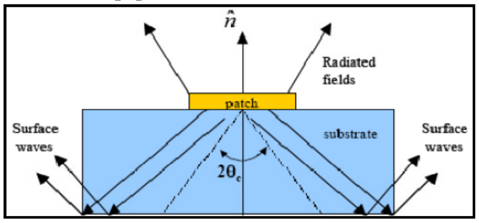


Fig-7 Field lines radiating from a Patch Antenna

VIII. SURFACE WAVE

The purpose of an antenna is to radiate space waves. But there are also other types of waves excited in an antenna that are unwanted. Among those the surface waves are most nefarious. These waves propagate slightly downwards from the patch into the patch substrate. Then the waves hit the ground plane and are reflected and hit the dielectric-to-air boundary and are again reflected and so on and on. Now these waves abate the signal energy and thus decrease the antenna efficiency.

To eliminate surfaces waves we can create EBG structure with micro strip antenna, by making holes in the dielectric or in the ground plane or in both, of same diameter and distance or it may be variable; through which most of the EM waves radiate in the environment and thus we can improve the gain and efficiency of the antenna as shown in figure

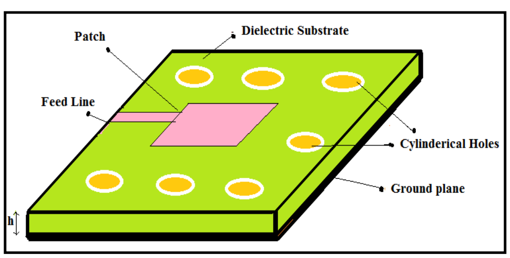


Fig-8 Micro strip Antenna with EBG Structure

However, this has the fundamental drawback that the complexity of the micro strip antenna increases, thus negating many of the advantages using micro strip antennas.

IX. SIMULATION & RESULTS

Our aim is to design the EBG structures with micro strip patch antenna. For this we may use different dielectric materials like FR_4 Epoxy, duroid, rogger etc. But in our project we used FR_4 Epoxy as a dielectric material and effective dielectric constant of this is εr = 4.4 and its thickness is 1.6, which is fixed for this dielectric material. We can use number of layers of dielectric material but for the micro strip patch antenna to be used in cellularphones, it is essential that the antenna is not bulky. Hence, the height of the dielectric substrate is not more. So we can use three, four or five layers, not more than that.

Three layers are necessary for any MS Antenna. One layer is for support of ground plane (lower) and other is for patch (upper).And in mid we can take number of FR_4 Epoxy layers .In our project we take three layers. We drilled the air cavities (cylindrical holes) of different radius(like 2mm,4mm) at different dimensions to make EBG structure. Also not make the air cavities in dielectric 1 and dielectric 3 because these are the supportive layers for metals.

X. MODEL

EBG Structures are made with MS antenna by drilling the air cavities in cyllindrical form and drilled only in dielectric 2 because dielectric 1 and dielectric 3 are supportive layers for antenna metals as shown in figure .

4 air cavities are formed in this model and the radius of cylinders are r = 4 mm.

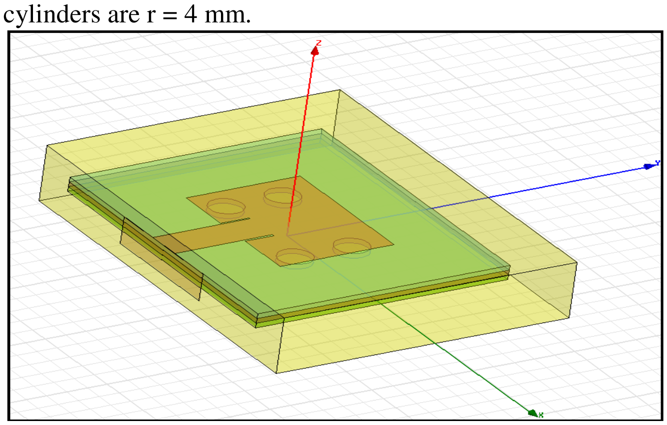


Fig-9 MS Antenna with EBG Structure (4 air cavities of radius r = 4 mm)

Result:

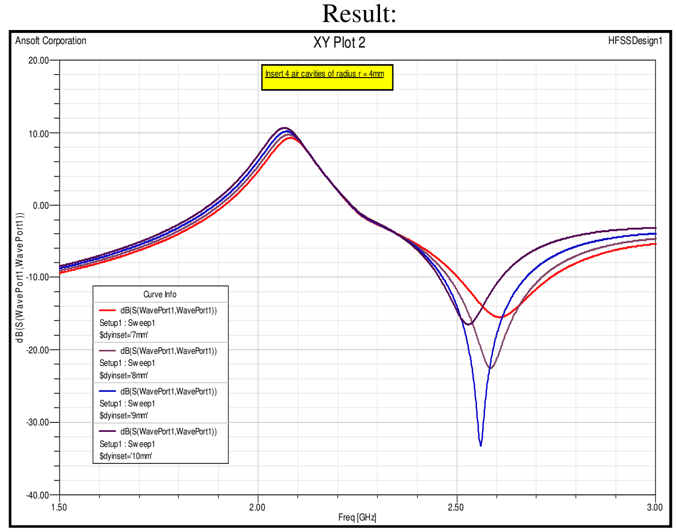


Fig-10 Result of Model N3 – Rectangular Plot

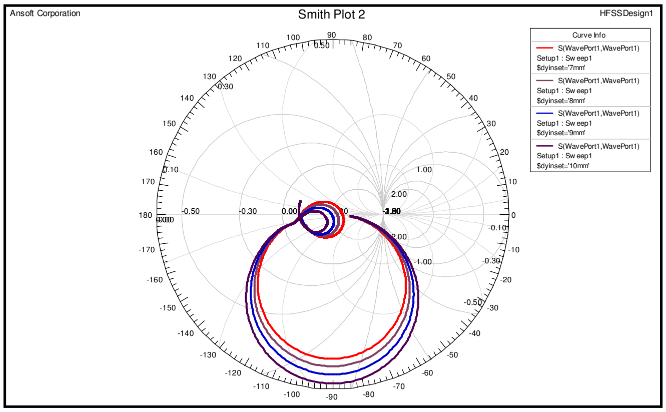


Fig-11 Result of Model N3 – Smith Chart

From the above curves we see that the insertion loss is -33dB at the frequency 2.55GHz for inset 9mm. TheVSWR is good for 10mm inset (dark purple color). And for 9mm inset VSWR is closer to +1. But we consider the curve of 9mm inset because at 10mm inset the insertion loss is very high(-17db) rather than 9mm(-33db).

Now we will see the effects on insertion losses, when the dimension of the air cavities are changed and drilled 6 air cavities rather than 4 air cavities of same radius r = 4mm.

IN o	Item	Material (ϵ_r)	Coordinates(mm) X_o	Y_o	Z_o	Dimensions(mm) X_i	Y_i	Z_i
1	Ground Plane	Metal	-38	-31	0	76	62	Z
2	Dielectric 1	FR_4 Epoxy	-38	-31	0	76	62	1.6
3	Dielectric 2	FR_4 Epoxy	-38	-31	1.6	76	62	1.6
4	Dielectric 3	FR_4 Epoxy	-38	-31	3.2	76	62	1.6
5	Patch	Metal	-19	-14	4.8	38	28	Z
6	Feed Line	Metal	-4.5	-31	4.8	9	$dyfeed	Z
7	Inset	-	-5	-14	4.8	10	$dyinset	Z
8	Waveport	-	-16	-31	0	32	y	9
9	Airbox	Air	-48	-31	-9.4	96	72	18.8
10	Cylinder 1	Air	-14	-7	1.6	r = 4	h = 1.6	Z
11	Cylinder 2	Air	-14	7	1.6	r = 4	h = 1.6	Z
12	Cylinder 3	Air	14	-7	1.6	r = 4	h = 1.6	Z
13	Cylinder 4	Air	14	7	1.6	r = 4	h = 1.6	Z

XI. CONCLUSION

We studied that the Micro strip antenna is a conductor printed on top of a layer of substrate with a backing ground plane and are used for radio wireless communication and many others due to their compact size & low cost. But the major disadvantage is that all the EM waves do not radiate through air in desired direction and some part of it are trapped in the substrate.

To increase the radiation we created structure named "Electromagnetic Band Gap (EBG) structure". EBG structures are periodic arrangement of objects that prevent the propagation of EM waves in a specified band of frequency for all incident angles. The band gap features of EBG structures found useful applications in suppressing the surface waves in micro strip antenna designs.

We concluded that, when we reduce the diameter of air cavities, insertion losses are also increased. And when we keep the air cavities of same diameter(when comparing the 2 models) in the models and increase the no. of air cavities, then also insertion losses are increased. So antenna performance is good if we use minimum no. of air cavities and are of greater diameter as possible.

EBG structures for micro strip antennas are studied by different software's but we used the software named "Ansoft HFSS software" through which we can design, analysis and simulate the antennas.

In our dissertation stage-1 we fulfill our objectives. We learn about the HFSS software and design and simulate Micro strip antennas, which will be very fruitful for me in my dissertation.

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