Implementation of Microstrip Patch Antennas for Mutual Coupling Using Electromagnetic Band-Gap Structure

1Rachana Shandilya, 2Asmit Kumar Soni
1Master's student, 2Professor
Digital communication, Shri Ram Institute of Science and Technology, Jabalpur

Abstract: **Communication between humans was first by sound through voice. With the desire for slightly more distance communication came, devices such as drums, then, visual methods such as signal flags and smoke signals were used. The main objective of this work is to propose equilateral triangular micro strip patch antenna with Electromagnetic Bandgap Structure and Superstrate. A considerable improvement in bandwidth is observed in antennas having mushroom like EBG patterns and superstrate. Hence, we are able to improve the low bandwidth problem of a patch antenna.**

INTRODUCTION

Communication between humans was first by sound through voice. With the desire for slightly more distance communication came, devices such as drums, then, visual methods such as signal flags and smoke signals were used. These visual communication devices, of course, utilized the light portion of the electromagnetic spectrum. It has been only very recent in human history that the electromagnetic spectrum, outside the visible region, has been employed for communication, through the use of radio. One of mankind's greatest natural resources is the electromagnetic spectrum and the antenna has been instrumental in harnessing this resource.

Microstrip patch antennas are the most common form of printed antennas. They are popular for their low profile geometry, light weight and low cost. These antennas have many advantages when compared to conventional antennas and hence have been used in a wide variety of applications ranging from mobile communication to satellite, aircraft and other applications [1].
Electromagnetic bandgap (EBG) structures have attracted much attention in the recent years in the microwave community for its unique properties. These structures are periodic in nature that forbids the propagation of all electromagnetic surface waves within a particular frequency band called the bandgap thus permitting additional control of the behavior of electromagnetic waves other than conventional guiding and/or filtering structures. Various compact structures have been proposed and studied on antenna systems. Radiation efficiency and directivity of antennas have been improved using such structures [2] [3].

Similarly a dielectric superstrate is desirable to protect the copper patch of the microstrip antenna in many applications, especially for the outdoor wireless communications. The dielectric cover offers such a protection while keeping the antenna in low profile. Many theoretical and experimental investigations on single- or stacked-patch antennas covered with a superstrate show that the resonant/mean frequency of patch antenna decreases monotonically with superstrate thickness whereas the impedance bandwidth and radiation efficiency also varies with increases in superstrate thickness [4].

Problem Definition

In spite of the many advantages that patch antennas have in comparison to conventional antennas, they suffer from certain disadvantages. The major drawback of such antennas is the narrow bandwidth [1].

In this dissertation, the narrow bandwidth problem of a patch antenna is tackled and solved. A triangular patch antenna is used as a reference antenna and efforts are made to improve its bandwidth by using mushroom type EBG structure. Then superstrate layer introduced over the patch and simulated results confirm a considerable improvement in bandwidth.

Proposed Methodology

Various efforts have been made by researchers all over the world to improve the bandwidth of a patch antenna. Some of the different techniques are mentioned in this section.

One way to increase the bandwidth is to either increase the height of the dielectric or decrease the dielectric constant [1]. However, the first approach would make it unsuitable for low profile structures while the latter approach will make the matching circuit to the patch impractical due to excessively wide lines. Equation (1.1) shows the relationship of bandwidth to VSWR, impedance BW of the MSA is defined as the frequency range over which it is matched with that of the feed line within specified limits. The BW of the MSA is inversely proportional to its quality factor *Q* and is given by [9]

$$\mathrm{VSWR} = \frac{1+|\rho|}{1-|\rho|}$$

The bandwidth is defined as the fractional bandwidth relative to the center frequency for a VSWR less than 2:1. VSWR stands for voltage standing wave ratio, shown in Equation (1.3), and is measured according to the reflection coefficient of the input feeding network:

$$BW=\frac{VSWR-1}{Q\sqrt{VSWR}}$$

The reflection coefficient is found from the input impedance, Z, into the patch and is shown in Equation (1.4), where Z_0 is the characteristic impedance and is usually 50Ω.

$$\rho = \frac{Z-Z_0}{Z+Z_0}$$

A VSWR of 2:1 implies a reflection coefficient of approximately -10dB.

The use of U slot and L probe in the design of small size microstrip antennas has been considered by Shake ford *et al*[18]. Different designs have been proposed by these authors who utilized various size reduction techniques: utilizing a microwave substrate material, the addition of a shorting wall, and the addition of a shorting pin.

A considerable improvement in bandwidth is observed in all the designs. Another method employed by researchers is using compound techniques [6]. These techniques include adjusting the displacement of patches, setting two pairs conducting bars around the lower patch as parasitic radiator and loading a capacitive disk on the top of probe. A new type of stacked microstrip patch antenna is studied using these compound techniques and the frequency bandwidth has been remarkably improved.

The bandwidth of an aperture coupled microstrip patch antenna has been studied and improved by using an appropriate impedance matching network using filter design techniques. The initial useful antenna characteristics were maintained for the proposed new feed configuration.

The use of two triangular structures [7] for microstrip patch antennas to improve the bandwidth also has been studied. In it, two separate triangular patches are used to form patch antenna with a small spacing left between the two triangular patches. A full-wave spatial-domain technique together with the closed-form Green's function [1] is employed for obtaining the S-parameters of microstrip antennas and simulated results confirm a considerable improvement in bandwidth.

The use of unbalanced structures in the design of patch antenna to improve VSWR characteristic has also been studied previously. Similar to , a full wave spatial domain MoM together with the closed-form Green functions have been employed for characterizing high-frequency S-parameters of microstrip discontinuities. The obtained numerical results are compared with existing data which show a good agreement to each other. Also, improvement in bandwidth is observed in the design. Another technique that has been employed recently to improve the bandwidth of patch antennas is using electromagnetic bandgap (EBG) structures [5]. Different shapes and sizes of EBG structures such as mushroom EBG structure and spiral EBG structure have been proposed and studied and has led to considerable improvement in bandwidth of patch antennas.

Microstrip Patch Antennas

Microstrip patch antennas are the most common form of printed antennas. They are popular for their low profile, geometry and low cost [1].

A microstrip device in its simplest form is a layered structure with two parallel conductors separated by a thin dielectric substrate. The lower conductor acts as a ground plane. The device becomes a radiating microstrip antenna when the upper conductor is a patch with a length that is an appreciable fraction of a wavelength (λ), approximately half a wavelength ($\lambda / 2$). In other words, a microstrip patch antenna consists of a radiating patch on one side of a dielectric substrate which has a ground plane on the other side as shown in Fig. 1.

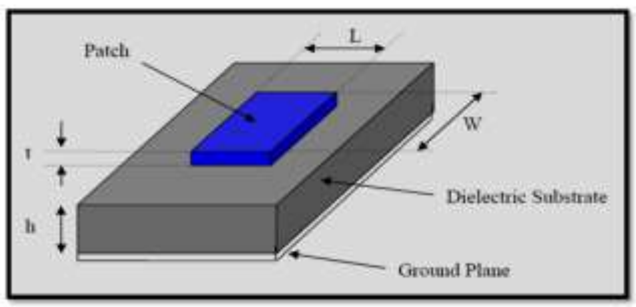

Figure. 1: Typical microstrip patch antenna

The patch is generally made of conducting material such as copper or gold and can take any possible shape. Some of the typical patch shapes are shown in Fig. 2.

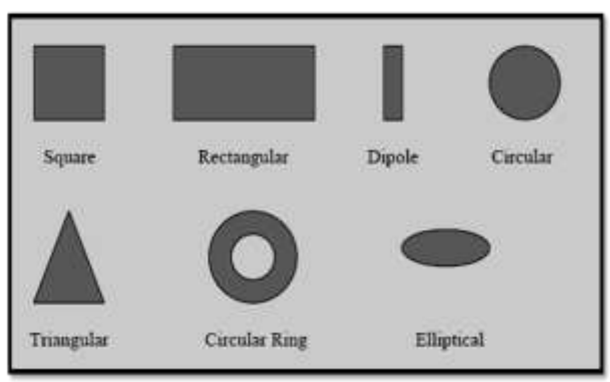

Figure 2: Different shapes and sizes of patch

The radiating patch and the feed lines are usually photo etched on the dielectric substrate. Microstrip patch antennas radiate primarily because of the fringing fields between the patch edge and the ground plane.

Microstrip patch antennas have many advantages when compared to conventional antennas. As such, they have found usage in a wide variety of applications ranging from embedded antennas such as in a cellular phone, pagers etc. to telemetry and communication antennas on missiles and in satellite communications. Some of their principal advantages discussed by Kumar and Ray are [9]:

Feed Techniques for Patch Antennas

Microstrip antennas are fed by a variety of methods that are broadly classified into two main categories, namely, contacting and non-contacting. In the contacting method, the RF power is fed directly to the radiating patch using a connecting element such as a microstrip line. In the non-contacting method, electromagnetic field coupling is done to transfer power between the microstrip line and the radiating patch.

The four most popular feed techniques used are the microstrip line, coaxial probe (both contacting schemes), aperture coupling and proximity coupling (both non-contacting schemes). These are discussed in subsequent sections.

Microstrip Line Feed

In this type of feed technique, a conducting strip is connected directly to the edge of the microstrip patch as shown in Fig. 2.3. This strip is smaller in width as compared to the patch. The major advantage of this arrangement is that the feed can be etched on the same substrate to provide a planar structure [9].

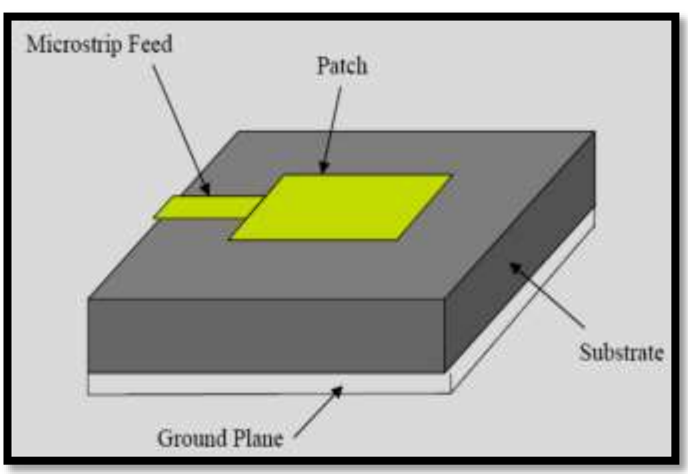

Figure 3: Microstrip line feed for patch antenna

In many cases, an inset cut feed is preferred over edge feed. The purpose of the inset cut in the patch is to match the impedance of the feed line to the patch without the need for any additional matching element. It is an easy feeding technique that is easy to fabricate and provides simplicity in modeling as well as impedance matching. However as the thickness of the dielectric substrate being used increases, surface waves and spurious feed radiation also increases, which hampers the bandwidth of the antenna. The feedline radiation also leads to undesired cross polarized radiation.

RESULT AND DISCUSSION

In this section investigation has been carried out for same parameters for antenna with EBG structure and for antenna with EBG structure and superstrate. I have been discussing S_{11} parameters, bandwidth, and radiation pattern for both antenna structures. We obtained simulated results for all antenna structures with ansoft HFSS-11 simulation software. It will be shown that a significant improvement in bandwidth can be obtained by etching feed line with EBG patterns and introducing a dielectric layer over patch.

The S_{11} parameter value Vs frequency in GHz graph for the reference antenna shown in Figure 4. As fig shows 10 dB return loss is -26.3670 and resonant at 4.66 GHz. In case of reference antenna we achieve higher frequency 6.0266 GHz while lower frequency is 2.4214 GHz. In this case percent bandwidth is 38.62%. As we know that minimum point below 10 dB line indicated minimum return losses, fig 6.1 shows that minimum point is at -26.3670 hence we can say that antenna losses is minimum.

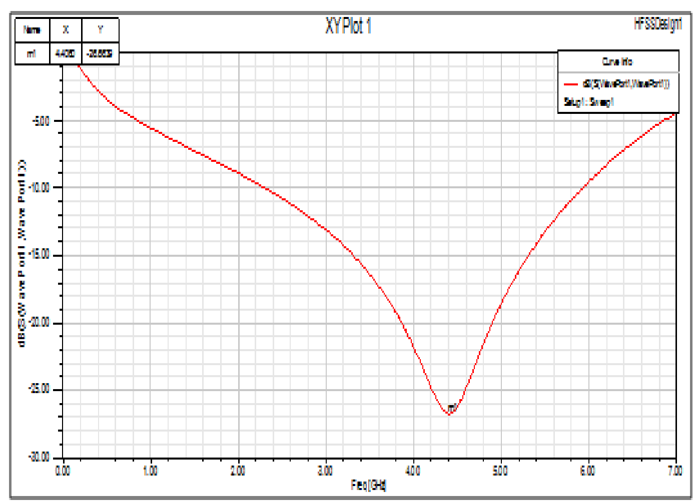

Figure 4: Return Loss Vs Frequency of reference antenna

Voltage standing wave ratio of reference antenna is 1.1009 as shown in fig. 6.2. We know that ideal value of VSWR is 1 and simulated result shows that value of VSWR is almost nearer to 1, hence we can say that antenna is most likely to matched.

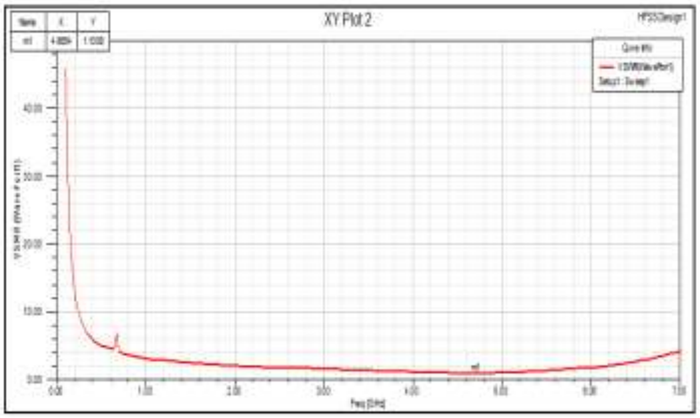

Figure 5: VSWR plot reference antenna

The Smith chart

The Smith chart shows that the proposed antenna is resistive at resonance frequency of 4.66 GHz as the circle intersects the middle line near the origin i.e. it radiates more power. Smith chart for reference antenna shown in fig. 6.

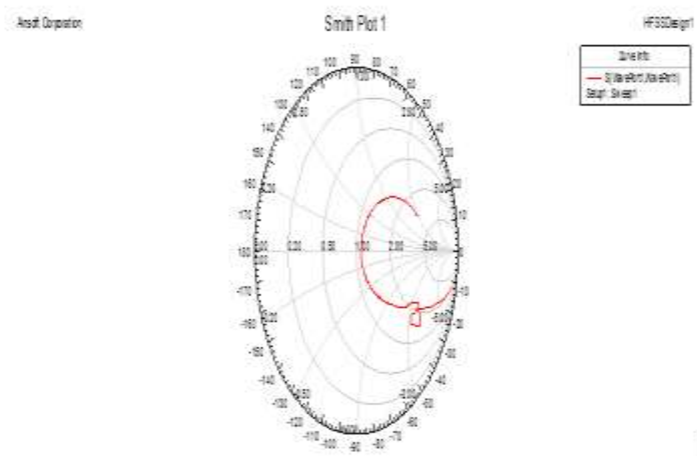

Figure 6: The smith chart reference antenna

Comparison between Reference Antenna, Antenna with EBG Structure and Antenna with EBG and Superstrate

As comparison table 1 shows bandwidth of patch antenna is increased by 2.5 % by implementing Electromagnetic bandgap structure, return loss is also minimized by implementing electromagnetic bandgap structure. Further when we implemented superstrate layer over electromagnetic bandgap structure bandwidth is increased by 9.23% as shown in comparison table 1.

s.no	Parameters	Reference antenna	Antenna with EBG structure	Antenna with EBG and Superstrate
1	10dB Return Losses	-26.3670	-26.6639	-22.019
2	Resonant Frequency	4.6654	4.4060	4.0947
3	Higher Frequency	6.0266	5.9219	6.0563
4	Lower Frequency	2.4214	2.2998	2.1377
5	Bandwidth	38.62%	41.12%	47.85%
6	VSWR	1.1009	1.0974	1.1723

Table 1: Comparative chart

Conclusions

From the work conducted on the microstrip patch antenna, it can be concluded that microstrip antennas are low profile, simple and inexpensive to manufacture using modern printed circuit board technology, mechanically robust when mounted on rigid surfaces, and when the particular patch shape and mode are selected they are very versatile in terms of resonant frequency, polarization, pattern and impedance.

Patch antennas are very popular because of their low profile nature, light weight and low costs. They have many advantages over conventional antennas. However, narrow bandwidth is a major problem.

In this thesis, the narrow bandwidth problem of a dual patch microstrip antenna was studied. The method employed to improve its bandwidth is use of mushrooms like Electromagnetic Bandgap Structure and then using a dielectric layer over triangular patch.

The EBG pattern and superstrate are proposed and simulated results confirm that antennas having EBG pattern and superstrate have considerable improvement in bandwidth when compared to a reference antenna having no EBG pattern and superstrate layer over patch.

Firstly, analysis has been carried out for comparision of the bandwidths of reference antenna and antenna with EBG structure and then antenna with both EBG structure and superstrate layer over patch. It is found that the best increment in bandwidth is obtained when the both EBG structure and superstrate layer are implemented. Percent bandwidth of reference antenna found to be 38.62% and percent bandwidth of antenna with EBG pattern is 41.12% , while this can be achieved 47.85% in case of EBG structure with superstrate layer over patch.

Future Work

In this work, we have been examined an equilateral triangular patch antenna and the use of EBG structure and superstrate to help improve the bandwidth. The future work can involve changing the antenna type (including antenna shape and the dielectric of the substrate) and carry out further research into the EBG structures, and superstrate.

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