DESIGN ANALYSIS AND FABRICATION OF MICROSTRIP PATCH ANTENNAS FOR VARIOUS APPLICATIONS USING ELECTROMAGNETIC BANDGAP AND DEFECTED GROUND STRUCTURES

A thesis submitted towards the partial fulfilment of the requirements
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IN
ELECTRONICS AND COMMUNICATION

Submitted by

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DECLARATION

I hereby declare that the work which is being bestowed in the thesis entitled "**Design analysis and fabrication of microstrip patch antennas for various applications using electromagnetic band gap and defected ground structures**," is an authoritative record of my own work borne out as the requirement for the award of degree of Master of Engineering in Electronics and Communication Engineering at Electronics and Communication Engineering Department of Thapar University, Patiala, under the joint guidance of **Dr. Rajesh Khanna** (Professor) and **Dr. Jaswinder Kaur** (Lecturer), Electronics & Communication Engineering Department.

The stuff conferred in this thesis has not been submitted in any other University/Institute for the award of degree.

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ABSTRACT

In an era of increasing mobility, there is a necessity that people communicate with each other irrespective of the location or information of the individuals. Wireless communication plays a critical role in this regard. The rise in demand of wireless communication has paved the way for better comprehension of cardinal issues in electromagnetic and communication theory. In various wireless communication system, a significant role in making the system reliable and elevating its performance is played by a device known as 'antenna'. The use of wireless communication is not omissible in the present era.

Microstrip antennas have been utilised broadly in various fields such as in satellite communications, aerospace, radars, biomedical applications and reflector feeds, as a result of their benefit of a low profile, light weight and affinity with integrated circuits. Nevertheless, they go through from disadvantages for example narrow bandwidth; low gain and excitation of surface waves, appreciable return loss etc. All the above mentioned drawbacks have restricted their functions in various fields. In order to swamp the drawbacks of bandwidth of microstrip antennas, many approaches have been developed. Because of above mentioned reasons, new techniques are still being probed, and electromagnetic band gap materials, as antenna substrates, have captivated consideration. The ever growing requirement for low profile wireless communication antennas resulted to probe of artificial structures with distinguishing electromagnetic characteristics. Amid they are the man-made metamaterial, electromagnetic band gap structures (EBG), high impedance surfaces (HIS), and defected ground structure (DGS).

In this work represented, Transmission line model is utilised to simulate rectangular Microstrip Patch Antenna with the help of microstrip centre feed line. The aim is improvement of the antenna parameters like bandwidth, surface wave suppression, gain, efficiency, and high return loss etc. using new EBG and DGS structures. The radiating patch can have any structure like rectangular, circular, disc shaped, cylindrical etc. but rectangular is favoured. The structural design includes selection of the patch, slots width and dimensions of EBG and DGS structures are the major specifications along with the feed line depth.In this thesis report various antenna designs are presented and studied various effects of different specifications for example length and width of patch, height of substrate, dielectric constant EBG and DGS parameters for WLAN, DBS and RF portable devices applications. The antennas are designed using CST 10 microwave studio.

INDEX

MPA	Microstrip Patch Antenna
RMPA	Rectangular Microstrip Patch Antenna
LAN	Local Area Network
WLAN	Wireless Local Area Network
CST	Computer Simulation Technology
VNA	Vector Network Analyzer
DRA	Dielectric Resonator Antenna
DR	Dielectric Resonator
EBG	Electromagnetic Band Gap
EDRA	EBG Dielectric Resonator Antenna
DGS	Defected Ground Structure
HIS	High Impedance Surface
RF	Radio Frequency
VSWR	Voltage Standing Wave Ratio
RL	Return Loss

CHAPTER 1
INTRODUCTION

Mode of communication among humans was initially with the help of sound through voice. With the motive for telecommunication, there came alternatives like drums, some visual methods for example smoke signals and signal flags etc. The optical communication equipments used the light (visible portion) of the electromagnetic spectrum as the medium with the help of optical fibres. With the advancement of the technology, the visible region of the electromagnetic spectrum has been occupied for communication, with the help of radio. One of the mankind's tremendous natural resource is the electromagnetic spectrum and important element for using this resource is antenna.

1.1 Wireless Communication

Wireless communication system has been advanced extensively and rapidly in the modern world particularly amid the last two decades. The future advancement of the personal communication structures will goal to provide image, speech and data communications at any time, and anywhere around the world. It signifies that the future communication transceiver antennas meet necessarily the requirement of multi-band and wideband to adequately include the feasible operating bands.

Wireless operation allows the services, like telecommunications, that are preposterous to implement with the help of wires. The familiar benefits of wireless networks are to connect the laptop/mobile data communication users who navigate from location to location. Another important usage is for mobile networks that have a link through antennas, via satellite communications. Different modes of Wireless communication are:

1. RF communication
2. Microwave communication like long range line-of-sight high directional antennas and short range communications.
3. Infrared short range communication like remote controls etc

The field of wireless communication has been experiencing a subversive hike in the last decade like 2G-cellular communication (portable mobile phones), 3G- Bluetooth, 4G- the mobile WiMAX standard and LTE standard, LAN.

1.2 Need of Antennas

The crucial component of a wireless network is the 'Antenna'. Antenna is one of the fundamental components in the Radio Frequency field working as a transducer which converts electrical power into radio waves. Without appropriate design of the antenna, the signal produced by the RF system will not be transmitted properly and no or interfered signal can be detected at the receiver. Antenna engineering is a vital ground that is erupting with continuous activities and is probably to be increasing in the ascertainable future. Various types of antenna have been made to provide various applications and perfects for their requirements. In the last two decades the most eminent classes of antennas probed and devastatingly established are:

1. **Microstrip patch antenna**: These antennas have use in space applications, government and commercial applications. They include radiating patch of metallic material on substrate with ground structure on its back. These antennas are placed on the surface of high performance aircraft, spacecraft, satellites, missiles etc.
2. **Dielectric Resonator Antenna:** Radio antenna generally used at microwave frequencies and higher, consisting different shapes of ceramic material placed on a substrate with grounded structure on back.

The microstrip antenna has been considered to be the most ingenious field in the engineering of antenna having the properties like low material cost and not difficult to be designed, simulated and fabricated. Since the frequency bounds of interest have slightly increased and the frequencies in millimeter region (100-300GHz) are being utilized, the conduction losses in metallic antennas have expanded to such a level that relevant operation of the systems is affected. So an idea to use dielectric material as a radiator was perceived.

1.3 Antenna Parameters

There are different parameters of antenna which are utilised to examine the efficient functioning of the antenna. The following are the few antenna parameters:

- **Return Loss:** It is the power loss in the signal that is reflected due to discontinuity in the transmission line. As we already know, when impedance matching between the transmitter and antenna is not perfect, the radiations within the substrate results into the standing waves. As a result the return loss is the criteria similar to VSWR that indicates the perfect impedance matching between the transmitter and the antenna. The return loss is formulated as

$$RL = -20 \log_{10}(P_i/P_r)$$

Where P_i =Incident power

P_r= Reflected power

- **Smith Chart:** It was created by Phillip H. Smith and is a wonderful tool for viewing the impedance of the transmission line and antenna working as a function of frequency. They are exceptionally advantageous for impedance matching. The complex reflection coefficient denoted by Ѓ for the load impedance Z_L attached to the transmission line with characteristic impedance Z_0 is represented by:

$$Ѓ= (Z_L- Z_0) / (Z_L+Z_0)$$

We represent all the values of Ѓ on the real and imaginary axis. The centre point denotes the point where the reflection coefficient is zero.

- Vo**ltage Standing Wave Ratio (VSWR):** It states that how well the matching takes place between antenna and transmission line or the receiver which illustrates the maximum energy transfer. Imperfect impedance matching results into reflected back waves approaching the transmitter. The interpaly between the reflected waves and the forward waves results into standing waves.

$$VSWR= (1+ Ѓ) / (1- Ѓ)$$

Where Ѓ =Reflection coefficient

Ideally, VSWR =1 is perfectly matched, that is no power is reflected back.

- **Directivity**: The measure of directionality of an antennas radiation pattern is known as directivity. An antenna which radiates evenly in every direction has directivity equal to 1 or 0 dB. It is also defined as the radiation intensity in a given direction from the antenna divided by the radiation intensity averaged over every direction. Analytically, it is represented as

$$D = U / U_0 = 4\Pi U / P_{rad}$$

U = radiation intensity (power density per unit solid angle)

U_0 = radiation intensity of isotropic source (power density per unit solid angle)

P_{rad} = total radiated power (W)

- **Gain**: It is relative measure of an antennas ability to direct RF energy in particular direction. It is defined as how much power is transmitted in the direction of peak radiation to that of an isotropic source. Mathematically it is be represented as

$$Gain = 4\Pi U/P_{in}$$

U = radiation intensity

P_{in} = total input power

- **Radiation Pattern**: It can be described as “a mathematical function or graphical representation of the variation of the power radiated by an antenna as a function of the direction away from the antenna”. We can also say that the radiation pattern is a graphical or directional dependence of the relative strength of the radio waves transmitted from or received by the antenna or any other source. The plot is typically shown as a three dimensional graph or as a separate graphs in vertical or horizontal plane. It is basically depicted on a linear scale or in dB.

1.4 Introduction of Microstrip Patch Antenna

The idea of the microstrip antenna was brought in 1950’s but it became prominent and has been utilized in various applications since 1970’s.

A microstrip antenna includes conducting patch that radiates, fabricated on a substrate having ground plane on its back. Specifications of the emanating patch involving length, width, type of feed technique etc. and of the substrate involving material and height of the substrate etc. concludes the behaviour of the antenna. Various kinds of feeding methods are being used to excite the antenna like microstrip feed line, aperture coupled, coaxial, coplanar waveguide, rectangular waveguide etc. Microstrip patches designed so far are of various forms like rectangular, cylindrical, square, circular or disk patches. Patch antennas are the type of radio antennas with low cost, low profile and can be conveniently fabricated.

Figure 1 depicts the typical microstrip patch antenna fed by a microstrip transmission line. The microstrip patch antenna, microstrip feed line and ground structures are formed from metal (usually copper) with high conductivity. The patch of length L, width W is placed on front of a substrate having thickness h with relative permittivity $\mathcal{E}_r$. Ground plane or microstrip feed line thickness is not precariously significant. Specifically, the height of the substrate that is ‘h’ is lesser than the wavelength of operation, but not much lesser than $(1/20)^{th}$ of a wavelength.

The frequency of operation of the patch antenna is basically calculated by the length L of the patch. The centre frequency can be relatively determined with the help of [2]

$$f_c = C / 2L\sqrt{\mathcal{E}_r} = 1/ 2L\sqrt{\mathcal{E}_o \mathcal{E}_r \mu_o}$$

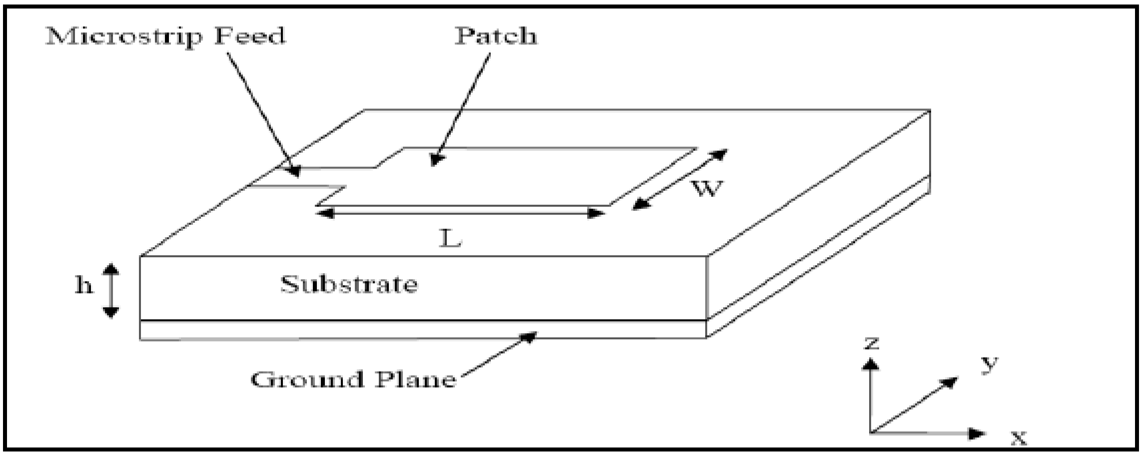


Figure1: Conventional Microstrip Patch Antenna [2]

The electric field does not exist at the middle of the patch, and is maximum or we can say positive at one side, and minimum or negative electric field on the other side. The positive and negative electric fields repeatedly alter side in accordance to the applied signal's instantaneous phase. As in cavity, the electric field does not cease abruptly around the periphery of the patch but the fields prolong to the outer verge to little extent. The extension of the fields is called *fringing fields* and are the source for the radiation of the patch.

The dielectric substrate that acts as a kind of insulator is an element that provides eminent resistance to the movement of electric current. Generally, the dielectric constant ($\mathcal{E}_r$) of the substrate must be less than 2.5 to increase the fringing fields which are responsible for the occurrence of radiations. Nevertheless, requirements for the other applications may precept the use of dielectric material having dielectric constant higher than 4 [2].

1.4.1 The Advantages & Disadvantages of Microstrip Antenna

Microstrip antennas have various benefits in comparison to the typical microwave antennas and have many functions that include the broad range of frequency from approximately 100 MHz to 100 GHz. The following advantages are:

- Light weight, low volume, thin structural compositions
- Low cost of fabrication, easily agreeable to production on a large scale
- Both linear and circular polarization are attainable due to simplified feeding technique
- Dual frequency and dual polarization antennas can be fabricated without difficulty
- Can be unified with microwave integrated circuits easily

- Simultaneously fabrication of feed lines and matching networks along with the antenna configuration

On the other hand, some limitations also exist in comparison to the typical antennas which are as follows:

- Limited bandwidth and correlated tolerance difficulties
- lesser gain of approximately 6 dB
- Enormous ohmic losses
- Many of the microstrip antennas emanate into half-space
- Some feeding techniques required for high performance arrays are complicated
- Purity of polarization is cumbersome to achieve
- Indigent end-fire radiator, except tapered slot antenna
- Intrinsic radiations from different feed and connections
- Inferior capability of power handling
- Excitation of surface waves
- Microstrip antenna mounted on a substrate with high dielectric constant is mostly favoured for easy integration with MMIC RF front-end circuitry. Also use of high dielectric constant substrate results into inferior efficiency and limited bandwidth.

1.4.2 Applications of Microstrip Antenna

The applications of microstrip antenna include a broad range from transportation, communication to biomedical [2].

- Airplanes and pinnace antennas - Communication and navigation, blind landing
- Missiles systems - Radar, contiguity fuses and telemetry
- Satellite communications – TV broadcasting, whip antennas
- Mobile communication - radio Pagers and hand phones, resolve light weight man pack jammers or systems, mobile vehicle
- Remote sensing – archaeological surveying
- Biomedical Applications - microwave hyperthermia
- Additional applications - Interloper alarms, personal communication etc

1.5 Introduction of Dielectric Resonator Antenna (DRA)

A **dielectric resonator antenna** is a type of radio (wireless) antenna that is mainly utilised at microwave and higher frequencies. It is manufactured from high dielectric constant materials usually ceramic or glass. The dielectric resonator, that is designed to function as a resonator for radio waves, is fabricated on a metal surface, a ground structure or on a dielectric substrate having ground plane on its back and comparatively less permittivity. We import radio waves inside the resonating dielectric material with the help of the transmitter circuit and rebound back and forth amid the resonator walls, resulting into the standing waves. The resonator peripherals are partly transparent to electromagnetic waves, acknowledging the electromagnetic waves to emanate into space. For a given DRA geometry, the radiation pattern can be made to change by exciting different resonant modes.

One of the fascinating characteristic of DRA is that it can be fabricated in a number of shapes. DRAs of cylindrical, hemispherical and rectangular shapes are most widely used and investigated. The following figure depicts the DRA's of various shapes [1].

Figure 2: Different DR geometries used [1]

1.5.1 Dielectric Resonator (DR)

Dielectric resonator components made up of dielectric material usually ceramic presents resonance for a limited range of frequencies, usually in the microwave and millimetre wave range. These components are identical in fundamentals compared to the rectangular or cylindrical cavities. The resonator with high dielectric constant illustrates that many of the fields are occupied in the dielectric in comparison to metallic cavities, also field fringing exists or leakage from the peripherals of the dielectric resonator takes place [3]. Such types of resonator are usually lesser in cost, size, and weight in comparison to cavity made up of metallic material, and incorporation in to microwave integrated circuits and coupling to transmission lines is very simple. Dielectric resonators that we are being utilized in microwave applications have dielectric constant of approximately greater than 20 and quality factor denoted by Q of about 50-500. Dielectric resonators are used as energy storage devices but if the cavity is not completely enclosed by metallic walls that is conducting boundary, then the EM fields exist beyond the geometrical boundary of the cavity, and if exposed to free space it can radiate because of boundary conditions at the dielectric to air interface [4].

Materials with dielectric constants usually from 10 to 100 are ideally appropriate for antenna applications. Most of the energy is stored in the resonator at a given resonant frequency for a adequately high dielectric constant. Extremely high Q factor of DR usually between 50 and 500 can be compared to a metal walled cavity. Losses due to conductors are not present, but losses due to dielectric generally grow with dielectric constant. Due to above mentioned required characteristics, dielectric resonators have evolved into major factor for integrated microwave filters, dielectric resonator antennas and oscillators. When a dielectric resonator is not completely surrounded by a conducting periphery, it can emanate, and so it acts as an antenna, titled as Dielectric resonator antenna (DRA) [5].

1.5.2 Features of DRA

Dielectric resonator antenna (DRA) offers the below mentioned fascinating characteristics:

- The dimension of a DRA is $\lambda_0/\sqrt{\in_r}$, where λ_0 is the wavelength of free-space and $\in_r$ is the dielectric constant of the resonator material. Hence, by selecting a large value of $\in_r$ ($\in_r \approx 10 - 100$), the dimensions of the DRA can be extremely decreased.
- No latent conductor loss exists within dielectric resonators. It results to immense radiation efficiency of the antenna. It is usually fascinating for millimetre wave antennas, in which the loss is high if made from metallic materials.
- DRA provides easy coupling techniques.
- Depending upon the shape of the resonator, excitement of a number of modes can take place within the dielectric resonator antenna. The outcome of such modes results into various radiation patterns for different needs on coverage. Along with it, the Q-factor of

such modes will rely upon the aspect ratio of the DRA, thus favouring another degree of adaptability in the structure.

- The bandwidth of operation of a DRA is assorted through a large range by preferably selecting parameters of the resonator. Like, the bandwidth of the lower order modes of a DRA can be simply diverse from a portion of a percent to about 10% or more with the help of an appropriate selection of the dielectric constant of the resonator material.
- Every mode of a DRA consists an exclusive interior and correlated exterior distribution of fields. As a result, various features of radiation can be received with the help of excitation of various modes of a DRA.

1.6 Introduction of EBG

1.6.1 Need of EBG

The requirement of high speed, wide bandwidth and low profile structures has triggered the researchers to research at the millimetre and micrometre frequency range. Due to their zero loss because of metallic structure, low dielectric losses, immense radiation efficiency, ease of excitation, size reduction and wide bandwidth, a developing consideration to the probe of dielectric resonator antennas (DRA's) for the millimetre-wave devices in comparison to the typical microstrip antennas has been paid. Impenetrable and comparatively substrates with more thickness help in providing better coupling and wide bandwidth. Moreover, the impedance bandwidth of DRA relies on the dielectric constant of resonator material, so if the dielectric constant increases, surface waves become dominant and as a result the radiation efficiency is depraved. So the radiation characteristic, bandwidth, and gain of DRA can be enhanced with the help of EBG (Electromagnetic Band Gap) structure for the DRA.

Figure 3 illustrates the suppression of surface waves that takes place as a result of using EBG structure that prevents the electromagnetic waves from reflecting within the substrate and hence leading to the constructive addition with the space waves, hence resulting in reduction of back lobe radiations and suppression of surface waves [3].

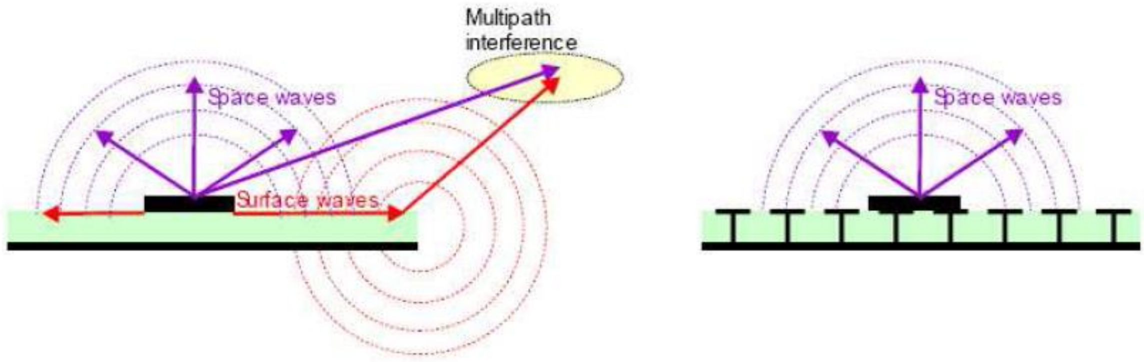


Figure 3: (a) Substrate without EBG (b) Substrate with EBG

Another disadvantage of the DRA is its low gain characteristics. EBG dielectric resonator antennas (EDRA) can be referred as **Fabry-Perot cavity antennas**. They can provide gains of about 20 dB. Electromagnetic band gap structures (EBG) are utilized to increase the efficiency of the radiations.

1.6.2 EBG Structure

EBG designs are repeated components that depict exclusive electromagnetic characteristics, like frequency band gap is generated for surface waves, also in-phase reflection coefficient for incident plane waves, that forms them appropriate for antenna with low profile design. Figure 4 illustrates various types of EBG structures for example mushroom-like, fan structure, circular patches, swastika, hexagonal etc.

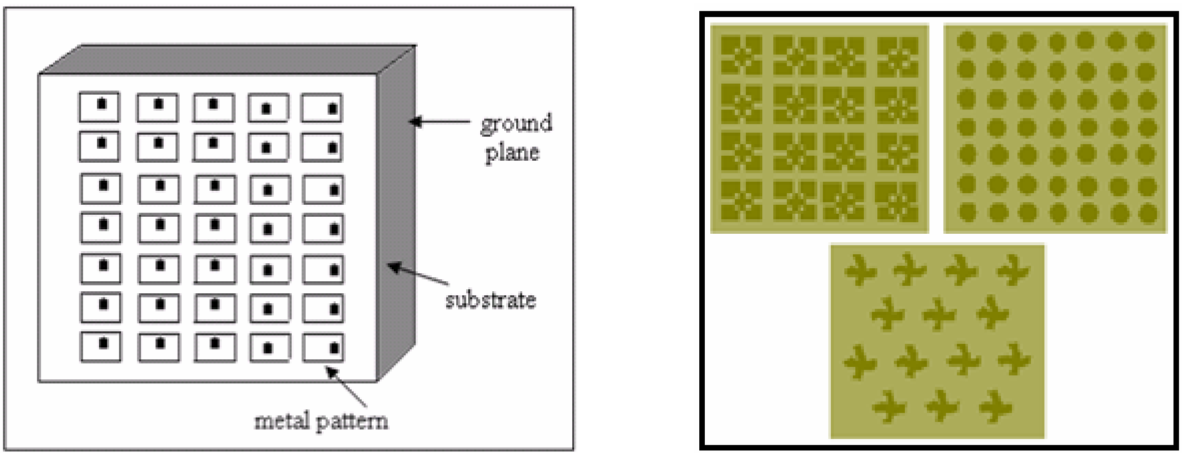


Figure 4: Various types of EBG structures [4]

EBG supports a stop band frequency where propagation is not allowed; hence encircling the DRA with the help of an EBG component will clog the surface-waves in the band gap as shown in Figure 5 and enhance the radiation efficiency.

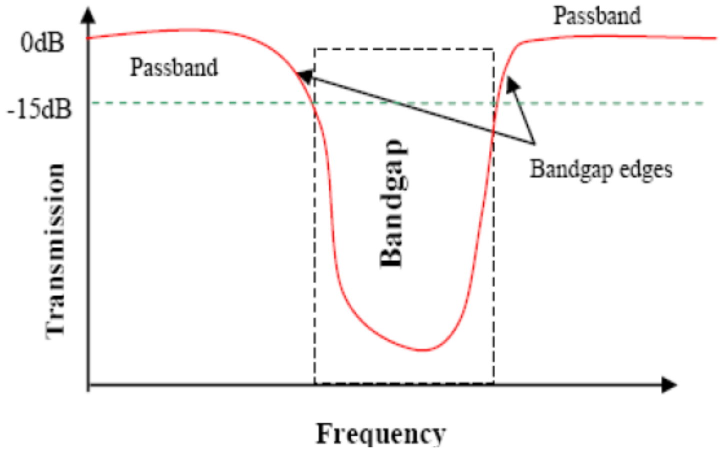


Figure 5: Transmission loss plot illustrates band gap in a micro strip transmission line at microwave frequencies [5]

The EBG material comprises of dielectric rods cylindrical in shape known as vias with dielectric constant ranging from 10 to 100. The vias are placed parallel and periodically also isolated by air. EBG material can be specified with the help of behaviour of its reflection and transmission coefficient in contrast with frequency. The familiar feature is the presence of a band gap in which the reflection coefficient is very low and as a consequence the transmission coefficient is about 0 dB. The frequency band gap can be selected by altering the dimensions of the dielectric rods. Increasing the width of the EBG patches can increase the bandwidth. To enhance the miniaturization in EBG components, distinct structures with distinct gaps have been proposed. As a result the shape and design of the EBG configurations have become more challenging in the recent technology of the antenna design. EBG configurations can be characterized into 3 parts in accordance to their geometrical behaviour: (1) 3-D volumetric configurations (2) 2-D planar areas (3) 1-D transmission lines. Various EBG structures can be as follows: spiral, stack, fork-like, hexagonal shaped, elongated mushroom type, cylindrical etc.

A high-impedance surface subsists of a group of metal protrusions mounted on a leveled metallic surface. It is organized in a 2D structure, and is generally designed as metal surfaces, linked to the ground with the help of vertical posts or vias as shown in figure 3. They can be anticipated as mushrooms or thumb stacks or other shapes bulging from the surface. High Impedance Surfaces referred as two dimensional EBG structures can be utilized as antenna substrate to eradicate the surface waves.

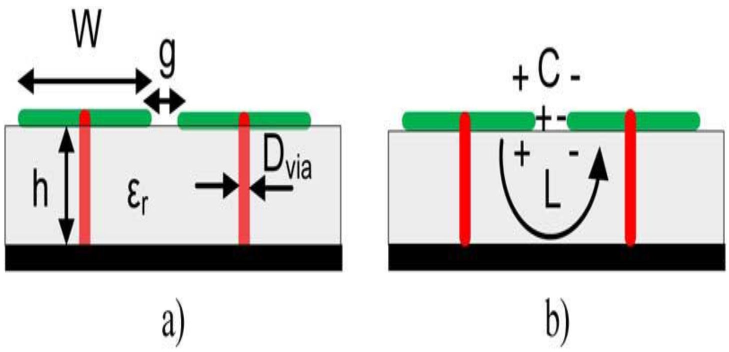


Figure 6: Mushroom-like EBG (a) design parameters (b) lumped element model [6].

For a mushroom type EBG, the value of capacitance 'C', inductance 'L' and resonant frequency are given by [6]

$$C = \frac{W\varepsilon_0(1+\varepsilon_r)}{\pi} cosh^{-1}\left(\frac{W+g}{g}\right)$$

$$L = 2 * 10^{-7} h \left[\ln\left(\frac{2h}{r}\right) + 0.5\left(\frac{2r}{h}\right) - 0.75\right]$$

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

The capacitance is because of the adjacency of the top metal patches, while the inductance arises from current loops within the adjacent metal structures.

The impedance of a parallel resonant LC circuit is represented by [6]

$$Z_s = \frac{j\omega L}{1-\omega^2 LC}$$

Inductive properties are shown at low frequencies, hence favours TM surface waves. Capacitive properties are shown at high frequencies, hence favours TE surface waves. The impedance is usually very high in a limited band around the LC resonance. Within this frequency range, currents originating on the surface of the structure emantes and suppress the procreation of both types of surface waves very efficiently.

1.6.3 Advantages of EBG

- EDRA's provide high gain and wide bandwidth and also very small height approximately λ/15 instead of λ/2 for a usual EBG antenna [2].
- The side lobes are reduced.
- A fantastic circular polarization can be achieved with a relevant feeding technique.
- A wider bandwidth is possible to be attained with the help of an EBG structure having distinct faults.
- A limited band permits a filtering response within the antenna.
- The antenna appears to be very competing in comparison to the typical high-gain antenna for example horns, reflectors, and lenses, while the thickness is smaller. Planar array antennas are thinner, but they require a feeding structure which introduces losses and difficulties to design.
- They provide a high degree of flexibility and versatility over a broad frequency range, suiting the designer's requirements.
- DRAs come in easy shapes for example circular, cylindrical, hemispherical, rectangular etc. those are easily accessible and can be easily fabricated.
- DRAs have been fabricated to work over a broad frequency band (1 GHz to 44 GHz) in comparison to rest of the antennas.
- DRAs have more dielectric strength and consequently more power handling capacity.
- The temperature-stable ceramics permits the antenna to work in a broad range of temperature.
- No latent conductor loss for a DRA exists. In case of DRA's, high radiation efficiency is possible. It is especially enticing for high frequency millimetre wave applications, where the loss from metallic antennas can be high.
- In comparison to the microstrip antenna, DRA has broader impedance bandwidth. This is because the microstrip antenna radiates only through two narrow radiation slots, on the other hand the DRA radiates through the whole antenna surface except the grounded structure. Moreover the operating bandwidth of a DRA can be altered by preferably selecting the dielectric constant of the resonator material and its dimensions [3].

1.6.4 Applications

- DRA's can be used for ultra fast medical and sensor applications. A shaped DRA has been designed for breast cancer detections.
- DRA placed over a vertical or horizontal ground structure with broadside radiation patterns can be used as thin antennas and can be effortlessly incorporated with RF portable devices.
- Cylindrical shaped DRA on high conducting substrate has been used to operate on 60 GHz band for WPAN (Wireless personal area networks).
- Dielectric resonators have become major factor in the field of integrated microwave filters and oscillators as a result of high temperature stability and low loss.
- A dielectric material on the front part of the ground plane can also operate as an optical antenna in the frequency band (THz). ODRA (Optical DRA**)** can be utilized for concentrated beam in an amazing transmission in plasmonic devices [2].

1.7 Work Covered in the Thesis

The thesis covered the basic principles of design of dielectric resonator antenna with the help of mushroom-like electromagnetic band gap structure, the design and simulation of Triple-Band Rectangular Zigzag Microstrip Patch Antenna having Defected Ground Structure (DGS) for improved bandwidth for WLAN AND DBS applications, the design and simulation of U-Slot Microstrip Patch Antenna for RF Portable Devices with the help of Electromagnetic Band Gap and Defected Ground Structure. The fabrication and testing of Triple-Band Rectangular Zigzag microstrip patch antenna has been done.

1.8 Thesis Outline

The synopsis of the thesis given below:

Chapter 1: The knowledge of the wireless communication, the conventional Microstrip patch antenna and dielectric resonator antenna and the introduction of new advanced technology that is electromagnetic band gap structures are shown in this chapter.

Chapter 2: A concise literature review of the microstrip and dielectric resonator antenna in order to get its basic fundamentals is presented in chapter 2. Important aspects of the microstrip antenna like its parameterization, radiation patterns, polarization, feeding techniques, analytical mecahnisms etc are covered. Various approaches used in the improvement of the bandwidth, return loss, efficiency and suppression of the surface waves by various authors is depicted in this chapter.

Chapter 3: It shows the design process of Triple-Band Rectangular Zigzag Microstrip Patch Antenna with Defected Ground Structure (DGS) for improved bandwidth for WLAN AND DB S Applications. The designing and simulation is done with the help of CST 10 Microwave Studio of rectangular Microstrip patch antenna. Simulated and fabricated results are bestowed in this chapter. The bandwidth can be improved using the following techniques:

- By using slots on the radiating patch.
- By introducing defects in the grounded structure
- By using impedance matching

Chapter 4: This chapter presents design and simulation of U-Slot Microstrip Patch Antenna for RF Portable Devices using Electromagnetic Band Gap and Defected Ground Structure and the improvement in its performance of the parameters like bandwidth enhancement, return loss improvement, suppression of surface waves and reduction of back lobes.

Chapter 5: This chapter includes another antenna design having dielectric resonator material of the patch instead of microstrip patch named as "Dielectric Resonator Antenna Using Mushroom- like Electromagnetic Bandgap structure". Mushroom like electromagnetic bandgap structure has been introduced which helps in surface wave suppression; return loss improvement and reduction back lobe radiations.

Chapter 6: The conclusion to this thesis and the scope of the future work to be continued by using a different structure configuration, the use of different dielectric substrate material as well as combination of different substrate in one structure is shown in this chapter.

1.9 Conclusion

In this chapter the overview of wireless communication, microstrip patch antenna and dielectric resonator antenna has been examined. The design procedure and fabrication for the microstrip patch antenna has also been studied. The parameters which affect the performance of the microstrip antenna have been discussed.

CHAPTER 2

LITERATURE REVIEW

In this chapter, overview of the work, regarding dielectric resonator antennas and microstrip patch antennas utilizing EBG and defected ground structures and their design methods has been done.

2.1 Progress of MPA using EBG structure and DGS

S.F Roslan et al. (2014) presented a Multi input multi output (MIMO) rectangular dielectric resonator antenna (RDRA) operating at 2.6 GHz for Long Term Evolution (LTE) applications. The antenna has a broadside and unidirectional radiation pattern, with reasonable gain for both antennas at the operating frequency. Furthermore, the proposed antenna has excellent correlation coefficient (0.03) and diversity gain (10 dB) over the operating band that is at frequency 2.6GHz. Two different feed mechanisms used for exciting the two orthogonal modes of RDRA are coaxial probe and coplanar waveguide (CPW). The MIMO RDRA gave isolation of above 20 dB over the operating frequency. The gain of 4.97 dBi was obtained for port 1 and 4.51 dBi for port 2 at 2.6 GHz. The proposed antenna was efficient and provided satisfactory performances for LTE applications [7].

Raheel M.Hashmi et al. (2014) presented a design of single-feed high-gain EBG resonator antennas (ERAs) with significantly wider bandwidth. A wideband EBG resonator antenna (ERA) was designed using a wide defect-mode produced by unprinted dielectric slabs of different permittivity and thickness values, and by significantly truncating its superstructure area. The defect-mode bandwidth roughly depicts the 3dB directivity bandwidth of ERAs having superstructures, provided the reflections from the superstructure were strong enough. Experimental results demonstrated 18.2 dBi peak gain and a 3dB gain. Because of a single feed and unprinted dielectric slabs, hence, the need for expensive feeding networks, complex design, and printed super structures were avoided. The antenna had a well matched feed over the operating bandwidth (VSWR<1.6) and its area was only 15% of the conventional ERAs [8].

A. Mehmood et al.(March 2014) presented A DRA-based phased array by using LC technology which included including a 1-by-4 dielectric resonator antenna (DRA) array, liquid crystal (LC) based phase shifters, RF-feeding and biasing networks. They used the DRAs to radiate the signal above from the antenna surface to reduce the surface currents. The gain losses at wide scan angles were reduced, enlarging the antenna's beam scan angle. The far-field power structures of the antenna were measured in an anechoic chamber for various beam directions. And the results confirmed that the gain losses were less than 1.5 for a beam scanning range of ±30° for the broadside [9].

Mohsen Khalily et al. (2014) designed a rectangular dielectric resonator antenna (RDRA) to generate linearly polarized (LP) with omnidirectional radiation patterns. LP DRA was fed centrally by a coaxial probe and offered an impedance bandwidth of 130 MHz between 5.15 and 5.35 GHz for return loss than -10 dB, which can be useful for 5.2-GHz WLAN applications. Circularly polarized (CP) fields were generated by introducing several inclined slits to the diagonal and sidewalls of the RDR and also deducting a rectangular part of the top wall of the LP RDRA .The proposed omnidirectional CP DRA with axial-ratio(AR) bandwidth of 210 MHz was designed for WLAN (5.15-5.35 GHz) applications [10].

Naizhi Wang et al. (2013) designed a broadband EBG resonator antenna working at Ku band. The EBG structure was generated by two dielectric substrates with different dielectric constants and thicknesses which enhances the bandwidth of the antenna. An improved 3dB gain bandwidth of 26% was obtained with a peak gain of 15dBi. This design method also can be easily applied to antenna designs at other frequencies [11].

Mu'ath J. Al-Hasan et al. (2013) presented a millimetre-wave (MMW) electromagnetic band-gap (EBG)-based dielectric resonator antenna (DRA) array. A new compact MMW electromagnetic band-gap (EBG) structure when mounted between the cylindrical DRAs depicts a symbolic reduction in the mutual coupling. The level of reduction ranged between 9 dB to 24dB over the frequency span from 57 GHz- 64 GHz [12].

Mu'ath J. Al-Hasan et al. (2012) presented a millimetre-wave, aperture coupled dielectric resonator antenna with EBG structure. Mushroom like -EBG configuration in shape of circular patches has enhanced the radiation efficiency of the antenna and has efficiently diminished the back radiation. Simulated consequences depict 18 dB improvement in the backward radiation in comparison to the case in which no EBG is used [13].

Kevin A. O'Connor et al. (2012) investigated a dielectric resonator antenna as a compact high power antenna for sub-GHz applications. When high dielectric constant resonator materials were incorporated it requires low volume, low profile form factor, and high power scalability. The microstrip coupling transmission line was designed to be 50Ω for compatibility with low power measurement equipment without the addition of matching lines. The dielectric constant approximately 100 of the resonator improved the return loss of the antenna down to 475 MHz. Peak gain was measured approximately 6 dBi at 700 MHz [14].

Abhinav Bhardwaj et al. (2012) proposed a dielectric resonator antenna in optical frequency range. It presents that a dielectric dot on the front view of a ground structure can operate as an antenna in optical frequency band. High directivity could be achieved using the group of optical dielectric resonator antenna. Fabrication of this geometry is possible using materials silicon and gold, also using shapes like cylindrical and rectangular [15].

Ahmed A Kishk et al. (2010) presented a DRA structure with broadside radiation for UWB wireless applications and limited pulse sensor for breast cancer detection. The rectangular DRA placed on a vertical ground structure provided smaller antenna volume in comparison to the horizontal ground structure. The composition of A-shaped DR overpowers the problem of distorted E-plane radiation patterns and had large antenna efficiency with stable gain over the frequency range. It had wonderful characteristics that made it a good example for sensor functions and also as thin antennas preferably integrated with portable wireless devices [16].

Yacouba Coulibaly et al. (2010) proposed a unique approach for the gain and bandwidth increase of dielectric resonator antennas using a cylindrical Electromagnetic Band Gap (EBG) structure. The structure consisted of a Dielectric Resonator (DR) an centre structure, an aperture coupled feed, and an electromagnetic band gap structure. The EBG structure depends upon the mushroom-like structure with a circular symmetry. This resulted in a gain enhancement of 6dB and an impedance bandwidth of 24 % being attained with the new substrate [17].

Yuehe Ge et al. (2009) designed a compact, stacked rectangular DRA with 10 dB return loss including 3.1 to 10.6 GHz UWB applications. The antenna was composed of a dielectric resonator with higher permittivity mounted on a thin dielectric structure with lesser permittivity to widen the bandwidth operation. Both were mounted on a ground structure and were excited with the help of coaxial feeding technique [18].

M.S.M Aras et al. (2008) proposed a design on DRA using disk shape. The disk was operating at 2.4GHz frequency (which is appropriate for WLAN application) and dielectric constant of 34.73.Microstrip feed line was used. The antenna was designed on the FR-4 microstrip board with the help of wet etching method and was simulated with the help of Computer Simulation Technology (CST) Microwave Studio [19].

Emad El-Deen et al. (2006) presented a rectangular DRA where the flat perfect electric conductor ground plane is substituted with Mushroom-like EBG. The analysis illustrates that the M-EBG ground planes contributes in diminishing the back lobe radiation and suppression of the surface waves. The analytical radiation patterns of the M-EBG rectangular DRA was observed at 4.3 GHz [20].

Tso Wei Li et al. (2005) proposed a method by which the bandwidth of a DRA was enhanced using a seperate parasitic strip placed on the dielectric resonator and there was an increase in bandwidth by 10dB in excess of 11% by shifting the displacement between the dielectric resonator and microstrip feedline. Using this design the bandwidth was increased almost thrice more than pure microstrip fed DRA. This paper predicted that low dielectric constant have wider bandwidth [21].

Cyril Cheype et al. (2002) proposed a new explanation of the electromagnetic band gap (EBG) material characteristics using the study of the EBG structures, an allowed Band was created inside the band gap, by introducing the defects in the structure and the space characteristics allowed selecting the direction of propagation. These properties were used to make an EBG Resonator Antenna. Hence this device helped to obtain a high gain with a very thin structure [22].

A.Ittipiboon et al. (1996) proposed a DRA as a substitute to the popular microstrip patch. He reported a single point fed DRA competent of radiating a circularly polarized signal with a much broader axial ratio bandwidth than a similar single point fed microstrip patch. The antenna was fabricated from ferrite material. The purpose of this paper was to depict a novel enhancement of DRA. The improvement in wider operational bandwidth with a simple slot feed and without a matching circuit or a complicated stacking procedure which is generally needed by a microstrip patch [23].

Gregory P. Junker et al. (1994) computed the input impedance of a cylindrical dielectric resonator antenna excited by an aperture slot. He used the method depending upon the surface integral equation formulation for bodies of revolution coupled to arbitrary objects. He observed the equivalent magnetic current in the slot with the help of the method of Moments together with an matrix solution algorithm. Thus the input impedance was calculated as a function of frequency for a slot excitation with a delta source shifted from the centre of the slot, hence can be adjusted by altering the delta source location without affecting the resonant frequency of the antenna [24].

J.T.H. ST Martin et al. (1991) proposed a practical antenna used at microwave and millimetre wave frequencies which consist of a circular cylindrical dielectric resonator fed by a microstrip coupling aperture feed line in the ground plane between them. Experimental results showed antenna operating between 13 and 16 GHz. It showed that the aperture coupled dielectric resonator antenna is preferred for MMIC applications [25].

2.2 Research Gaps

- Size reduction of the DRA has been achieved, but at the cost of antennas bandwidth. In this era of nanotechnology a solution for this has to be finding out.
- In EDRA (EBG dielectric resonator antenna) and microstrip patch antennas the 3dB directivity bandwidth certain parameters were predicted and the reflections from the superstructure were strong enough, which was the gap observed.
- MPA’s and DRAs have been shown to operate over a large range of frequencies from 1.3 GHz to over 40 GHz, but they have shown certain limitations in the UHF band below 1 GHz.

2.3 Thesis Objective

- To Design, Simulate and make a parametric analysis of Triple-Band Rectangular Zigzag Microstrip Patch Antenna with Defected Ground Structure (DGS) for improved bandwidth for WLAN AND DBS Applications.
- To Design and Simulate U-Slot Microstrip Patch Antenna for RF Portable Devices using Electromagnetic Band Gap and Defected Ground Structure and improvement in antenna parameters.
- To Design and Simulate Dielectric Resonator Antenna Using Mushroom- like Electromagnetic Bandgap structure.
- To fabricate the antenna using PCB Technology and testing the antenna using VNA.
- To publish research papers related to work done.

2.4 Conclusion

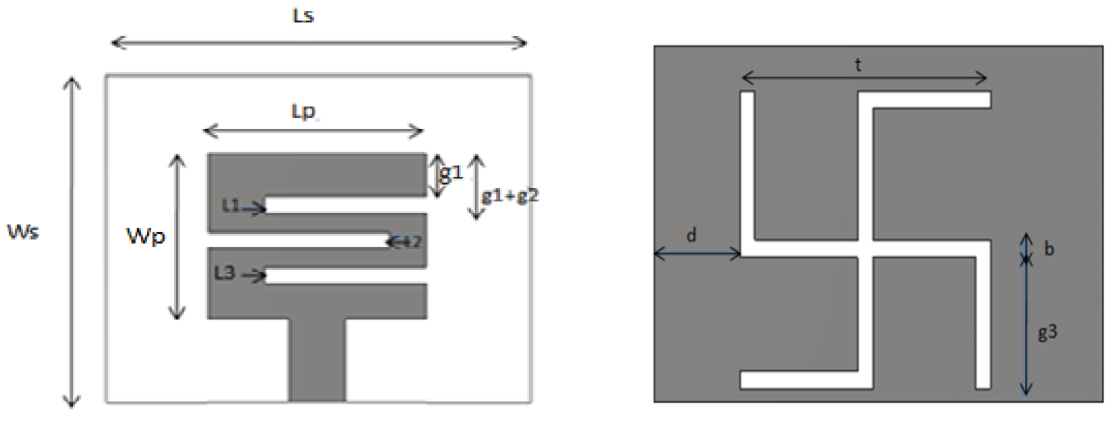
The literature survey of microstrip patch antennas and dielectric resonator antennas and techniques to enhance the antenna parameters has been studied in this chapter. The research gaps and thesis objective is also mentioned in this chapter.

CHAPTER 3

Design of Triple-Band Rectangular Zigzag Microstrip Patch Antenna with Defected Ground Structure (DGS) for improved bandwidth for WLAN and DBS Applications

3.1 Antenna design

MPA comprises of a slotted radiating patch on top of the substrate and a ground plane which is defected with the help of swastic shape structure on bottom of the substrate. The front and back outlook of designed antenna are shown in Figures 7(a) and 1(b) respectively. The rectangular microstrip antenna of length L_p = 12 mm and width W_p = 8 mm is designed with the epoxy glass FR-4 substrate having dimensions $L_s \times W_s \times H_s$= 24×16×1.6 mm^3, relative permittivity, ε_r = 4.3 and loss tangent, tan δ = 0.0024. Excitation is made through microstrip feed line having 50-ohm characteristic line impedance Three rectangular open-ended slots at a distance g_1= 2.1mm, g_1+g_2= 3.4 and $g_1+g_2+1.6$ from top of patch are inserted inside the RMPA. The length of upper and lower open ended slots that is L_1 and L_3 is 8.9mm and that of middle slot that is L_2 is 10.



(a) (b)

Figure 7: Antenna configuration of the designed antenna

(a) Front view - Radiating structural design having Rectangular zigzag shape

(b) Back view - Swastic shape defected ground structure.

The ground structure performs as return path for the signal and the slot created in it results in discontinuance in the signal return path and produces a slow wave effect that is responsible to shift down the resonant frequency to lower values.

The position of swastic shaped DGS [26] is adjusted a number of times with hit and trial approach and finally the optimized dimensions of the symmetrical ground slot are taken as length t = 13.4 mm, b = 0.8 mm, d = 4.6 mm and g3 = 6.5 mm., The lengths, widths and positions of the rectangular open ended slots of the patch and DGS were adjusted carefully for good radiation characteristics. The slots of the swastic shape DGS and the patch play a significant aspect in the favourable excitation of three desired resonating frequency bands [27].

3.2 Results

3.2.1 Return loss

Based on finite integration technique, CST MWS V10.0 software has been used for the examination and optimization of geometrical specifications of the proposed antenna. Simulated reflection coefficient versus frequency plots of rectangular zigzag MPA with and without defected ground structure are shown in Figure 8. Transient solver in the main menu contains a parameter sweep option, with the help it, the analytical parameters were regulated precisely after executing a number of experimental repetitions. Finally, for the proposed configuration, the optimal parameters are obtained [28].

Return loss, measured in dB, is the difference between forward and reflected power [29]. The antenna was fed using micro strip feed line with the characteristic impedance of 50 Ω in order to match the input impedance of the patch antenna [34]. From Figure 8, it is substantiated that the antenna without DGS shows a return loss of -20.9 dB at the resonating frequency 12.5 GHz with a return loss less than 10 dB at other two bands. Also, the obtained simulated bandwidth for the resonating band 11.86-12.85 GHz is 981 MHz.

The designed antenna with DGS exhibits a return loss of -14.3 dB, -23 dB and -32 dB at three resonating frequencies 4.55GHz, 5.8GHz and 12.4 GHz respectively. The impedance bandwidths of the bands operating at three distinct frequencies having return loss below 10-dB are about 100 MHz (4.5-4.6 GHz) (for S-band applications), 110 MHz (5.71–5.82 GHz) (for IEEE 802.11a WLAN band applications) [35] and 1.64 GHz (11.9–13.6 GHz) (for DBS applications) respectively. Hence, the perfect gaps between three slots of the patch and DGS [36] plays a significant role for enhancing the bandwidth and achieving a remarkable return loss [37].

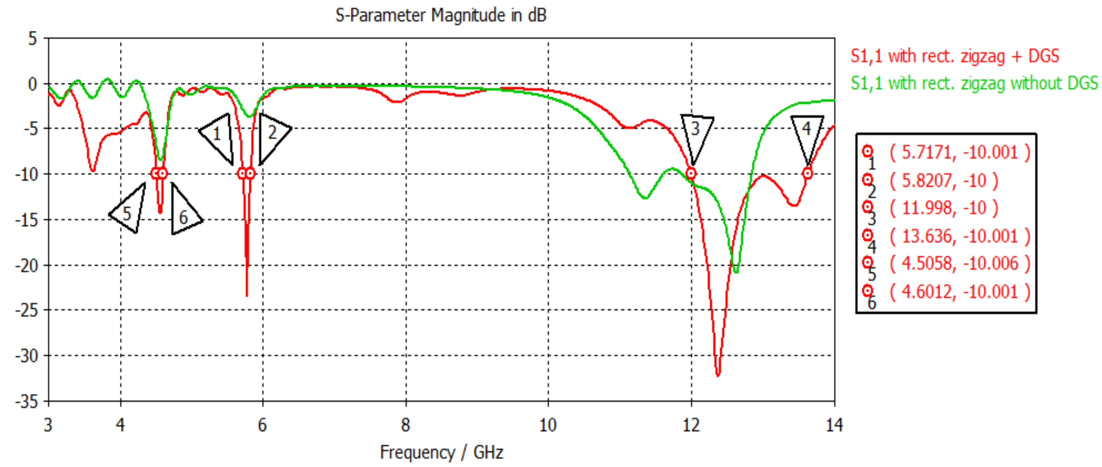


Figure 8: Simulated reflection coefficient versus frequency plots of rectangular zigzag MPA with and without defected ground structure.

3.2.2 Effect of length of rectangular slots in patch

Firstly, the length L_1 of the rectangular slot of the MPA is varied from 8.5 to 10.5 which shows the decrease in return loss as the length of the slot increases depicted in Figure 9.Also the band at 5.8 GHz shifts towards left with increase in the length. Secondly, the length L_2 of the rectangular slot of the MPA is also varied from 8.5 to 10.5 and the variations are depicted in the Figure 10.The best optimised result was with length 10mm to cover the IEEE 802.11a WLAN band and DBS and weather radar applications.

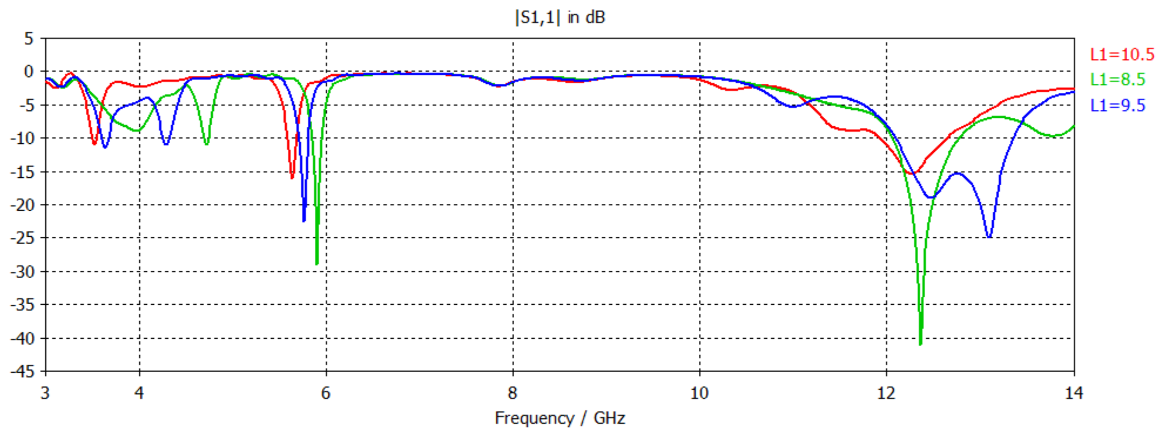


Figure 9: Variations of the resonant frequency and return loss for different lengths of L_1 in triple slotted antenna with swastic shape symmetrical DGS.

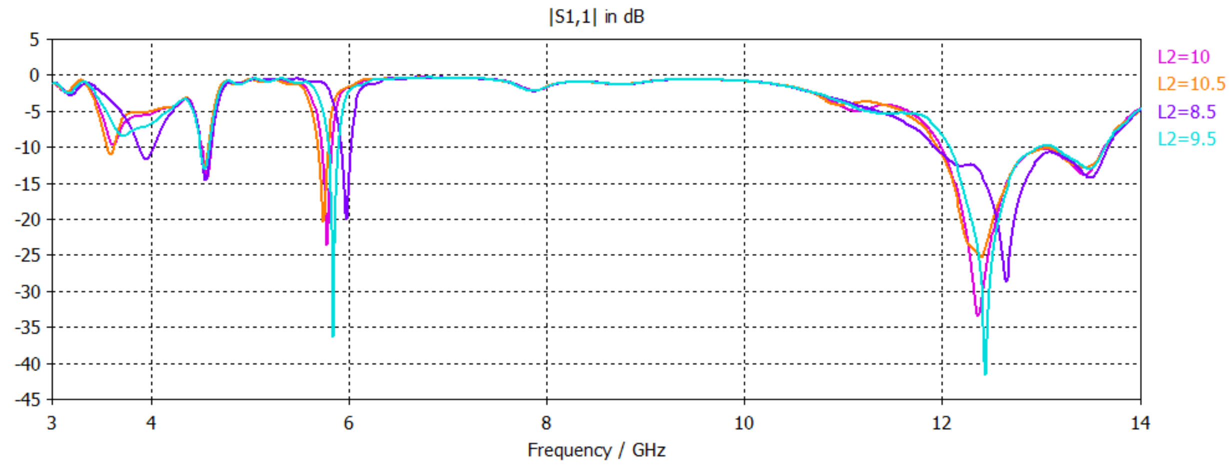
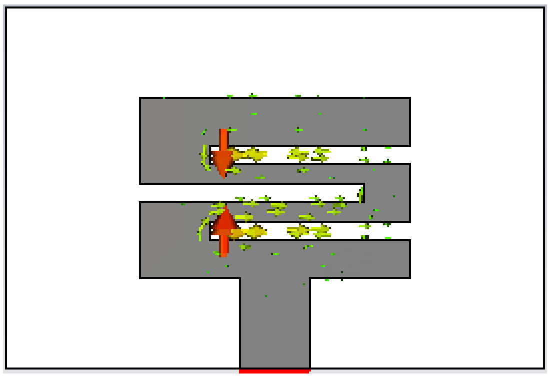


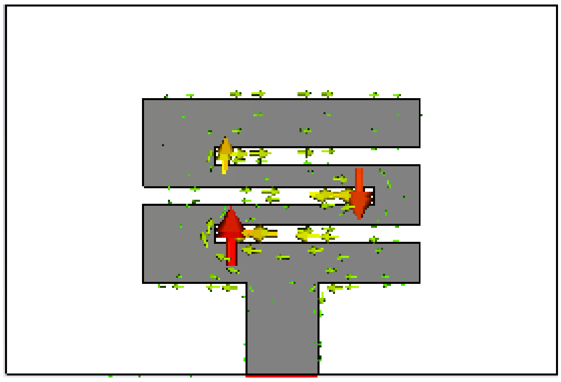
Figure 10: Variations of the resonant frequency and return loss for different lengths of L_2 in triple slotted antenna with swastic shape symmetrical DGS.

3.2.3 Current Distribution Results

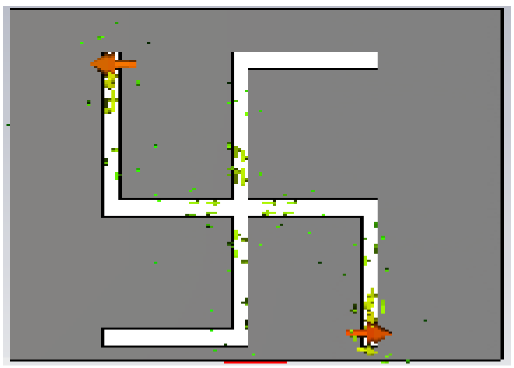
The return loss can only depict the behaviour of the antenna as a lumped load at the end of the feeding line. The analysis of field/current distributions beneath and over the patch can only reveal the detailed electromagnetic behaviour of the antenna.



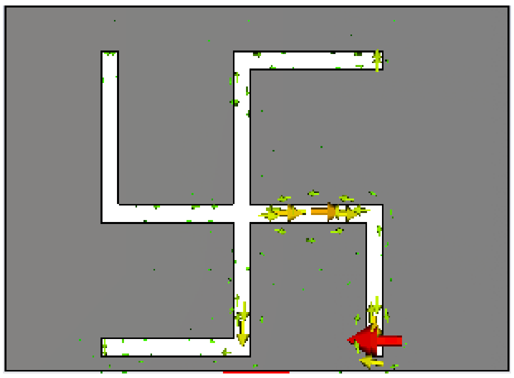
(a) Front View



b (i) Front View



(c) Back View



(d) Back View

Figure 11: Distributions of the surface current of the designed antenna at

(a) 4.55GHz

(b)(i) and (ii) 5.8 GHz

(c) 12.4 GHz

The typical distributions of the surface current of the proposed antenna at the resonating frequencies 4.55 GHz, 5.8 GHz and 12.4 GHz, are depicted in Figures 11(a), 11(b) and 11(c). From above figures, it can be observed that firstly the upper and lower open ended slots were strongly responsible for the resonating frequency at 4.55 GHz. Secondly, the current distributions in the middle and lower open ended slots incorporated in the patch and left and right arm of the swastic shaped DGS were responsible for augmenting the bandwidth of the band resonating at 5.8 GHz. Finally, the current distribution at the end points of right arm and in the middle arm of the swastic shaped DGS clearly justify that DGS is responsible for band at 12.4 GHz. Hence all these factors play an important role in covering WLAN standards, DBS and S-band applications.

3.3 FABRICATION AND MEASUREMENT RESULTS

After examination and optimization of the geometrical specifications, the simulated antenna was fabricated on a dielectric substrate named Epoxy Glass-FR4 ($\varepsilon_{r=4.4,}$ tanδ=0.0024, thickness h=1.6) and was examined analytically. Photolithography technique along with wet etching facility was embraced for fabrication of the proposed antenna and its photograph is presented in Figure 12(a) and (b). The return loss of the fabricated antenna was tested with the help of Agilent E5071C vector network analyzer at Antenna Research Laboratory, Thapar University, Patiala.

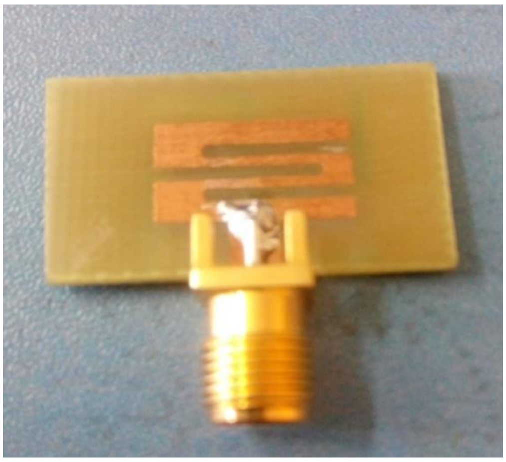


Figure 12(a): Photograph of the front view of the designed antenna

Figure 12(b): Photograph of the back view of the designed antenna

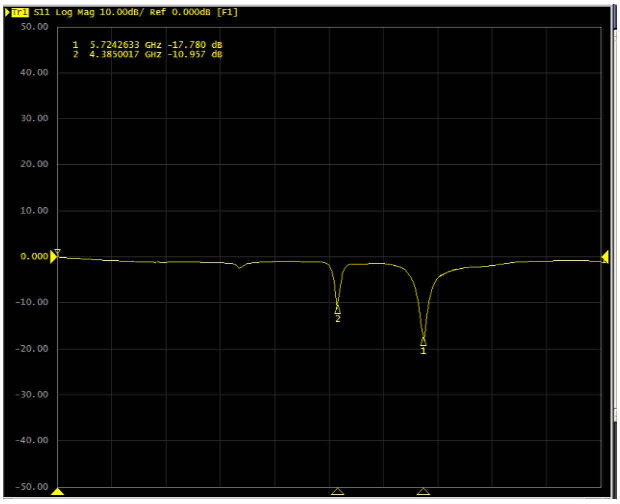


Figure 13: Measured return loss of the designed antenna

The return loss of proposed antenna measured with the help of VNA is shown in Figure 13. It comes out to be -10.9 dB and -17.7dB at frequency band of 4.38 GHz and 5.72 respectively. It indicates the impedance bandwidth of 98MHz at the resonating frequency 4.38 GHz and 100 MHz at 5.72 GHz which is large enough to envelope the required bandwidth for WLAN applications. The third band in the simulated results operating at 12.4 GHz could not be shown in the measured results because of the limitation of the VNA working up to 8.5 GHz frequency available in Antenna Research Lab, Thapar University, Patiala. The slight disagreement in simulated and fabricated results of the designed antenna could be attributed to fabrication errors, mismatch between SMA connector and feeder, noise and interference.

3.3 CONCLUSION

A compact triple-band rectangular zigzag MPA with swastic shape DGS has been designed and presented in this paper that covers the WLAN/DBS/S-band applications. To improve the impedance bandwidth and return loss values, three rectangular open-ended slots in the zigzag shape and a swastic shape structure in the ground plane were proposed. In this specific antenna configuration, a new shape of defected ground structure has been integrated which is basically incumbent for the increase in impedance bandwidth of 12% from 11.998 to 13.636 GHz. The simulated impedance bandwidths of the bands operating at three specific resonating frequencies with return loss below 10-dB are around 1.64 GHz (11.9-13.6 GHz) (for DBS applications), 110 MHz (5.71-5.82 GHz) (for IEEE 802.11a WLAN band applications), 100 MHz (4.5-4.6 GHz) (for S-band applications) respectively. It can be concluded from this research paper that the accomplishment of the microstrip antenna rely laboriously on the geometrical dimensionality of the rectangular slots of the patch and the swastic shape DGS been used.

CHAPTER 4

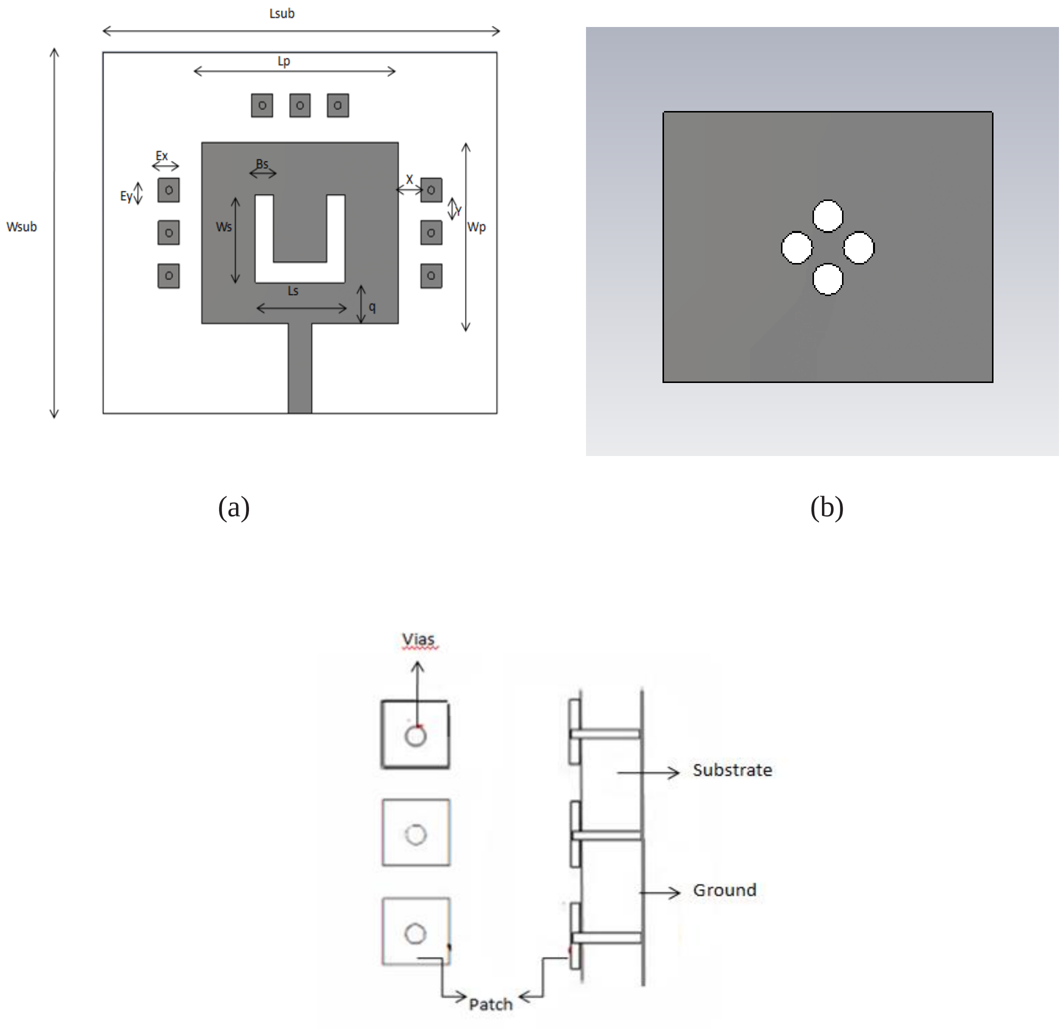
Performance Improvement of U-Slot Microstrip Patch Antenna for RF Portable Devices using Electromagnetic Band Gap and Defected Ground Structure

4.1 Antenna Design

Figure 14(a) depicts the front view of the U-slot microstrip patch antenna on one side of a dielectric substrate including the mushroom type EBG structure surrounding the patch, Figure 14(b) illustrates the back view of MPA demonstrating the modified ground structure using circular and Figure 14(c) shows the structure of electromagnetic band gap. Initially, taking only the U-Slot in the patch without incorporating EBG and DGS, the antenna resonates at 6.1 GHz occupying a bandwidth of 155 MHz. The antenna was fed using microstrip feed line having the characteristic impedance of 50 Ω in order to match the input impedance of the patch antenna. The substrate used for the antenna is FR4 having dimensions $L_{sub}×W_{sub}×H_{sub}$ = 53×43×1.6 mm^3 and relative permittivity, ε_r = 4.3 and loss tangent, tan δ = 0.0024. A ground plane is used below the substrate having equal length. The patch situated on the substrate and the ground plane is Perfect Electric Conductors (PECs) made of conducting material usually copper. The ground plane acts as a body that reflects electromagnetic waves thus creating a directional radiation pattern. A U-slot with dimensions Bs = 2.4, Ls = 12mm, Ws = 10.5mm is made in the patch with dimensions Lp = 21.5 mm and Wp = 26.5 mm.

In order to enhance the bandwidth of proposed U-slot MPA, defected ground structure with the shape of circular patches is used [38]. Bandwidth has been increased to 202 MHz using this approach. But the return loss was still not satisfactory. So, further the technique used to improve the return loss was artificially introduced mushroom-like EBG structure connected with ground plane through a vias [39]. This approach prevented the electromagnetic waves from being reflected within the substrate and hence leading to constructive addition with the space waves, thus resulting in the decrease of back lobe radiations and suppression of surface waves. These EBG structures were introduced on the substrate while keeping other parameters of the antenna unaffected. The position, size, gap between EBGs and number of EBG structures were changed and improvement was evident after doing a number of trials

[40]. The return loss initially was -20.2 dB and was improved remarkably to -31.5 dB using EBG structures.



(a) (b)

(c)

Figure 14: Geometrical configuration of the proposed antenna

(a) Front view - Radiating structure having U-slot surrounded by EBG structure

(b) Back view – Defected ground structure

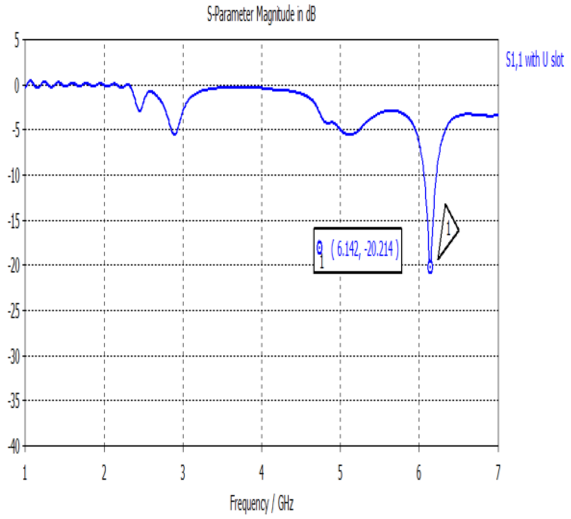
(c) EBG structure

4.2. Results

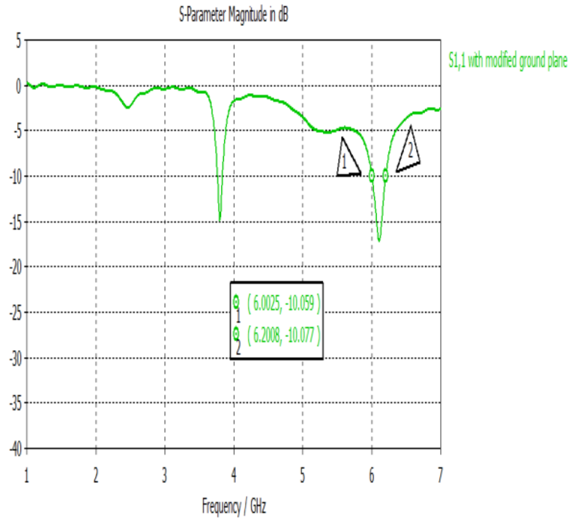
The dimensions of proposed antenna are optimized by hit and trial method using parameter sweep option available in transient solver window of CST MICROWAVE STUDIO Version 10.0.

4.2.1 Return loss

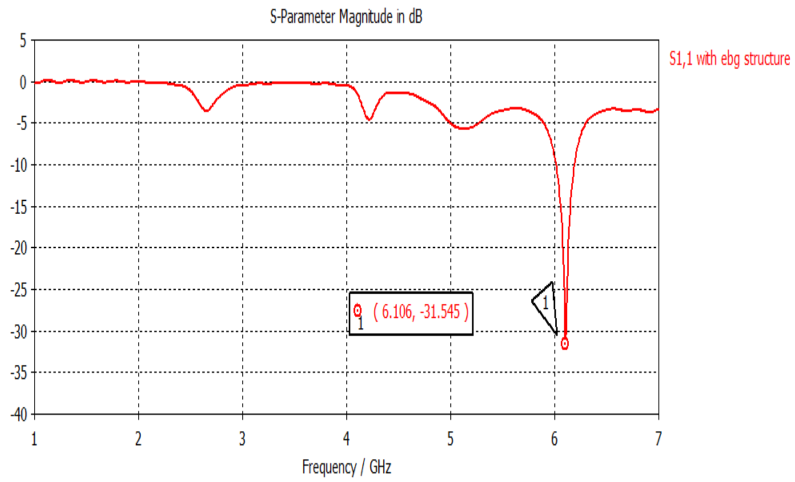
S_{11} parameter indicates return loss and it is defined as maximum reflection of power from the given antenna.The various simulated results are illustrated in Figure 15.



(a)



(b)



(c)

Figure 15: Simulated reflection coefficient versus frequency plots of U-Slot MPA

(d) Patch with U-slot only

(e) Patch with U-slot and DGS

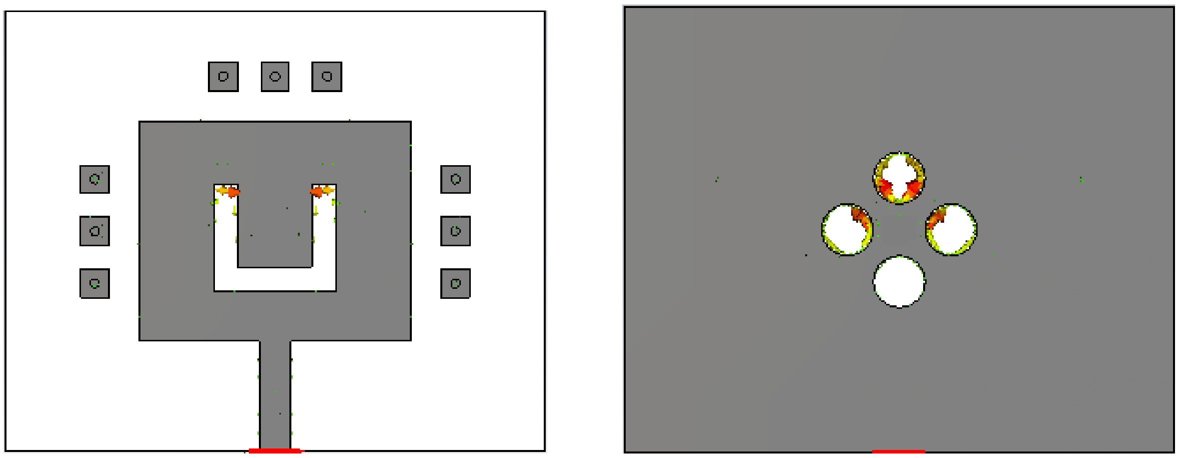
(f) Patch with U-slot, DGS and EBG

The return loss curve of U-slot microstrip patch antenna shown in Figure 15(a) demonstrates that return loss is -20.2 dB and bandwidth is 155 MHz for the resonating frequency of 6.1 GHz. By modifying the ground plane using circular slots in it, the bandwidth was improved to 202 MHz but the return loss reduced to -17.14 dB as shown in Figure 15(b).

To compensate for the decrease in return loss, mushroom like EBG structures were deployed on the substrate surface around the patch [41]. As a result, the return loss in the 6.1 GHz resonating band showed remarkable improvement to -31.5 dB and back lobes suppression shown in Figure 15(c).

4.2.2 Current distribution results

The return loss can only depict the behaviour of the antenna as a lumped load at the end of the feeding line. The analysis of field/current distributions beneath and over the patch can only reveal the detailed electromagnetic behaviour of the antenna.



(a) (b)

Figure 16: Distributions of the surface current of the proposed antenna at 6.1 GHz

(c) Front view of the antenna

(d) Back view of the antenna

The typical current distributions of the antenna at the resonating frequency 6.1 GHz is depicted in Figure 16(a) and 16(b). From above Figures, it can be observed that the upper ends of the U-slot patch situated at the centre of the substrate and circular shaped defected ground structure constructed in the ground plane are strongly responsible for enhancing the bandwidth for the band resonating at 6.1 GHz. The above Figure also illustrates that the current distribution in electromagnetic band gap structures is responsible for the improvement in the return loss and suppression of the back lobes [42].

4.2.3 Directivity

Another fundamental parameter of antenna that is directivity is the measure how directional the radiation pattern is. It is important to understand the requirement for high directivity antenna to maximize the power transfer in a particular direction and reduce signal from unwanted directions. Figure 17 depicts the simulated three dimensional directivity pattern of the proposed antenna that comes out to be 7.09 dBi at 6.1 GHz.

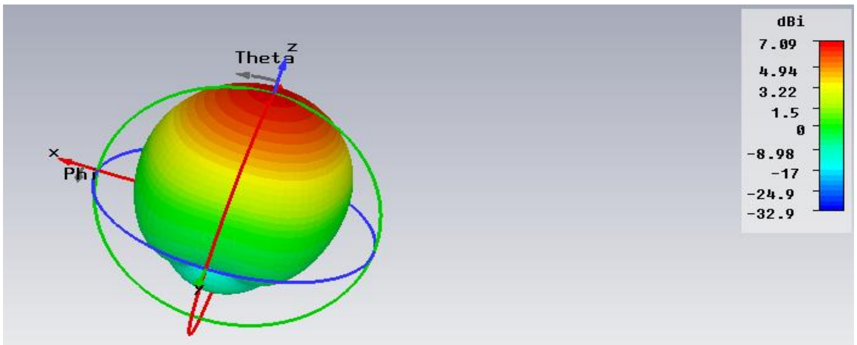


Figure 17: Simulated 3D directivity pattern of proposed antenna at 6.1 GHz.

4.2.4 Gain

Antenna gain describes power transmitted in the direction of peak radiation to that of an isotropic source.

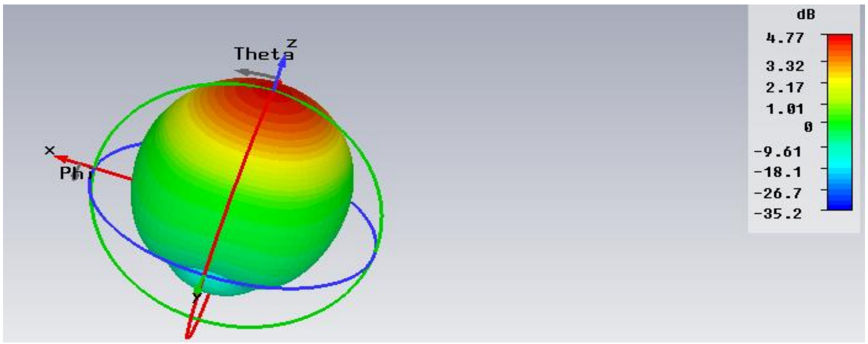


Figure 18: Simulated 3D plot of gain of antenna at 6.1 GHz.

An antenna with a gain of 3 dB depicts that the power received far from the antenna is 3 dB higher almost twice than that would be received from a lossless isotropic antenna with same input power. Figure 18 depicts the simulated three dimensional plot of the gain of antenna is 4.77 dB at 6.1 GHz.

Hence EBG and DGS have played a significant role in enhancing the return loss, gain, directivity and bandwidth of the proposed antenna [43].

4.3 CONCLUSION

A compact microstrip U-slot patch antenna using DGS involving circular slots was proposed in this paper. The use of mushroom like EBG structure to achieve the enhanced performance of antenna resonating at 6.1 GHz is also discussed. Firstly, the microstrip patch antenna with U-Slot only demonstrates the return loss of -20.2 dB and bandwidth 155 MHz Secondly, by modifying the ground plane using circular slots in it, the bandwidth was improved to 202 MHz but the return loss reduced to -17.14 dB. Finally, to compensate for the decrease in return loss, mushroom-like EBG structures were composed around the patch resulting in refinement of return loss to -31.5 dB and remarkable suppression in back lobes. The above designed antenna is appropriate for Radio Frequency portable devices operating at 6-7 GHz.

CHAPTER 5

Dielectric Resonator Antenna Using Mushroom- like Electromagnetic Bandgap structure

The methodology of this project starts by understanding of the dielectric resonator antenna with and without using EBG technology. This includes study of the antenna such as operating frequency, radiation pattern, polarization and antenna gain. The related literature reviews are carried out from reference books and IEEE research papers. The simulation has been done by using a three dimensional electromagnetic simulator - CST Microwave Studio .The simulation results have been demonstrated in terms of Return Loss S_{11} [45]. The designing of DRA with EBG has been initiated by first calculating the dimensions of a dielectric resonator antenna alone operating at frequency of 5.7 GHz but having a return loss of -15 dB .To resolve the problem of surface waves and improve the return loss value the rectangular DRA has been designed using the EBG structure that reduced the value of return loss (S_{11}) to -40dB approximately, hence resulting in suppression of surface waves drastically [46]. Figure 19 shows the flow chart of the design methodology of the project.

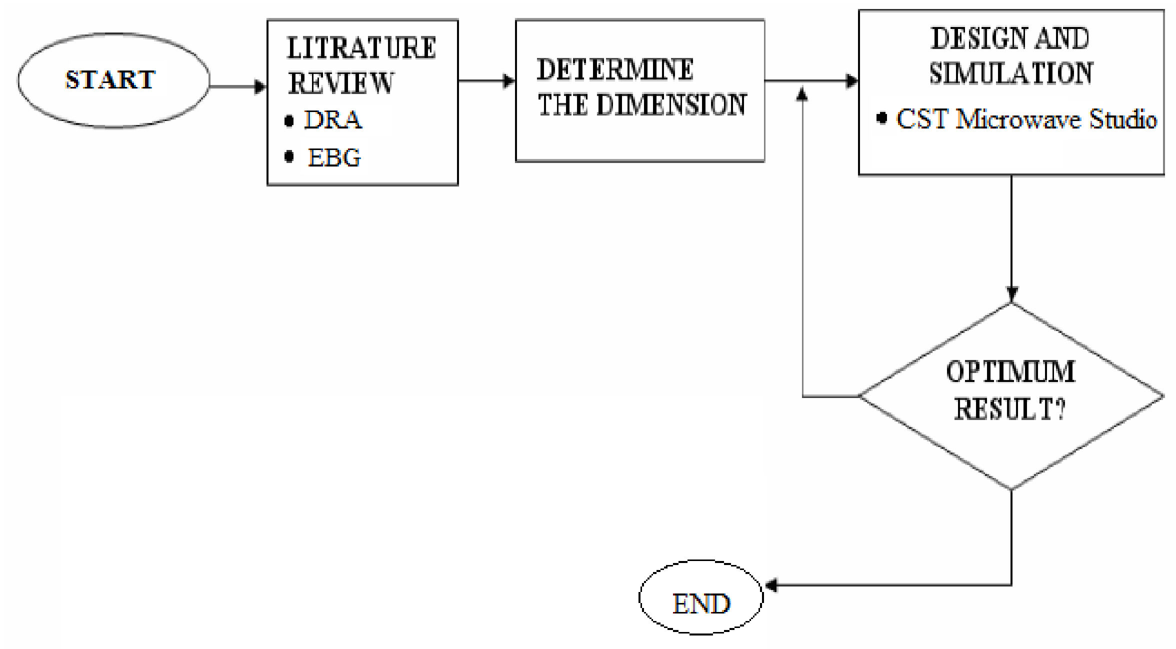
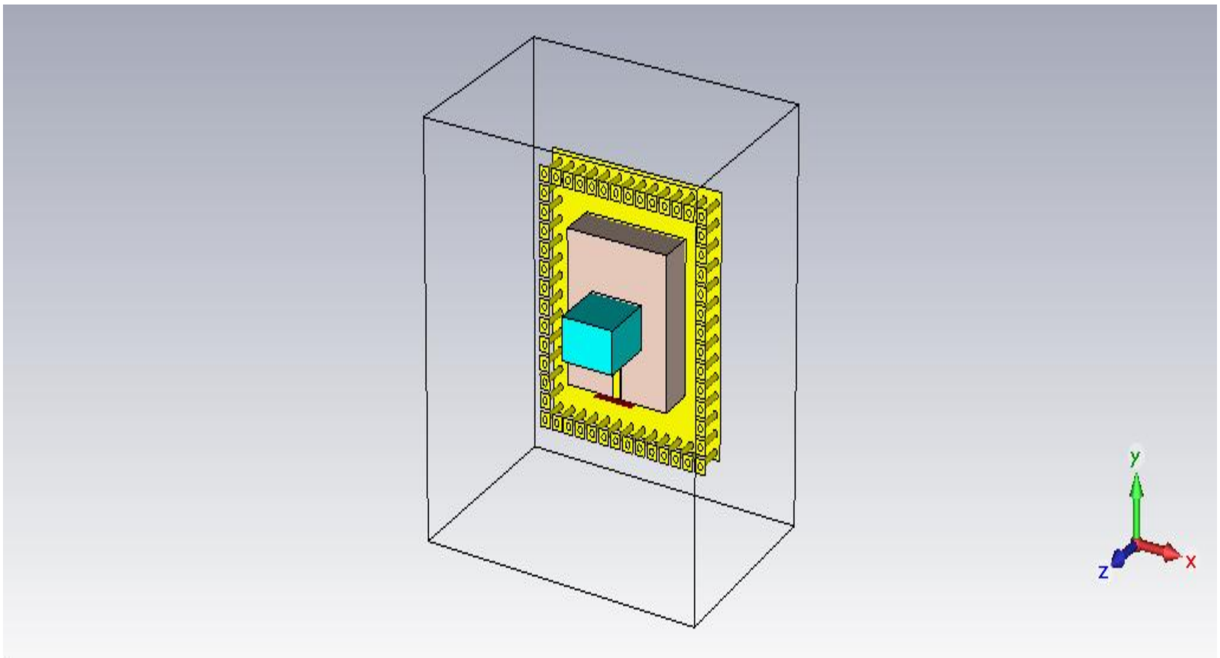


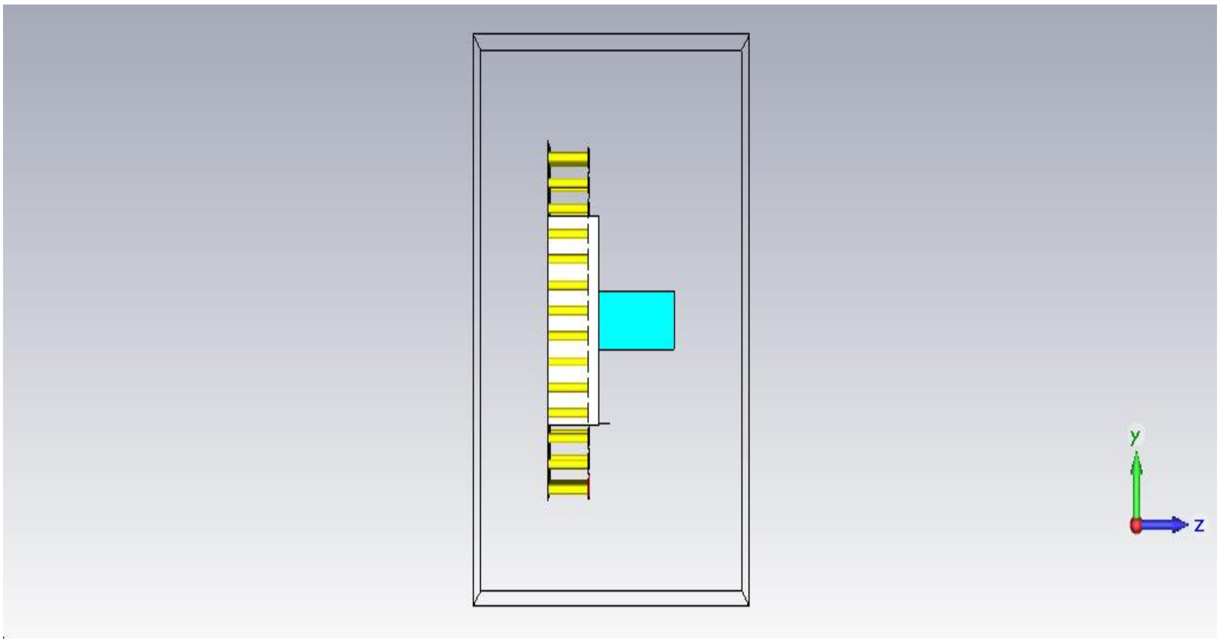
Figure 19: Flow chart of the design methodology of the project [18]

5.1 ANTENNA DESIGN

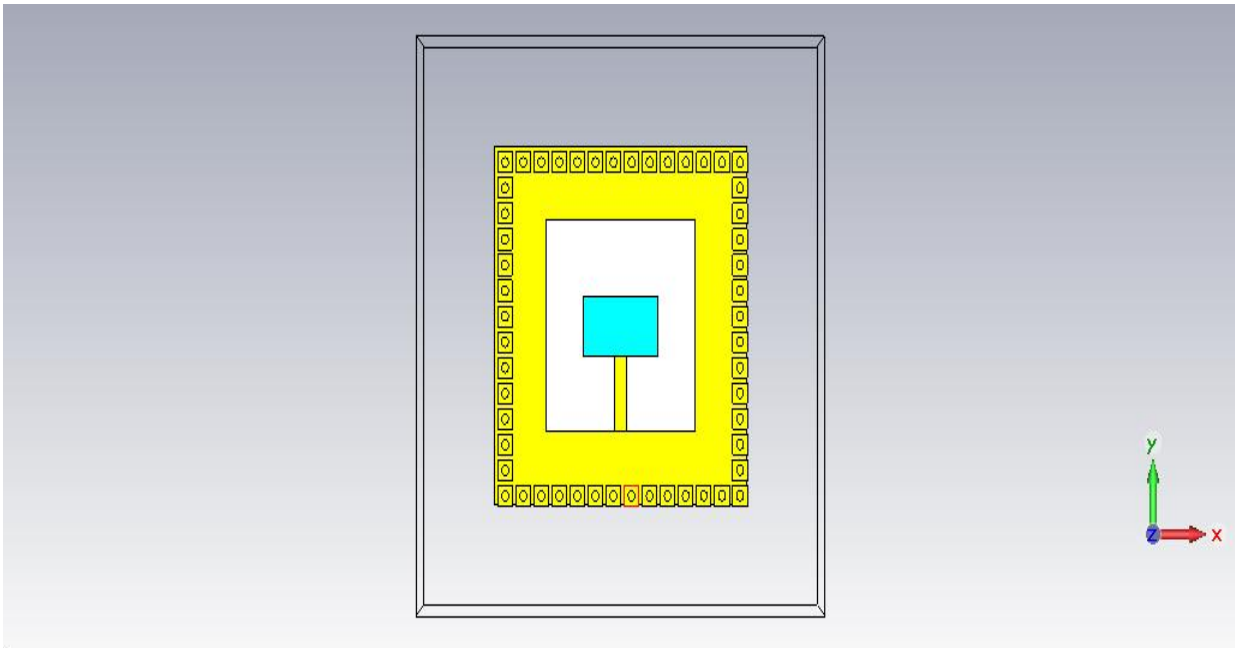
Figure 20 shows the various views of a microstrip-fed rectangular DRA using mushroom-like electromagnetic band gap structure. The feeding strip is placed at the centre of the DRA side wall on the substrate. The dimensions of the DRA structure are width=14.3 mm, length =25.4 mm, height=26.1 mm, and dielectric constant ε_r = 9.8.The rectangular DRA located at the centre of a FR4 substrate is surrounded by a finite mushroom-like EBG(M-EBG) structure placed on the ground plane. The M-EBG is designed at 5.3 GHz having the dimensions of the patch as following: Width of patch W= 5mm, height of vias h=14mm, gap between successive patches g = 1.2 mm. The comparison of return loss S_{11} against the frequency is depicted in Fig.8 for the rectangular DRA without and with M-EBG. The design illustrates a drastic reduction in return loss hence conclude that with the help of EBG structure the surface waves are suppressed successfully.



(a)



(b)



(c)

Figure 20: Proposed dielectric resonator antenna [19]

(a) 3-D view

(b) Side view

(c) Top view

5.2 RESULTS

The results of DRA using EBG structure design in terms of return loss have been obtained by using the CST Microwave Studio software. The proposed antenna with optimal parameters is shown above. Figure 21 shows the simulated scattering parameter of the antenna without using the electromagnetic band gap structure that has a return loss of -15 dB only. As a result of which the surface waves comes into role, hence degrades the antenna efficiency and increases the back lobe radiations. Figure 22 shows the simulated scattering parameter of the antenna using the electromagnetic band gap structure. The simulated resonant frequency of proposed DRA with EBG is approximately 5.3 GHz. A narrow bandwidth with S_{11} (-39.7dB) has been observed. The band gap ensures that the entire surface wave signal radiates in this frequency band gap and cannot propagate on EBG structure. As a result, the surface waves are suppressed to a large extent [44].

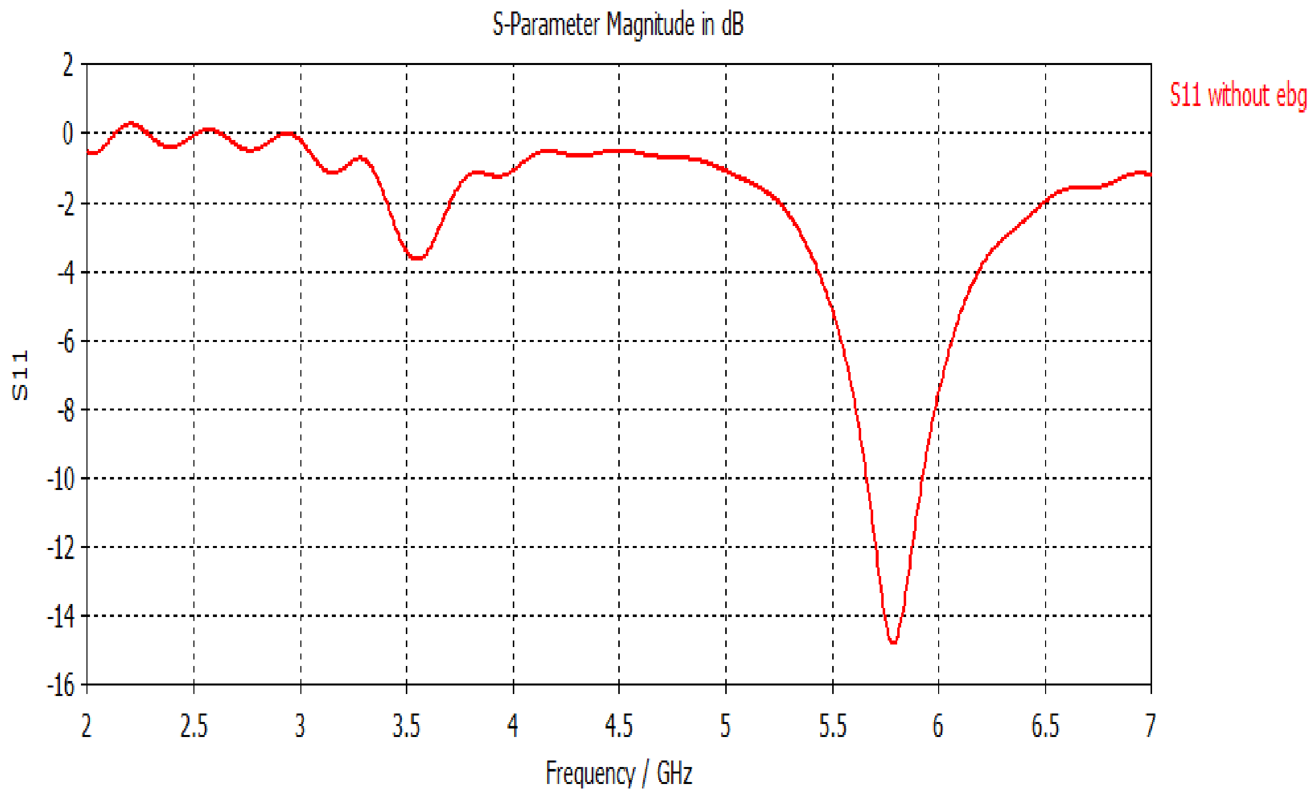


Figure 21: Simulated S-parameter of the Rectangular DRA without using EBG versus Frequency [19]

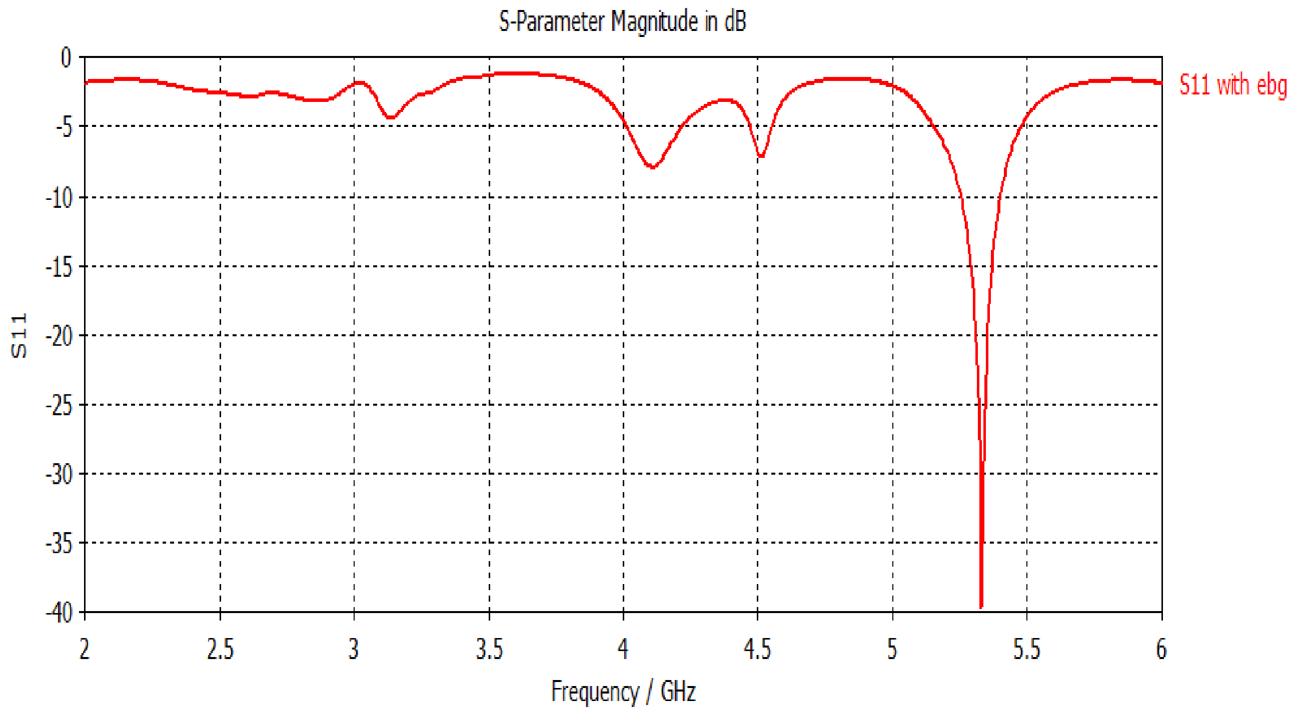


Figure 22: Simulated S-parameter of the Rectangular DRA with EBG structure versus Frequency [19]

The proposed antenna achieves an impedance bandwidth from 5.01GHz to 5.52 GHz covering 5.3 GHz WLAN band. Based on the information gathered from the parametric study, an antenna for 5.3GHz 802.11a WLAN applications is designed.

5.3 CONCLUSION

A new rectangular dielectric resonator antenna is designed with the help of the periodic structure of mushroom-like electromagnetic band gap on the ground plane. The resonance microstrip feeding is incorporated with that of a rectangular dielectric resonator so as to accomplish desired band for WLAN operation. The simulated consequences depict that the proposed antenna offered desired resonant frequency at 5.3 GHz, which includes the WLAN applications band. This antenna contributes maximum gain of 5.5 dBi. The designed rectangular DRA is overall relevant for wireless local area networks (WLAN). Dielectric resonator antennas have lower losses and are more adept as compared to metal antennas at high microwave and millimeter wave frequencies. Thus are used in some compact portable wireless devices, and military millimeter-wave radar equipment having distinct designs.

CHAPTER 6

CONCLUSION AND FUTURE SCOPE

6.1 Conclusion

In this thesis, probe has been done on designing a rectangular dielectric resonator Antenna (RDRA), slotted microstrip patch antennas along with electromagnetic band gap and defected ground structures for wideband high frequency applications. The performance of the RDRA and MPA with the use of mushroom-like electromagnetic band gap structure on ground plane and substrate respectively, with alteration in the number of elements and dielectric materials has been also verified.

The antenna with EBG structure suppresses the surface wave propagation to large extent in comparison to the antenna without EBG structure. The DGS is responsible for enhancement of the bandwidth. The antenna designs show a good return loss more than -10dB. The utilization of the software involved in the process helps in minimizing the processing time for the calculation and the simulation of the design. As an overall conclusion, all the planned works and the objectives of this project that is suppression of the surface waves, advancement of bandwidth, improvement of return loss have been successfully implemented and achieved.

6.2 Scope for future work

The research work on rectangular dielectric resonator antenna and microstrip patch antenna presented in the thesis can be further extended in following ways:

- To miniaturize the EBG structure to achieve the compactness of the antenna design.
- Study different structures of EBG in order to improve the performance of the microwave devices.
- In case of aperture-coupled feeding method, the dielectric resonators are directly placed on the ground plane and hence there is no source of surface wave which contributes to losses. Thus, the RDRA can be designed with an aperture-coupled feeding method to provide sufficient isolation between the dielectric resonator and the feed circuits which can provide better performance in the wideband frequency range.
- The performance of the antennas can be optimized by implementing suitable optimization techniques and hence the bandwidth and gain can be increased.

LIST OF PUBLICATIONS

COMMUNICATED

- Nitika Mittal, Rajesh Khanna, Jaswinder Kaur**, "**Design of Triple-Band Rectangular Zigzag MPA with DGS for improved bandwidth for WLAN AND DBS Applications", communicated to ***International Journal of Microwave and Wireless Technologies*** on 28th June, 2015 with manuscript ID MRF-RP-15-251.

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