Comparative Analysis of Microstrip Patch Antenna for Gain and Directivity Enhancement

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Abstract –A microstrip antenna is one which offers low profile and light weight. It is a wide beam narrowband antenna can be manufactured easily by the printed circuit technology such as a metallic layers in a particular shape is bonded on a dielectric substrate which forms a radiating element and another continuous metallic layer on the other side of substrate as ground plane. Not only the basic shapes any continuous shape can be used as the radiating patch. Instead of using dielectric substrate some of the microstrip antennas use dielectric spacers which results in wider bandwidth but in the cost of less ruggedness. Microstrip antennas are low profile antenna and mechanical rugged and can be easily mounted on any planar and non planar surfaces. The size of microstrip antenna is /2. The applications of microstrip antennas λ related to the wavelength of operation generally are above the microwave frequency because below this frequency the use of microstrip antenna doesn't make a sense because of the size of antenna. At frequencies lower than microwave, microstrip patches don't make sense because of the sizes required. Now a day's microstrip antenna is used in commercial sectors due to its inexpensiveness and easy to manufacture benefit by advanced printed circuit technology. Due to the development and ongoing research in the area of microstrip antenna it is expected that in future after some time most of the conventional antenna will be replaced by microstrip antenna.

Keywords:- Microstrip Antenna, Frequency Selective Surface, Gain, Directivity, Return Loss, Resonant Frequency.

I. INTRODUCTION

Different types of application requires antenna with different parameters. Like for cellular mobile communication a circular polarized antenna is requires with high gain and for satellite communication in downlink a high directive antenna is required. The selection and the performance of an antenna is characterize on the basis of some parameters these are Bandwidth, Polarization, radiation, Pattern, Efficiency, Gain. These parameters are described in brief below.

Radiation Patterns: Also known as Antenna Pattern or Far-Field Pattern. Radiation pattern of an antenna is graphical representation of radiated power at as fix distance from the antenna as a function of azimuth and elevation angle. So the antenna pattern shows that how the power is distributed in the space. For simplicity the radiation pattern can be drawn in 2D plane for different azimuth and elevation angle referred as azimuth plane pattern and elevation plane pattern. It is good to plot the radiation patterns in Cartesian (rectangular) coordinates, especially when antenna radiation pattern consists of different side lobes and where these side lobes levels plays an important role. There are different types of antenna patterns described below

Field Regions: The radiations from antennas are varies and the field regions can be categorized in Far field region and Near Field (Fresnel) Region. Far field region is the region beyond the Fraunhofer distance called Fraunhofer region. It is the region after that the radiation patter does not change with the distance. The Fraunhofer distance is related to antenna's larger dimension and can be calculated as:

$$R=2D^2/\lambda$$

Where

R= distance from antenna

D= larger dimension of antenna

λ= wavelength in free space

Directivity: Directivity of an antenna shows that how much the antenna is able to radiate in a particular given direction. It is a major requirement when antenna is working as a receiver. If an antenna radiates equally in all direction then the directivity of antenna is 1 or when measured with respect to isotropic antenna is 0dB. Directivity in its simple form can be described as the comparison of maximum radiation intensity to average radiation intensity. As

$$\text{Directivity} = \frac{\text{maximum radiation intensity}}{\text{average radiation intensity}}$$

Directivity of an antenna with given angle shows that the antenna radiations are more concentrated in that given direction when talking about antenna at transmitting end. While in case of receiving antenna it will receive the power efficiently from the particular direction.

Gain: Antenna Gain is also referred as Power gain or simply Gain. This combines of antenna efficiency and directivity. For a transmitting antenna it shows how efficiently antenna is able to radiate the given power into space in a particular direction. While in case of receiving antenna it shows how well the antenna is to convert the received electromagnetic waves into electrical power. When it is calculated with efficiency and directivity *D* it is referred as Power Gain.

$$\text{Power Gain} = E_{an}£_{enna} \cdot D$$

When the directivity with a particular direction is given it is known as Directive Gain. Directive Gain (0,rc) =

E *antenn a* **. *D (0,x)***

Antenna polarization: Polarization of an antenna is polarization of the electromagnetic waves radiated from the antenna. Polarization on a wave is the orientation or path traces by the electric field vector as a function of time. Polarization can be categorized in three parts

a. Linear polarization

b. Circular polarization

c. Elliptical polarization.

If the electric field vector of the wave at a given point in

space follows a linear path then the polarization is linear. Linear polarization is of two types Vertical and Horizontal. In case of circular and elliptical polarization electric field vector follows a circular and elliptical path. They can be Left hand polarized, if the electric field vector tracking the path by making clockwise rotation and Right hand polarized, if the vector tracking the path by making anti clockwise rotation.

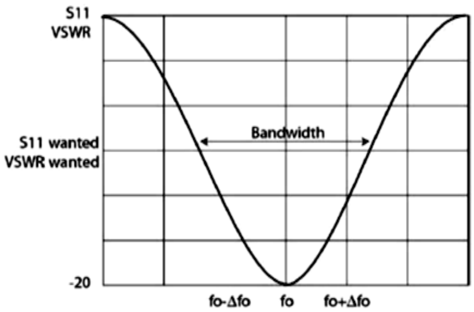
Antenna Bandwidth: Antenna bandwidth is another important parameter of antenna can be described as the range of frequencies over which antenna fulfil some desired characteristics. Bandwidth can be described on the basis of gain, axial ratio bandwidth, Impedance or vswr bandwidth. The impedance bandwidth is the range of frequencies over which the input impedance of antenna is perfectly matched to the characteristic impedance of the feeding transmission line. Impedance bandwidth related to Q factor can be described as

BW=S---1(VSWRS:1)

$$BW = \frac{f_h - f_l}{fc}$$

Generally Fractional bandwidth is used for microstrip antenna. Given by

Where ft_h and ft are the upper and lower frequencies where the VSWR matches to S: 1. Generally VSWR is taken 2:1 and ideally it is 1:1. To maximize the impedance bandwidth for VSWR 2:1 proper impedance matching is required. To feed at the driving point where antenna impedance is Z_0 = 50 ohm generally. One can get a little bit more bandwidth by feeding at the point where the antenna impedance is 65ohm.



II. DESIGN OF MICROSTRIP PATCH ANTENNA

Microstrip Antenna

In a most basic form a microstrip antenna comprises of two thin metallic layers (t«X_0 ,wh e re X_0 i s wave 1 e n gth i n free space) one as radiating patch and second as ground-plane and a dielectric substrate sandwiched between them. The conductor patch is placed on the dielectric substrate and used as radiating element. On the other side of the substrate there is a conductive layer used as ground plane. Copper and gold is used normally as a metallic layer. Radiating patch can be of any shape but simple shapes are used to design a patch because patches basic shapes are easy to analysis by the available theoretical models and it is easy to predict the performance. Square, rectangular, dipole, triangular, elliptical, circular are some basic shapes. Circular, rectangular and dipole are the most often used shapes because of easy of analysis and fabrication. A variety of dielectric materials are available for the substrate with dielectric constants 2.2< a_r > 12[8]. The height of substrate plays an important role in antenna characteristics generally are in the range 0.0031_0< h > 0.051_0.

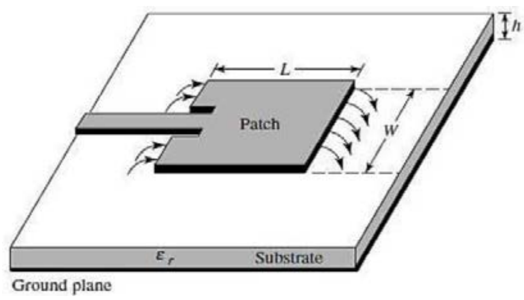


Figure: 1. 1 Microstrip Patch Antenna

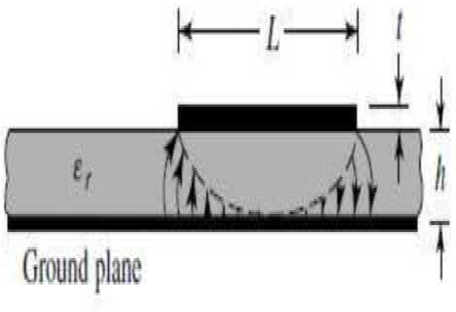


Figure: 1.2 Side view of Microstrip Patch Antenna

Microstrip antenna suffers from very Narrow frequency bandwidth. However some application where narrow bandwidth is essential such as government security systems, microstrip antennas are useful. Bandwidth of microstrip antenna is directly proportional to height of substrate. There are two main techniques two improve the bandwidth; one *circuit theory* and second *structural.*

An antenna characteristics is not only depends on the antenna element but also be influenced by the TX-line and antenna combination. Generally the input impedance of microstrip antenna is complex and the characteristic impedance of TX-line is real (usually 50 ohm). This will results in impedance mismatching and causes a voltage standing wave pattern on transmission line results in low impedance bandwidth. One way to overcome this problem is use of impedance matching

networks between antenna and transmission line. There are several impedance matching techniques are available, Circuit theory deals with the impedance matching techniques.

Structural technique deals with the modification of substrate properties such as height and dielectric constant. By increasing the height increase the bandwidth can be increased. But it will also introduce surface waves which increases loss of the power and leads to performance and characteristics degradation. Various types of methods are introduced by the researchers such as stacking, defected ground plane, parasitic patches and improvement of bandwidth of microstrip antenna is still an interesting topic for investigation. By choosing a particular shape one can easily design an antenna with desired resonance frequency radiation pattern, polarization. It is easy to design a microstrip antenna with reconfigurable polarization, resonance frequency and radiation patterns just by adding loads like PIN diode, Varacter diodes.

Radiation Mechanism

In 1969 den linger noted that if the microstrip line left open ended on one end and fed on the other end then due to the discontinuity created some part of the power is radiated in the space from both the ends as electromagnetic waves. Denlinger also realized that the amount of power radiated in space is maximum when both the discontinuities kept a half wavelength or a multiple of half of wavelength apart from each other[6]. Denlinger concluded that radiations took place from the open end due to the fringing fields arising from the discontinuity. To understanding the mechanism behind the radiation from microstrip antenna considers a rectangular antenna with a half wavelength long radiating patch fed by microstrip feed line. A rectangular antenna can be considered as a microstrip line left open ended on one side and energy is fed from the other end. Since the patch is half wavelength long and left open ended on other side, the current at the corners (at the beginning and end) of the patch should be zero and is maximum at the centre of the patch. Current and voltage will be 90 degree out of phase. The voltage will be maximum positive at the beginning and maximum negative at the end of patch[8].

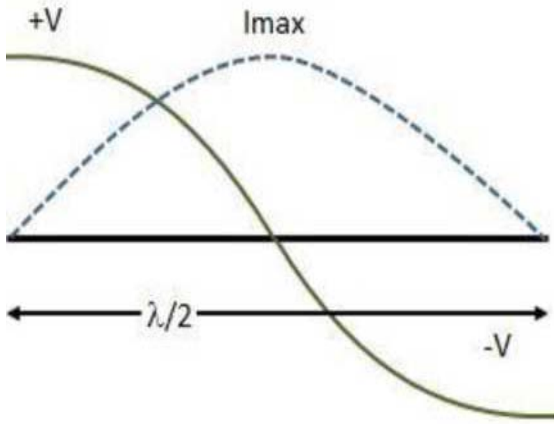


Figure: 1. 3 Current and voltage variation along the Patch length

Field distribution along the patch is like shown in figure below. The field lines are below the patch towards corner are opposite in direction. This field lines does not stop abruptly ant the end. At the corners fringing fields are created and the field lines are in bow shape. More the fringing field bow more the radiation. Therefore these fringing are the reason behind the radiation from the microstrip antenna.

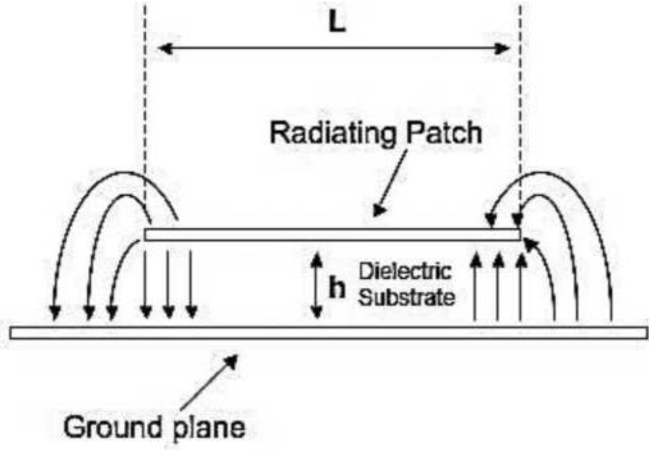


Figure: 1.4 Fringing fields

Advantages and Disadvantages:

Microstrip antenna is a low profile antenna that has light weight and is very easy to installation due to which it is very popular in handheld wireless devices such as cell phones, pagers and in some high performance communication systems such as in satellite, missile, spacecraft, aircraft etc. Some of the major advantages of microstrip antenna as discussed by Randy Bancroft [3] and Garg [10] are given below:

- *Inexpensive and easy to fabricate.*
- *Can be planted easily on any surface.*
- *Can easily get reconfigurable characteristics.*
- *Can easily design antenna with desired polarization.*
- *Mechanically robust, Resistant against vibration and shock.*
- *Suitable to microwave integrated circuits (MICs).*
- *For high gain and directivity Array of antennas can be easily formed.*

onversely microstrip antennas also have a number of disadvantages and limitations when compared to other antennas. Some of the major disadvantages of microstrip antennas are written below:

- *High quality factor.*
- *Cross polarization.*
- *Poor polarization efficiency.*
- *Suffers from spurious feed radiation.*
- *Narrow impedance bandwidth (5% to 10% without any technique)*
- *High Dielectric and conductor losses.*
- *Sensitive to environment conditions like temperature and humidity.*
- *Suffers from surface wave when high dielectric constant material is used.*
- *Low gain and power handling capability.*

There are various methods to overcome this limitations, bandwidth of microstrip antenna can be increase by using some special methods like defected ground plane strategy,stacked patches, slotted patches, parasitic patch. Gain and the power handling ability of antenna can be improved by making an antenna array. Use of Electromagnetic Band Gap (EBG) structure and metamaterial also results in the improvement of the antenna characteristics[20].

Applications:

After a number of limitations due to the several advantages microstrip antenna found very useful in different applications. Microstrip antenna widely used in the defence systems like missiles, aircraft, satellites and rockets. Now a day's microstrip antenna is used in commercial sectors due to its inexpensiveness and easy to manufacture benefit by advanced printed circuit technology. Due to the development and ongoing research in the area of microstrip antenna it is expected that in future after some time most of the conventional antenna will be replaced by microstrip antenna. Some of the major applications of microstrip antennas are:

- *Mobile Communication:* -Antenna used in mobile applications should be light weight, small size. Microstrip antenna possesses this entire requirement. The most of mobile applications are handheld gadgets or pocket size equipment, cellular phones, UHF pagers and the radar applications in vehicles like car, planes, and ships. Various types of designs are made and used for radar applications like marine radar, radar for surveillance and for remote sensing.

- *Satellite Communication :-In* satellite communication antenna should have the circular polarization. One of the major benefit of microstrip antenna is that one can easily design an antenna with require polarization by using dual feed networks and different techniques. Parabolic antennas are used in satellite communication to broadcasting from satellite. A flat microstrip antenna array can be used in the place of parabolic reflector.

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- *Global Positioning System :-*Initially the satellite based GPS system are used for only in military purposes but now a day's GPS found a large application in everyone's life and now used commercially. GPS found an essential requirement in vehicles, ships and planes to track the exact location and position. 24 satellites are working in GPS encircling the earth in every 12 hours at altitude 20,200 km. GPS satellite using two frequencies in L-band to transmit the signal which is received by thousands of receivers on earth. The receiver antenna should be circularly polarized. An omnidirectional microstrip antenna has wide beam and low gain can be easily design with dual frequency operation in L-band.

III. LITERATURE REVIEW

N. Elavarasi and R. S. Sabeenian, [1] Antenna arrays becoming increasingly important in wireless communications. Here is a method proposed to alleviate the mutual coupling problem in an antenna array by using two polygon shape microstrip patch antenna array which in turn reduces the surface wave excitation in printed antenna geometries. The advance design system (ADS) verifies the polygon features of surface wave repression by plotting the variations of transmission coefficient S12 with a frequency and dispersion graph. Thus the implementation of a polygon design proves to be a useful method in reducing the mutual coupling at definite frequencies between the radiator elements which also improves the antenna directivity.

F. Fertas, M. Challal and K. Fertas [2] In this paper, a novel and low profile CPW-Fed triple-band microstrip antenna for wireless applications is proposed. The proposed antenna is implemented on FR4-Epoxy dielectric substrate with dimensions of 24×40 mm^2 and generates three desired resonant frequencies at about 2.44 GHz, 3.56 GHz and 5–6 GHz for WLAN and WiMAX applications.

Table: 2.1 Brief Literature Review

SR.NO.	TITLE	YEAR	WORK DONE	REMARKS
1	"Analysis of mutual coupling reduction using 2 × 2 polygon structure for microstrip patch antenna array,"	2017	The implementation of a polygon design proves to be a useful method in reducing the mutual coupling at definite frequencies	The two polygon shape microstrip patch antenna array
2	"Design and implementation of a miniaturized CPW-Fed microstrip antenna for triple-band applications,"	2017	An antenna with good performances can be suitable for various applications	A novel and low profile CPW-Fed triple-band microstrip antenna for wireless applications
3	"Design and analysis of a microstrip patch antenna for medical applications,"	2017	A dual band Microstrip patch implantable antenna for biomedical applications has been presented to operate in both Medical Implant Communications Service	A dual band Microstrip patch implantable antenna
4	"Square-shaped slot Microstrip Antenna for LTE applications,"	2017	A new design of patch antenna with square shaped structure antenna design consists of a “square” shaped slot bounded by another “square” with a rotation of 45° with respect to its symmetry.	A new design of patch antenna with square shaped structure
5	"A novel miniaturzed dual-band microstrip antenna for WiFi/WiMAX applications,"	2017	A new design approach of a hexagonal fractal ring patch antenna antenna operates at two resonant frequency bands to cover 2.45-GHz WiFi and 3.5-GHz WiMax applications.	A new design approach of a hexagonal fractal ring patch antenna
6	"A novel broadband and high-isolation dual-polarized microstrip antenna array based on quasi substrate integrated waveguide technology,"	2017	microstrip antenna array is excited by two orthogonal 4-way corporate (parallel) feed networks, which not only has a multistage structure with broadband but also provides pairs of differential outputs	A 2×2 dual-polarized aperture-coupled microstrip antenna array with high isolation, broadband and low cross polarization
7	"Inkjet Printed Wideband Circularly Polarized	2017	A wideband right hand circularly polarized (RHCP) high gain 4×4	A wideband right hand circularly

	Microstrip Patch Array Antenna on a PET Film Flexible Substrate Material,"		microstrip patch array antenna on a PET film flexible substrate material is investigated.	polarized (RHCP) high gain 4×4 microstrip patch array antenna
8	"Harmonic suppression in microstrip patch antenna using spur-line filter,"	2017	The microstrip antenna is designed to operate at frequency 2.45 GHz. For the antenna input impedance design, it was used a combination of quarter-wavelength transformer and inset feed impedance matching technique	A method for suppression of higher order harmonics in microstrip antenna

Numerical results for the return loss and 2D radiation patterns of the antenna are presented. Good agreement between measured and simulated results is achieved. The obtained results represent that the proposed antenna with good performances can be suitable for various applications such as future developed technologies and handheld devices.

W. Grabssi, S. Izza and A. Azrar [3] In this work, a dual band Microstrip patch implantable antenna for biomedical applications has been presented to operate in both Medical Implant Communications Service (MICS) with a range of 402–405 MHz and 2.4–2.5 GHz band chosen among the Industrial Scientific and Medical (ISM). A rectangular antenna has been first simulated to operate in MICS band with dimensions of 179.7 × 228.3 × 1.63 mm, then, a new meandered serpentine shape, with single feed point, has been used in order to lengthen the current path and covers both MICS and ISM bands with new dimensions of 31 × 25 × 1.63 mm printed on dielectric material of 4.3 constant.

Rise, S. Chandra, P. Kumar and J. S. Roy, [4] In this paper, a new design of patch antenna with square shaped structure has been studied. Proposed antenna design consists of a “square” shaped slot bounded by another “square” with a rotation of 45° with respect to its symmetry. Moreover it is to be noted that both “square” is bounded by “square” shaped slot having larger area. Results of the proposed antenna shows good candidate for LTE, PCS and UMTS application. Uniform radiation pattern and VSWR with value less than 2 gives good impedance matching and good gain.

K. Djafri, M. Challal, M. Dehmas, F. Mouhouche, R. Aksas and J. Romeu, [5] This paper proposes a new design approach of a hexagonal fractal ring patch antenna for dual-band applications. The proposed antenna operates at two resonant frequency bands to cover 2.45-GHz WiFi and 3.5-GHz WiMax applications. To achieve dual-band operation, a first-iterative fractal-ring radiating patch is printed on a substrate layer coupled with another identical fractal ring printed in the other side of the substrate. A Y-shaped fed line is used to feed the antenna. The numerical analysis and simulation are carried out with CST MWS. The measured results of the proposed antenna with compact size of 13×18.9×1.6 mm^3 show excellent performance and good agreement with the simulated ones.

W. Wang, J. Wang, A. Liu and Y. Tian [6] A 2×2 dual-polarized aperture-coupled microstrip antenna array with high isolation, broadband and low cross polarization for Ku band is proposed based on quasi substrate integrated waveguide (Q-SIW) technology. The proposed microstrip antenna array is excited by two orthogonal 4-way corporate (parallel) feed networks, which not only has a multistage structure with broadband but also provides pairs of differential outputs. The Q-SIW structure, composed of several reflectors and substrate integrated metal pillars, is employed to increase the bandwidth, improve the isolation and reduce the influence of feed network. The measured and simulated results show that the dual-polarized array exhibits an impedance bandwidth of 26.37% for vertical port and 27.77% for horizontal port. The cross polarization level is better than -34dB and -40dB for two ports, and the isolation between the two ports is above 32dB.

A. T. Castro and S. K. Sharma, [7] In this letter, a wideband right hand circularly polarized (RHCP) high gain 4×4 microstrip patch array antenna on a PET film flexible substrate material is investigated. A comparison between the planar and curved surface study is also presented to show impact of curving the array on antenna performance parameters since it is employing a flexible substrate material. Due to some unknown properties of the PET material, some disagreement is noticed between the simulated and measured results in reflection coefficient magnitude, axial ratio and gain in addition to radiation patterns. The radiation patterns are consistent with some rise in cross-polarization levels. This array can applications in body wearable communication systems.

F. F. Batista, L. L. de Souza, J. P. Fernandes da Silva, P. Henrique da Fonseca Silva, M. A. de Oliveira and G. Fontgalland, [8] This paper proposes a method for suppression of higher order harmonics in microstrip antenna using spur-line filter. The microstrip antenna is designed to operate at frequency 2.45 GHz. For the antenna input impedance design, it was used a combination of quarter-wavelength transformer and inset feed impedance matching technique. To suppress the second and third harmonics a spur-line filter was inserted in the antenna microstrip feed line. The measured and simulated results are presented for the proposed antenna. The analysis of the antenna radiation properties shows that beyond the accuracy of high order mode suppression, the insertion of spur-line filter does not any degradation into the radiation pattern.

IV. PROBLEM STATEMENT

The common shapes of the microstrip patch are rectangular, square, circular, triangular, etc. All these have been theoretically studied and there are well established design formulae for each of them. Antenna design is an innovative task where new types of antenna are studied. So, here a new shape of microstrip patch antenna is designed which will cover the entire Ultra Wide Band. One of the major problem for UWB systems are electromagnetic interference (EMI) from existing frequency bands, because there are many other wireless narrowband application that are allocated for different frequencies band in the UWB band. Therefore it is necessary for the designer to design the UWB antenna they can reflect the interference from the other existing bands. To overcome this interference problem UWB antennas should have band notches therefore they can reject the existing frequency bands within the ultra-wide band. Here three designs with different band notches for UWB applications are proposed. The goal of this research is to study how the performance of the antenna depends on various parameters of microstrip patch antenna. This is a simulation based study. CST Microwave studio software, one commercial 3-D full-wave electromagnetic simulation software tool is used for the design and simulation of the antenna. Then, the antenna parameters are varied to study the effect of variation of the antenna parameters on the antenna performance.

V. CONCLUSIONS

This research paper has provided a comprehensive study of the dielectric covered microstrip patch antennas as a resonant gain enhancement method. One or more dielectric layers with proper permittivities, thicknesses, and heights are placed above the patch. Under these conditions, the resonance is created for the field inside the layered's fructure of the antenna, which results in a high directivity. In the SSC of microstrip patch antenna the directivity maximizes at a particular superstrate height near half wavelength, while its thickness is one quarter wave-length o The input resistance peak value moves to lower frequencies and increases, and its bandwidth becomes natïo\Mer, all in proportion to the superstrate thickness or permittivity. This work still has several scopes for future research, while improving the directivity bandwidth still remains as the main challenge. They can be summarized as follows: a detailed study of the effect of finite ground plane and superstrate size and shape. A detailed study from the aperture antenna point of view. More experimental verifications to confirm the accuracy of the simulations u More studies on single-superstrate-patch configuration o Studies on EBG materials, in regard torealizingwide-band directive MSAs

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