International Journal of Engineering Research and Development
***e**-ISSN: 2278-067X, **p**-ISSN: 2278-800X, www.ijerd.com*
Volume 3, Issue 12 (September 2012), PP. 79-84

Enhancement of Directivity of Rectangular MicroStrip Antenna Using Multilayer Multidielectric Structure

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Abstract— ***In this paper the directivity of microstrip patch antenna is enhanced by using covered dielectric layer which is separated from feed patch by air as an another dielectric. Here two patches, one feed patch and one parasitic patch are used to enhance the directivity and bandwidth and whole structure resonates at their resultant frequency which is in the ISM band. Air is used as dielectric between feed patch and ground plane as well as between feed patch and parasitic patch. The dimensions of feed patch are adjusted to achieve desired resonant frequency. In this microstrip antenna the coaxial probe feed technique is used for its simplicity. This antenna structure is simulated using zeland IE3D software package and effects of physical parameters are investigated. This work leads to conclusion that directivity, bandwidth and gain of microstrip antenna can be increased by covered dielectric and multidielectric structure with parasitic patch. The results shows that the directivity is enhanced by 56% as compare to conventional rectangular patch antenna.***

Keywords— ***Directivity, Rectangular Microstip Antenna, IE3D, VSWR***

I. INTRODUCTION

An MICROSTRIP ANTENNA (MSA) [1] in its simplest form consists of a radiating patch on one side of a dielectric substrate and a ground plane on the other side. The top view and side views of a rectangular *MSA* (RMSA) are shown in Figure-1and 2.

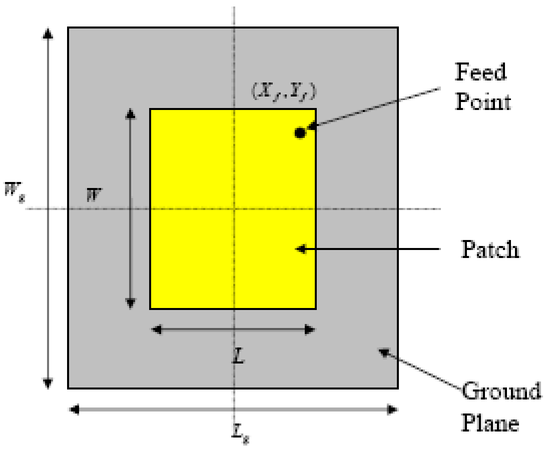

Figure-1: The top view of a rectangular *MSA* (RMSA).

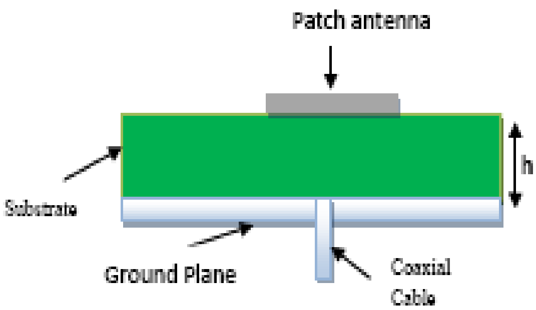

Figure-2: side view of patch antenna

However, other shapes, such as the square, circular, triangular, semicircular, sectoral, and annular ring shapes are also used. Microstrip antennas are popular for their attractive features such as low profile, low weight, low cost, ease of fabrication and integration with RF devices. The major disadvantages of Microstrip antennas are lower gain and very narrow bandwidth [2, 3]. Microstrip patch antenna consists of a dielectric substrate, with a ground plane on the other side. Due to its advantages such as low weight , low profile planar configuration, low fabrication costs and capability to integrate with microwave integrated circuits technology, the microstrip patch antenna is very well suited for applications such as wireless communications system, cellular phones, pagers, Radar systems and satellite communications systems [1,4].

The directivity is the issue in fixed wireless local area network (WLAN) application where high directive antennas are required. The directivity can be increased by using the microstrip antenna array structure but this again increases the size. Hence the directivity of microstrip antenna (MSA) is increased by slightly increasing the dimensions of patch antenna and multilayer structure with covered dielectric [5]. The MSA also should have good bandwidth and for this two patch technique called feed patch and parasitic patch are used. The resonant frequency of patch antenna is the function of the length of patch. The two patches have different length so their resonant frequencies are also different. Whole structure resonates at their resultant of resonant frequencies. This increases the bandwidth and directivity of MSA. Here FR4 dielectric material is used for its low cost and ease of availability.

The paper is organized as follows: section 2 presents the brief literature survey about microstrip antenna and directivity enhancement techniques. The structure and dimensions of the proposed antenna is presented in section 3 followed by the result and analysis of the simulated and fabricated antenna in section 4. Finally, section 5 provides the conclusion. Results are based on an antenna simulation software package IE3D.

II. PREVIOUS RELATED WORK

The microstrip antenna concept dates back about 26 years to work in the U.S.A. by Deschamps [13] and in France by Gutton and Baissinot [6].Shortly thereafter, Lewin investigated radiation from stripline discontinuities. Additional studies were undertaken in the late 1960's by Kaloi, who studied basic rectangular and square configurations. However, other than the original Deschamps report, work was not reported in the literature until the early 1970's, when a conducting strip radiator separated from a ground plane by a dielectric substrate was described by Byron. This half wavelength wide and several wavelength long strip was fed by coaxial connections at periodic intervals along both radiating edges, and was used as an array for Project Camel. Shortly thereafter, a microstrip element was patented by Munson [7] and data on basic rectangular and circular microstrip patches were published by Howell. Weinschel developed several microstrip geometries for use with cylindrical S band arrays on rockets. Sanford showed that the microstrip element could be used in conformal array designs for L band communication from KC-135aircraft to the ATS-6 satellite. Additional work on basic microstrip patch elements was reported in1975 by Garvin et al, Howell, Weinschel and Janes and Wilson. The early work by Munson on the development of microstrip antennas for use as low profile flush mounted antennas on rockets and missiles showed that this was a practical concept for use in many antenna system problems and thereby gave birth to the new antenna industry.

In recent years the design of highly directive cavity-type antennas has attracted many researchers in the field of antenna technology [8, 9, 10, 23]. In a previous work, Shen and Vandenbosch [11] have used the electric field distribution on top surface above a superstrate to determine its shape and size that minimize its edge diffraction. However, neither the issue of directivity variation with frequency is considered in the above work, nor is the phase variation in the aperture, which obviously controls the directivity, is investigated. Although the literature on FP resonators is quite extensive (see e.g., [12]), most of the prior works deal with large structures, whose lateral dimensions are large in terms of the wavelengths at the operating frequency of the antenna.

Several authors have proposed the use of superstrates to improve the performance of microstrip patch antennas [21, 22] that are used to excite the Fabry-Perot resonators [12, 13]. Other researchers working independently, suggested that directivity enhancement of MPAs can also be obtained by using either a plain dielectric slab, or a thin FSS [11, 12, 14]. [15, 16] proposed the use of DNGs as superstrates to enhance the directivities of small antennas by focusing at infinity the radiation emanating from them. Feresidis [17] and Zhou [18] showed that the half wavelength restriction of a Fabry-Perot cavity antenna can be reduced to respectively a quarter wavelength and a tenth (10th) wavelength by using a novel type of metamaterial-based resonant cavity in order to design compact directive electromagnetic sources based on a single radiating antenna.

III. PROPOSED METHODOLOGY

3.1 Proposed structure

The dimensions of this MSA are designed for the resonant frequency of 5.8GHz. The feed patch is set at 2mm height above ground plane and parasitic patch at height of $\lambda/2$ above feed patch. The FR4 substrate is on parasitic patch with thickness of 1.6mm. Air is used as dielectric between ground plane and feed patch as well as between feed patch and parasitic patch. This is also called as space fed MSA and shown in Fig 3. Top parasitic patch is mounted using foam material which is having dielectric constant equal to air and acts as supporting to parasitic patch and top substrate.

3.2 Choice of Substrate

Choosing a substrate is as crucial as the design itself. The substrate itself is part of the antenna and contributes significantly to its radiative properties. Many different factors are considered in choosing a substrate such as dielectric constant, thickness, stiffness as well as loss tangent. The dielectric constant should be as low as possible to encourage fringing and hence radiation. A thicker substrate should also be chosen since it increases the impedance bandwidth. However, using a thick substrate would incur a loss in accuracy since most microstrip antenna models use a thin substrate approximation in the analysis. Substrates which are lossy at higher frequencies should not be used for obvious reasons. The choice of a stiff or soft board basically depends on the application at hand. In this paper FR4 is selected as the dielectric material having dielectric constant as 1.

3.3 Input Impedance Matching

Impedance matching is critical in microstrip antennas since the bandwidth of the antenna depends upon it. Besides this, a poor match results in lower efficiency also. Line fed rectangular patches may be fed from the radiating or the non-radiating edge. To find an impedance match along the non-radiating edge we may use the Transmission Line Model. The input impedance along the non-radiating edge is lowest at the centre since two equally high impedances at the two ends are transformed into a low value at the centre and connected in parallel. Matching along the edge is also symmetrical about the mid-point of the length.

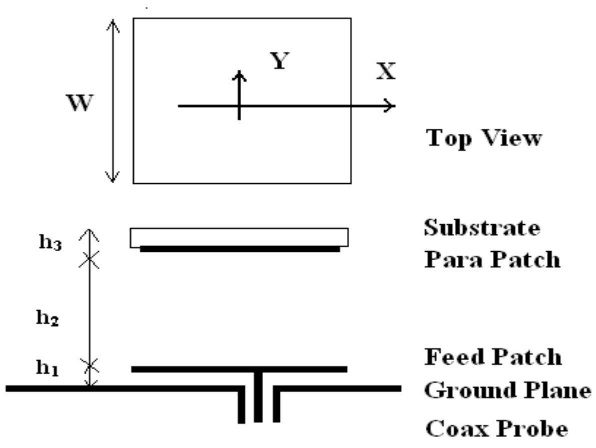

Fig.3 Space Fed MSA

Coaxial probe feed technique is used for its ease of feed. Top substrate is FR4 material acts as protective cover to parasitic patch. Air acts as low dielectric material which helps to increase directivity. Parasitic patch is kept at λ/2 height from the feed patch. The patch dimensions are designed using basic patch antenna design [19].

Patch width

$$W = \frac{c}{2f_0\sqrt{(\varepsilon_r + 1)/2}}$$

Patch length

$$L = \frac{c}{2f_0\sqrt{\varepsilon_{reff}}}$$

Where ε_r is dielectric constant and ε_{reff} **effective** dielectric constant of material. The MSA structure is called multidielectric because more than one dielectric material is used here. Complete specifications are given in Table 1.

***Table 1*: Parameters of multidielectric microstrip patch antenna (f_0=5.8GHz)**

S.No.	Layer Geometry	Dimensions
1	Top substrate	ε_{r3}=4.4, h_3=2
2	parasitic patch	W_P=24mm, L_P=14mm
3	Air gap 2	ε_{r2}=1 h_2=26mm
4	Feed patch	W_F=24mm L_F=22mm
5	Air gap 1	ε_{r1}=1 h_1=2mm
6	Ground plane	Aluminum
7	Feed	50Ω ,SMA probe X_f=2.8mm Y_f=0mm

IV. ANALYSIS AND RESULTS

The result of designed and fabricated rectangular microstrip antenna is analyzed as described below. Simulation is done using IE3D simulation software package [20]. The photograph of fabricated microstrip antenna along with test set up on vector network analyzer is shown in fig 4.

The directivity is the function of patch width and dielectric constant [19]. For normal patch antenna with single substrate, the directivity is 6-8 dB. For given dimensions, the MSA structure is simulated using IE3D simulation software for the frequency range of 5GHz to 6.5GHz and directivity is plotted and shown in fig. 5. The probe is fed at X_f =3.8mm and Y_f =0. It is observed that this patch antenna has directivity of 14 dB which is higher than normal patch antenna. This patch antenna resonates at 5.8GHz which is in ISM band. Air gap between ground and feed patch helps to increase gain.

The table 2 shows the comparative results for return loss, impedance. VSWR and directivity, efficiency and it is seen that the results of simulated antenna structure and fabricated structure are almost similar. Directivity of conventional patch antenna is around 6 to 8db and directivity of our designed antenna is 14 db and for fabricated antenna directivity is 13.6.That means, the directivity enhancement is approximately 56% higher than that of conventional rectangular patch antenna. As shown in fig 7, the return loss of simulated antenna is -24 db whereas that of fabricated antenna is -22 db as shown in fig 6. The impedance at resonance for both simulated and fabricated antenna is found same i.e. 50 ohms. VSWR of designed and fabricated antenna is almost similar and is equal to 1 as shown in fig 8 and 9. As shown in fig 10, the antenna efficiency of the designed antenna is 88% and radiation efficiency is stable between 85 to 91%, whereas the antenna efficiency of fabricated antenna is found to be 86%. The radiation pattern of designed is shown in fig 11 which shows that it has very narrow beam width.

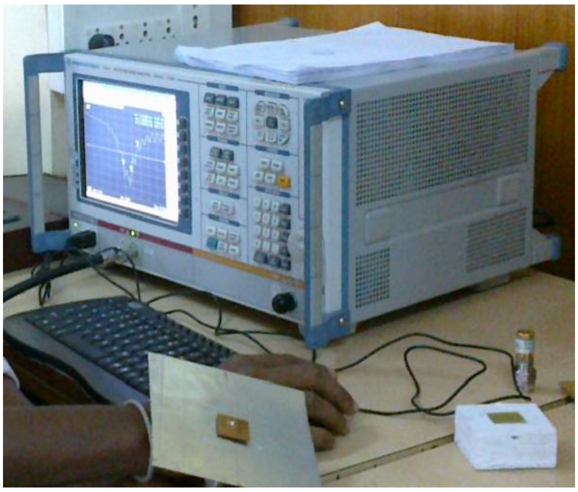

Fig.4-Photograph of fabricated microstrip antenna.

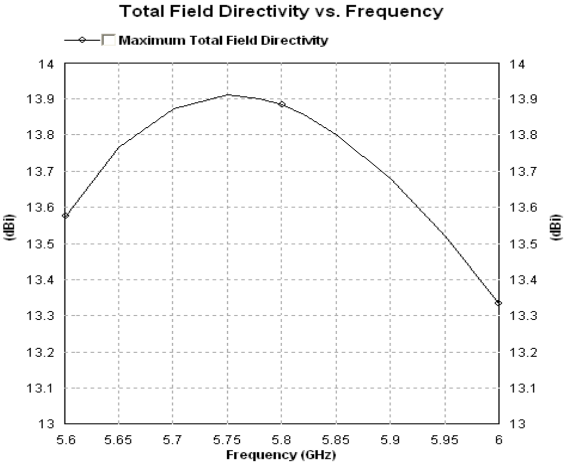

Fig 5- Directivity of designed microstrip antenna.

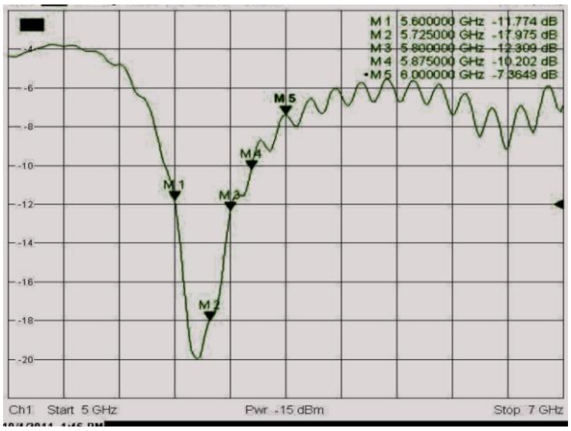

Fig 6- Return loss of fabricated microstrip antenna

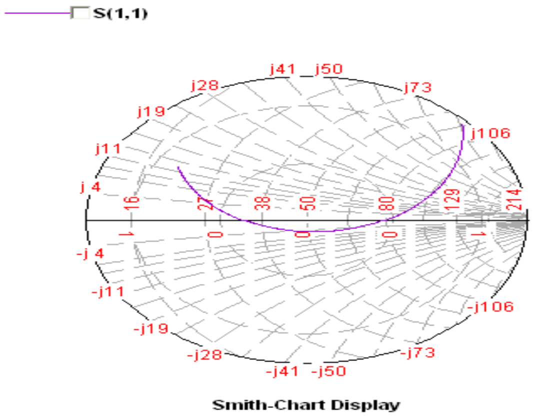

Fig 7- Return loss of designed microstrip antenna

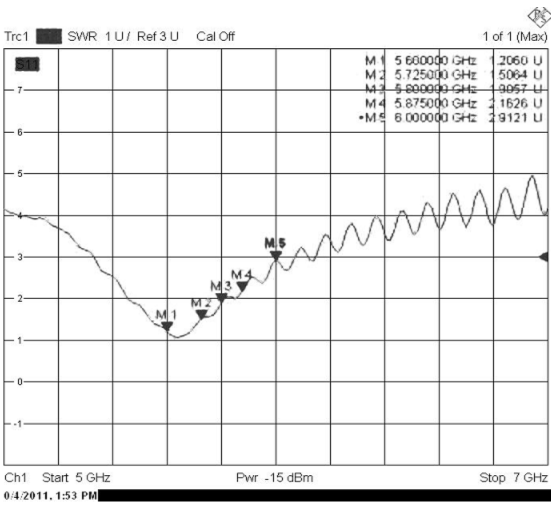

Fig 8- VSWR of fabricated microstrip antenna

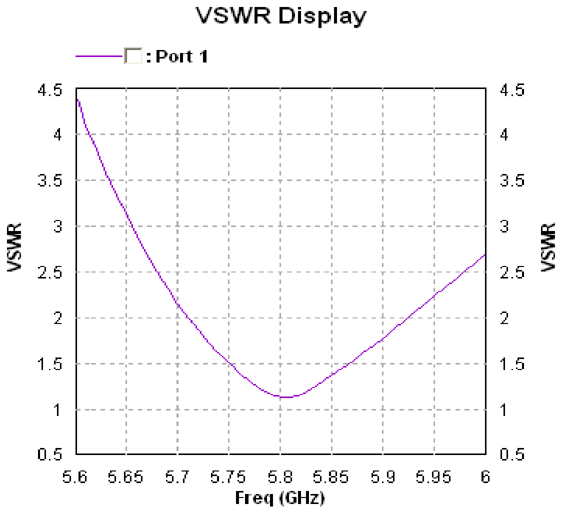

Fig 9-VSWR of designed microstrip antenna.

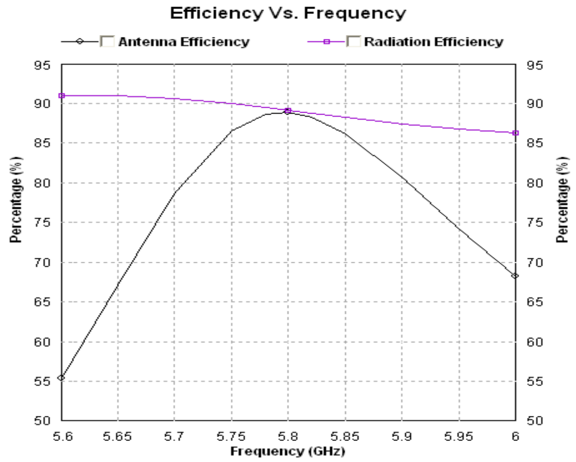

Fig 10-Efficiency of designed microstrip antenna.

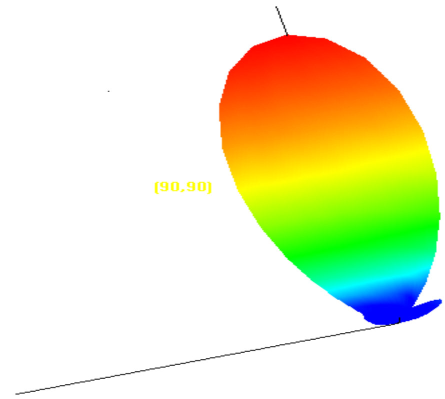

Fig 11- Radiation pattern of designed microstrip antenna

***Table 2*- Comparison of Simulated and Fabricated antenna Results**

S.No.	Parameters	Designed Antenna	Fabricated Antenna
1	VSWR	1.05	1.0
2	Directivity	14 db	13.9 db
3	Antenna efficiency	88%	86%
4	Return Loss	-24 db	-22 db
5	Impedance	50 ohm	50 ohm

V. CONCLUSION

Directivity can be increased by using multilayer dielectric covered layer structure and increasing patch dimensions however bandwidth and directivity can be increased by using parasitic patch and air gap between ground plane and feed patch. This work leads to the conclusion that high directive broadband antenna with high gain are designed using multilayer multidielectric antenna. It is observed that the directivity of designed antenna is 14 db which is 56% more than conventional rectangular patch antenna. Other antenna parameters like VSWR, efficiency, return loss, impedance are measured for designed and fabricated antenna and observed that results are comparatively almost same. Further directivity can be increased by using more dielectric substrate and proper air gap spacing. Such high directive antennas are useful in fixed wireless local area network (WLAN).

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