Design and Evaluation of High Gain Microstrip Patch Antenna Using Double Layer with Air Gap

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Abstract - Wireless technology is one of the main areas of research in the world of communication and a study of communication system is incomplete without understanding the operation of an antenna. Recent trends of wireless mobile communication technology are towards the miniaturization and demand for more robust and compact designs. This paper proposed a low cost, efficient, high gain and wideband Microstrip Antenna (MSA) using rectangular patch for wireless applications. In this paper an attempt is made to optimise and fabricate a double layer RMSA with air gap to obtain a high gain antenna operating over a 2.4-2.483 GHz ISM band. It consist of double sided copper ensure using one side as ground plane and other side as feed network. By inserting an air gap between radiating and ground planes. The air gap reduces both the electric field concentration on the lossy epoxy and the effective dielectric constant of the radiating plane. This structure is low cost, easy for fabrication and FR4 is used which is easily available substrate with permittivity 4.4, height 1.59 mm and loss tangent of 0.02. The structure is optimised using Zeland IE3D version 14.10. The optimised MSA provides a maximum gain of about 8.6 dBi with less than 1dBi gain variation over the operating frequency band, RL< - 9.5 dB, VSWR < 2, SLL < -16dB, front to back ratio > 18 dB and efficiency > 75% . The close similarity between simulation results and fabricated results has been observed.

Keywords - *MSA, FR4, Air gap, SSL, High gain*

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I. INTRODUCTION

Nowadays, due to their several key advantages over conventional wire and metallic antennas, Microstrip Antennas have been used for many applications, such as Direct Broadcasting Satellite (DBS) Systems, mobile communications, Global Positioning System and various radar systems .Their advantages include low profile, light weight, low cost, ease of fabrication and integration. [1] But Microstrip patch antennas also possess major disadvantages such as narrow impedance bandwidth, low efficiency and gain, which seriously limit the application of the Microstrip patch antennas. These limitations are due to the impedance mismatch of the feeding circuitry. In order to match the element the simplest matching method involves choosing the feed location where the resonant resistance is equal to feed-line impedance. In most application, the Microstrip patch antenna is fed using either coaxial probe feed or inset Microstrip line as both are direct contact methods providing high efficiency [2].Generally, both the bandwidth and gain will increase with substrate thickness (up to certain limit), but decrease with increasing dielectric constant. One common method for bandwidth enhancement is using parasitic patches, either in co-planar or stacked geometry. The gain can also be increased in co-planar geometry by placing the parasitic patches adjacent to fed patch to form an array [3].The performance of Microstrip patch antennas greatly depends on substrate parameters i.e. their dielectric constant and tangent loss. Means that, the efficiency and gain are low when the dielectric constant and tangent loss are high [4] In designing a Microstrip Antenna, numerous substrates can be used to achieve good response [5]. Utilization of thick substrate with low dielectric constant is considered as a method of bandwidth enhancement technique [6]. Further to increase the efficiency and to decrease the high substrate loss, an air gap is inserted between radiating element and the ground plane. This air gap reduces both the electric field concentration on the lossy epoxy and the effective dielectric constant of the radiating plane. [7]. In comparison to a normal Microstrip patch antenna, antenna loaded with metamaterial structure has the capability to increase the gain and reduce the return loss as its dielectric constant reduces because of the structure[8]. Patch antennas are feasible for both on–body and off-body communication due to the low profile they utilized. The ground plane of such antenna effectively shields both the antenna (from the influence of the human body) and the user (from negative effects of electromagnetic field) [9]. The size, the patch and hence the patch array and also the integrability of the patch array with RF front end can be improved by using GaAs substrate and employing micro matching [10] By properly selecting the thickness of the substrate and the superstrate layers, a very large gain be realized using electromagnetic band gap (EBG).[11-12]. In this paper, instead of using a patch antenna with low –loss expensive dielectric materials such a Teflon or ceramic, a simple rectangular patch antenna with a standard low-cost FR4 is utilized by inserting an air gap between radiating element and ground plane to obtain a high gain and high efficiency .The method of feeding used is Probe feed technique, with the advantage that the feed can be placed at any

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place in the patch to match with its input impedance (usually 50 ohm).

II. ANTENNA GEOMETRY AND DESIGN THEORY WITH FINITE GROUND PLANE

The Microstrip patch Antenna is designed and optimised using a finite ground plane since there are various disadvantages using an infinite ground plane. The main advantage of using finite ground plane is that it is designed practically. It increases the gain and reduces the unwanted radiations. MSA is designed using FR4 material and air 4mm with Dielectric constant (ε_r) 4.4, substrate thickness (h) 1.59mm, loss tangent 0.02. The design of double layer with air gap MSA has been calculated by using following equation below.

$$W = C\sqrt{(\in r + 1)/2}\ /2f_o \qquad (2.1)$$

$$L = \frac{c}{2fo\sqrt{\in r}} - 2\Delta L \qquad (2.2)$$

$$\in e = \frac{\in r1h1 + \in r2h2}{h1+h2} \qquad (2.3)$$

$$\Delta L = \frac{0.412h\ [\in r+0.300)(W/h+0.264)]}{(\in r-0.258)(W/h+0.8)} \qquad (2.4)$$

Where,ε_{r1} is the FR4 dielectric constant, ε_{r2} is the air gap dielectric constant,h_1 is the FR4 substrate thickness and h_2 is the air gap thickness. Afterwards, the patch width (W) and length (L) have been calculated by considering air gap thickness h_2 [7]. Side view of double sided MSA with air gap is shown in fig 1.

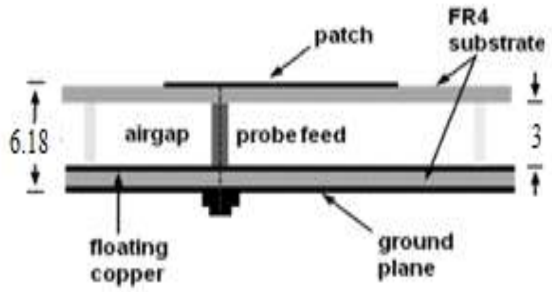

Fig.1. side view of double layer with air gap

Air gap= 3mm, length (L) = 44.35mm, Patch width (w) = 53mm, probe feed distance 13.5mm, and finite ground plane 125x125mm. The geometry of top view antenna is shown in fig. 2.

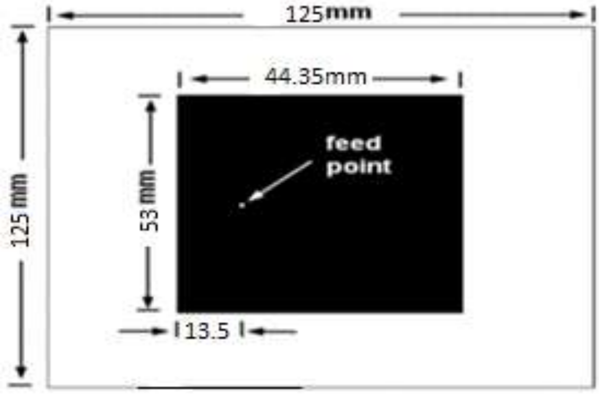

Fig.2.Geometry of top view the high gain Microstrip Rectangular patch Antenna

The upper layer contains a radiating rectangular patch element and the lower layer double sided FR4 copper clad laminate sheet.

III. SIMULATED RESULTS

The effect of change in air gap on radiation parameters such as Return loss is studied. Return loss vs. frequency plot as shown in fig.3.

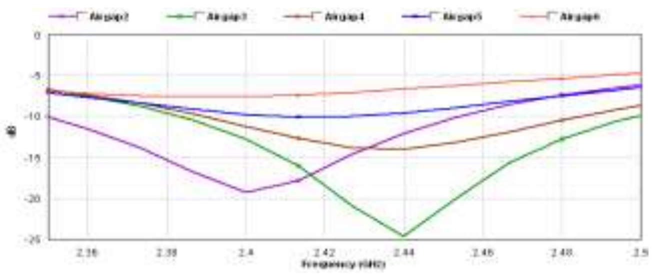

Fig 3 Return loss vs. Frequency

The return loss (R.L) is parameter indicate the amount of power that is lost to load and does not return as a reflection. When the air gap thickness is 3 mm, better than -9.5 dB return loss is obtained at desired frequency. Therefore, a 3 mm air gap thickness is decided for this design. The antenna structure is optimized to obtain VSWR is less than 2 over the frequency range of 2.4-2.483GHzas shown in fig.4.

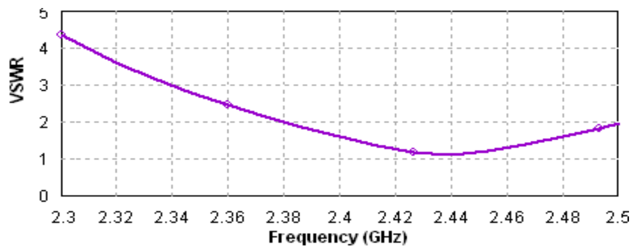

Fig.4. VSWR Vs frequency

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The impedance variation is shown in fig.5.

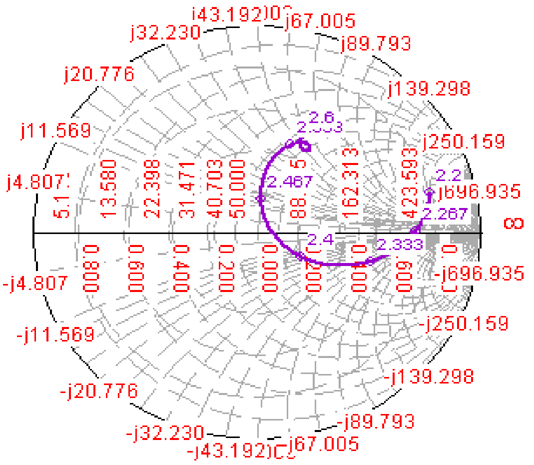

Fig.5. Smith chart

The structure is capacitive for lower frequencies while inductive at higher frequencies.The antenna provides 8.61dBi gain with less than 1 dBi variation over 2.4-2.483GHz.Gain variation of antenna is shown in fig.6.

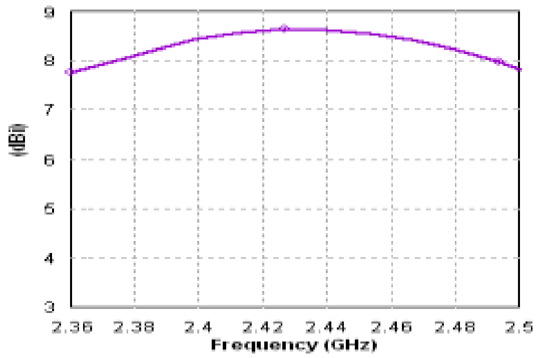

Fig.6.Total gain Vs Frequency

Antenna efficiency is obtained maximum 79.43% as shown in fig.7.

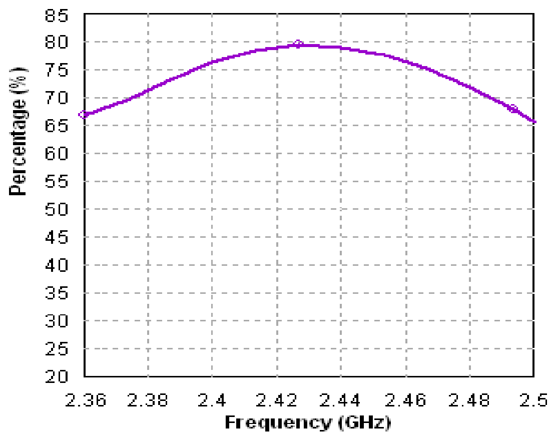

Fig.7. Antenna efficiency Vs frequency

Antenna efficiency increases due to decreases in dielectric and conducting losses.

As shown in Fig.9. (Side Lobe Level) S.L.L<-17dB, (Front to back ratio) F/B > 18dB.

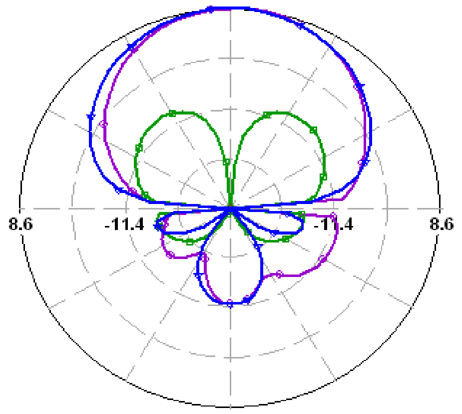

Fig.9. Antenna 2D Radiation Pattern

The radiation pattern shows that the antenna radiates more power in a broadside direction and less in other direction. 3D Radiation pattern current density variation scale as shown in Fig.10.

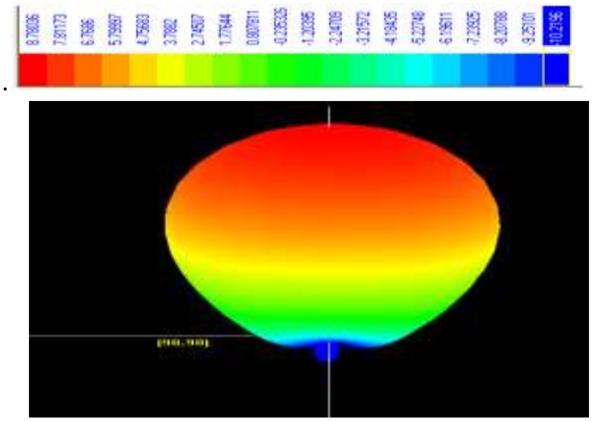

Fig.10. 3D Radiation pattern

Side view of fabricated rectangular Microstrip patch antenna using double layer with air gap as shown in fig.11.

Fig.11. Fabricated Antenna structure

The return loss of fabricated antenna as shown in Fig.12.The testing of antenna is done by using Network Analyzer.

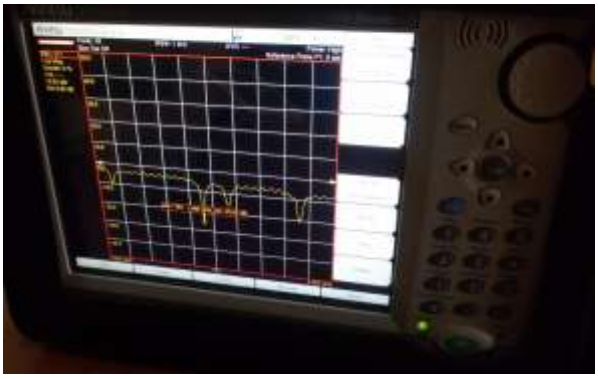

Fig.12. Return Loss of Fabricated Antenna

Comparison the performance of simulated and fabricated MSA double layer with air gap as shown in table 1.

TABLE I

Antenna	Resonance Frequency (GHz)	Return Loss (dB)	VSWR	BW (MHz)
Simulated results	2.44	-24.98	1.19	89
Fabricated results	2.424	-24.09	1.21	85

IV. CONCLUSION

In this paper an attempt is made to optimise MSA using double layer with air gap and successfully fabricated a low cost antenna using an easily available FR4 material. A single element Microstrip rectangular patch antenna with air gap is proposed to obtain high gain and efficiency and good agreements are observed in comparison with the measured and simulated results. The optimised structure provides a maximum gain of 8.6 dBi, efficiency > 7 5%, R.L < - 9.5dB, S.S.L < -17dB and F / b > 18 dB and gain variation of less than 1dBi is obtained over 2.4-2.483 GHz ISM band. Gain and efficiency can be further improved by using array antenna.

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