EFFECT ON PERFORMANCE CHARACTERISTICS OF RECTANGULAR PATCH ANTENNA WITH VARYING HEIGHT OF DIELECTRIC COVER

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ABSTRACT

In this paper, we study the effect on performance characteristics of rectangular patch antenna with varying thickness of dielectric cover. In this case a coaxial cable fed microstrip line is used which leads to good impedance matching and its operating frequency is 2.4 to 2.4835 GHz(ISM band). Simulated results are first used to indicate the design procedures to achieve good impedance matching are discussed. In addition, its characteristic effects on resonant frequency, impedance matching, band width and gain are simulated. And it has been observed that resonance frequency is shifted toward the lower side of frequency of operation, while other parameters have slight variation in their values with the thickness of loading.

Keywords - Microstrip Antenna, Dielectric Covers, Frequency Alteration, Environmental Hazards.

I. INTRODUCTION

Microstrip antennas have several advantages compared to conventional microwave antennas; therefore have many applications over broad frequency range. Microstrip antenna is very small radiating element that can be constructed very precisely due to its easy construction method. Its other attractive and unique properties are; low profile, light weight, low cost, conformable structure and flexibility with regard to frequency, polarization, pattern and impedance [1]. Although the sizes of microstrip antenna with circular polarization(CP)_radiation are considerably compact, they are always marred by problems such as narrow CP operating bandwidth and high edge impedance that due to slenderized microstrip. The major drawback of the microstrip antenna is its inherent narrow bandwidth, which is a major obstacle that restricts wider applications. In order to enhance the bandwidth of MSA, the numbers of techniques have been proposed. The available literatures, reveal that the environmental effects (such as snow, raindrops, etc.) deteriorate the performance of antenna; particularly resonance frequency/bandwidth wherever they are used for long duration. This is the reason, superstrate (cover) dielectric layers are often used to protect microstrip antenna from external hazards, or naturally formed (e.g. ice layers) during flight or severe weather conditions. Whether a cover layer is naturally formed or imposed by design, it may affect adversely the antenna performance characteristics, such as gain, directivity, radiation and efficiency. For this reason, it is important to analyze superstrate loading effects from a fundamental point of view, so that the performance may be understood better or a proper choice of cover parameters may be implemented.

Therefore, several researchers have studied the effect of dielectric covers on effective permittivity and resonant frequency. The resonance and input impedance of covered microstrip antennas using Spectral domain has been analyzed [2]. While the variational technique with transmission line model was proposed to calculate the resonant frequency of covered rectangular antenna. And variational technique in Fourier domain to calculate the rectangular structure's effective permittivity and resonant characteristics of antenna using Method of Moments has been done by [3-5]. All of these methods are complex and time consuming and not suitable for direct integration into computer aided design (CAD). The cavity model approach used for a superstrate-loaded circular patch [6] is extended and a comprehensive theoretical formulation is presented. The present analysis does not involve rigorous mathematical steps or computation as in [7]. The change in the fringing electric field and hence the effective patch dimension caused in the presence of the superstrate is accounted for very accurately.

Therefore, in this paper, we have observed the effects of dielectric cover on the antenna characteristics. Theoretical results for the multi-band performance, gain, and directivity also are presented. In this paper, commercial simulator was employed to study the designs of the key parameters for this rectangular patch microstrip antenna fabricated on RT-Duroid substrate. Follow up by constructing and testing several antenna prototypes with various side length at a fixed substrate thickness, details of the measured antenna performances such as bandwidth, operating centre frequency and peak gain are presented and discussed. In addition to the above investigation, superstrate with various thickness and dielectric constant loaded on the rectangular patch microstrip antenna are measured. Although it is well known that the characteristic effects of superstrate loading on patch antenna includes resonant frequency, resistant and radiating efficiency reduction etc. [8], these effects can be eliminated by fine tuning the key parameters of the reactangular patch microstrip antenna introduced.

II. DESIGN OF RECTANGULAR PATCH ANTENNA

The microstrip antennas have two slots of width *W* and height *h*, separated by a transmission line of length *L*. The microstrip is essentially a non homogeneous line of two dielectrics, typically the substrate and air. Hence, most of the electric field lines reside in the substrate and parts of some lines in air. As a result, this transmission line cannot support pure transverse-electric-magnetic (TEM) mode of transmission, since the phase velocities would be different in the air and the substrate. Instead, the dominant mode of propagation would be the quasi-TEM mode. Hence, an effective dielectric constant (ε_e) must be obtained in order to account for the fringing and the wave propagation in the line. The value of (ε_e) is slightly less then εr because the fringing fields around the periphery of the patch are not confined in the dielectric substrate but are also spread in the air. The expression for (ε_e) is given by [2]:

$$\varepsilon_e = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]$$

Where ε_e = Effective dielectric constant

ε_r = Dielectric constant of substrate

h = Height of dielectric substrate

W = Width of the patch

Consider Fig 1a below, which shows a rectangular microstrip patch antenna of length *L*, width *W* resting on a substrate of height *h*. The co-ordinate axis is selected such that the length is along the x direction, width is along the *y* direction and the height is along the *z* direction.

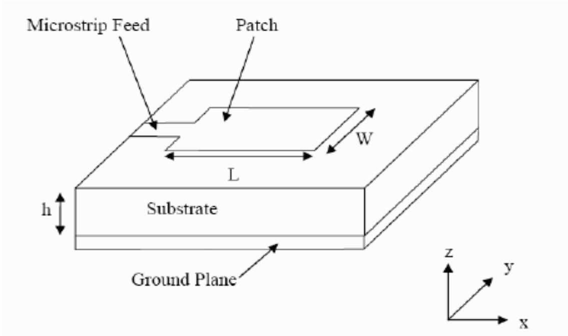

Fig 1a. Microstrip Patch Antennas

In order to operate in the fundamental TM_{10} mode, the length of the patch must be slightly less than λ/2 where λ is the wavelength in the dielectric medium and is equal to $\lambda_o/\sqrt{(\varepsilon_e)}$ where λ_o is the free space wavelength. The TM_{10} mode implies that the field varies one λ/2 cycle along the length, and there is no variation along the width of the patch. In the Fig 1b shown below, the microstrip patch antenna is represented by two slots, separated by a transmission line of length *L* and open circuited at both the ends. Along the width of the patch, the voltage is maximum and current is minimum to the open ends. The fields at the edges can be resolved into normal and tangential components with respect to the ground plane.

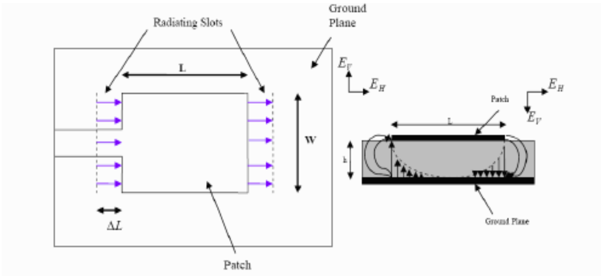

Fig. 1b Top View of Antenna Fig 1c Side View of Antenna

It is seen from Fig 1c that the normal components of the electric field at the two edges along the width are in opposite directions and thus out of phase since the patch is λ/2 long and hence they cancel each other in the broadside direction. The tangential components (seen in Fig 1c), which are in phase, means that the resulting fields combine to give maximum radiated field normal to the surface of the structure. Hence the edges along the width can be represented as two radiating slots, which are λ/2 apart and excited in phase and radiating in the half space above the ground plane. The fringing fields along the width can be modeled as radiating slots and electrically the patch of the microstrip antenna looks greater than its physical dimensions. The dimensions of the patch along its length have now been extended on each end by a distance ΔL, which is given empirically by:

$$\Delta L = 0.412h\frac{(\varepsilon_r + 0.3)\left(W/h + 0.264\right)}{(\varepsilon_r - 0.258)\left(W/h + 0.8\right)}$$

The effective length of the patch L_{eff} now becomes;

$$L_{eff} = L + 2\Delta L$$

For a given resonance frequency f_0 ,the effective length is given as;

$$L_{eff} = \frac{c}{2f_r\sqrt{\varepsilon_r}}$$

For a rectangular microstrip patch antenna, the resonance frequency for any TMmn mode is given by;

$$f_r = \frac{c}{2\sqrt{\varepsilon_r}}\left[\left(\frac{m}{L}\right)^2 + \left(\frac{n}{W}\right)^2\right]^{1/2}$$

Where m and n are the modes along L and W

For efficient radiation the width W is given by [3] as:

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

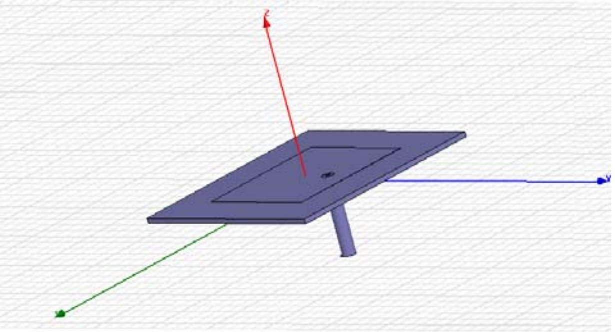

Fig 2a Structure and design parameters of the antenna

The geometry and design parameters of a rectangular patch coaxial cable fed antenna are shown in Fig 2a. A substrate width and length are used as 57.05 mm and 49.05 mm respectively .The dielectric constant of the substrate used is 2.33.The operating frequency is in between 2.4 to 2.4835 GHz. Coaxial feeding is given to the point where input resistance is 50 ohms. The main advantage of this type of feeding scheme is that the feed can be placed at any desired location inside the patch in order to match with its input impedance. This feed method is easy to fabricate and has low spurious radiation. However, its major disadvantage is that it provides narrow bandwidth and is difficult to model since a hole has to be drilled in the substrate and the connector protrudes outside the ground plane, thus not making it completely planar for thick substrates.

III. EFFECT OF DIELECTRIC COVER

In particular, due to dielectric cover the resonance frequency of antenna changes, and reason behind that effective dielectric constant changes due to dielectric layer. And corresponding fractional change in resonance frequency Δf_r is calculated using **[2, 7]**.

$$\frac{\Delta f_r}{f_r} = \frac{1}{2}\frac{\frac{\Delta\varepsilon_e}{\varepsilon_{eo}}}{1 + \frac{1}{2}\frac{\Delta\varepsilon_e}{\varepsilon_{eo}}}$$

Where,

ε_e = effective dielectric constant with cover

ε_{eo} = effective dielectric constant without cover

$\Delta\varepsilon_e$ = change in dielectric constant due to cover

Δf_r = fractional change in resonance frequency

f_r = Resonance frequency

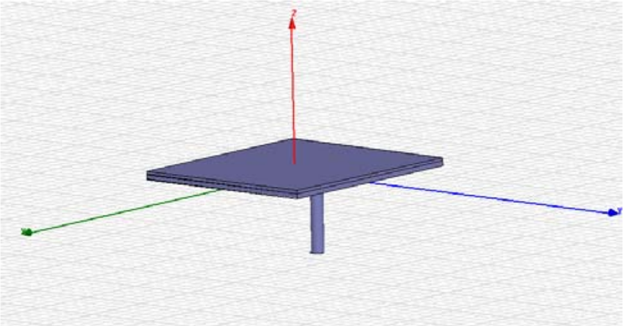

Fig 2b. Structure of antenna with dielectric cover.

The geometry of rectangular patch antenna having dielectric cover is shown in Fig 2b. In reality, the microstrip antenna attached to an electronic device will be protected by a dielectric cover (superstrate) that acts as a shield against hazardous environmental effects. These shielding materials, normally plastics (lossy dielectric), will decrease the overall performances of the antenna operating characteristics such as resonant frequency, impedance bandwidth and radiating efficiency [9-10]. In this paper we have used the dielectric cover of various thicknesses and analyze the effects of dielectric cover on the different antenna parameters.

IV. RESULT AND DISCUSSION

A. Result of rectangular patch antenna

In order to present the design procedure of achieving impedance matching for this case, dimensions of width and length of 57 mm and 49 mm are selected initially respectively. This dimension is calculated corresponding to 2.3 GHz center frequency. The first parameter to alter is *s* and Fig. 3(a) as depicted shown the simulated results of the input impedance. The constant resistance of 50 ohm is taken initially.

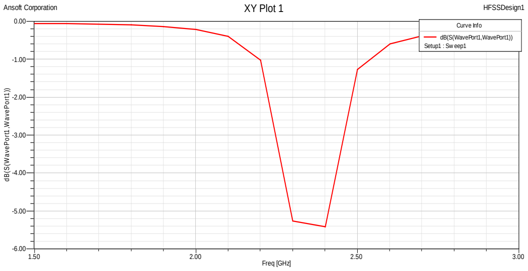

Fig 3(a) s-parameter of rectangular patch antenna

B. Result of rectangular patch antenna after optimization

After optimization it is observed that the results are better. The s-parameter is shown in Fig 3(b). We got the center frequency as 2.4GHz and improved antenna characteristics. Bandwidth after optimization is achieved to be 4.34%.The dimensions of length and width of rectangular patch are same at it is 57.05 mm and 49.05 mm, at which we get the required center frequency of 2.4 GHz. The return loss is -15 dB, which is better as compared to that of the return loss before optimization which was 5.8 dB.

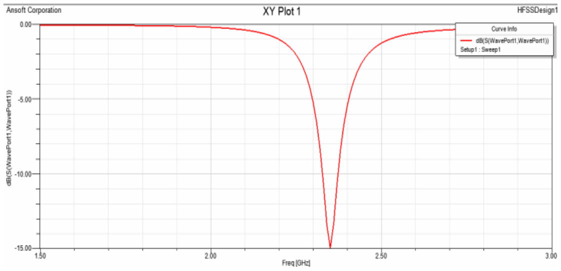

Fig 3 (b). Return loss of the microstrip antenna

C. Result of rectangular patch antenna after dielectric cover

Effects on the antenna characteristics after applying dielectric cover is shown in Figs 4(a) - 4(d). The performance characteristics of antenna are decreased after using dielectric cover as shown. The dimensions of the dielectric cover are 77 mm, 69 mm and 4mm+2*a. Here 'a' is a variable and its value varies from 0.2 mm to 1mm having step size of 0.2 mm. Here 'p' shows the variation in the thickness of the dielectric cover. The variations in the return loss characteristics and the smith chart are shown below in the diagrams.

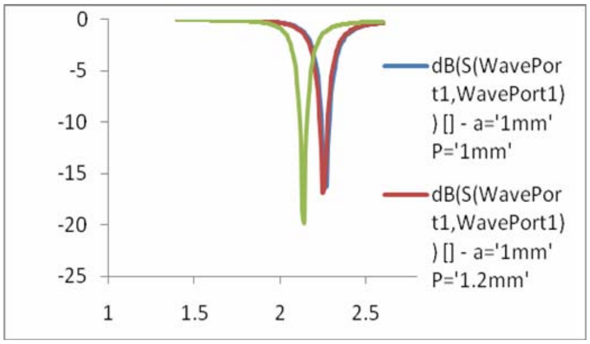

Fig 4(a) Return Loss Vs frequency

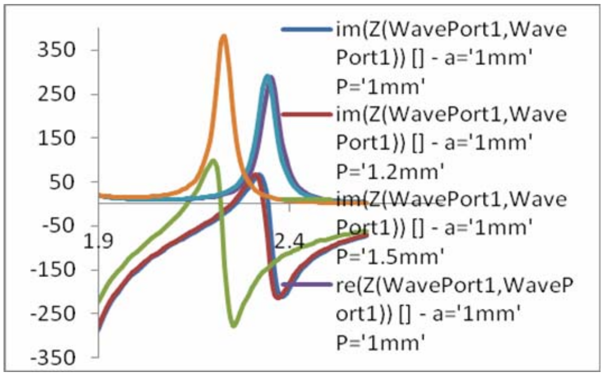

Fig 4(b) Impedance Vs frequency

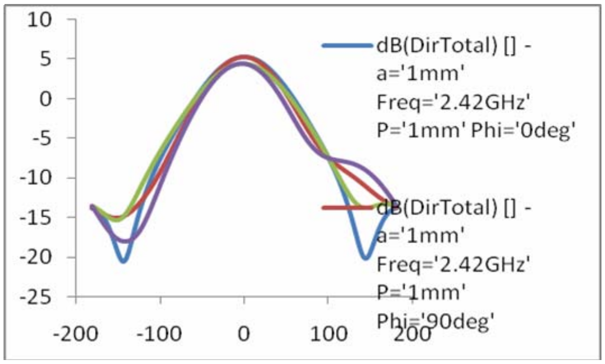

Fig 4(c) Directivity Vs frequency

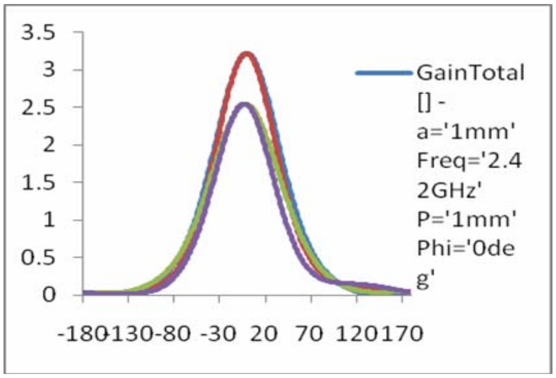

Fig 4(d) Gain Vs frequency

V. CONCLUSION

The key parameters of a rectangular patch microstrip antenna are presented and the design procedures for impedance matching are studied. Several antenna prototypes with various sizes and substrate thicknesses have been constructed, and the results revealed that it could reduce the patch size for the rectangular patch microstrip antenna operated at a given frequency. Based on the information obtained, superstrate of different thickness were loaded on the rectangular-patch microstrip antenna for evaluation. The results show that the antenna performances such as centre frequency; bandwidth and radiating efficiency are reduced as expected. IN particular with superstrate loading of thickness 1.0mm and 1.2 mm, the return loss is found to be -16.29 dB and -16.817 dB at frequencies 2.26 GHz and 2.25 GHz respectively. Therefore, there is shift of 0.01 GHz frequency. The variation of impedance with frequency shown in Fig 4 (b) indicates that there is effect of dielectric loading on impedance matching of the antenna. As the thickness of superstrate loading changes the resonance frequency shifted toward the higher side of frequency band. It is also observed that antenna structure exhibits resonances at frequencies; 2.06 GHz, 2.05 GHz and 1.98 GHz that are resonance frequency lower as the thickness of loading increases. The variation of directivity and gain with orientation of antenna shows that there is no much influence of loading on these parameters of the antenna. Only slight changes are being found with the thickness of the loading.

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