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Design of dual band rectangular Microstripantenna

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Abstract: The thesis covers three aspects of Microstrip antenna designs. The first is the analysis and design of single element rectangular Microstrip antenna which operates at the central frequency of 2.4 GHz and the second aspect is the design of dual band rectangular Microstrip antenna which is operates as 2.4 & 3.08 GHz. Both antennas have been modelled, designed and simulated. Basically, transmission line and cavity modelling is going to use to model both antennas. First, the design parameters for single element of rectangular patch antenna have been calculated from the transmission line model equation and extend the antenna design to Dual Band rectangular Microstrip patch antenna using the slots at radiating edge. The simulation process has been done through IE3D electromagnetic software which is based on method of movement (MOM).For rectangular Microstrip antenna design used RT- Duriod which is Teflon based, Microstrip board with dielectric constant 2.4 and the substrate height is 1.58 mm, scaling factor 0.95 and loss tangent is 0.001. The properties of antenna such as bandwidth, S-Parameter has been investigated and compared between different optimization scheme and theoretical results

I INTRODUCTION

Satellite communication and Wireless communication has been developed rapidly in the past decades and it has already a dramatic impact on human life. In the last few years, the development of wireless local area networks (WLAN) represented one of the principal interests in the information and communication field. Thus, the current trend in commercial and government communication systems has been to develop low cost, minimal weight, low profile antennas that are capable of maintaining high performance over a large spectrum of frequencies. This technological trend has focused much effort into the design of Microstrip (patch) antennas. Using the Dual Band Microstrip Antenna concept in this thesis dual band rectangular Microstrip antenna is designed simulated and tested. There are a few software available which allow the optimization of the antenna. IE3D one of the most imperial electromagnetic software which allows to solving for radio and microwave application. It works based on method of movement (MOM) .The simulator tool computes most of the useful quantities of interest such as radiation pattern, input impedance and gain etc.

A) Overview of Micro strip Antenna

A micro strip antenna consists of conducting patch on a ground plane separated by dielectric substrate. This concept was undeveloped until the revolution in electronic circuit miniaturization and large-scale integration in 1970. After that many authors have described the radiation from the ground plane by a dielectric substrate for different configurations. The early work of Munson on micro strip antennas for use as a low profile flush mounted antennas on rockets and missiles showed that this was a practical concept for use in many antenna system problems. Various mathematical models were developed for this antenna and its applications were extended to many other fields. The number of papers, articles published in the journals for the last ten years, on these antennas shows the importance gained by them. The micro strip antennas are the present day antenna designer's choice.

Low dielectric constant substrates are generally preferred for maximum radiation. The conducting patch can take any shape but rectangular and circular configurations are the most commonly used configuration. Other configurations are complex to analyse and require heavy numerical

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computations. A micro strip antenna is characterized by its Length, Width, Input impedance, and Gain and radiation patterns. Various parameters of the micro strip antenna and its design considerations were discussed in the subsequent chapters. The length of the antenna is nearly half wavelength in the dielectric; it is a very critical parameter, which governs the resonant frequency of the antenna. There are no hard and fast rules to find the width of the patch.

(B)Waves on Micro strip

The mechanisms of transmission and radiation in a micro strip can be understood by considering a point current source (Hertz dipole) located on top of the grounded dielectric substrate (fig. 1.1) This source radiates electromagnetic waves. Depending on the direction toward which waves are transmitted, they fall within three distinct categories, each of which exhibits different behaviours

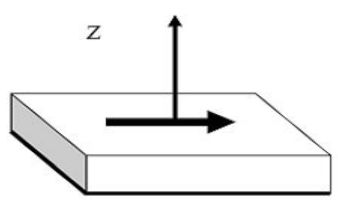

Figure 1.1 Hertz dipole on a microstrip substrate

Microstrip patch antenna consists of a radiating patch on one side of a dielectric substrate which has a ground plane on the other side.

(C)Surface Waves

The waves transmitted slightly downward, having elevation angles θ between π/2and π - arcsin (1/√εr), meet the ground plane, which reflects them, and then meet the dielectric-to-air boundary, which also reflects them (total reflection condition). The magnitude of the field amplitudes builds up for some particular incidence angles that leads to the excitation of a discrete set of surface wave modes; which are similar to the modes in metallic waveguide.

The fields remain mostly trapped within the dielectric, decaying exponentially above the interface (fig1.2). The vector α, pointing upward, indicates the direction of largest attenuation. The wave propagates horizontally along β, with little absorption in good quality dielectric. With two directions of α and β orthogonal to each other, the wave is a non-uniform plane wave. Surface waves spread out in cylindrical fashion around the excitation point, with field amplitudes decreasing with distance (r), say1/r, more slowly than space waves. The same guiding mechanism provides propagation within optical fibres.

Surface waves take up some part of the signal's energy, which does not reach the intended user. The signal's amplitude is thus reduced, contributing to an apparent attenuation or a decrease in antenna efficiency. Additionally, surface waves also introduce spurious coupling between different circuit or antenna elements. This effect severely degrades the performance of micro strip filters because the parasitic interaction reduces the isolation in the stop bands.

In large periodic phased arrays, the effect of surface wave coupling becomes particularly obnoxious, and the array can neither transmit nor receive when it is pointed at some particular directions (blind spots). This is due to a resonance phenomenon, when the surface waves excite in synchronism the Floquet modes of the periodic structure. Surface waves reaching the outer boundaries of an open micro strip structure are reflected and diffracted by the edges. The diffracted waves provide an additional contribution to radiation, degrading the antenna pattern by raising the side lobe and the cross polarization levels. Surface wave effects are mostly negative, for circuits and for antennas, so their excitation should be suppressed if possible.

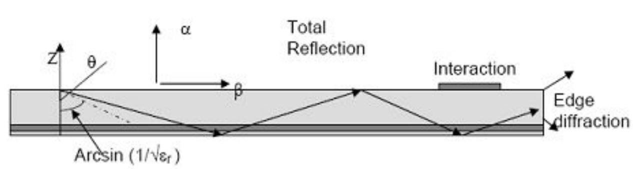

Figure 1.2 Surface waves

(D)Guided Waves

When realizing printed circuits, one locally adds a metal layer on top of the substrate, which modifies the geometry, introducing an additional reflecting boundary. Waves directed into the dielectric located under the upper conductor bounce

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back and forth on the metal boundaries, which form a parallel plate waveguide. The waves in the metallic guide can only exist for some Particular Values of the angle of incidence, forming a discrete set of waveguide modes. The guided waves provide the normal operation of all transmission lines and circuits, in which the electromagnetic fields are mostly concentrated in the volume below the upper conductor. On the other hand, this build up of electromagnetic energy is not favourable for patch antennas, which behave like resonators with a limited frequency bandwidth.

(E)Antenna Characteristics

An antenna is a device that is made to efficiently radiate and receive radiated electromagnetic waves. There are several important antenna characteristics that should be considered when choosing an antenna for your application as follows:

• Antenna radiation patterns • Power Gain

• Directivity • Polarization

II MATHMATICAL ANALYSIS

Theoretical analysis and calculations from of all dimensions will be obtained;

The width of the patch element (W) is given by.

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

Substituting c = $3\text{x}10^8$ m/s, εr = 2.2, and fo = 5 GHz, then W =2.3717cm or 933.74 mile.

The effective of the dielectric constant (εreff) depending on the same geometry (W, h) but is surrounded by a homogeneous dielectric of effective permittivity εreff, whose value is determined by evaluating the capacitance of the fringing field.

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

Substituting εr = 2.2, W =2.3717cm, and h =0.1575cm, then εreff = 2.1074cm or 829.69mile, The effective length (L eff) is given:

$$L_{eff} = \frac{c}{2f_o\sqrt{\varepsilon_{reff}}}$$

Substituting c = $3\text{x}10^8$ m/s, εreff = 2.0475cm, and f o = 5 GHz, then Leff = 2.0665cm or 813.6 mile.

The length extension (ΔL) is given by:

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

Substituting Ereff = 2.1074cm, W= 2.3717cm, and h =0.0787cm, then ΔL= 0.041469cm or 16.3266mile.

The actual length (L) of patch is obtained by:

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

Substituting ΔL= 0.041469cm, and Leff = 2.0665cm, then L=1.9835cm or 780.92mile.

III ANTENNA DESCRIPTION

The results of proposed circular polarised Multiband micro strip patch antenna verified in IE3D Simulator with optimization.

A. *Proposed Equivalent circuit:*

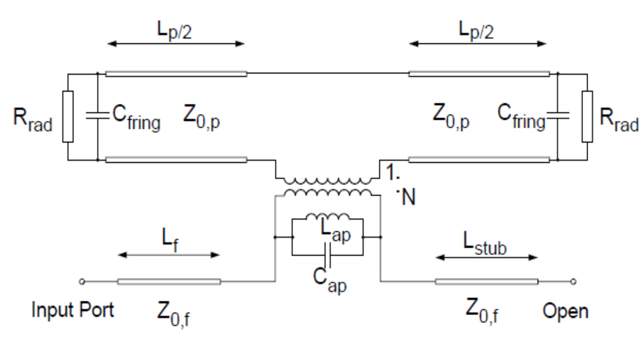

Fig. Equivalent circuit for an aperture-coupled micro-strip antenna

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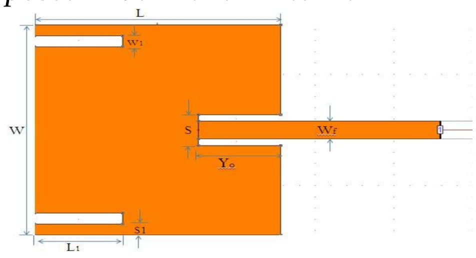
B. *Proposed Dual Band Antenna*



IV RESULTS AND DISCUSSION

Following are the simulated and fabricated results between the frequency range of 2.2-3.4 GHz.

Return loss and Antenna Bandwidth :
Theoretical result:

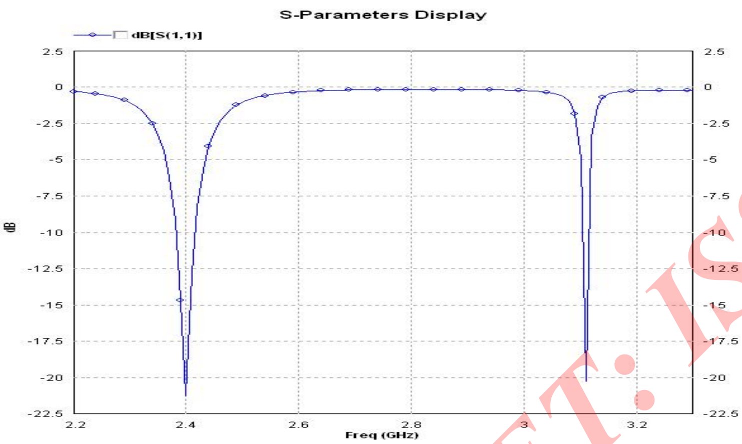


Figure (a) Return loss is -21.124dB (2.3998 GHz) and
Return loss is -20.1766dB (3.1103 GHz)

Fabricated Result:

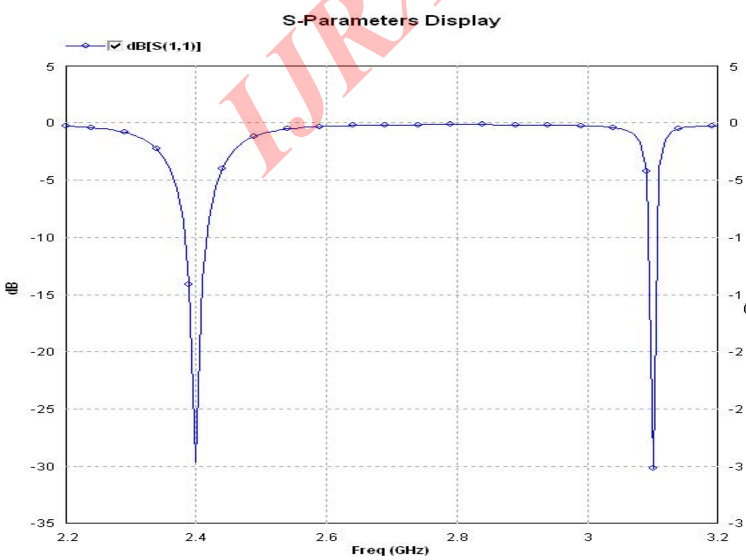


Figure (b) Return loss is -29.6008 (2.3995 GHz) and
Return loss is –30.057 (3.1004 GHz)

Radiation pattern plot:
Figures show the 2D radiation pattern of the antenna at the designed frequency for Φ=0 and Φ=90 degrees.

Theoretical result:

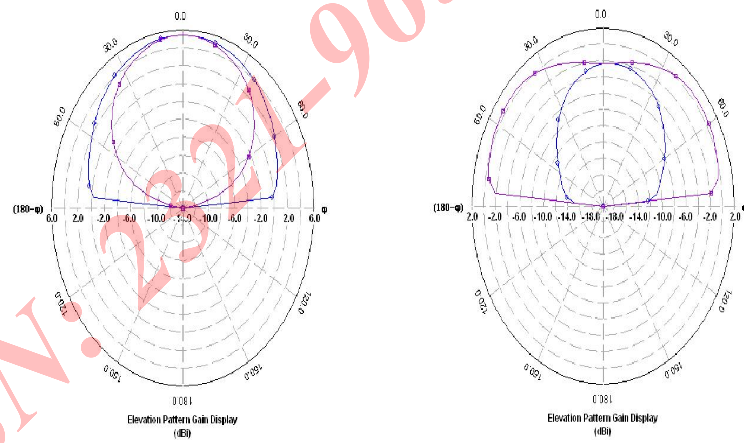


Figure (a) (i) Elevation Pattern for Φ=0 and Φ= 90 degrees at f=2.3998 GHz
(ii) Elevation Pattern for Φ=0 and Φ= 90 degrees at f=3.1 GHz

Fabricated Result:

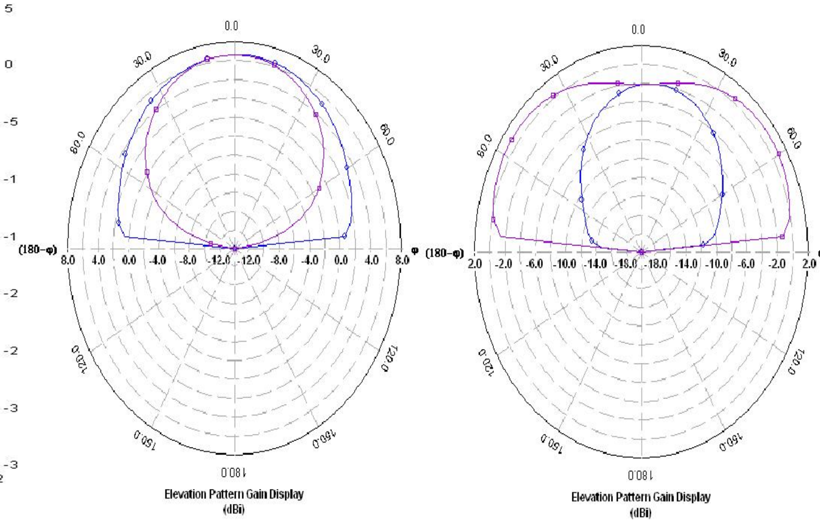


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Figure (b) (i) Elevation Pattern for Φ=0 and Φ= 90 degrees at f=2.3995 GHz
(ii) Elevation Pattern for Φ=0 and Φ= 90 degrees at f=3.1004 GHz

VSWR Plot:
In the case of Microstrip patch antenna the value of VSWR is always less than 2 . At f_1= 2.4 GHz the value of VSWR is 1.08 and at f_2 = 3.08 GHz. the value of VSWR is 1.3

Theoretical result:

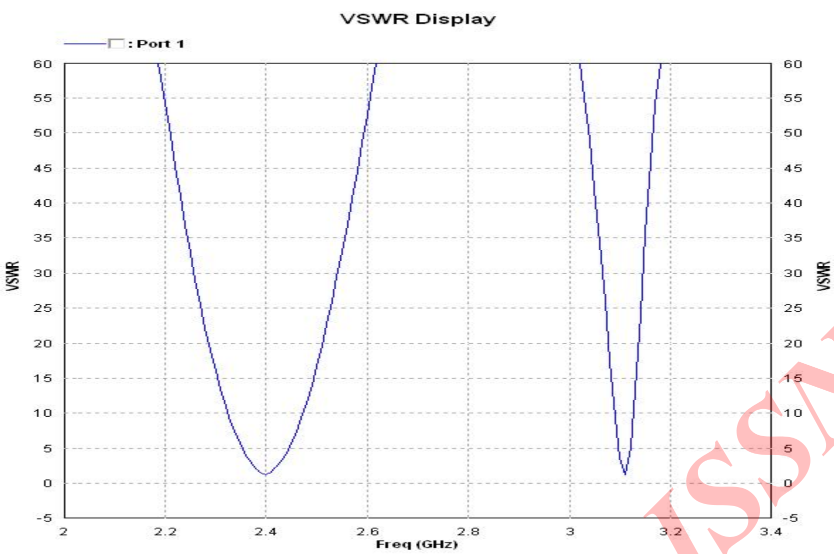

Figure (a) VSWR of Microstrip patch antenna is 1.2 at f_1= 2.3995 GHz and 1.37 at f_2 = 3.1103GHz

Simulated result:

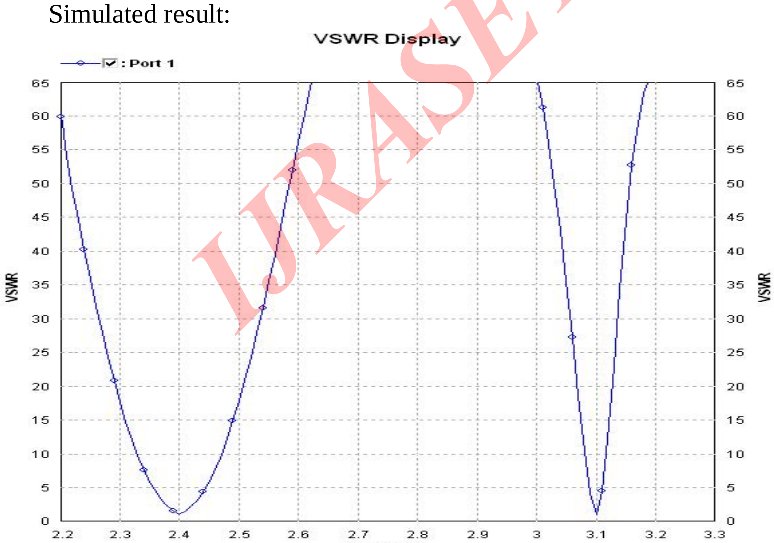

Figure (b) VSWR of Microstrip patch antenna is 1.15 at f1 = 2.3995 GHz and 1.12 at f2 = 3.104GHz.

Compression between the Theoretical and Fabricated results of dual band antenna.

<table>
<tr><td>Antenna Parameter</td><td colspan="2">Theoretical Results</td><td colspan="2">Fabricated Results</td></tr>
<tr><td>Length(L)</td><td colspan="2">47.9 mm</td><td colspan="2">47.9 mm</td></tr>
<tr><td>Width(W)</td><td colspan="2">39.6 mm</td><td colspan="2">39.483 mm</td></tr>
<tr><td>Inset Depth</td><td colspan="2">13 mm</td><td colspan="2">12.75 mm</td></tr>
<tr><td>Slot Length(L_1)</td><td colspan="2">14.2 mm</td><td colspan="2">14.323</td></tr>
<tr><td>Slot Width(w_1)</td><td colspan="2">1.4 mm</td><td colspan="2">1.4</td></tr>
<tr><td>Frequency(f1) And Return Loss</td><td colspan="2">2.3998 GHz (-21.1524 dB)</td><td colspan="2">2.3995 (-29.6008)</td></tr>
<tr><td>Frequency(f2) And Return Loss</td><td colspan="2">3.1103 GHz (-20.1766 dB)</td><td colspan="2">3.1004 (-30.137)</td></tr>
<tr><td>Impedance(Ω)</td><td colspan="2">60 Ω</td><td colspan="2">50 Ω</td></tr>
<tr><td rowspan="2">VSWR At f1 and f2</td><td>2.3998</td><td>3.1103</td><td>2.3995</td><td>3.1004</td></tr>
<tr><td>1.27</td><td>1.37</td><td>1.15</td><td>1.12</td></tr>
</table>

V CONCLUSION

Two aspects of Microstrip antennas have been studied in this paper. The first aspect is the design of typical rectangular Microstrip antenna and the second is the design of dual band Microstrip antenna. A simple and efficient technique of inset method has been introduced for an impedance matching improvement of the antennas. Main concern of this paper is to study of Dual band patch antenna using different techniques and frequency ratio of the Microstrip antenna. The dual band Microstrip antenna is a more conventional approach for the implementation of a broadband antenna and for satellite communication where the low

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frequency ratio is used. Initially, single element rectangular Microstrip antenna is designed to operate at frequency 2.4 GHz. And then, the dual band Microstrip antenna is designed to resonate at frequency range 2.4 GHz to 3.08 GHz. The dual band antenna shows that with correct selection of slot dimensions and positions, a dual frequency response can be achieved, while still allowing the use of a planar feed.

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