Parametric Study of Microstrip Patch Antenna

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Abstract **-** 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 (MSA) [1].

An MSA in its simplest form consists of a radiating patch on one side of a thin dielectric substrate backed by a ground plane. The radiating patch could be of any arbitrary shape but generally regular shapes are considered for ease of analysis and design. One of the simplest and widely used configurations is rectangular MSA. A rectangular patch is defined by its length L and width W. For a simple microstrip line the width is much smaller than the wavelength. However, for the RMSA, the width is comparable to the wavelength to enhance radiation from edges. The thickness is much smaller than the wavelength. The objective of this paper is to study the effect of various parameters on the antennas characteristics like return loss and impedance. For this purpose a simple rectangular micro strip antenna (RMSA) is considered for ease of analysis. To start with, first a RMSA is designed and then its various parameters are changed to study effects of it on antennas characteristics.

Index Terms **–** *Micro Strip Antenna (MSA).*

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I. INTRODUCTION

In the era of 1950's microstrip antennas (MSA) are invented but serious research had begun only after significant research of printed technology in the era of 1970's [14]. Researchers are attracted towards printed antennas due to low profile of these antennas. On the printed circuit board (PCB) there is always a conducting plane on a substrate that can radiates if properly feed and grounded at bottom. This is the basic principle of MSA also known as patch antennas.

An MSA in its simplest form consist of substrate sandwiched between radiating patch and ground plane [4]. In this configuration, in this configuration, the upper conducting layer or "patch" is the source of radiation where electromagnetic energy fringes off the edges of the patch and into the substrate. The lower conducting layer acts as a perfectly reflecting ground plane, bouncing energy back through the substrate and into free space. The configuration is shown in the fig.1.1.

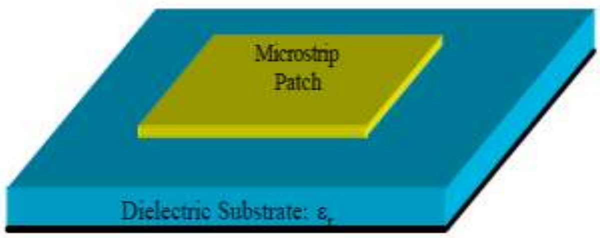

Fig. 1.1 Simple Structure of Micro strip Antenna

II. FEEDING OF MSA

The maximum power transfer theorem states that, "to obtain maximum external power from a source with a finite internal resistance, the resistance of the load must equal the resistance of the source as viewed from its output terminals". This theorem is also valid in case of antennas. That's why feeding technique of MSA influence its input impedance characteristics.

2.1 CO-AXIAL FEEDING TECHNIQUE:

This type of feed is the common technique used for the feeding of the Microstrip patch antennas. Coupling of the power through a probe is one of the basic studies that can be seen in the transfer of the microwave power. In This Feeding Technique the external or the outer conductor is connected to the ground plane and the inner conductor of the coaxial connector extends through the dielectric and is soldered to that of the radiating patch. The coaxial probe in this feed would be an inner conductor of the coaxial line or this can be used as the power transfer from the strip line to the MSA from the slot in the ground plane. Unlike from the other feed techniques, here the advantage is that it has the flexibility to place the feed anywhere in the inside the patch in order to match the input impedance. This gives an easy way for the fabrication and it haw low spurious radiation.With the connector extending out of the ground plane, this results in non-planar surface to the substrates which are thick, i.e. having a height that is greater than 0.02λ. With the extended or the increase probe length the input impedance becomes more inductive, which leads to the matching problems of the impedance.

2.2 MICROSTRIP FEED TECHNIQUE:

This type of feed technique excitation of the antenna would be by the Microstrip line of the same substrate as the patch that is here can be considered as an extension to the Microstrip line, and these both can be fabricated simultaneously. This conducting strip is directly connected to the edge of the Micro strip patch. This type of structure has actually an advantage of feeding the directly done to the same substrate to yield a planar structure as said above. The coupling between the

Microstrip line and the patch is in the form of the edge or butt-in coupling. However as the thickness of the dielectric substrate being used, increases, surface waves and spurious feed radiation also increases, which hampers the bandwidth of the antenna. The feed radiation also leads to undesired cross polarized radiation [5].

2.3 APERTURE COUPLED FEEDING TECHNIQUE:

This type of feed technique comes under the non-contacting feed techniques and here the radiating patch and the micro strip feed line are being divided by the ground plane. The main features in this particular feed technique is that it has a wider bandwidth and the shielding of the radiating patch from the radiation gets from the structure [14].
From the fig.3.4 below it can be seen that the configuration of this feed and as said above the radiating patch and Microstrip feed line are separated by the ground plane.

The coupling between the patch and the feed line is trough aperture in the ground plane i.e. the line feed on the lower substrate of coupled electromagnetically to the patch through the aperture. The amount of coupling depends on the size, shape and also the location of the aperture.

There is minimization of the spurious radiation as the ground plane separates the feed line and the patch; this can be achieved when there is a usage of thin, high dielectric material for the lower substrate and thick, low dielectric constant material for the upper substrate.

2.4 PROXIMITY COUPLING FEEDING TECHNIQUE:

This is one of the non-contacting non coplanar Microstrip feed technique. In this particular configuration, the patch antenna is on the upper layer substrate and the Microstrip feed line on the lower layer substrate as its uses 2 layers of substrate.There is an open end to the feed line beneath the path. This feed technique is also known as electromagnetically the current coupled (proximity coupled Microstrip feed).A particular feature of this differs from the other feed techniques i.e. the coupling capacitive in nature between the patch and the Microstrip [6].

2.5 COMPARISON OF VARIOUS FEEDING TECHNIQUES

Characteristics	**Co-axial Feed**	**Microstrip Feed**	**Aperture Coupling**	**Proximity Coupling**
Configuration	Non-Planer	Planer	Planer	Planer
Spurious Feed Radiation	More	More	More	More
Polarization Purity	Poor	Poor	Poor	Excellent
Ease of Fabrication	Etching and Drilling Requires	Etching Requires	Alignment Requires	Alignment Requires

Table.2.1 Comparison of Feeding Technique

III. DESIGN OF RECTANGULAR MICROSTRIP ANTENNA

3.1 DESIGN CONSIDERATIONS

Three important parameters for designing the RMSA are:

1. **Frequency of operations (*fr*):** The main aim for designing the MSA is to design it for some application. International Telecommunication Union (ITU) decides frequency for every application e.g. GPS satellite transmits data on two frequencies L1 i.e. 1.57GHz and L2 1.22GHz [2]. Thant means application decides frequency of operation also called as resonance frequency (*fr*). Let's design a RMSA for GPS frequency i.e.1.57 GHz.
2. **Dielectric Constant (ε_r) of Substrate:** A dielectric material is a substance that is a poor conductor of electricity, but an efficient supporter of fields. The dielectric constant is the ratio of the permittivity of a substance to the permittivity of free space. It is an expression of the extent to which a material concentrates electric flux, and is the electrical equivalent of relative magnetic permeability. Let's consider glass epoxy (FR4) as a substrate for designing the antenna. It's ε_r is 4.47.
3. **Height of Substrate (h):** As we fixed substrate as glass epoxy, commonly used glass epoxy has height 1.56mm.

Hence essential parameters for designing RMSA are:
fr = 1.57GHz
ε_r = 4.47
h=1.56 mm

IV. DESIGN PROCEDURE

Figure 4.1 shows the front view of RMSA. The transmission line model explained in chapter 3 is used for designing the RMSA. Let's design it step by step as given below.

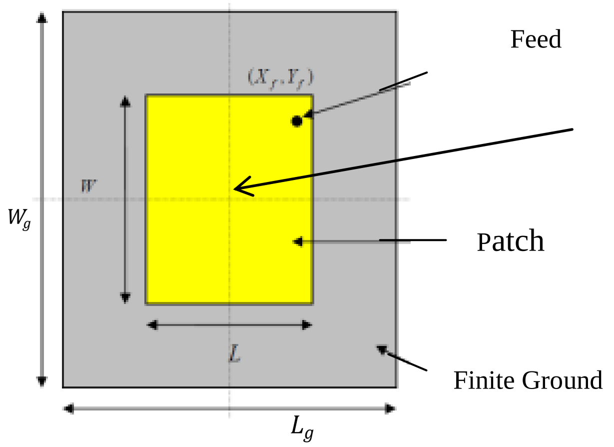

Fig.4.1 Front View of RMSA

STEP 1. Calculation of the Width (W): The width of the Microstrip patch antenna is given byequation (3.5) as:

$$W = \frac{c}{2f_r\sqrt{\frac{\varepsilon_r+1}{2}}} \quad (4.1)$$

Substituting, c = $3e^8$ m/s; $\varepsilon_r = 4.47$ and $f_r = 1.57e^9$ Hz

We get, **W = 57 mm**

STEP 2. Calculation of Effective dielectric constant (ε_{eff}): The ε_{eff} is given by the equation 3.3 as:

$$\varepsilon_{eff} = \frac{(\varepsilon_r+1)}{2} + \frac{(\varepsilon_r-1)}{2}\left[1 + \frac{12\,h}{W}\right]^{-\frac{1}{2}} \quad (4.2)$$

Substituting $\varepsilon_r = 4.47, h = 1.56\ mm$ and $W = 57\ mm$
We get; $\boldsymbol{\varepsilon_{eff} = 4.24}$

STEP 3. Calculation of the Effective length (L_{eff}): From Equation 3.2 we have

$$L_{eff} = \frac{c}{2f_r\sqrt{\varepsilon_{eff}}} \quad (4.3)$$

Substituting c = $3e^8$ m/s; $\varepsilon_{eff} = 4.24$ and $f_r = 1.57e^9$ Hz we get;
$\boldsymbol{L_{eff} = 46.34mm}$

STEP 4. Calculation of the length extension (ΔL): From equation 3.3 we have;

$$\Delta L = 0.412h\left[\frac{(\varepsilon_{eff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{eff}-0.258)\left(\frac{W}{h}+0.813\right)}\right] \quad (4.4)$$

Substituting h=1.56 mm,$\varepsilon_{eff} = 4.24$ *and* W= 57mm we get;
$\boldsymbol{\Delta L = 0.7184\ mm}$

STEP 5. Calculation of the actual length (L): It is given by equation 4.4

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

Substituting $L_{eff} = 46.34mm$ and $\Delta L = 0.7184\ mm$ we get;
L = 47.77 mm

STEP 6.Calculations of finite plane dimensions (W_g and L_g): The transmission line model is applicable to infinite ground planes only. However, for practical considerations, it is essential to have a finite ground plane. It has been shown by [15] that similar results for finite and infinite ground plane can be obtained if the size of the ground plane is greater than the patch dimensions by approximately six times the substrate thickness all around the periphery. Hence, for this design, the ground plane dimensions would be given as:

$L_g = 6h + L$ = 6(1.56) + 47.77= 57.13 mm
$W_g = 6h + W$=6(1.56) + 57 = 114.13 mm

For studding effect of various parameters on antenna characteristics like return loss, impedance, etc. parametric study is carried out in next subtopic. Here above designed antenna is used for study.

4.2 SIMULATION TOOL

Electromagnetic simulation is an advanced technology to yield high accuracy analysis and design of complicated microwave and RF printed circuit, antennas, high speed digital circuits and other electronic components. IE3D is an integrated full-wave electromagnetic simulation and optimisation package for the analysis and design of 3D and planer microwave circuits, MMIC, RFIC,RFID, antennas, digital circuits and high speed printed circuit boards (PCB). Since its formal introduction in 1993 IEEE international Microwave Symposium (IEEE IMS 1993), the IE3D has been adopted as an industrial standard in planer and 3D electromagnetic simulation. Much improvement has been achieved in the IE3D has become the most versatile. Easy to use, efficient and accurate electromagnetic simulation tool [7].

V. PARAMETRIC STUDY OF RMSA

A coaxial-fed RMSA of L = 4.55 cm and W = 5.5 cm is considered to study the effects of various parameters on its performance. The probe diameter is taken as 0.12 cm for the 50Ω coaxial probe feed using an SMA connector. Thesubstrate parameters are ε_r = 2.55, h = 0.156 cm, and tan δ = 0.01. Theantenna has been analysed using commercially available IE3D software basedon MoM. Fig.4.2 shows designed antenna on IE3D simulation tool.

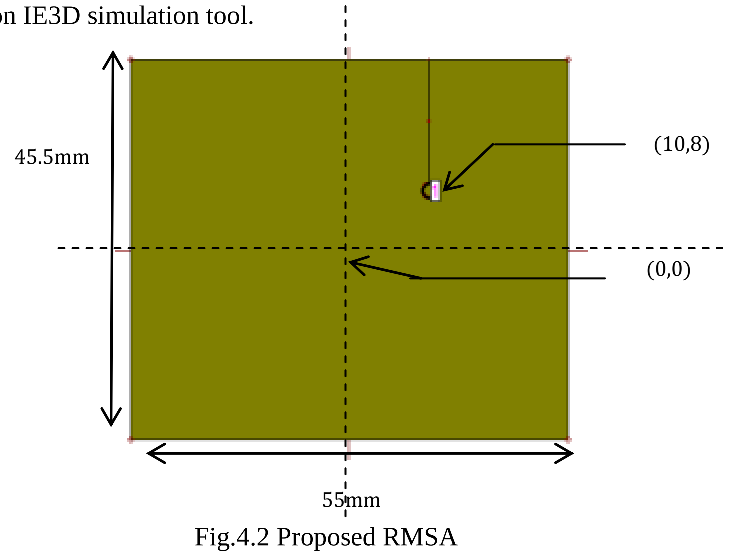

Fig.4.2 Proposed RMSA

5.1. EFFECT OF FEED LOCATION

The feed-point should be located at a point on patch where input impedance is 50 at resonance frequency. Return loss at different locations on the patch is compared and a point where return loss (RL) is most negative is selected as a feed-point. The centre of the patch is taken at origin and feed-point location is given by coordinates (Xf, Yf) with respect to origin. There exists a point along length where RL is minimum [1].Fig.4.3 shows the return loss plot. The feed point at (10, 8) giving most negative RL while from smith chart feed at (10, 8) giving 50Ω of impedance.

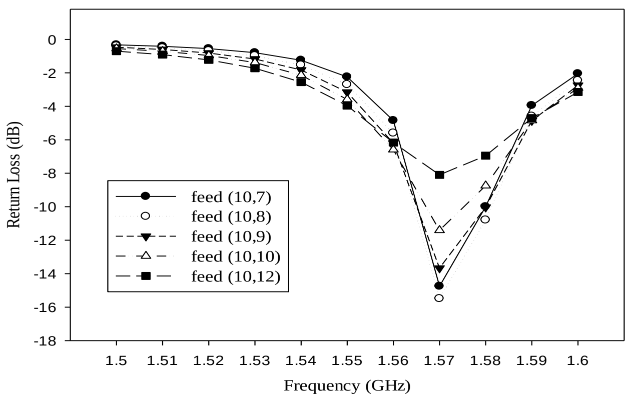

Fig.4.3. Effect of Feed Location on Return Loss

5.2. EFFECT OF HEIGHT

The RL plots for two different values of h (15 mm and 3 mm) are shown in Fig.5 for L = 55 mm,W = 44.5 mm, εr = 4.4 and feed at (10,08). Fig.4.4 shows the effect of height on return loss. With an increase in h from 1.5 mm to 3 mm, following effects are observed:

- With the increase in h, the fringing fields from the edges increase, which increases the extension in length L and hence the effective length, thereby decreasing the resonance frequency.
- On the other hand with the increase in h, the W/h ratio reduces which decreases e and hence increases the resonance frequency. However, the effect of the increase in ΔL is dominant over the decrease in εr. Therefore, the net effect is to decrease the resonance frequency.
- The input impedance plot moves clockwise (i.e., an inductive shift occurs) due to the increase in the probe inductance of the coaxial feed.
- The BW of the antenna increases. However, for the thicker substrate, this BW is not the maximum [8].

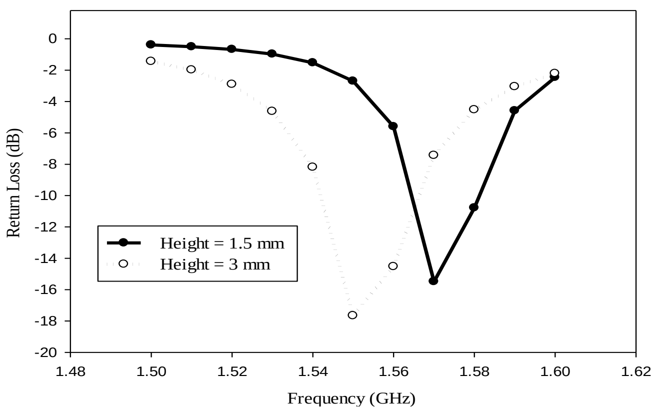

Fig.4.4. Effect of Height on Return Loss

5.3. EFFECT OF WIDTH

With an increase in W from 43.5 mm to 44.5 mm, the following effects are observed:

The resonance frequency decreases from 1.64 GHz to 1.57 GHz due to the increase in ΔL and εr.From fig.4.5 it is clear that, the BW of the antenna increases; however, it is not very evident from these plots, because the feed point is not optimum for the different widths. Accordingly, a better comparison will be obtained when the feed point is optimized for the individual widths [2].

5.4. EFFECT OF εr

For RMSA with L = 55 mm, W= 44.5 mm and feed at (10, 08), when εr is decreased to 1, the resonance frequency increases. A better comparison of effect of εr is obtained when the antenna is designed to operate in the same frequency range for different values of εr [1]. Fig.4.6 shows effect εr on return loss and bandwidth.

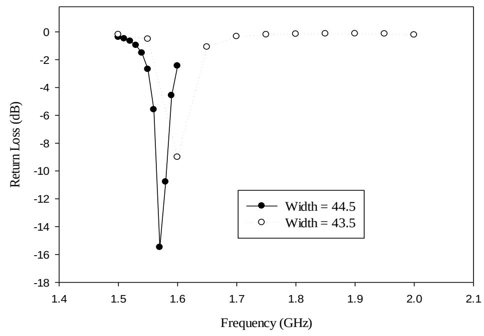

Fig.4.5. Effect on width on return loss and bandwidth.

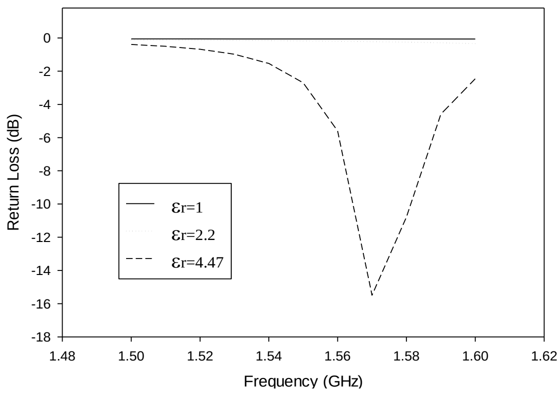

Fig.4.6. Effect of εr on Return Loss

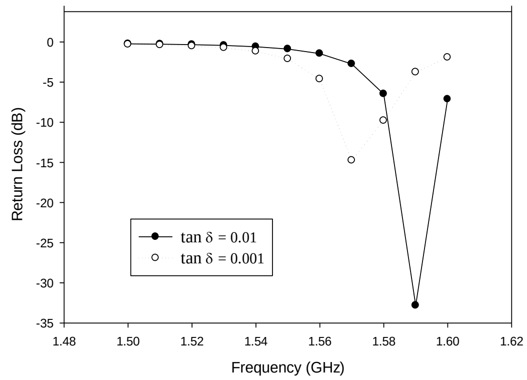

Fig.4.7. Effect of loss tangent on return loss

5.5. Effect of loss tangent (tan δ)

For RMSA with L = 55 mm, W= 44.5 mm and feed at (10, 08), when tanδ is decreased from 0.01 to 0.001 the resonance frequency decreases. Also it is found that lesser the loss tangent less the loss in probe giving the wider bandwidth. Fig.4.7 shows effect of loss tangent on return loss and bandwidth.

VI. RESULTS AND DISCUSSION

The table below show the above comparisons in a tabular format so that we can conclude the effect of parameters on resonance frequency and bandwidth.

Parameters	Resonance Frequency	Bandwidth
Feed Location	No shift	No Chage
Height	Increases	Increases
Width	Decreases	Decreases
εr	Decreases	Decreases
Loss Tangent	Increases	Decreases

A comparative study of effect various parameters on bandwidth and return loss of patch antenna is presented in this chapter. It was observed that, to increases resonance frequency height and loss tangent is to be increased whereas width and εr to be decreases. For increasing bandwidth, height is to be increased whereas width,εr, loss tangent is to be decreased.

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