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Impedance Matching For L-Band & S- Band Navigational Antennas

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***Abstract* - This paper presents an efficient design procedure for Impedance matching of L band & S Band patch antennas for Navigational applications .Computation used in designing is the transmission line method as it offers good physical insight. The designs are simulated using "ADS Advanced Design System". The paper presents simulated results for return loss, bandwidth & gain.**

***Keywords* - Coaxial fed micro strip antenna, Advanced Design System (ADS), Rectangular patch, Transmission line method, Return loss, FR4 substrate, Gain, Directivity**

I. INTRODUCTION

Antennas play a very important role in the field of wireless communications. Some of them are parabolic reflectors, patch antennas, slot antennas and folded dipole antennas. Each type of antenna is good in its own properties and usage. We can say antennas are the backbone and almost everything in the wireless communication without which the word could have not reached at this age of technology.

Patch antennas play a very significant role in today's world of wireless communication systems. A microstrip patch antenna is very simple in the construction using a conventional micro strip fabrication technique. The patch can take any shape but rectangular and circular configurations are the most commonly used configurations. These patch antennas are used as simple and for the widest and most demanding applications. Dual characteristics, circular polarizations, dual frequency operation, frequency agility, broad band width, feed line flexibility and beam scanning can be easily obtained from these patch antennas.

A microstrip antenna consists of conducting patch on a ground plane separated by dielectric substrate. Low dielectric constant substrates are generally preferred for maximum radiation, so we used the dielectric constant substrate 4.6.[1]

II. METHODOLOGY ADAPTED

A. Antenna Shape

In its most basic form, a Micro strip patch antenna consists of a radiating patch on one side of a dielectric substrate which has a ground plane on the other side as shown in Figure 1. The patch is generally made of conducting material such as copper or gold and can take any possible shape. The radiating patch and the feed lines are usually photo etched on the dielectric substrate.

Microstrip patch antennas radiate primarily because of the fringing fields between the patch edge and the ground plane. For good antenna performance, a thick dielectric substrate having a low dielectric constant is desirable since this provides better efficiency, larger bandwidth and better radiation .

B. Method of Analysis

This model represents the microstrip antenna by two slots of width W and height h , separated by a transmission line of length L. The microstrip is essentially a nonhomogeneous line of two dielectrics, typically the substrate and air.

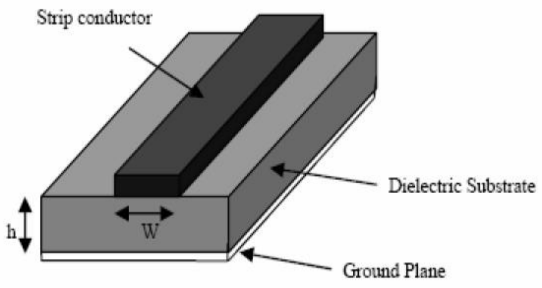

Figure 1 Micro strip Line

Hence, as seen from Figure 1, 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_{reff}) must be obtained in order to account for the fringing and the wave propagation in the line. The value of ε_{reff} is slightly less then ε_r because the fringing fields around the periphery of the patch are not confined in the dielectric substrate but are also spread in the air as shown in Figure 1 above. The expression for ε_{reff} is given by :[2]

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

Equation 1

Where
ε_{reff} = Effective dielectric constant
ε_r = Dielectric constant of substrate
h = Height of dielectric substrate
W = Width of the patch

Consider Figure 2 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.

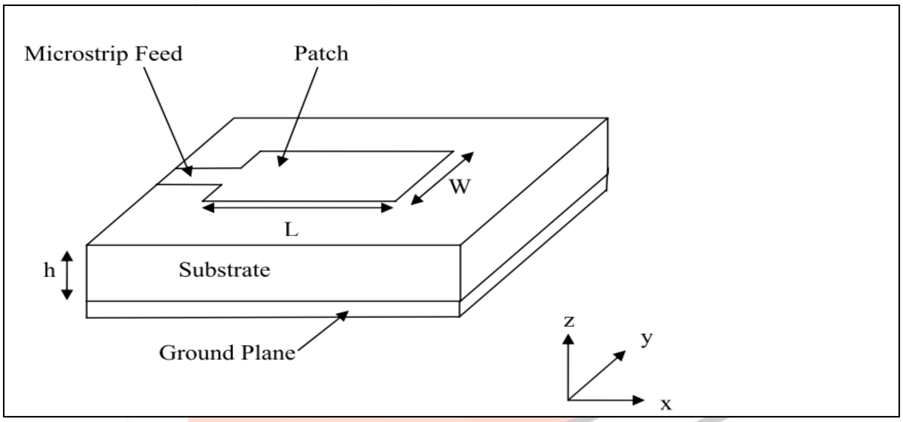

Figure 2: Basic configuration of the rectangular microstrip patch antenna

In order to operate in the fundamental TM10 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 λo /√(ε_{reff}).

Where λo is the free space wavelength. The TM10 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 Figure 3 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 due to the open ends. The fields at the edges can be resolved into normal and tangential components with respect to the ground plane.

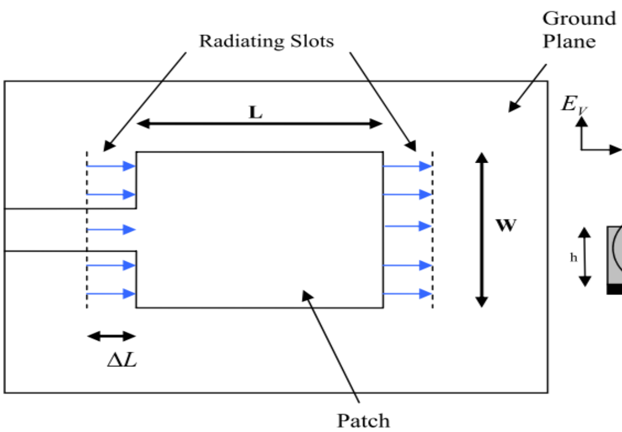

Figure 3: Top View of Antenna

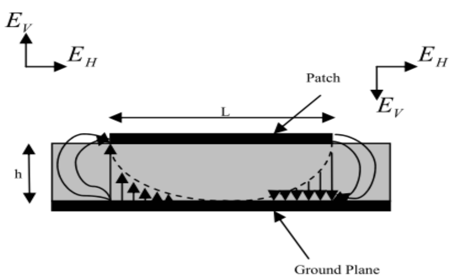

Figure 4: Electric Field Lines

It is seen from Figure 4 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 Figure 4), 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 modelled 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 Δ L, which is given empirically by Hammerstad as:

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

Equation 2

The effective length of the patch Leff now becomes:

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

Equation 3

For a given resonance frequency fo, the effective length is given by [1] as:

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

Equation 4

For a rectangular Micro strip patch antenna, the resonance frequency for any TMmn mode is given by James and Hall as[9]:

$$f_o = \frac{c}{2\sqrt{\varepsilon_{reff}}}\left[\left(\frac{m}{L}\right)^2+\left(\frac{n}{W}\right)^2\right]^{\frac{1}{2}}$$

Equation 5

Where m and n are modes along L and W respectively.

For efficient radiation, the width W is given by Bahl and Bhartia [10] as:

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

Equation 6

C. Feed Point

The Coaxial feed or probe feed is a very common technique used for feeding Micro strip patch antennas. As seen from Figure 5, the inner conductor of the coaxial connector extends through the dielectric and is soldered to the radiating patch, while the outer conductor is connected to the ground plane. The feed co-ordinates were calculated $Y_f = W/2$ and $X_f = X_0 - \Delta L$ where,[2]

$$X_0 = \frac{L}{\pi}\cos^{-1}\sqrt{\frac{50}{Z_0}}$$

Equation 7

$$Z_0 = \sqrt{50 \times Z_{in}}$$

Equation 8

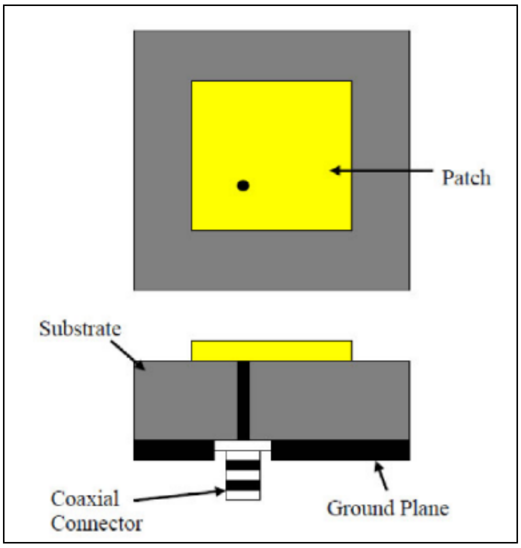

Figure 5: Coaxial Feed

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 ($h > 0.02\lambda_0$). Also, for thicker substrates, the increased probe length makes the input impedance more inductive, leading to matching problems [2]. It is seen above that for a thick dielectric substrate, which provides broad bandwidth, the micro strip line feed and the coaxial feed suffer from numerous disadvantages. The non-contacting feed techniques which have been discussed below, solve these problems.

D. Dielectric Substrate

Considering the trade-off between the antenna dimensions and its performance, it was found suitable to select a thin dielectric substrate with low dielectric constant. Thin substrate permits to reduce and low dielectric constant − for higher bandwidth, better efficiency and low power loss. The simulated results were found satisfactory.[3]

III. DESIGN ANALYSIS

A. Design Specification

The three essential parameters for the design of a rectangular Micro strip Patch Antenna are:

• *Frequency of Operation*:

The resonant frequency of the antenna must be selected appropriately. The resonant frequency Selected for my design is L Band (1.5 GHz) and S Band (2.6 GHz).

• *Dielectric constant of the substrate (ε_r):*

The dielectric material selected for my design is FR4 which has a dielectric constant of 4.6.

• *Height of dielectric substrate (h)*

Height of dielectric substrate is 1.5mm.

Sr No.	Parameter	Design-1	Design-2
1	Frequency Band	L band(1.5 GHz)	S band(2.6 GHz)
2	Dielectric constant of the substrate (ε_r)	4.6	4.6
3	Tangent Loss	0.01	0.01
4	Height of dielectric substrate (h)	1.5 mm	1.5mm
5	Calculation of the Width (W)	60 mm	35 mm
6	Calculation of actual length of patch (L)	44 mm	25 mm

Table 1: Dimension of microstrip [8]

B: Simulation Result for L band[7][8]

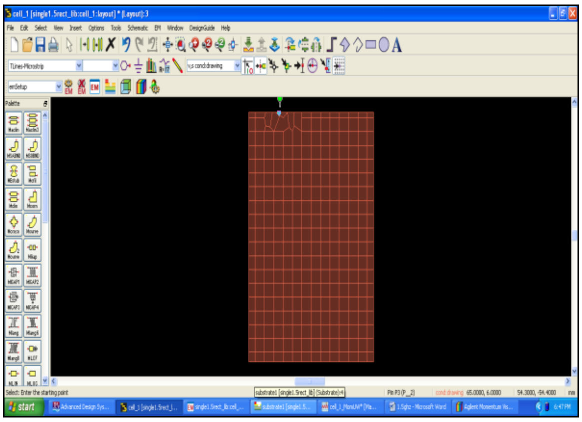

Figure 6: Geometry of purposed antenna

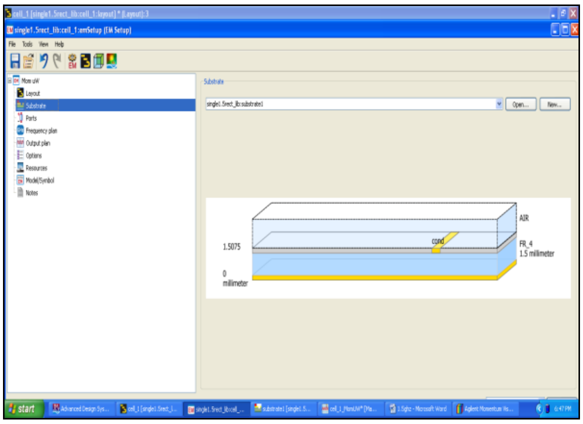

Figure 7: Substrate Selection

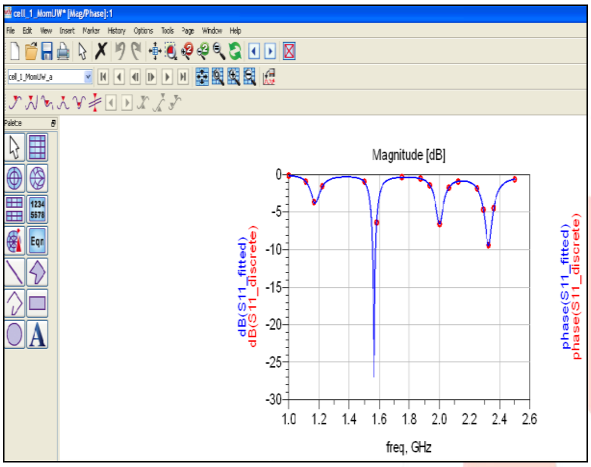

Figure8: Return loss Vs frequency plot

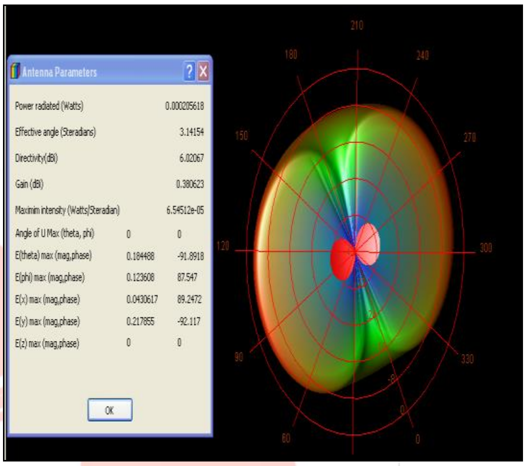

Figure 9: Radiation Pattern

C: Simulation Result for S band:[7][8]

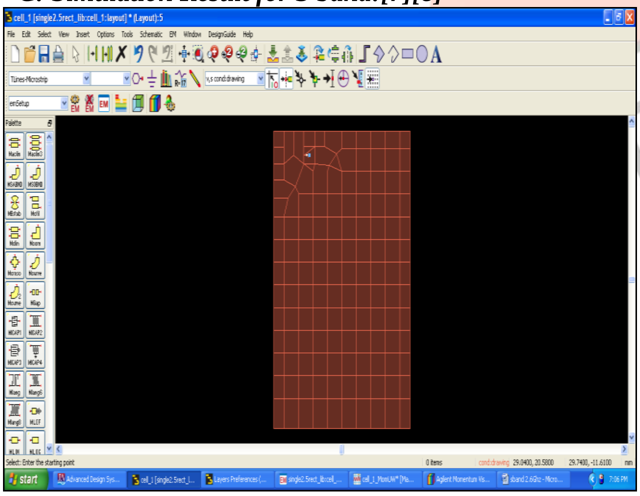

Figure 10: Geometry of purposed antenna

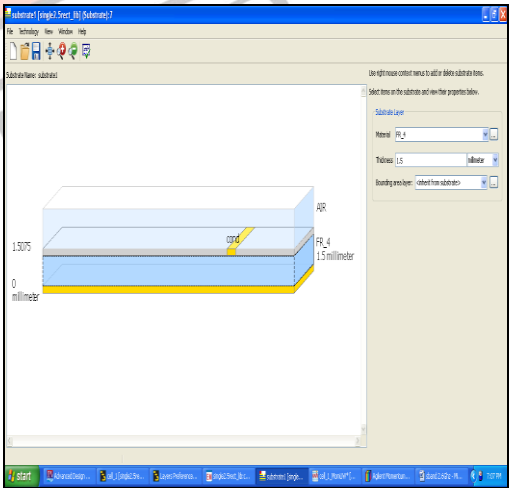

Figure 11: Substrate Selection

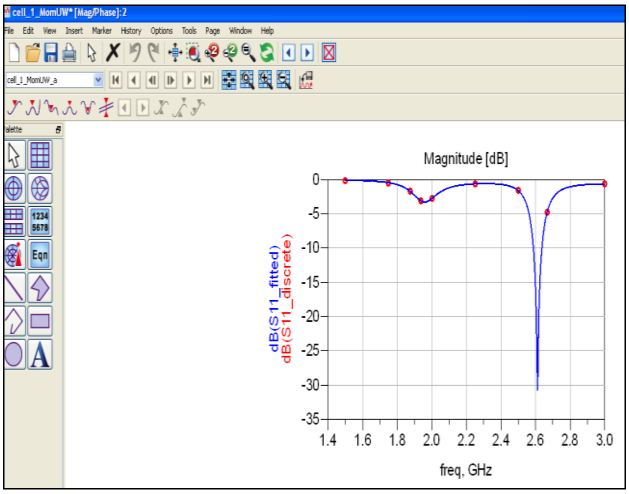

Figure 12: Return lossVs frequency plot

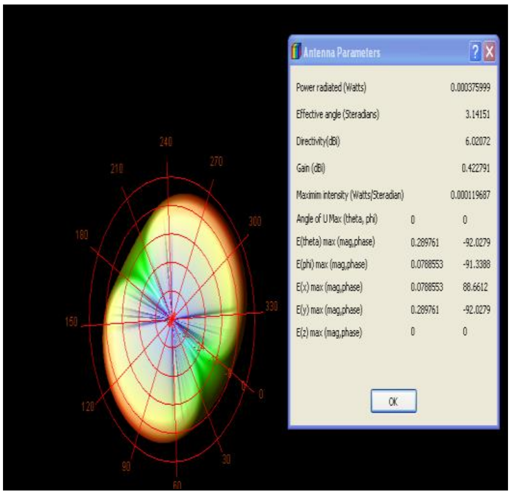

Figure13: Radiation Pattern

IV. CONCLUSIONS & FUTURE WORK

The rectangular microstrip patch antenna was designed with FR4 material as a substrate at frequency of 1.5GHz and 2.6 GHz. The dielectric constant of the FR4 is 4.6.The Simulation is carried out using ADS software and its characteristics such as directivity ,power radiated , gain and return loss are analysed. In future we will design dual band antenna Navigational Satellite with high bandwidth and gain which can be useful for application such as accurate positioning as well as for Defense.

V. ACKNOWLEDGEMENT

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