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Effect of quality factor on parameters of planar antenna for wireless applications

KEYWORDS Antenna Losses, Bandwidth, Planar antennas, Quality Factor (Q), Radiation Efficiency.

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ABSTRACT The quality factor is a figure-of-merit that is representative of the antenna losses. Typically there are radiation, conduction (ohmic), dielectric and surface wave losses present in planar antennas. Planar antennas are high-Q devices with Qs sometimes exceeding 100 for the thinner elements. But, high-Q elements have small bandwidths. Also, the higher the Q of an element, the lower is its efficiency. Increasing the thickness of the dielectric substrate will reduce the Q of the planar element and thereby increase its bandwidth and its efficiency. There is a need to analyze individual quality factors also and optimize them to achieve a significant trade-off between gain and losses. When the losses are low but not lowest the radiation efficiency is also found to be optimum. We design planar antenna for 7.5 GHZ frequency subtracting three different material like FR4, Rogers RT(5870) and Teflon(PTFE).and find out effect of different antenna parameters. And also make competitive table of different losses in term of Quality factor Q.

In this Paper I have analyze two different planner antenna using two different materials such as FR4 and Teflon (PTFE). I have designed planner antenna using computer simulatation technology (CST).

After analyzing the result of two different materials of planner antenna will the different types of Quality factor losses. I can conclude that the Teflon (PTFE) material is best with the compare FR4. We can also getting good result with other materials of planner antenna. To further reducing the Quality factor losses.

I. INTRODUCTION

Microstrip antennas (MSA) offer many attractive features such as low weight, small size, ease of fabrication, ease of integration with Microwave Integrated Circuits (MIC) and can be made conformal to host surface. However, they suffer from low gain, narrow bandwidth, low efficiency, and low power handling capability . Cutting a slot in microstrip patch antenna is used to reduce impedance mismatch and to enhance the bandwidth. The configuration of an air gap is competent influencing a stronger fringing field at the edge of the patches. The fringing fields become stronger as the distance is getting increased. A strong fringing fields leads for the patches to radiate even further. The air gap increased the radiated power and reduced conductor loss .However the bandwidth, gain and size of the antenna are generally mutually conflicting properties that is improvement of one of the characteristics normally results in the degradation of the other.[1]

With using C band range 6-9GHZ application of satellite communication we using the 7.5 GHZ frequency. The proposed microstrip antenna is design and simulated using CST Microwave Studio.

Microstrip patch antennas can be fed by a variety of methods. These methods can be classified into two categories – contacting and non-contacting. The four most popular feed techniques used are the microstrip line, coaxial probe, aperture coupling and proximity coupling.

1) Microstrip Line Feed

In this type of feed technique, a conducting strip is connected directly to the edge of the microstrip patch as shown in Figure 1. The conducting strip is smaller in width as compared to patch and this kind of feed arrangement has the advantage that the feed can be etched on the same substrate to provide a planar structure.[1]

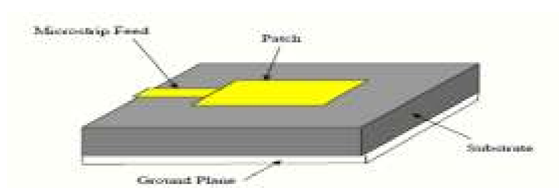

Figure 1: Microstrip Line Feed

The purpose of the inset cut in the patch is to match the impedance of the feed line to the patch without the need for any additional matching element. This is achieved by properly controlling the inset position. The feed radiation also leads to undesired cross polarized radiation.[1]

2) Coaxial Feed

The Coaxial feed or probe feed is a very common technique used for feeding Microstrip patch antennas. As seen from Figure 2, 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 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.[1]

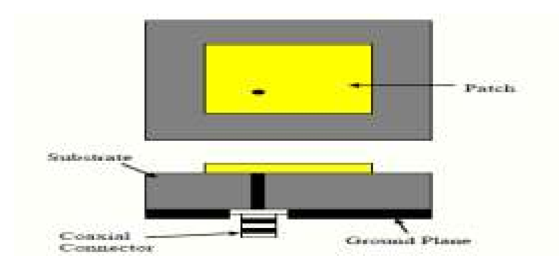

Figure 2: Probe fed Rectangular Microstrip Patch Antenna

This feed method is easy to fabricate and has low spurious radiation. Its major disadvantage is that it provides narrow

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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 > 0.02λo). Also, for thicker substrates, the increased probe length makes the input impedance more inductive, leading to matching problems.[1]

3) Aperture Coupled Feed
In this type of feed technique, the radiating patch and the microstrip feed line are separated by the ground plane as shown in Figure 3.

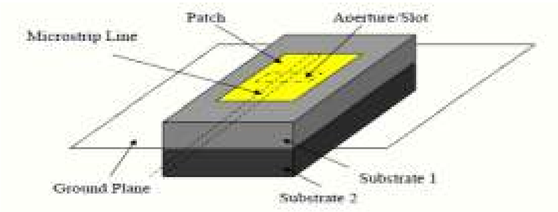

Figure 3: Aperture-coupled feed

The coupling aperture is usually centred under the patch, leading to lower cross polarization due to symmetry of the configuration. The amount of coupling from the feed line to the patch is determined by the shape, size and location of the aperture. Since the ground plane separates the patch and the feed line, spurious radiation is minimized. The major disadvantage of this feed technique is that it is difficult to fabricate due to multiple layers, which also increases the antenna thickness. This feeding scheme also provides narrow bandwidth.[1]

4) Proximity Coupled Feed
This type of feed technique is also called as the electromagnetic coupling scheme. As shown in Figure 4, two dielectric substrates are used such that the feed line is between the two substrates and the radiating patch is on top of the upper substrate. The main advantage of this feed technique is that it eliminates spurious feed radiation and provides very high bandwidth, due to overall increase in the thickness of the microstrip patch antenna. This scheme also provides choices between two different dielectric media, one for the patch and one for the feed line to optimize the individual performances. Matching can be achieved by controlling the length of the feed line and the width-to line ratio of the patch. The major disadvantage of this feed scheme is that it is difficult to fabricate because of the two dielectric layers which need proper alignment.[1]

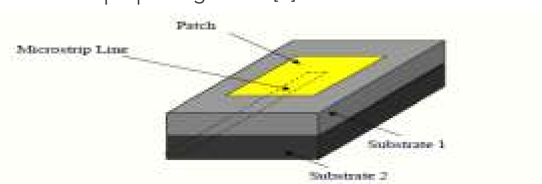

Figure 4: Proximity-coupled Feed

II. FUDENTAMEL AND FOOTPRINT EQUATION

As a measure of antenna performance, the quality factor can generally be defined in three ways: (i) as a relation between the stored reactive energy and the radiated power of the antenna, (ii) as a function of its impedance or admittance, and (iii) as a function of its bandwidth. Every approach has its own physical meaning and yields different operational limits.[6]

The quality factor is a figure-of-merit that is representative of the antenna losses. Typically there are radiations, conduction (ohmic), dielectric and surface wave losses. Therefore the total quality factor Qt is influenced by all of these losses and is, in general, written as,

$$\frac{1}{Qt} = \frac{1}{Qrad} + \frac{1}{Qc} + \frac{1}{Qd} + \frac{1}{Qsw} \qquad (1)$$

Where, Qt = total quality factor
Qrad= Quality factor due to the radiation (space wave) losses
Qc= Quality factor due to the conducting (ohmic) losses
Qd= Quality factor due to the dielectric losses
Qsw= Quality factor due to the surface waves

For very thin substrates, the losses due to surface waves are very small and can be neglected. However, for thicker substrates they need to be taken into account. These losses can also be eliminated by using cavities. There are approximate formulas to represent the quality factors of the various Losses can be expressed as,

$$Qc = h\sqrt{\pi f \mu \sigma} \qquad (2)$$

$$Qd = \frac{1}{\tan \delta} \qquad (3)$$

$$Qrad = \frac{2\omega \varepsilon r}{hGt/l} K \qquad (4)$$

Where, tan δ is the loss tangent of the substrate material, Σ is the conductivity of the conductors associated with the patch and ground plane, Gt/l is the total conductance per unit length of the radiating aperture.[6]

III. DESIGN AND SIMULATION RESULT
The rectangular patch antenna is approximately a one-half wavelength long section of rectangular Microstrip transmission line. When air is the antenna substrate, the length of the rectangular Microstrip antenna is approximately one-half of a free-space wavelength. The length of the antenna decreases as the relative dielectric constant of the substrate increases.

The resonant length of the antenna is slightly shorter because of the extended electric "fringing fields" which increases the electrical length of the antenna slightly.

Frequency of operation (fr): The Resonant frequency of the antenna must be selected appropriately. The ISM Systems uses the frequency band 6-9 GHZ .The resonant frequency selected for my design is 7.5GHz. [2]

Dielectric constant of the substrate (Er): The dielectric constant of substrate material plays an important role in the patch antenna design. A substrate with a high dielectric constant reduces the dimensions of the antenna but it also affects the antenna performance. So, there is a trade-off between size and performance of patch antenna. The Dielectric constant of the substrate selected for my Design is Er = 4.3, 2.1. [2]

Height of dielectric substrate (h): For the Microstrip patch antenna to be used in communication systems, it is essential that the antenna is not bulky. Hence, the height of the dielectric substrate should be less. The height of the substrate selected for my design is 1.6 mm. After the proper

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selection of above three parameters, the next step is to calculate the radiating patch width and length.[2]

Step 1: Calculation of Width (W) [2]
For an efficient radiator, practical width that leads to good radiation efficiencies is,

$$W = \frac{c}{2f_0\sqrt{\frac{\varepsilon r+1}{2}}} \tag{5}$$

Where c is the free space velocity of light.

Step 2: Calculation of Effective Dielectric Coefficient (εreff)[2]
The effective dielectric constant is

$$\varepsilon reff = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2}\left[1+12\frac{h}{W}\right]^{-\frac{1}{2}} \tag{6}$$

Step-3:- Calculation of Effective Length (Leff)[2]

$$Leff = \frac{c}{2f_0\sqrt{\varepsilon reff}} \tag{7}$$

Step 4: Calculation of the Length extension (ΔL) [2]

$$\Delta L = 0.412h\frac{(\varepsilon reff+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon reff-0.258)\left(\frac{W}{h}+0.8\right)} \tag{8}$$

Step 5: Calculation of actual Length of Patch (L) [2]

$$L = Leff - 2\Delta L \tag{9}$$

The actual length of radiating patch is obtained by
Design Rectangular Micrstrip Patch antenna using three different subtracting materials with using different length, width, height and tangent losses as shown in table 1.

Table 1: Input parameter comparison in terms of different substrate

Material Name	Dielectric Constant	Loss tangent	Height Of the Substrate (mm)	Length Of the Patch (mm)	Width Of the Patch (mm)
FR4	4.3	0.025	1.6	8.98	12.28
Teflon (PTFE)	2.1	0.0002	1.6	12.75	16.05

Comperratative Return Loss Plot

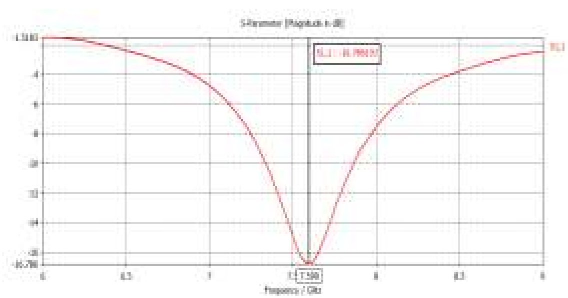

Figure1: Return Loss Plot using Fr4

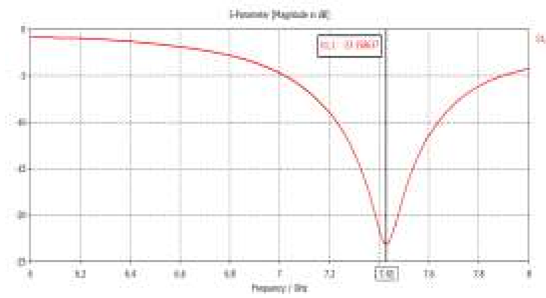

Figure 2: Return Loss Plot using Teflon (PTFE)

Table 2: Output parameter comparison in terms of different substrate

Material name	Return Loss (S11)	VSWR	BW (MHZ)	BW (%)	Gain (db)	Directivity (dbi)
FR4	-16.78	1.33	0.5263	6.92	4.8	6.4
Teflon	-23.15	1.14	0.4064	5.46	5.84	5.9

Table 3: Comperratative table of Quality factor due to different Losses

Material Name	Qc	Qd	Qsp	Qsw	Qt
FR4	1.2499×10ˆ9	39.99 16	1.4522	0.4247	43.118×10ˆ9
Teflon	1.2221×10ˆ9	4.99×10ˆ3	1.97139 ×10ˆ7	1.43698×10ˆ7	9.62047×10ˆ26

Conclusion
Here in this, report I have presented the design of rectangular microstrip patch antenna using two different materials like FR4, Teflon (PTFE) and their various results obtained such as return loss, VSWR, bandwidth, radiation pattern in polar plot, which are presented in this report.

Using a FR4 material I got the 5.11% Bandwidth, 31.655 Quality factor and using Teflon (PTFE) material I got the 2.52% bandwidth, 4.803Quality factor. Using Teflon (PTFE) Achieve less bandwidth and Quality factor losses. Bandwidth decreases so radiation power is also decreases and efficiency increases compare to FR4.

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