Different Substrates Use in Microstrip Patch Antenna-A Survey

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Abstract: ***Here we discussed different dielectric substrate frequently used in microstrip patch antenna to enhance overall efficiency of antenna. Various substrates like foam, duroid, benzocyclobutane, roger 4350, epoxy, FR4, Duroid 6010 are in use to achieve better gain and bandwidth. A dielectric substrate is a insulator which is a main constituent of the microstrip structure, where a thicker substrate is considered because it has direct proportionality with bandwidth whereas dielectric constant is inversely proportional to bandwidth as lower the relative permittivity better the fringing is achieved. Another factor that impact directly is loss tangent it shows inverse relation with efficiency the dilemma is here is that substrate with lower loss tangent is costlier. A clear pros and cons are discussed here of different substrates for judicious selection. A substrate gives mechanical strength to the antenna.***

Keywords: Microstrip Patch Antenna, Metamaterials, Survey of Substrates, Circular Patch, FR 4 epoxy

1. Introduction

1.1 Microstrip Patch Antenna

Microstrip patch antenna in recent years emerged a lot in different field of communication such as mobile communication, satellites, wireless local area networks etc. its pros are its light weighted, low volume, low fabrication though it has disadvantages as well but mostly worked on is its narrow bandwidth which is challenging to meet high data rate. Many techniques have been implemented by researchers like cutting slots, different patch shapes and notches are used. Demand of compact and easy to fabricate antenna is escalating.

To design a Microstrip Patch Antenna the following are the requirements:

- Type of substrate
- Shape of patch
- Dimension of patch
- Feeding technique
- Resonant frequency
- Substrate thickness

Though all above are the requirements for antenna fabrication but for the best results right substrate selection is a must on the basis of cost, efficiency and size. Role of feeding technique is considerable. Feeding techniques divided into following:

a) Contacting: radio frequency is fed directly to the radiation patch using the connecting element e.g. Micro strip line.
b) Non-contacting: electromagnetic field coupling is done to transfer power between the microstrip line and the radiating patches e.g. aperture feeding technique and proximity feeding technique.

2. Related Work

Lot of work has been done on different substrates .Substrates use in microstrip patch antenna varies from 2.2≤Ɛ≤12. Lower the permittivity of dielectric material larger the size of the antenna but it achieves better efficiency and larger bandwidth. The ε_r is limited by radio frequency or microwave circuit connected to antennas. When substrate of higher dielectric constants were used than the performance result degrades. Air with least dielectric constant of 1 shows least return loss of -22.6449 whereas Benzocyclobutane with dielectric constant of 2.6 return loss is -18.1248[1]. With the use of Duroid 6010 which is counted among the higher dielectric constant substrate i.e. 10.7 used in phased array 1×4 at 1.35 GHz . It showed optimized results [5].

A nylon fabric is a substrate considered among medium dielectric constant with dielectric constant 3.6. Work has been done to demonstrate the antenna fabricated using nylon fabric .antenna resonates at 989 MHz it result in return loss of -35.42dB, directivity of 6.72dB, Gain of 6.11dB.

Fractal shaped microstrip patch antenna is also implemented using the foam substrate. It reduced the size of the antenna up to 84%. RT-Duroid substrate is costlier than LCP (liquid crystal polymer) but RT-Duroid gives better performance in term of gain, directivity and bandwidth [4].

3. Theoretical Evaluation and Effect of Substrate Permitivity

Width W controls the input impedance larger width shows larger bandwidth.

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

Effective substrate permittivity:

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

Substrate permittivity effect on resonant frequency:

$$(f_r)_{110} = \frac{1.8412 v_0}{2\pi a_e \sqrt{\varepsilon_r}}$$

In rectangular patch antenna effective substrate and effective length relation:

$$L_{eff} = \frac{c}{2 f_0 \sqrt{\varepsilon_{reff}}}$$

For circular patch effective radius relation with substrate permittivity:

$$a_e = a\left\{1+\frac{2h}{\pi\varepsilon_r a}\left[\ln\left(\frac{\pi a}{2h}\right)+1.7726\right]\right\}^{1/2}$$

4. Limitations

Most compact microstrip antenna designs show decreased antenna gain due to the antenna size reduction. To overcome this disadvantage and obtain an enhanced antenna gain, high permittivity dielectric constant substrate to fabricate compact microstrip patch antenna. If we use a substrate of a high-permittivity antenna gain that can be achieved is 10 dBi with a smaller radiating patch. Conductor and dielectric losses become more severe for thinner substrate. Surface wave losses become more severe for thicker substrate. When the dimensions of antenna is large than surface waves and spurious feed radiation increases. Effective dielectric constant is larger than relative permittivity this is because of fringing effect as it is not confined to dielectric constant speared in the air.

5. Comparison on Various Substrates of Antenna

Substrates	*Ɛr*	*Loss tangent*	*Resonance frequency*	*Return Loss*	*Gain*
Benzocyclobutane	2.6	0	2.04GHz	-18.124	5.5
Duroid 6010	10.7	.0060	2.455	-9.449	4.02
Nylon fabric	3.6	.0083	989MHz	-35.42	6.11
Roger 4350	3.48	.004	2.586GHz	-25.29	4.62
RT-Duroid	2.2	.0009	10GHz		12.03
Foam	1.05	0	454MHz	-16.732	2.73
FR-4	4.4	.018	5.8GHz	-14.73	9.8

Substrates	*Size Reduction*	*Bandwidth*	*Efficiency*
Benzocyclobutane	Medium	medium	96.51
Duroid 6010	Lowest	minimum	93.51
Nylon fabric	Medium	medium	
Roger 4350	Medium	medium	99.66
RT-Duroid	Medium	medium	88.64
Foam	Highest	maximum	61
FR-4	Medium	medium	99.60

6. Conclusion

There are many more substrates available. They are not found naturally. They can be developed in laboratories that have negative refractive index. There are large numbers of metamaterials that are developed but not all are being used in the microstrip patch antenna designing due to the limitations. In the Table 1 we have shown comparison between few substrates. The criterion for selection of right substrate is its price, efficiency and size. Minimum size is achieved by using foam substrate but it is costlier and losses are higher in it even the efficiency is much less than others. Maximum efficiency is achieved in roger 4350 but the size and price are the issues in it. Than an optimal solution is FR-4 substrate but it sometimes requirement dependent.

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