EFFECTS OF SUBSTRATE PERMITTIVITY ON PIFA ANTENNA

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***Abstract*:**

The wireless communication is popular for communication as our day to day need is increasing for better service. In recent, wireless systems are so advanced and for better response they need small size antennas but at the same side they have to give good performance. The PIFA is advised to use in small equipments like mobile phones. Substrate permittivity affects the matching bandwidth, polarization and gain. The paper configures the bandwidth matching and returns loss variations with different dielectric substrates. The radiating square patch of fixed dimension 26mm × 38mm is examined with effects of lossy and perfect dielectric substrate.

Keywords- PIFA, substrate materials, Return Loss, Radiation Pattern, FR4, WiMAX, UMTS, HyperLAN, WLAN.

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I. INTRODUCTION

A PIFA antenna with broad AR and impedance bandwidth is proposed. The antenna is covering the whole required band of RFID from 840MHz to 960MHz [1]. Also by analyzing with variation in design and materials antenna can achieve UMTS, WiMAX 3500 and Hyper LAN2 (5.47-5.825) bandwidths. PIFA antenna is popular for wireless devices because of its small size, low profile. It's also have some advantages like fabrication is easy, low manufacturing cost and simple structure. The big Disadvantage of PIFA antennas is that they put out result having narrow bandwidth. So there should be some ways to better out the results by making antennas to have Broadband in PIFAs.

The Objective of this report is to make the PIFA antenna with Broadband achievement and modifying it to examine and achieve better Capacity, broadband, return loss and gain. For this different method like using different permittivity materials in an antenna can be examined.

Two methods can be used to examine the effects on bandwidth and return loss. First by examining the change with fixed antenna dimensions and second method is by making constant PIFA resonant frequency, while change in antenna dimensions. Here, in this paper the evaluation is done by having fixed patch dimensions. Air and other dielectric materials provided by HFSS, such as FR4_Epoxy, Mica, Silicon-Nitrate, Alumina, and Roger3210 are used to quantify the performance variations of the PIFA.

II. THEORY

PIFAs are compact micro-strip antennas with a shorting stub connecting the radiating element to the ground plane. The short introduces a return path for the facial currents of the antenna and triggers resonance for electrical dimensions smaller than half of wavelength (λ/2). The resonant frequency is given by

$$f_r \approx \frac{c}{4\sqrt{\varepsilon_{reff}}(l_1 + l_2 - w + h)}$$

where *c* is the velocity in free space, *l1* and *l2* are the dimensions of the radiating patch, *w* is the width of the short, *h* is the thickness of the substrate and ε_{eff} is the effective permittivity of the substrate material between the radiating patch and the ground plane[2]. The effective permittivity (ε_{eff}) is approximated using

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2}$$

It should be observed from the equation that the resonant frequency of a PIFA is affected not only by the physical lengths (*l1* and *l2*), but also by the width of the short (*w*) and the thickness (*h*) of the substrate material. For fixed radiating patch lengths, the resonant frequency increases as *w* decreases [2].

III. DESIGN AND MODELING

Using Ansoft HFSS v.13, the geometry of PIFA is evaluated. The patch is of dimension 26 mm × 38 mm. The substrate thickness is 1.6 mm. The shorting plate used in between the patch and ground of width 1 mm. Here we are using rectangular patch. The ground plane is of having dimensions 100 mm × 45 mm.

The design is fed by single feeding pin. The short is at located at the edge of the patch and it is 16 mm distance away from the feeding point. Thickness t of substrate is 1.6.And the width w of shorting pin is of value 1.The top view of proposed antenna is given Fig.1.

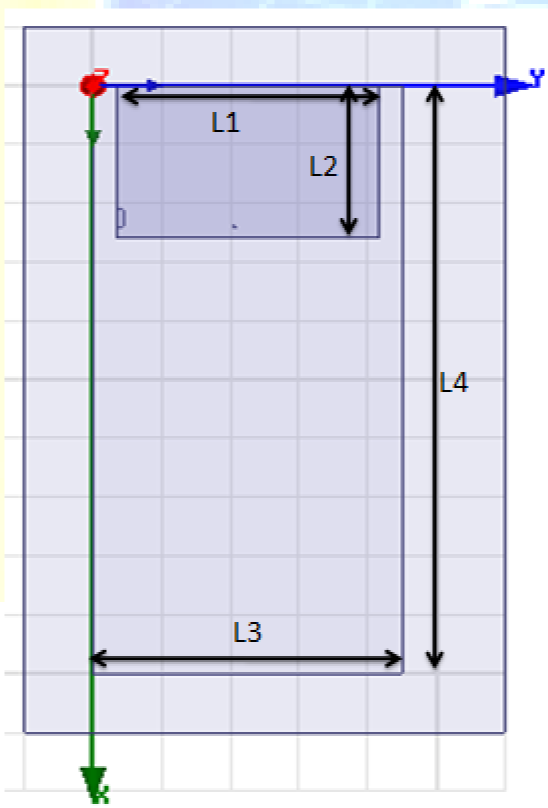


Fig. 1 Top view of Geometry

The side view of antenna geometry is shown in the Fig.2. In which the feed position and short plate positions can be seen.

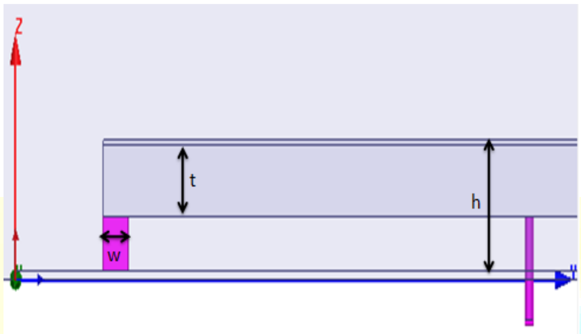


Fig. 2 Side view of Antenna

The Figure shows the inverted F structure is formed by coaxial pin and shorting plate. Also the dimensions of geometry are shown in Table I.

Table I Dimensions of Geometry

Parameter	L1	L2	L3	L4	h	t	w
Value(mm)	38	26	45	100	2.8	1.6	1

IV. SIMULATION RESULTS

We have examined the antenna with different substrate materials having different permittivity and loss tangent. We have used so many materials like FR4-epoxy, Mica, Silicon-Nitrate, Alumina, and Roger3210. In this paper we have showed the result of two of them. And the others are tabulated. The S11 parameter of FR4 substrate is shown below. FR4 substrate has Permittivity of 4.4 and the loss tangent 0.02. The S11 parameter using FR4 substrate is given below in Fig.3.

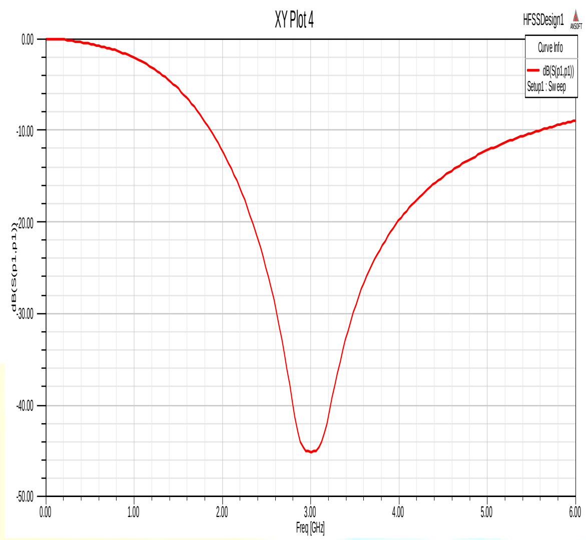


Fig. 3 Return Loss (S_{11}) parameter using FR4 substrate

Using FR4 Substrate, we have seen the effects on Bandwidth and Return Loss. As from this we can see the proposed antenna has broadband impedance matching characteristics from 1900 to 5600 MHz defined by s11<-10 dB which covers UMTS, WiMAX3500 and WLAN5800 band.

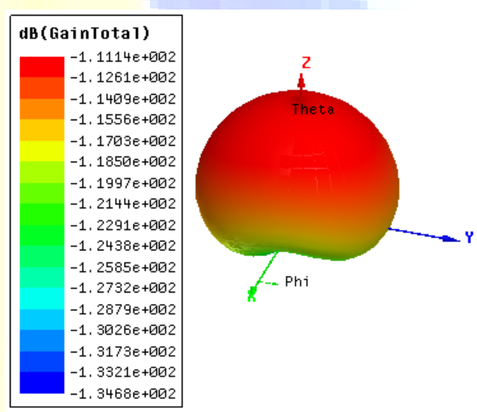
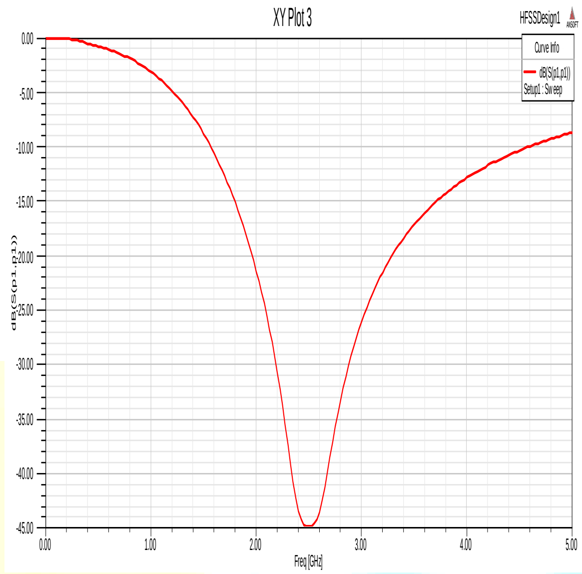


Fig.4 3D Radiation plot of antenna

Fig. 4 shows the simulated 3D radiation patterns of the antenna element. It can be seen that the antenna have orthogonal polarizations and radiation patterns.

The S11 parameter of the Mica substrate is given below. Mica substrate has permittivity of 5.7 and loss tangent 0.0002. The S11 parameter using Mica is given below in Fig.5.



. Fig.5 S11 Parameter using Mica

Using Mica we have seen the effects of Bandwidth and Return loss. As from the Fig.5 we can see the antenna has broad impedance matching characteristics from 1590 to 4600 MHz defined by S11<-10 dB WLAN 5800 band.

Now, the table II below will summarize the change in Bandwidth impedance and Return loss with using different substrate permittivity.

Table II Antenna results with fixed Dimensions and substrate variation

Material	ε_r	Loss Tangent δ	Matching Bandwidth (MHz)	Return Loss (dB)
FR4	4.4	0.02	3700	-45
Mica	5.7	0.002	3010	-45
Silicon Nitrate	7	0.001	3710	-45
Alumina	9.4	0.01	3700	-44
Roger3210	10.2	0.003	3720	-45

V. CONCLUSION

The antenna is designed with the rectangular patch. The Design is modified as by increasing the height of antenna to get better impedance matching and bandwidth. The design in this has modified by varying the substrate materials. We have examined the change in return loss and Bandwidth with the increase in substrate permittivity. We have seen the 3D polar plot of antenna element. The plot shows that antenna is Omni-directional in x-y-z plane. The S11 plots and Radiation patterns are shown in the report. From these plots we can recognize the Return loss for different substrates and its almost coming about -45 dB. The bandwidth is being decreasing as the substrate permittivity increases. We achieved the band of about 1900 to 5600 MHz defined by s11<-10 dB which covers UMTS, WiMAX3500, Hyper LAN2 (5.47-5.825) and WLAN5800 band.

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