To Study the Effect of Different Substrates and Superstrate material for Triple Band Micro Strip Patch Antenna

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Abstract — The requirement for the present day wireless communication system is compact, low profile antenna with simple feed which is inexpensive. In this paper rectangular patch antenna with F-shaped slot and defected ground plane are used to obtain three different bands which covers entire WLAN (2.4/5.2/5.8) and WiMAX (2.5/3.5/5.5) bands. HFSS (High frequency structure simulator) is used to design the antenna. The antenna is designed using different substrates and a superstrate which is placed at optimum distance above the antenna to increase the gain. The performance of an antenna is studied by changing the substrate material and the position of superstrate.

Key Words: Wireless Communication System; Triple-band; Substrate; Superstrate; WLAN; WiMAX;

1. INTRODUCTION

Modern wireless communication system requires low profile, light weight, high gain and simple structure antennas to assure mobility and high efficiency. Micro strip patch antenna can be used based on these requirements. The application of multiband patch antenna in wireless communication, mobile communication and satellite communication has increased in recent times. The communication standards are Worldwide Interoperability for Microwave Access (WiMAX) and Wireless Local Area Network (WLAN) [1] - [8]. These are the modern multi service wireless communication system which use multiband antenna.

An antenna is used as a transducer to transmit or receive electromagnetic waves. One side of micro strip patch antenna is made up of a radiating patch on one side and ground plane on the other side of the dielectric substrate. The antenna obtains mechanical strength from the substrate [9]. If the material of the substrate changes it changes the system performance because of different dielectric constant [10]. The dielectric constant of the substrates ranges from $2.2 \le \varepsilon_r \le 12$ [11]. The patch size of the antenna reduces for higher dielectric constant. Thus the selection of substrate material places an important role in designing the antenna.

The conventional micro strip patch antenna with superstrate increases the gain of the antenna by placing it at an optimum distance from the antenna. The superstrate material is same as of substrate material [12] – [15].

2. ANTENNA DESIGN AND CONFIGURATION

2.1. Conventional micro strip patch antenna.

The micro strip patch antenna has been designed using computed dimensional details. The geometry of the rectangular micro strip patch antenna is shown figure 1. The antenna is designed using FR4 substrate with thickness ‘h’ of 1.6 mm and Relative permittivity ‘ε_r’ of 4.4. The HFSS software is used for simulation.

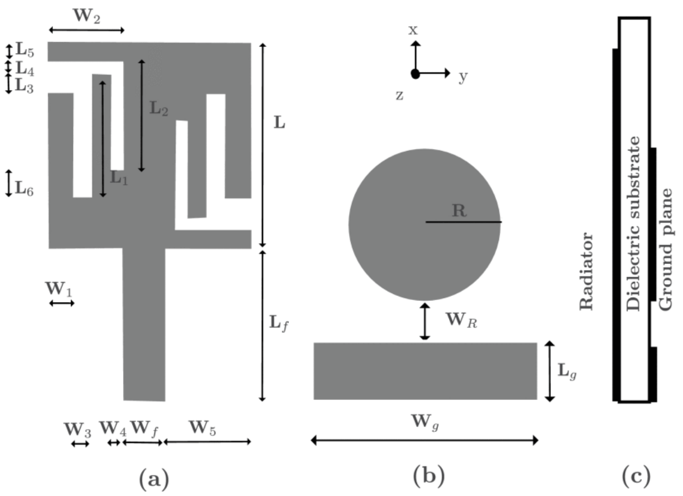

Fig 1: (a) Top view (b) Bottom view (c) Side view of the antenna

The designed specifications of the antenna are given below:

The overall width and length of the antenna is 0.152×0.2 where is the free space wavelength at first resonant frequency 2.4 GHz. The antenna consists of two F shaped slots of the same size are etched on the rectangular patch to obtain multi band frequencies. The impedance matching is done by printing the circular shaped patch with rectangular ground plane on the other side of the antenna. The specifications of the designed antenna are shown in Table 1.

Parameters	Unit (mm)	Parameters	Unit (mm)
L	15.0	W_R	2.8
L_1	9.0	W_1	1.25
L_2	8.8	W_2	5.25
L_3	0.6	W_3	1.0
L_4	1.0	W_4	0.4
L_5	1.0	W_5	6.25
L_6	1.2	R	7.9
L_g	3.9	W_g	19.0
L_f	9.0	W_f	3.0

Table 1: Design parameters of the antenna

2.2. Effect of lengths L_1 and L_2 on triple band patch antenna

The antenna is tested with different lengths L_1 and L_2. The length varies with different substrates. The different resonant frequencies can be calculated as,

$L_{r1} = (L - L_5) + (W_f + W_5) + (L_2 + L_6 - L_4)$ (1)

$L_{r2} = L_1 + L_2 + W_2$ (2)

$L_{r3} = L_2 + W_2 - W_4$ (3)

From the data in Table-I, L_{r1} = 32.25mm, L_{r2} = 23.05mm, L_{r3} = 13.65mm. The equation given in [16] is used to calculate the effective dielectric constant of the antenna. The effect of lengths L1 and L2 is as shown in Table 2.

$$f_r f_r = \frac{c}{2Lr\sqrt{\varepsilon_{reff}}2Lr\sqrt{\varepsilon_{reff}}} \quad (4)$$

Substrate	L_1(mm)	L_2(mm)	Freq	Return Loss
FR4	9	8.8	2.51 3.83 4.32 5.78	-12.39 -22.75 -18.66 -12.37
Bakelite	9.8	7.05	2.4 3.6 3.99 4.76 5.61	-12.98 -33.00 -29.37 -23.79 -12.85
Epoxy_ke vular_xy	8.2	11.8	2.29 3.61 4.59 5.15	-11.13 -27.53 -20.31 -32.02
Rogers 4350	8.25	11.55	2.26 3.62 4.61 5.12	-11.73 -19.57 -25.72 -37.52
Taconic TLC	7.6	13.75	2.16 3.25 4.48 5.6	-10.35 -27.39 -75.93 -27.67

Table 2: Effect of lengths L1 and L2 on patch antenna.

2.3. Effect of different substrates on patch antenna

The designed antenna is tested with different substrates by keeping all the parameters constant. The values differ for different substrates as shown in Table 3.

Substrate	ε_r	ε_{reff}	Freq	Return Loss
FR4	4.4	3.86	2.51 3.83 4.32 5.78	-12.39 -22.75 -18.66 -12.37
Bakelite	4.8	4.23	2.44 3.68 4.16 5.59	-13.18 -20.84 -21.06 -12.22
Epoxy_kevular_xy	3.6	3.216	2.67 4.02 4.66 6.13	-15.12 -16.61 -26.87 -11.27
Rogers 4350	3.66	3.267	2.63 4.00 4.64 6.11	-14.37 -17.15 -24.57 -11.38
Taconic TLC	3.2	2.875	2.74 4.13 4.88 5.58	-15.54 -15.89 -28.68 -12.70

Table 3: Return loss of different substrate material.

2.4. Effect of superstrate material on patch antenna

A superstrate layer of FR4 is used to improve the gain of an antenna. The FR4 layer has been placed at 13.5 mm above the antenna. The dimensions of both superstrate and substrate are kept same. By optimizing the gap between antenna and superstrate the gain can be optimized. The geometry of the structure is as shown in Fig 2.

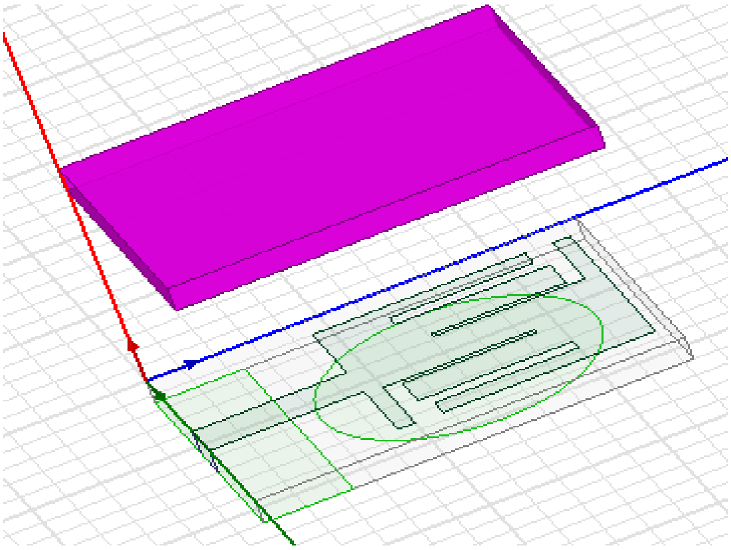

Fig 2: Antenna with superstrate

3. SIMULATED RESULTS AND DISCUSSION

3.1. Reflection coefficient

Fig 3 shows the return loss of triple band antenna with and without superstrate. It is clear that reflection coefficient reduces with superstrate, thus it improves impedance matching. Fig 3 shows the return loss of an antenna with and without superstrate.

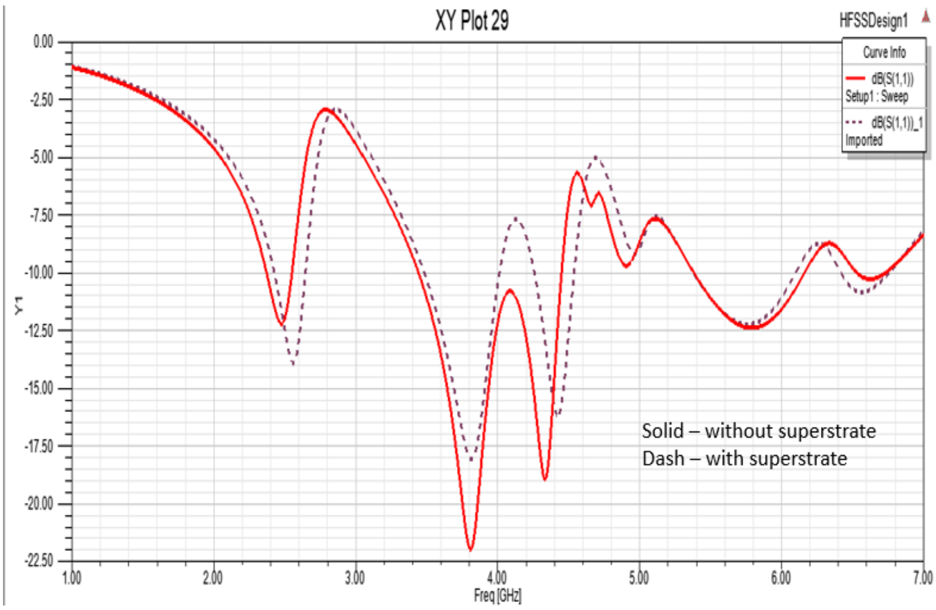

Fig 3: Simulated return loss for the triple band patch antenna with and without superstrate.

3.2. Radiation pattern

The Fig 4 shows the radiation pattern of an antenna with and without superstrate at sampling frequencies 2.5, 3.5 and 5.5 GHz. In these figures it is observed the radiation is omnidirectional.

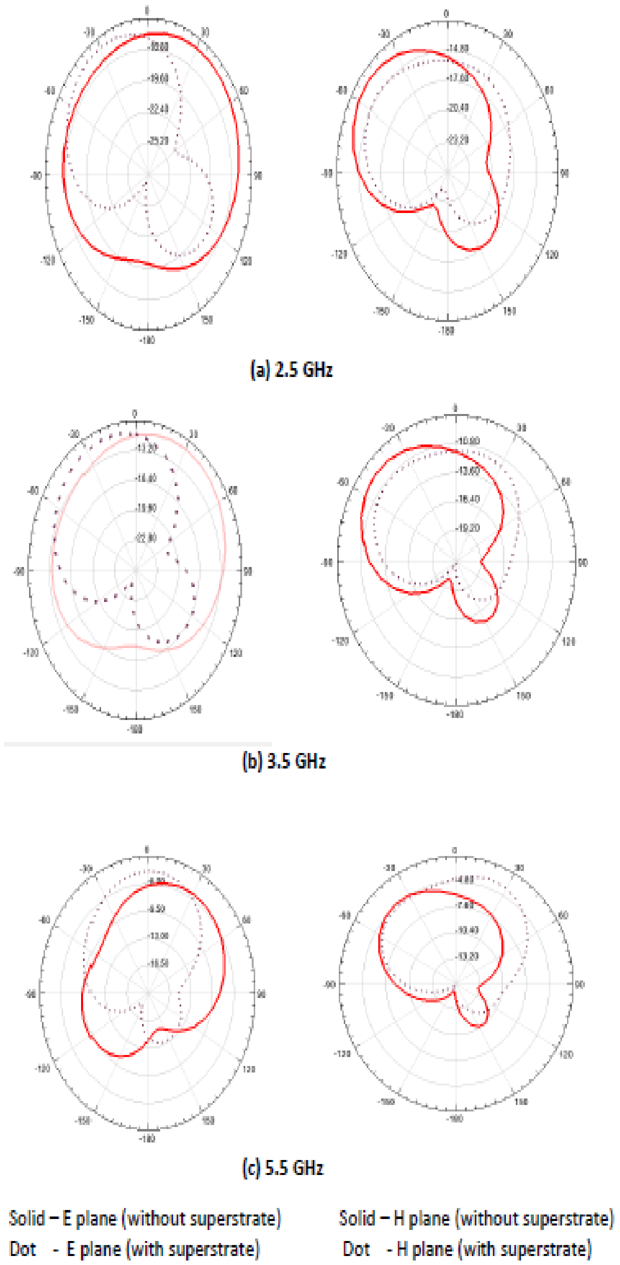

Fig 4: Simulated 2D radiation pattern of triple band antenna with and without superstrate.

3.3. Surface Current Distributions

The Fig 5 below shows the surface current distribution at different frequencies on the surface of radiating patch.

From the Fig 5 more current is concentrated at 2.5 GHz. The high level of current is concentrated at the radiating edges of an antenna for 3.2 GHz. For 5.5 GHz frequency the current is mainly concentrated on the strip of an antenna.

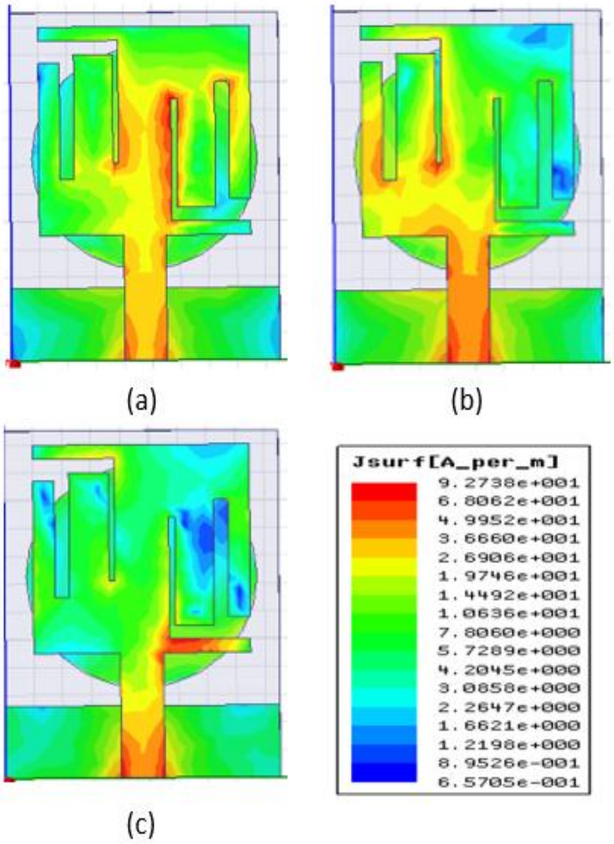

Fig 5: Surface current distributions at (a) 2.5 GHz (b) 3.5 GHz (c) 5.5 GHz

3.4. Gain

The gain values obtained for triple band antenna with and without superstrate are listed in Table 4. The antenna shows the improved gain. The superstrate layer focuses the radiation in a direction perpendicular to the antenna. Here superstrate layer acts as lens.

Frequency (GHz)	Gain without superstrate (dB)	Gain with superstrate (dB)
2.5	-3.04	-2.80
3.5	-2.67	-2.44
5.5	-2.21	-1.86

Table 4: Gain value of the antenna with and without superstrate.

4. CONCLUSION

The simulation studies of triple band micro strip patch antenna with different substrates and superstrate material have been presented. The antenna with dielectric substrate FR4 provides the required bandwidth for WLAN and WiMAX applications and the efficiency of the antenna increases. The gain of an antenna is improved by placing the superstrate material at an optimum distance.

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