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Design and Implementation of Ultra Wide Band Micro Strip Antenna

N Shesha Prasad[1], Adithya B R[2], Adithya N Simha[3]
[1, 2, 3]Dept. of ECE, BNMIT, Bengaluru, Karnataka, India-560070

Abstract— *This paper explains in detail about the design and simulation of ultra-wide band micro strip patch antenna which has a bandwidth of 5.357GHz (2.753GHz to 8.11GHz). The initial antenna designed resonates at 6.7GHz. By varying the ground plane and introduction of slots, the bandwidth has been enhanced.FR-4 (lossy) is chosen as the substrate with a dielectric constant of 4.4 and annealed copper is used as patch material. Computer Simulation Technology Microwave Studio (CST MWS) software has been used for simulation. Different parameters such as return loss, VSWR and directivity were analyzed. The proposed antenna operates for different applications such as Wi-Fi (3.6-3.7GHz), WiMAX (3.4-3.6, 3.7-4.2GHz), WLAN (5.3-6.3GHz), DSRC (5.8-5.9GHz), Hiper LAN(5.1-5.8GHz).*

Keywords— *Bandwidth Enhancement; Microstrip; Partial Ground; Slots; Ultra-Wide Band*.

I. INTRODUCTION

Modern telecommunication systems require antennas with wider bandwidths and smaller dimensions than conventionally available antennas. Ultra-wide frequency band is mainly used for high bandwidth communication, consuming very low energy for short range communication.

Microstrip antennas are those antennas that are designed or fabricated on a printed circuit board [1]. These antennas are small in size and are highly efficient. A microstrip antenna is basically several patches of a conducting material (metal like copper) mounted on one side of a substrate like a PCB layout. The other side of the substrate is also covered by a metal foil and is known as the ground plane.

Section II describes the design of base patch antenna and in section III, several iterations are performed on the base antenna using different bandwidth enhancing techniques. And in section IV simulated results are analysed. At last the conclusion and future scope is presented in section V.

II. ANTENNA DESIGN

Microstrip antenna has been used due to its advantages like low fabrication cost, light weight, robust, dual polarisation etc [2][3]. Fig. 1 and Fig. 2 gives the Front View and Back View of the Base Patch Antenna respectively. FR-4 (lossy) is used as the substrate material with dielectric constant of 4.4, annealed copper as patch and ground material. The dimension of substrate is 27.5mm x 14mm x 1.6mm. Annealed copper for ground plane has a thickness of 0.035mm with rest of dimension same as FR-4 (lossy).

To begin with, the operating frequency is chosen to be at 6.7GHz. The characteristic impedance Zo has to be set to 50 ohms. There is a reason to maintain Zo at 50 ohm that is an air filled coaxial line has minimum attenuation when Zo is 77ohm, while maximum power transfer occurs when Zo is 30 ohm. Hence, 50ohm Zo is a compromise between minimum attenuation and maximum power transfer.

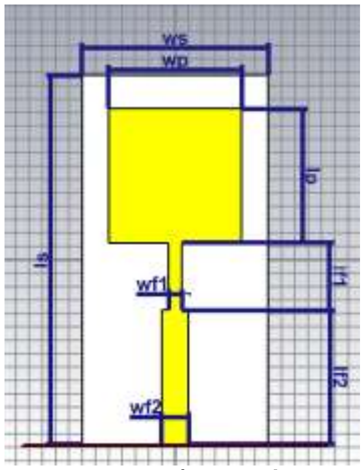

Fig. 1. Front View of Base Patch Antenna

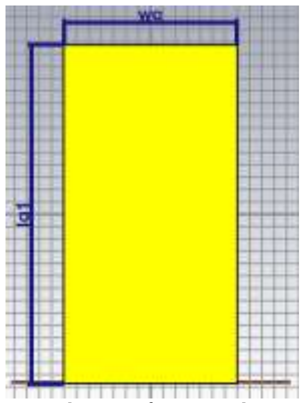

Fig. 2. Back View of Base Patch Antenna

Antenna Design Equations: [4][5][6]

The length and width of the basic patch is given by:

$$lp = wp = \frac{c}{2*fr*\sqrt{\epsilon r}} = 10.5mm \quad (1)$$

The wavelength of the antenna is given by:

$$\lambda o = \frac{c}{fr} = 44.4mm \quad (2)$$

The width of the quarter wave transition line can be calculated using the formula:

$$Zt = \frac{60}{\sqrt{\epsilon r}} \ln\left(\frac{8h}{Wf1} + \frac{Wf1}{4h}\right) \quad (3)$$

Which gives us wf1=0.75mm.

Length of the quarter wave transition line can be calculated using the formula:

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$$lf1 = \frac{\lambda o}{4 * fr * \sqrt{\varepsilon r}} = 5.29mm \quad (4)$$

Width of the 50 Ω Microstrip transmission line can be calculated by using the formula:

$$Zo = \frac{120\pi}{\sqrt{\epsilon reff\left(1.393+\frac{Wf2}{h}+\frac{2}{3}\ln\left(\frac{Wf2}{h}+1.444\right)\right)}} \quad (5)$$

Where Zo=50Ω, hence wf2=3.5mm

Length of the 50Ω Microstrip transmission line is given by the formula:

$$lf2 = \frac{L}{\pi}\cos^{-1}\sqrt{\frac{Zo}{Zt}} = 8.72mm \quad (6)$$

Table I gives a complete optimised dimensions of the antenna to get the best results.

Microstrip line feeding with quarter wave transition technique is used as the feeding technique [7]. The optimised values of the feed line width wf2=2 mm and length lf2=10 mm for the 50 ohm line impedance and the width and length of quarter wave line are 1mm and 5mm respectively. The GND plane dimensions are wg=14 mm, lg1=27.5 mm. The patch length is lp=10mm and Patch Width is wp= 10mm.

The simulation of the base antenna is done and the graph of return loss v/s frequency is plotted as shown in Fig. 3. The graph shows that the minimum return loss is at -12dB and it operates over a range of 6.57GHz to 6.83GHz (bandwidth of 0.26GHz).

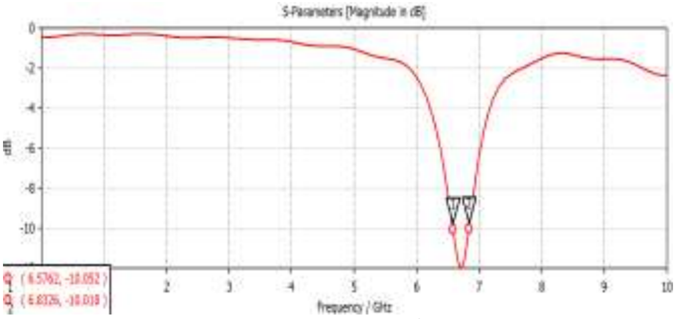

Fig. 3. Return loss v/s Frequency for base antenna

III. Bandwidth Enhancement Techniques

The main objective is to enhance the bandwidth of the basic patch antenna. For Ultra Wide Band application the minimum bandwidth requirement is 25%.

TABLE I. List of Dimensions of the proposed antenna

Parameter	Description	Value(in mm)
hp	Height of patch	0.035
hg	Height of ground plane	0.035
hf1	Height of feedline 1	0.035
hf2	Height of feedline 2	0.035
wf1	Width of feedline 1	1
hs	Height of substrate	1.6
wf2	Width of feedline 2	2
lf1	Length of feedline 1	5
wp	Width of patch	10
lp	Length of patch	10
lf2	Length of feedline 2	10
lg1	Length of ground plane	27.5
lg2	Length of partial ground	11.75
ws	Width of substrate	14
wg	Width of ground	14
ls	Length of substrate	27.5

Various methods to increase the bandwidth are listed as follows [8][9]:

i. Increasing the Patch Width.
ii. Increasing the substrate height.
iii. Increasing the Dimension of the feed Line.
iv. Length and Position of Slot on the radiating edge.
v. Insertion of Notch on the Corner of Patch.
vi. Suitable size of the Substrate.
vii. Use of Partial Ground surface (Reducing the Size of the Ground surface).

Besides these many researchers also utilize other ways to enhance the bandwidth which includes:

i. Aperture coupling feeding method.
ii. Use of multi layer substrate.
iii. Shorting pin method.

Iteration 1: In this iteration, partial ground plane technique is used to increase the bandwidth. Removal of a part of the ground plane reduces the back-lobe radiation of the micro strip antenna by supressing the surface wave diffraction from the edges of the antenna ground plane [10][11]. The parametric studies have been performed by using parameter sweep option in CST to obtain suitable position and width of the ground plane and it is observed that changing dimension, length and position of the ground plane cause noticeable changes in antenna performance [12]. The optimised ground plane length is 11.75mm as shown in Fig. 4 which gives the best results in terms of bandwidth.

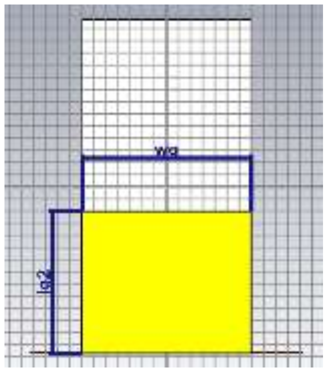

Fig. 4. Partial Ground Plane

With the introduction of partial ground plane the bandwidth has considerably increased to 4.21GHz (from 2.77GHz to 6.98GHz) and the antenna resonates at 3.4 GHz and 5.8GHz as shown in Fig. 5.

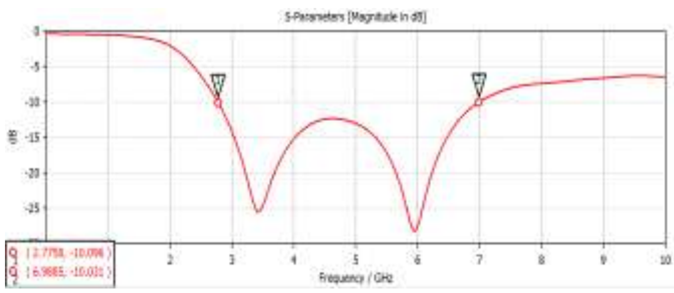

Fig. 5. Return loss v/s Frequency for iteration 1

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Iteration 2: In this iteration another bandwidth enhancing technique that is introduction of slots is used. The bandwidth of the antenna increases with the help of slots. These structures are periodic in nature that forbids the propagation of all electromagnetic surface waves within a particular frequency band called bandgap thus permitting additional control of the behavior of electromagnetic waves other than conventional guiding /filtering structure. Here square slots of 2mm*2mm dimension at four spots of the patch are introduced symmetrically. Fig. 6 shows the structure of the introduced slots.

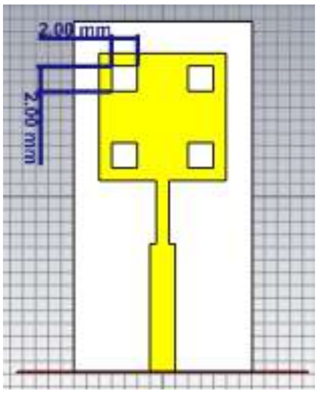

Fig. 6. Iteration 2

Fig. 7 gives the return loss characteristics for this design. With the introduction of slots the bandwidth has enhanced to 4.23GHz (2.77GHz to 7.00GHz).

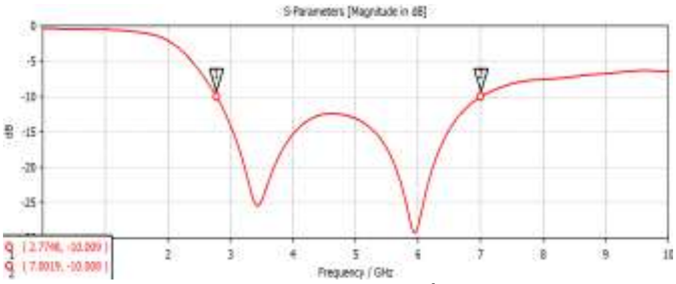

Fig. 7. Return Loss v/s Frequency for iteration 2

Iteration 3: In iteration 3 slots of dimensions 1mm*2mm are introduced symmetrically as shown in Fig. 8. This increased the bandwidth by another 10 MHz, giving us a final bandwidth of 4.24GHz. Fig. 9 shows the return loss characteristics of this antenna.

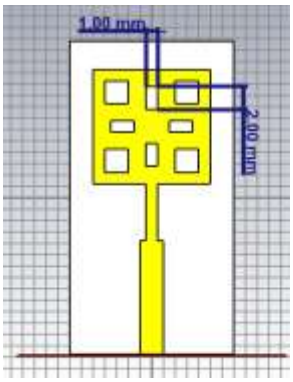

Fig. 8. Iteration 3

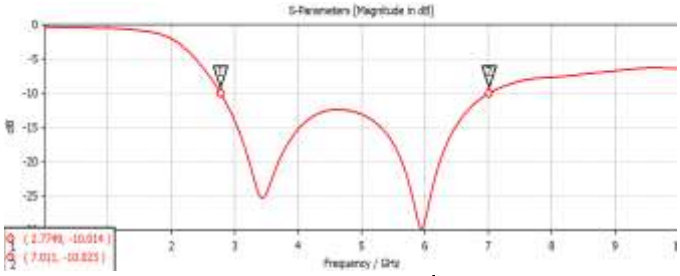

Fig. 9. Return Loss v/s Frequency for Iteration 3

Iteration 4 (Proposed Antenna): In this iteration third set of slots were introduced in the form of a plus symbol (+) as shown in Fig. 10. After introducing these slots, the bandwidth is increased to 5.47GHz (frequency range 2.75GHz to 8.22GHz), with minimum return loss of -28dB at frequency 5.8GHz.

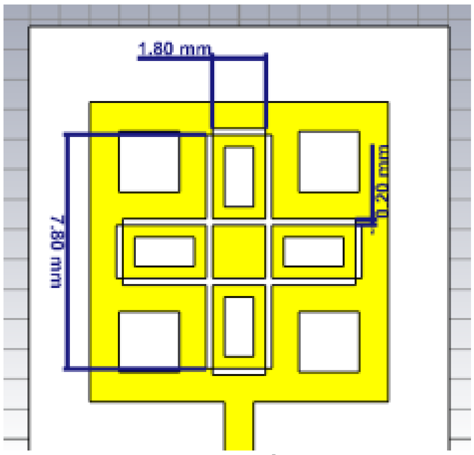

Fig. 10. Proposed antenna

Fig. 10 and Fig. 11 shows the proposed antenna design and its return loss characteristics respectively.

The proposed antenna design (Final iteration) yields the maximum bandwidth compared to the rest of iterations. It has a bandwidth of 5.46 GHz (2.76GHz to 8.22GHz). It has a gain of 1.731dB. This antenna can cover a wide range of applications like Wi-Fi (3.6-3.7GHz), WiMAX (3.4-3.6, 3.7-4.2GHz) and WLAN (5.3-6.3GHz).

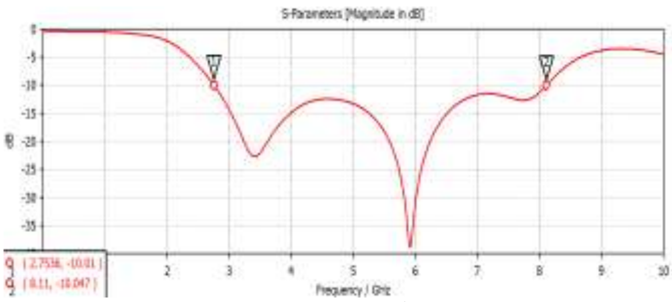

Fig. 11. Return Loss v/s Frequency for Proposed Antenna

IV. Result and Analysis

With the introduction of slots the resonant frequency decreased considerably because the current path increases with increase in slots. As the number of slots are increased, the effective patch area decreases which in turn reduces the gain of the antenna. The bandwidth increased drastically due to the partial ground plane because it reduces the back-lobe radiation of the micro strip antenna by suppressing the surface wave diffraction from the edges of the antenna ground plane. Initially the antenna resonates at 6.7 GHz with bandwidth of 0.26GHz. In the first iteration, antenna resonates between 2.77GHz to 6.98GHz with bandwidth of 4.21GHz because of the creation of partial ground plane. In the proposed last iteration the bandwidth has increased to 5.357GHz (2.75GHz-8.11GHz).

V. CONCLUSION AND FUTURE SCOPE

The proposed antenna is simulated using CST MWS and different parameters are analysed. This antenna works for multiple frequencies and has a large bandwidth (ultra wide band). The measured frequency parameters are well within the agreeable limit for the entire range in the simulation (VSWR < 2, S11 < -10dB). It covers several applications such as Wi-Fi (3.6-3.7GHz), WiMAX (3.4-3.6, 3.7-4.2GHz), WLAN (5.3-6.3GHz), DSRC(5.8-5.9GHz) and Hiper LAN(5.1-5.8GHz) [12].

By enhancing the bandwidth range on either side applications like satellite communication, radar tracking, zigbee, Bluetooth etc can be covered.

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TABLE II. Measured Antenna Parameters

	Microstrip Antenna	**First Iteration Antenna**		**Second Iteration Antenna**		**Third Iteration Antenna**		**Fourth Iteration Antenna (Proposed Design)**	
Frequency (GHz)	6.71	3.42	5.95	3.43	6.94	3.44	5.94	3.38	5.91
Directivity (dBi)	5.393	3.018	3.841	3.025	3.848	3.032	3.847	3.006	3.869
Gain (IEEE) (dB)	1.25	1.395	2.054	1.394	2.058	1.39	2.062	1.385	2.117
Realized Gain (dB)	0.8026	1.312	1.974	1.308	1.983	1.3	1.989	1.29	2.079
Peak Surface Current (A/m)	92.261	80.773	94.383	80.35	93.99	79.96	93.83	78	86.795
Reflection coefficient |S11|(dB)	11.924	25.46	28.19	25.4	29.19	25.27	29.75	22.58	38.81
VSWR	1.678	1.11	1.08	1.11	1.07	1.11	1.06	1.16	1.023
Radiation Efficiency In dB	-4.143	-1.623	-1.787	-1.631	-1.789	-1.642	-1.785	-1.622	-1.752
Total Efficiency	-4.591	-1.707	-1.867	-1.717	-1.864	-1.733	-1.858	-1.716	-1.79
Bandwidth	**0.256GHz**	**4.213 GHz**		**4.227 GHz**		**4.236 GHz**		**5.357 GHz**	

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