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COMPACT ULTRA-WIDE BAND MICROSTRIP ANTENNA FOR SATELLITE BASE STATION APPLICATION

Bhavana M*[1], Hari Priya A N*[2], Jagadish J*[3], Muniteja Reddy K*[4], Kalyan R*[5]

*[1,2,3,4]U.G. Students, Department Of ECE, Annamacharya Institute Of Technology And Sciences-Tirupati, A.P., India.

*[5]Assistant Professor, Department Of ECE, Annamacharya Institute Of Technology And Sciences-Tirupati, A.P., India.

ABSTRACT

In the recent years, wireless personal area network (WPAN) has been fascinating substantial attention and experiencing hasty expansion worldwide. In recent years, fast wireless connections between portable devices, computers and consumer electronics within a short range are provided by WPAN. In future WPAN provide stream less operation among home or business devices and systems and also provide fast data storage and exchange among all these devices. This demands a data rate which is much higher than what has been achieved in currently existing wireless technologies so the demand for high data rate is continually increasing. Antenna is an essential part for all communication systems. To cover various bands an ultra-wide band (UWB) antenna from 3.1 GHz to 10.6 GHz are preferred. As wireless devices are becoming more compact, increasing effort has been put to miniaturize the UWB antennas, which is becoming a new challenge for antenna designers. This communication enlightens design, simulation, fabrication and testing of a novel compact ultra-wide band (UWB) U-Shaped patch antenna. The planned antenna contains U-Shaped patch with partial ground plane. This compact antenna is effective and useful for short areas and can be easily incorporated in small devices. The results show that the antenna is having a band width from 2.77GHz to 13GHz. This antenna gains a worthy harmony between the simulated results and measured results.

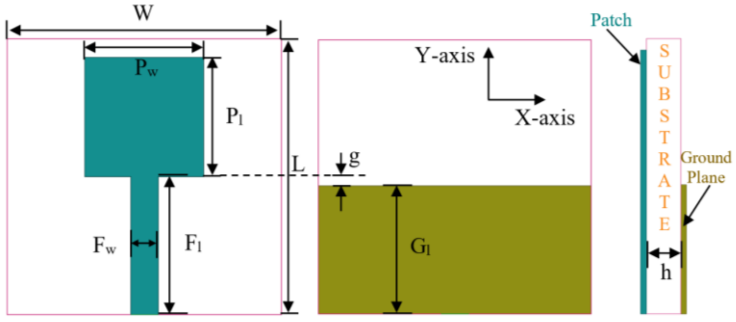
Keywords: UWB, FCC, U-Shaped Patch.

I. INTRODUCTION

There are plentiful understandings on planner type of antenna which have been prevailing in the literature [1]-[10] and antenna engineer's emphasis on the planar monopole design of antenna since the main challenge in UWB antenna design is attaining the wide impedance bandwidth while still upholding high radiation efficiency. Planar monopole antennas have been shown to exhibit a relatively wide impedance bandwidth and good radiation pattern characteristics over entire UWB range of frequencies [11]-[20]. This planner antenna is appropriate for wireless communication because of its ease of fabrication, simple structure, omnidirectional radiation characteristic, low profile, and lightweight. Usually, the antenna is able to achieve low bandwidth at VSWR below 2. In order to enhance the impedance bandwidth, some methods have been suggested. Initially, the shape of the antenna may be varied viz. Square, Rectangle, Circle, Trapezoidal, Pentagon and Triangular etc. A number of techniques have been used to create single or multiband stop band UWB antennas [21]-[23]. A typical multiband antenna, which is a composite structure of narrow band resonant components, has a great difficulty in design because of the sophisticated structure and extremely sensitive impedance bandwidth. Another technique for a multiband design is to create an ultra-wideband antenna having responsive part (became radiator) to specific band of frequencies of interests and non-responsive (resonator) to undesired band of frequencies. So, we initiated with simple planner monopole structure of antenna. There are many different shapes or types of planar monopole antennas that are being considered for UWB applications. It is very much need to design compact UWB antennas for wireless communication applications.

II. RECTANGULAR ANTENNA FOR UWB WITH PARTIAL GROUND PLANE

small and compact size of an Ultra-Wide Band (UWB) antenna is highly desirable due to their ease of integration into space-limited systems. Figure 1 shows the Structure of a rectangular antenna in different views. Proposed rectangular antenna is fabricated on a FR4 substrate of relative permittivity (εr) 4.4, loss tangent (tan δ) 0.02 and thickness (h) 1.6mm. W and L represents the Width and length of the substrate, Pw and Pl represents the width and length of the patch respectively. Patch is connected to a SMA connector with a feed line of length Fl and width Fw. Gl represents the length of partial ground plane.



(a) Top view (b) Bottom view (c) Side view

Figure 1: Structure of a rectangular antenna (a) Top view (b) Bottom view (c) Side view. (L=30mm, W=30mm, Gl=14mm, h=1.6mm, Fl=15mm, Fw=3mm, Pl=14mm, Pw=13mm, g=1.4mm).

As per simulations the performance of the antenna depends on gap between feed line, ground plane and also on patch of the antenna keeping ground plane constant. The designed antenna uses the concept of multiple resonance because ground plane of the proposed antenna is also a part of the radiating configuration and current distribution on the ground plane affects the characteristics of the antenna. It is to be noted that the radiation patch, the gap and the ground plane form an equivalent dipole antenna with fundamental resonance, mainly determined by the length of the antenna. It is worth mentioning that closely spaced multiple resonances which are harmonics of fundamental resonance overlap, resulting in ultrawide bandwidth. The simulation analysis has been carried out by varying the feed gap, patch width and patch length of the antenna. First parametric analysis is carried out for gap between the patch and ground plane which act as a coupling capacitance and plays important role to obtain ultra-wide band width. The simulated return loss values for gap (g) between feed line and ground plane is shown in Table 1. keeping the patch width and patch length as 10 mm and 11 mm respectively parametric analysis is carried for the feed gap. It is observed that the -10dB (return loss) band width is varied remarkably with the variation of gap between feed line and ground plane. When the gap is increased from 0.2mm to 1.4 mm there is increase in bandwidth from 2.5 to 6.6 GHz. The optimized feed gap is found at 1.4 mm where the band width starts from 3.4 GHz and ends at 10 GHz.

Table 1. Parametric study for gap between feed line and ground plane.

Gap (g) (mm)	f_l (GHz)	f_h (GHz)	BW (GHz)
0.2	4	6.5	2.5
0.6	3.7	7.5	3.8
1.0	3.5	8	4.5
1.4	3.4	10	6.6

It is well known that frequency and bandwidth are directly proportional to each other. Also, it is known that frequency and coupling capacitance are inversely proportional to each other. As gap increases the coupling capacitance decreases hence frequency increases which intern increases the bandwidth. So, bandwidth and gap are directly proportional to each other. Later the parametric analysis is carried for the patch width by keeping feed gap as 1.4 mm and feed length as 11 mm fixed as shown in Table 2. By varying the patch width from 10 mm to 13 mm the lower cutoff frequency is constant at 3.4 GHz whereas upper cutoff frequency is increased from 10 to 11.1GHz which increases the bandwidth. The optimum patch width is found at 13 mm where the bandwidth is 7.7 GHz.

Table 2. Parametric study for rectangular patch width (Pw).

Patch width (Pw)	fl (GHz)	fh (GHz)	BW (GHz)
10	3.4	10	6.6
11	3.4	10.5	7.1
12	3.4	10.7	7.3
13	3.4	11.1	7.7

Finally, the parametric analysis is carried for the length of the patch by keeping the feed gap as 1.4mm and patch width as 13 mm constant as shown in Table 3. By varying the patch length from 11 mm to 14 mm the band width of the antenna is increased from 7.7 to 8.7 GHz. It is also observed that lower cutoff frequency is reduced and upper cutoff frequency is increased while varying the patch length.

Table 3. Parametric study for rectangular patch length (Pl).

Patch length (Pl) (mm)	fl (GHz)	fh (GHz)	BW (GHz)
11	3.4	11.1	7.7
12	3.3	11.4	8.1
13	3.2	11.6	8.4
14	3.1	11.8	8.7

We can conclude that to increase the bandwidth of the antenna the gap between the patch and feed line, patch width and patch length should be increased. The optimum values to increase the band width is found at feed gap as 1.4 mm, patch width as 13 mm and patch length as 14 mm with a bandwidth of 8.7 GHz.

III. MODIFIED RECTANGULAR COMPACT ANTENNA CONFIGURATIONS

In modern communication the antenna system is integral part which is desired. To achieve compactness, etching slots on the patch is simple and easy method as shown in Figure 2. This starts with simple rectangular slot with length Sl and width Sw near the edge of the feed line since there is no change in the antenna characteristics because of low current density. Further the slot dimensions are increased to get the compact antenna. Figure 2(c) shows the fabricated photograph of the U-shaped antenna.

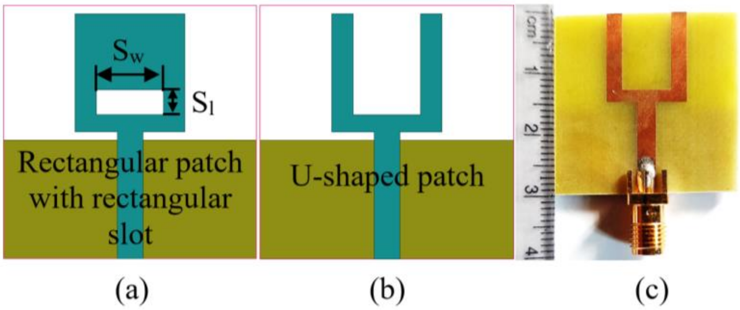


Figure 2: Various rectangular compact antenna configurations (a) Rectangular antenna with rectangular slot (S_w=8mm, S_l=4mm) (b) U shaped antenna (S_w=8mm, S_l=12mm) (c) Fabricated Photograph of the U-shaped antenna.

The simulated return loss curve for the rectangular patch without slot and with optimum slot length and width is shown in Figure.3. From Figure 3 it can be seen that there is a large variation in bandwidth with significance reduction in the size.

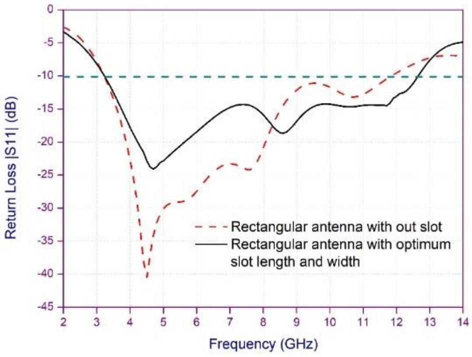


Figure 3: simulated return loss curve for the rectangular antenna without slot and with optimum slot length and width.

To analyze the performance of the antenna parametric analysis is carried for the slot dimensions. First parametric analysis is carried for slot width by keeping length as 4 mm constant. By varying width from 2 mm to 8 mm it is observed that the size reduction of 17.6 percentage is achieved at the center frequency of 7.8 GHz. Similarly, the parametric study has been carried over by keeping the width constant at 8mm and varying the length from 4mm to 12 mm. The detail parametric study by keeping length constant and varying the width the lower cutoff frequency, upper cutoff frequency, bandwidth along with size reduction has been given in Table 4.

Table 4. parametric study for slot width by keeping length constant, the lower cutoff frequency, upper cutoff frequency, bandwidth along with size reduction.

Slot width (S_w) (mm)	Area (mm^2)	f_l (GHz)	f_h (GHz)	BW (GHz)	(%) Size reduction
2	174	3.3	11.8	8.5	4.4
4	166	3.3	11.9	8.6	8.8
6	158	3.4	12	8.6	13.2
8	150	3.28	12.3	9.07	17.6

By varying the length and keeping the width constant the lower cutoff frequency, upper cutoff frequency, bandwidth along with size reduction has been given in Table 5. It is observed that width at 8mm, length at 12 mm the size reduction is over 52.7 percentage with bandwidth of 9.4 GHz. The optimum U-shaped antenna is fabricated on FR4 substrate of dielectric constant 4.4, loss tangent 0.02 and thickness of 1.6 mm.

Table 5. parametric study for slot length by keeping width constant, the lower cutoff frequency, upper cutoff frequency, bandwidth along with size reduction.

Slot length (Sl) (mm)	Area (mm2)	fl (GHz)	fh (GHz)	BW (GHz)	(%) Size reduction
4	150	3.28	12.3	9.07	21.3
6	134	3.3	12.5	9.2	26.4
8	118	3.3	12.7	9.4	35.2
10	102	3.22	12.9	9.74	44.0
12	86	3.1	12.4	9.3	52.7

IV. RESULTS AND DISCUSSION

The simulated results of optimum U-shaped antenna have been compared with the measured results as shown in Figure 4. The simulated and measured VSWR also observed which is shown in Figure 5. for VSWR less than 2 the bandwidth is approximately 9.3 GHz.

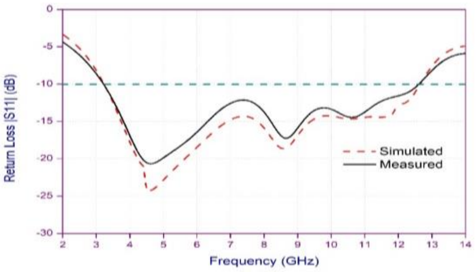


Figure 4: simulated return loss curve for the rectangular antenna without slot and with optimum slot length and width.

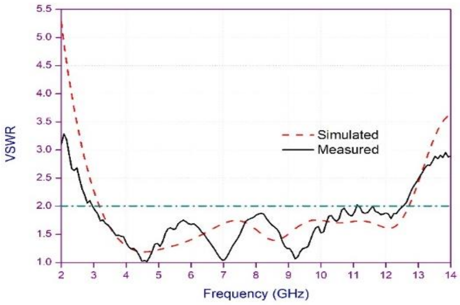


Figure 5: Simulated and measured VSWR curve for U-shaped antenna.

The simulated and measured results of U-shaped antenna is shown in Table 6. which are in agreement.

Table 6. Comparison of simulated and measured values for U-shaped antenna configurations

Antenna	Simulated (GHz)			Measured (GHz)		
	f_l	f_h	BW	f_l	f_h	BW
U-shaped antenna	3.1	12.4	9.3	3.1	12.4	9.3

For the U-shaped antenna the gain has been simulated and measured over the UWB which is shown in Figure 6.

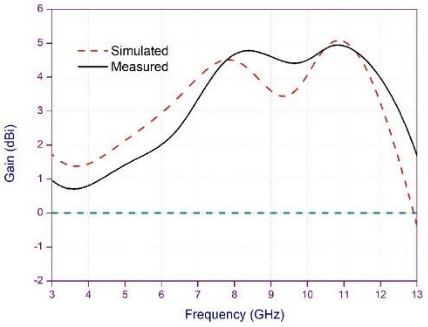


Figure 6: Simulated and measured gain curve for U-shaped antenna.

It is observed that the maximum gain over the band of frequency is 5 dBi. The gains provided in the entire thesis are realized gains. Simulated radiation efficiency is shown Figure 7. The radiation efficiency is about 90 percent for UWB range of frequency.

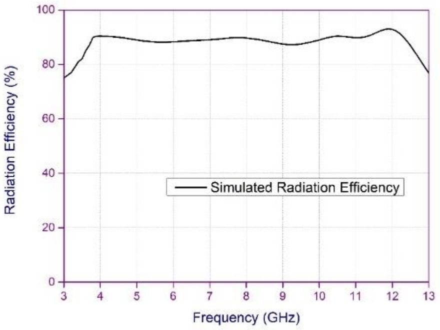


Figure 7: Simulated radiation efficiency of U-shaped antenna.

The simulated and measured radiation pattern of the U-shaped antenna at 5 GHz is shown in Figure 8. The E-plane pattern is simulated at theta values from 0 to 360 degrees and phi = 0 degrees. And H-plane is simulated at theta = 0 to 360 degrees and phi =90 degrees. The proposed antenna is placed in Y direction hence the E field is in Y-Z plane and H field is in X-Z plane. It is observed that the radiation pattern in E-Plane (Y-Z plane) is directional whereas the radiational patterns in H-Plane (X-Z plane) is isotropic which is the property of monopole antenna. Figure 9. Shows the three-dimensional radiation pattern of the proposed antenna.

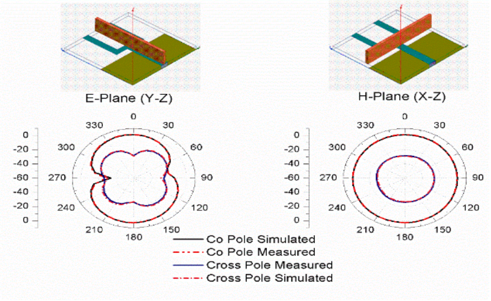


Figure 8: Simulated and Measured Radiation Pattern of the U-shaped antenna at 5 GHz

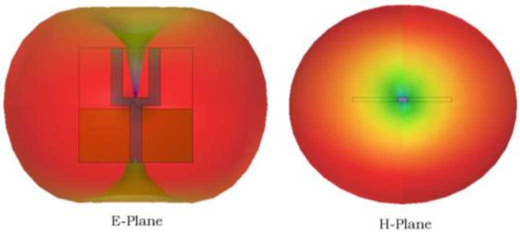


Figure 9: E-Plane and H-Plane view of 3-D Radiation pattern

V. CONCLUSION

The partial ground plane rectangular antenna is studied which achieve ultra-wide bandwidth. To reduce the size of the antenna an additional rectangular slot is introduced on the non-radiating area of the patch and the length of the slot is increased until U-shaped patch is formed. The study shows that operating bandwidth and impedance matching of the antenna critically dependent on the feed gap but not on the slot. The area of the antenna for this case is 86 mm2 with a bandwidth of 9.3 GHz. The U-shaped patch area has a compactness of 52.7 percent compared to rectangular patch. Wide investigation on all of the above proposed antennas in frequency domain is done. Based on the result of analysis, the antenna is developed for all the cases. The antennas are fabricated with FR4 substrate of thickness 1.6mm and characterized by measuring return loss, gain and radiation pattern. The measured results are appreciably in good agreement with the simulated results and this proves the validity of the proposed antennas.

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