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Design and Performance Analysis of Compact Microstrip-fed Multiple Edge Slotted Monopole Antenna for Wideband Applications

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Abstract- In this paper a microstrip-fed planar monopole antenna has been proposed for wideband applications. Three monopole antenna have been designed and analyzed for improving antenna performance parameters. Antenna performance parameter such as return loss, bandwidth, voltage standing wave ratio (VSWR), gain, directivity and radiation efficiency of proposed antenna have been analyzed and compared with each other. As a simulation tool CST Microwave Studio 2012 has been used. Proposed antenna showed the resonance at 6.46 GHz and 10.49 GHz. At these points return loss founded as -19.77 dB and -13.45 dB respectively. Obtained bandwidth of these points at -10dB are 20.14% and 5.79%. Later comparison of performance parameters have been done.

Index Terms- Monopole antenna, wideband, truncated ground, CST MWS 2012.

I. Introduction

In last few decades information technology has witnessed some of the most astonishing inventions never seen before. Among them wireless communication is one of the most prominent and fastest growing industries in modern era. Today it is difficult to comprehend life without wireless communication as it has changed our way of living. It has been widely engaged in the civilian and military applications such as satellite communications, television, mobile systems, broadcast radio, global positioning system, radio frequency identification, radar systems, remote sensing, missile guidance, surveillance system etc. In recent time desire for high data in wireless communication is continuously increasing in Wireless broadband, Internet browsing, mobile communication, video streaming etc. All these devices must have antenna to radiate or receive wave signal into open free space from one place to other. As the technology advances every year, the demand for low cost, low volume, low profile planar configuration, conformal, and wideband multi-frequency planar antenna has been growing exaggeratedly. Microstrip Patch Antenna satisfies all the requirements due to its printable circuit technology. It consists of a radiating patch on one side of a dielectric substrate which has a ground plane on the other side. MPAs are widely used due to their simplicity and compatibility in different microwave frequency spectrum to service commercial and scientific purpose [1-3]. Besides all benefit, this types of antenna has major drawbacks such as narrow bandwidth, low efficiency, and low gain [1-4]. As a result, it has captured the attention of investors and scientists to prompt more research into improvements in related fields. Researchers have made many efforts to overcome these problems. Modified configurations of different patch shapes of various dimensions of MPA leads to achieve desirable resonant frequency [5-7]. Another way to improve bandwidth by modifying the shape of common radiator patch by cutting slots in the metallic patches like U-slot patch antenna, V-slot patch antenna, half U-shape patch antenna or L shape or E shape [8-14].

Main objectives of this paper were to achieve wideband (>500 MHz) characteristics under -10dB return loss with multiple resonant frequencies and improve other performance parameters such as voltage standing wave ratio (VSWR), directivity, gain, efficiency etc. of proposed antenna. At first a reference antenna [15] has been designed in section II and performance parameters such as return loss, VSWR, bandwidth, gain, directivity and radiation efficiency have been analyzed in the section III. After that multiple slots at antenna edge have been imposed and performance analyzed to get multiband characteristics which also discussed in the section III. Finally all performance parameters have been tabulated and compared with one another in the same section.

II. Antenna Design

In this paper three monopole antennas have been designed. All of them designed on FR-4 (lossy) dielectric component which has relative permittivity of 4.3. Antenna patch and ground have been designed by using Perfect Electrical Conductor (PEC) material from CST MWS 2012 material library. Figure 1 shows the reference antenna, first proposed antenna which has four edge slots, second proposed antenna and backside view of all antennas.

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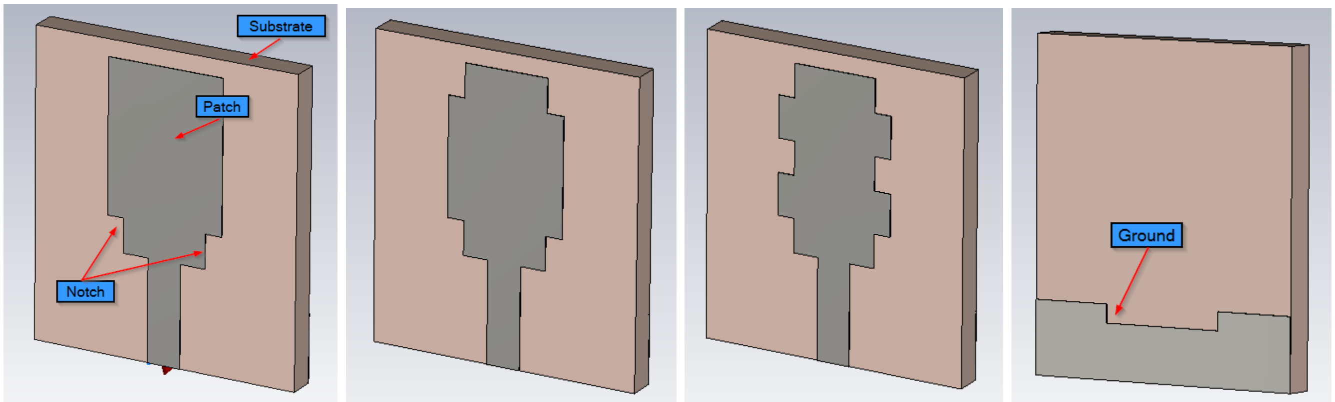

(a) Reference Antenna (b) Antenna with four slots (c) Antenna with six slots (d) Ground plane

Figure 1: Top view of the (a) reference antenna (Antenna A) (b) 1st proposed antenna (Antenna B) (c) 2nd proposed antenna (Antenna C) and (d) Back view of all antenna

Figure 1(a) shows the reference antenna (Antenna A), 1(b) shows the second proposed antenna (Antenna B), 1(c) shows the second proposed antenna (Antenna C) and 1(d) illustrates the common backside view of all three antennas. All six slots have identical dimensions which indicates slot has same width and length. Patch slot width and length have been taken as 1 mm and 2 mm respectively. Ground plane has been truncated which is also designed by PEC. Distance between the top of the patch and top of the substrate is taken as 1mm. Table 1 represents the antenna names for introducing flexibility in design.

Table 1: Antenna Identifications

Antenna	New Name
Reference Antenna	Antenna A
1st Proposed Antenna	Antenna B
2nd Proposed Antenna	Antenna C

Antenna design parameters for all of three antenna have been given in the Table 2.

Table 2: Antenna Design Specifications

Antenna Dimensions	Value (mm)	Material
Substrate Width	16	FR-4
Substrate Length	18	
Substrate Height	1.6	
Patch Width	7	PEC
Patch Length	11	
Patch Slot Width	1	
Patch Slot Length	2	
Patch Height	0.035	
Feed Width	2	
Feed Length	6	
Ground Slot Width	7	PEC
Ground Slot Length	1	
Ground Height	0.035	
Ground Width	16	
Ground Length	4	

III. Simulations and Results

After designing the antenna by CST MWS 2012 simulation work has been done. Simulated return loss plot of reference antenna which renamed as Antenna A has been given in the Figure 2. Magnitude of reflection coefficient has been found as -18.805dB at 6.49 GHz. At -10dB the bandwidth has been found as 1.36 GHz which covers 20.98% bandwidth at this resonant frequency.

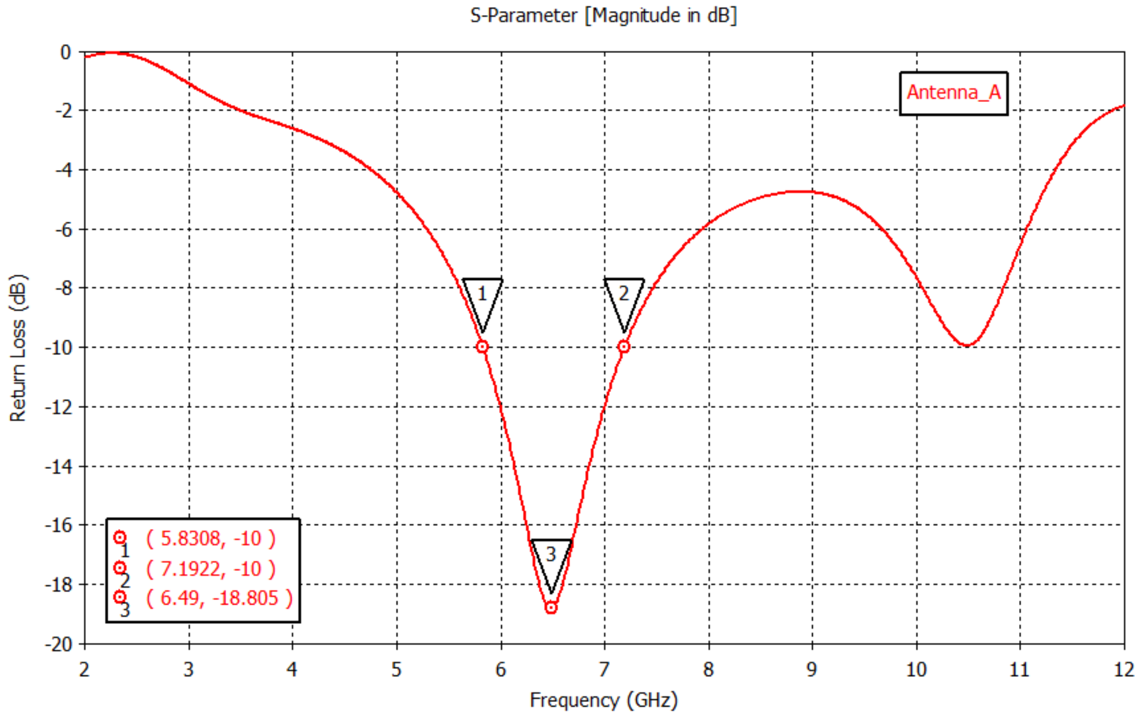

Figure 2: Return Loss Plot of Reference Antenna (Antenna A)

Figure 3 shows the return loss plot of Antenna B. In this case return loss found as -18.307 dB at 6.6 GHz resonant frequency. At -10dB total bandwidth found as 1.37 GHz which is greater than Antenna A.

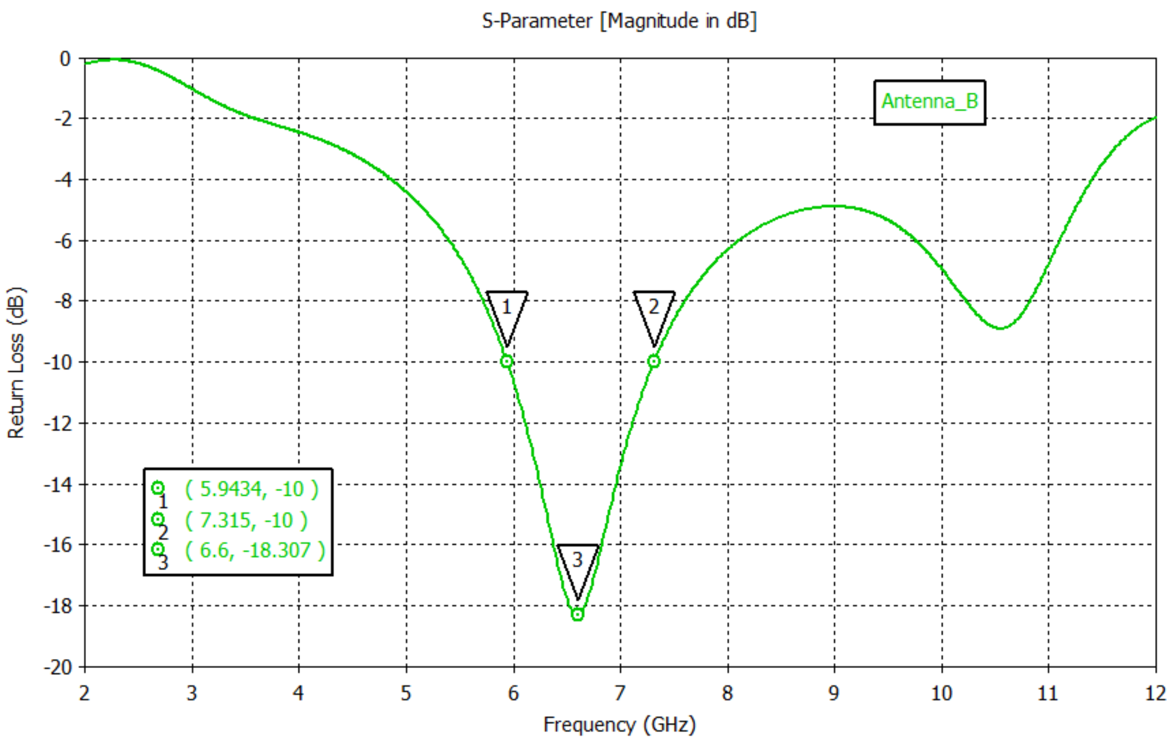

Figure 3: Return Loss Plot of First Proposed Antenna (Antenna B)

Figure 4 shows the return loss plot of second proposed antenna or Antenna C which shows that this antenna has two resonant frequency under -10dB, one is at 6.46 GHz and another one is at 10.49 GHz. Bandwidth found as 1.3 GHz at 6.46 GHz and 0.607 GHz found at 10.49 GHz. This result little bit lower than previous two antenna bandwidths.

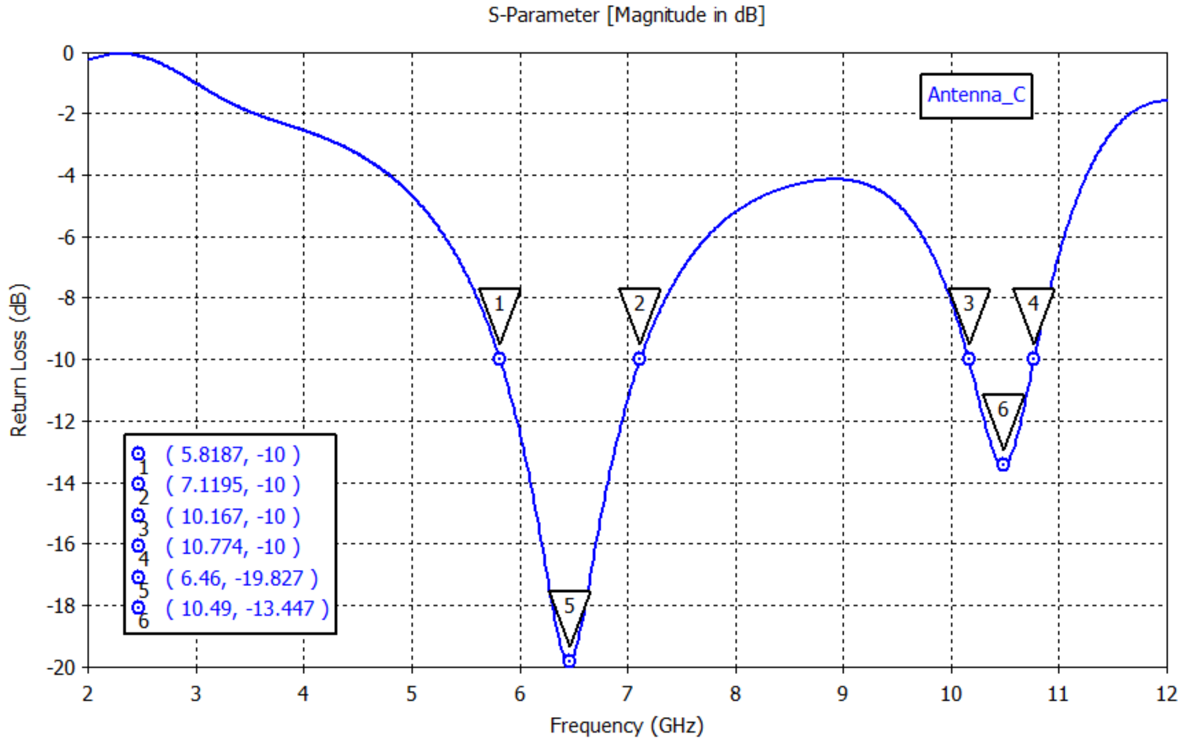

Figure 4: Return Loss Plot of Second Proposed Antenna (Antenna C)

Figure 5 illustrates the combined return loss plots of Antenna A, Antenna B and Antenna C. This figure shows that Antenna C has better resonance characteristics under -10dB.

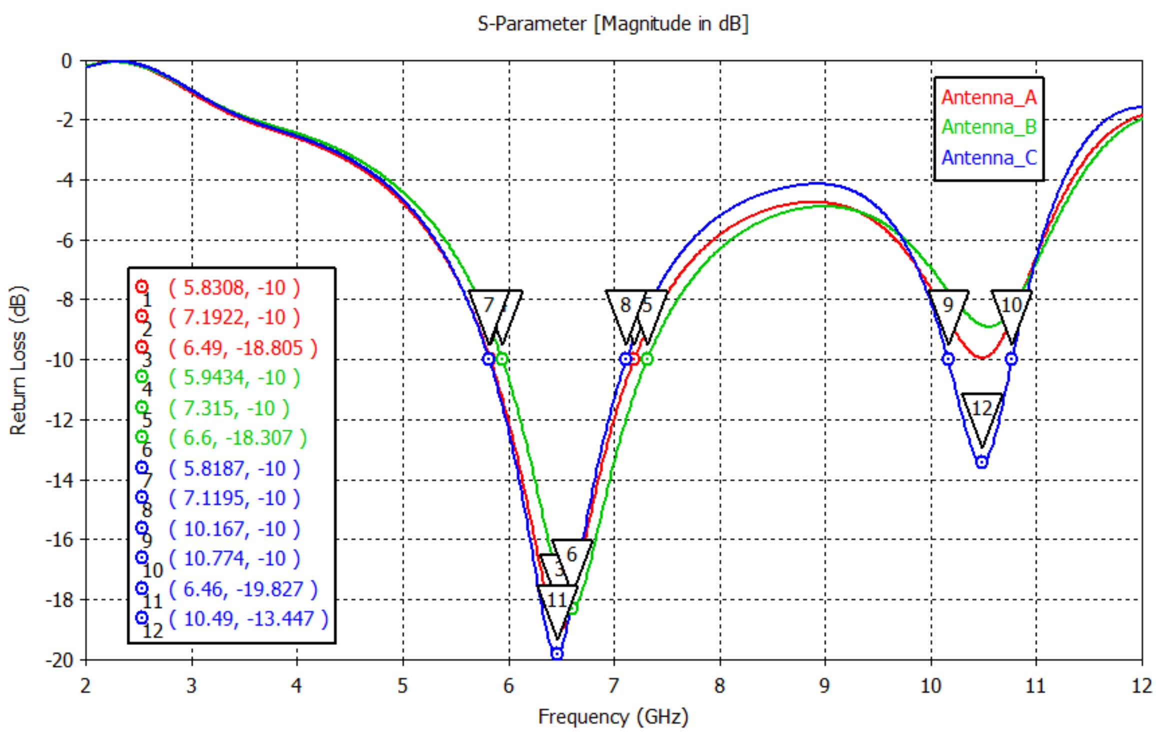

Figure 5: Combine Return Loss Plots of Antenna A, Antenna B and Antenna C

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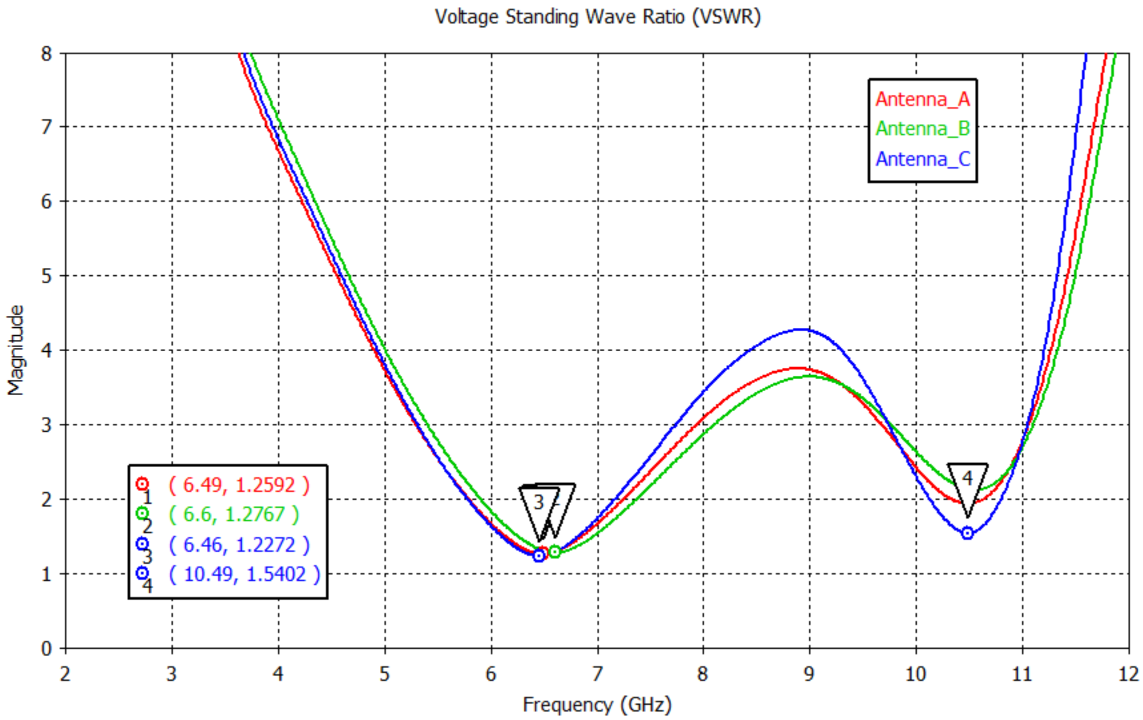
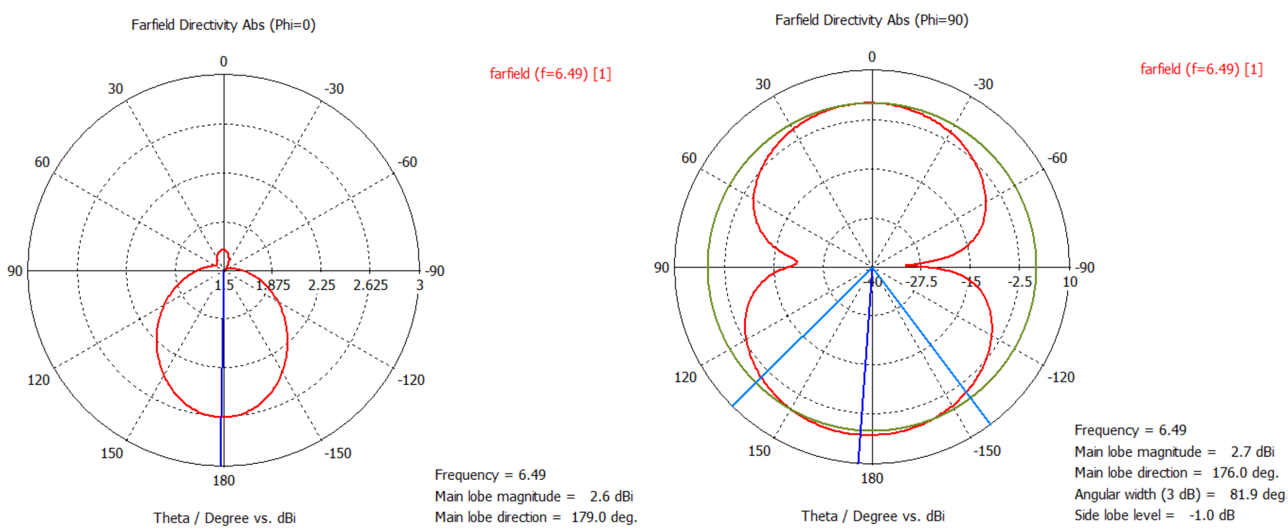


Figure 6: Combine VSWR Plots of Antenna A, Antenna B and Antenna C

Figure 6 shows the VSWR plot of three antennas, for the reference antenna VSWR found as 1.26 at resonant frequency. Whereas for slotted antennas it has been obtained at resonant frequency 6.6 GHz, 6.46 GHz and 10.49 GHz as 1.28, 1.23 and 1.54 respectively.



(a) E-field (Phi = 0 degree) (b) H-field (Phi = 90 degree)

Figure 7: Polar plot of (a) E-field and (b) H-field of Reference Antenna at 6.49 GHz

In the figure 7 polar plot of electric field and magnetic field of reference antenna have been given. Figure 7(a) shows the electric field which indicates main lobe directivity as 2.6 dBi and main lobe direction as 179 degree. Figure 7(b) shows magnetic field from which the main love directivity found as 2.7 dBi and angular width (3 dB) found as 81.9 degree.

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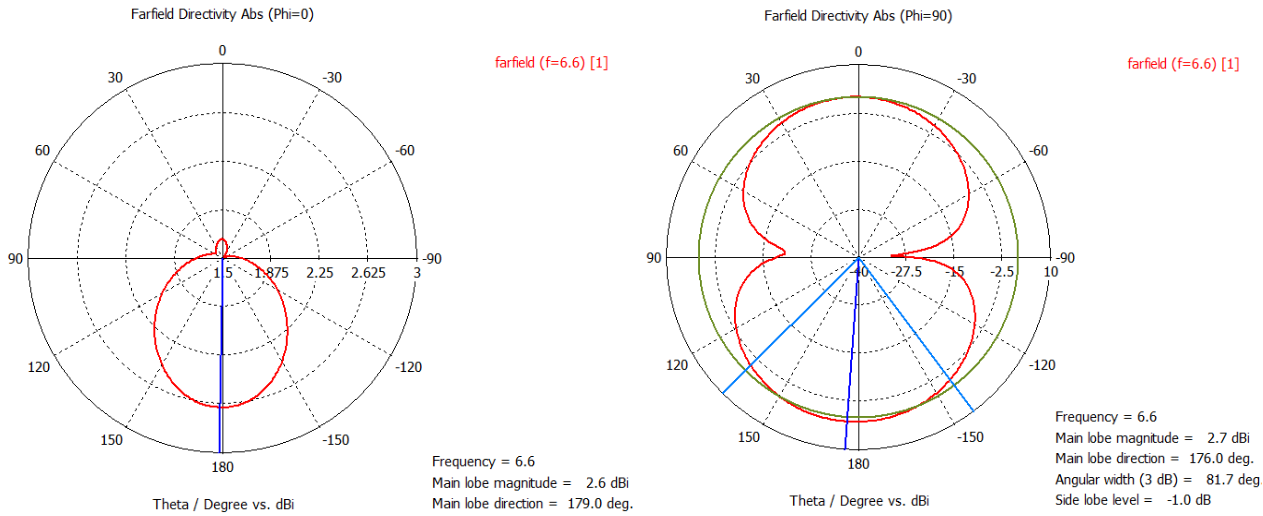
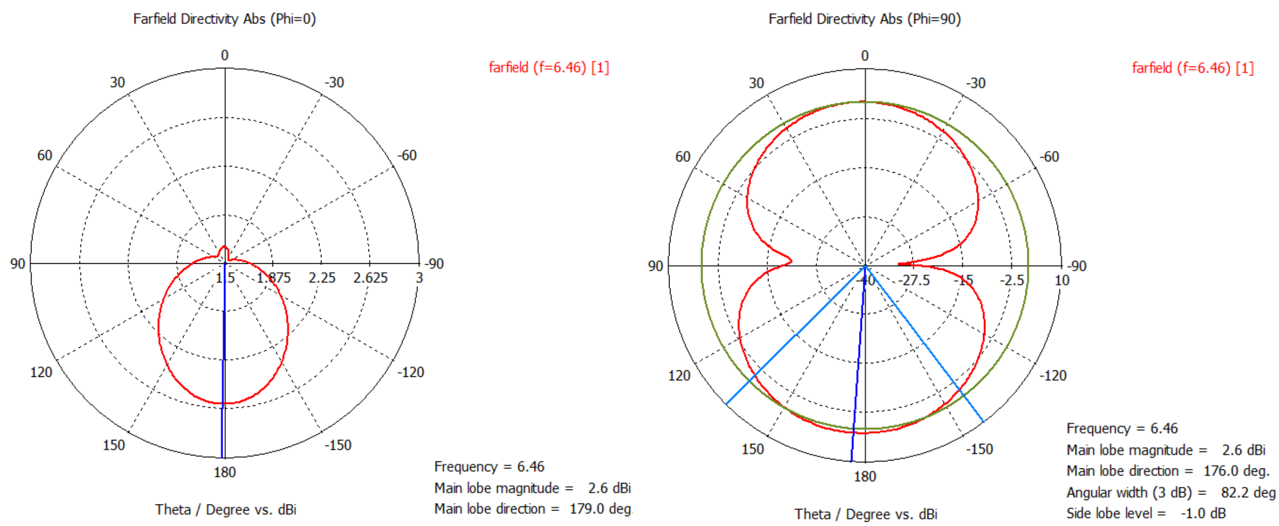


(a) E-field (Phi = 0 degree) (b) H-field (Phi = 90 degree)

Figure 8: Polar plot of (a) E-field and (b) H-field of 1st Proposed Antenna at 6.6 GHz

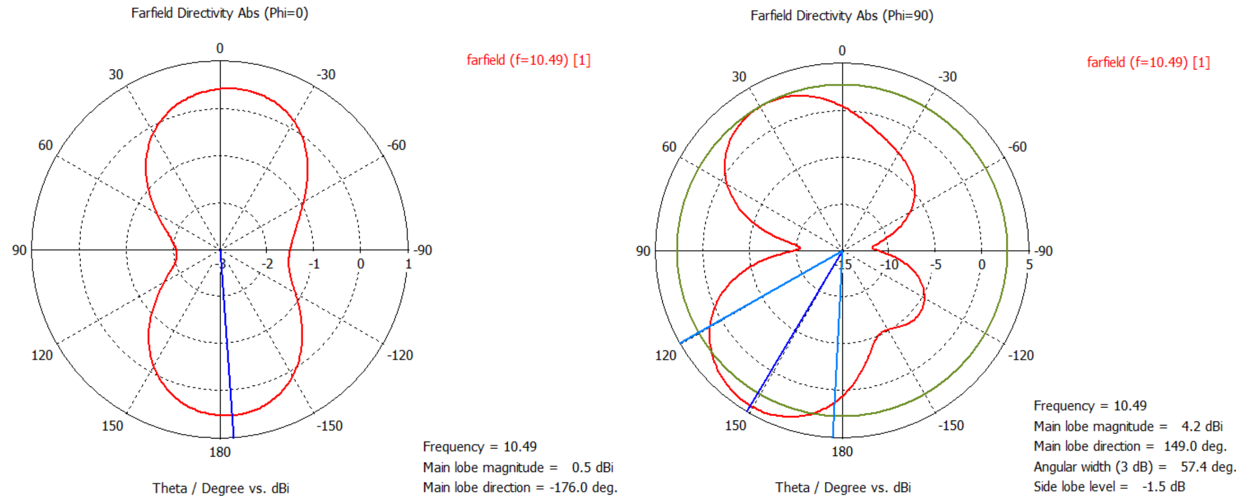
Figure 8 illustrates the polar plot of first proposed antenna at 6.6 GHz. Electric and magnetic field at resonant frequency have been shown in figure 8(a) and 8(b) respectively.



(a) E-field (Phi = 0 degree) (b) H-field (Phi = 90 degree)

Figure 9: Polar plot of (a) E-field and (b) H-field of 2nd Proposed Antenna at 6.46 GHz

Figure 9(a) and 9(b) shows the polar plot of electric and magnetic field respectively for second proposed antenna at resonant frequency 6.46 GHz. Main lobe magnitude found as around 2.6 dBi and angular width obtained as 82.2 degree.



(a) E-field (Phi = 0 degree) (b) H-field (Phi = 90 degree)

Figure 10: Polar plot of (a) E-field and (b) H-field of 2nd Proposed Antenna at 10.49 GHz

At the Figure 10(a) and 10(b) polar plot of second proposed antenna have been given at second resonant frequency 10.49 GHz. Main lobe directivity found as around 4.2 dBi and angular width seen as 57.4 degree. Finally from the CST MWS 2012 other parameters such as radiation efficiency, total efficiency, gain, directivity have been obtained and tabulated in the Table 3.

Table 3: Summery of Simulated Results

Performance Parameter	**Antenna A**	**Antenna B**	**Antenna C**
Resonant Frequency	6.49 GHz	6.6 GHz	6.46 GHz & 10.49 GHz
Return Loss	-18.805 dB	-18.31 dB	-19.77 dB -13.45 dB
Bandwidth at -10dB	1.36 GHz	1.37 GHz	1.3 GHz 0.607 GHz
Bandwidth%	20.98%	20.78%	20.14% 5.79%
VSWR	1.26	1.28	1.23 1.54
Gain	2.39 dB	2.41 dB	2.33 dB 3.28 dB
Directivity	2.66 dBi	2.68 dBi	2.61 dBi 4.25 dBi
Radiation Efficiency	94.1%	93.97%	93.82% 80.10%
Total Efficiency	92.87%	92.59%	92.85% 76.47%

From the comparison of performance parameters shown in the table 3 it is clear that 2nd proposed antenna or Antenna C has two resonant frequencies under -10 dB return loss. Bandwidth at this return loss obtained were 1300 MHz and 607 MHz which fits in ultra wideband [16]. Other parameters such as bandwidth, gain, directivity and radiation efficiency decreases than other two antennas. Lower directivity is necessary for using antenna in various devices such as mobile phone, car radio etc. In this sense 2nd proposed antenna is better. Moreover total efficiency is also better than 1st proposed antenna. But the requirement were to achieve multiband characteristics for wideband communications at -10dB, so the 2nd proposed antenna or Antenna C shows acceptable results in that case. It also shows better VSWR results at resonant frequencies other than previous two antennas. Because for impedance matching VSWR need to be close enough with unity. Radiation efficiency of the second proposed antenna comes better than first proposed antenna. Considering all of the above performance parameters it is obvious that second proposed antenna is better than other two.

IV. FUTURE SCOPES

There are few scopes to improve the performance like as return loss, bandwidth, VSWR, gain, directivity and radiation efficiency of the proposed antenna by optimizing design parameters. Authors would like to improve the performance in future by adding more slots on the patch and ground plane. Because slot on the ground plane against the patch increases the bandwidth [17]. Moreover multiple slot on the patch might be handful to get multiband characteristics of microstrip-fed monopole antenna [18].

V. CONCLUSION

In this paper a microstrip-fed monopole antenna has been compared with a reference microstrip-fed monopole antenna. There have been several performance differences between the reference antenna and newly designed antennas. Reference antenna shows some good result where the second proposed antenna or Antenna C shows better resonance after -10dB return loss. There always be a chance to improve this presented antenna with optimizations. This antenna shows good result at ultra wideband frequency spectrum. This antenna could be useful for multiband applications in ultra wideband spectrum. One of the main advantage of this antenna is compact dimension which could be useful to fit it within small wireless device cases.

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