TELKOMNIKA, Vol.16, No.6, December 2018, pp.2597~2607
ISSN: 1693-6930, accredited First Grade by Kemenristekdikti, Decree No: 21/E/KPT/2018
DOI: 10.12928/TELKOMNIKA.v16i6.10494

Proposed P-shaped Microstrip Antenna Array for Wireless Communication Applications

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Abstract

In this paper a P-shaped microstrip antenna array is proposed for X-band applications in the frequency range (8.1567-9.3811) GHz .The gain obtained in this frequency range is about 8.305 dBi. The reflection coefficient is less than - 10 dB in the above frequency range. The simulation results were obtained for the optimum parameters using the CST software while the practical test was carried out using Vector Network Analyzer (VNA). The microstrip antenna was manufactured using FR-4 substrate with relative dielectric constant of 4.3 and loss tangent $tan\,\delta = 0.002$.The simulation and practical results were compared. The size of the antenna array is $(33 \times 70 \times 1.6)\ mm^3$. This array is suitable for satellite communication, radar application.

***Keywords**:* UWB, microstrip antenna array, reflection coefficient, gain, radition pattern.

1. Introduction

In the recent year, ultra wide-band (UWB) technology was unfolded growth experience. The two serious merit of UWB technology are low power and high data rate by transmitting extremely short pulses and spread over the bandwidth and receive it short accurate and efficient pulses [1, 2].

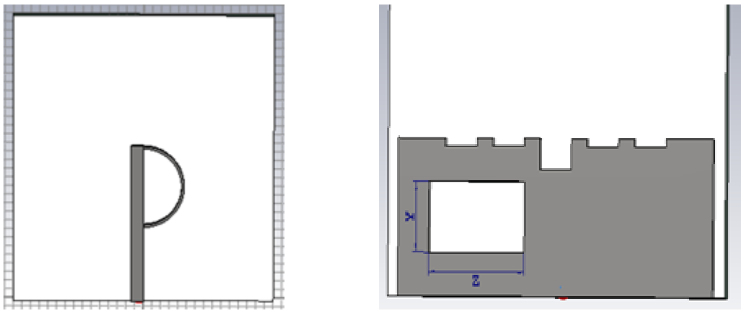
FCC (federal communication commission) give UWB technology industrial attention and attracted academia in wireless world it allowed wide unlicensed band about 7.5 GHz from (3.1-10.6) GHz with ERIP (Effective Isotropic Radiated Power) less than -41.3 dBm/MHz for communication application like imaging radar, remote sensing and localization application [3, 4]. Now adays, microstrip antenna plays an important role because of its light weight low cost planar fabricated and non-planar surface, when it is mounted on rigid surface has robust flexibility. However, microstrip antenna also has some disadvantages, low gain, narrow bandwidth, unacceptable efficiency [5-8].

Microstrip antenna array was used to enhance the performance of single element microstrip antenna. The efficiency and distribution voltage depend on feeding technique, when voltage induced in one point in feed that is suitable feed network [9]. Two feed technique are used in microstrip antenna array that responsible for improving antenna performance there are corporate feed network and series feed network. The corporate feed has high gain over frequency band that made broadside beam antenna with main drawback is rareness efficiency because of complicated and long feeding antenna [6, 7, 9-11].The series feed network, despite of simple and compact arrangement feed method but it has lower gain compared with corporate feed [6, 9]. To propose antenna array is worked within X-band location for wireless communication application especially for military application. Microstrip array antenna with corporate center feed was suggested and parametric study was investigated.

2. Single P-shaped Antenna

The single antenna structure for UWB is shown Figure 1. It was designed by FR-4 substrate with ε_r=4.3 and height h=1.6mm and loss tangent $\tan\delta$=0.002. The optimum parameters were listed in Table 1.

Received July 4, 2018; Revised October 1, 2018; Accepted October 29, 2018



(a) (b)

Figure 1. P-shape patch antenna array (a) patch plane (b) ground plane

Table 1. Antenna Parameters Values

Parameter	Value	Parameter	Value
Ls	33mm	X1	2
Ws	30	X2	2.8
Lg	10	X3	2.8
Wg	28	X4	0.5
Lf	18	X5	2.8
Wf	1.4	Y	4.5
R1	4.7	Z	8.5
R2	4.4		

However Figure 2 shows the practical result for reflection coefficient S_{11}, it was observed that the resultant bands is (5.75-7.74) GHz, (9.645-11.925) GHz in which $S_{11} < -10dB$. The maximum gain is (4.947) dBi as shown in Figure 3. Therefore a 2-element array antenna was proposed to improve the gain of such antenna

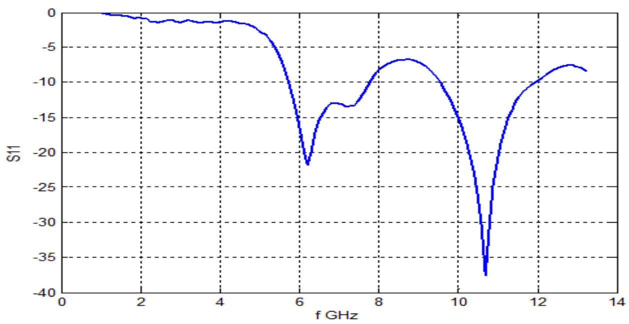


Figure 2. Measured result of reflection coefficient for P-shape patch antenna array

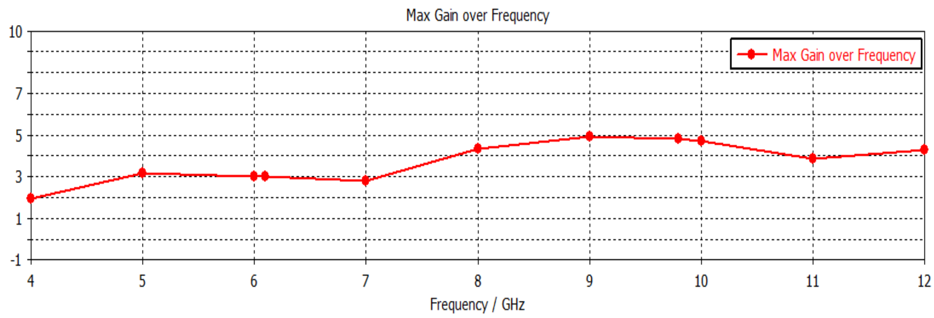
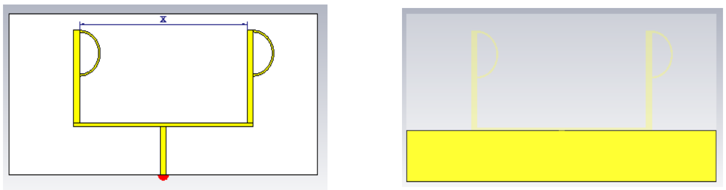


Figure 3. Gain curve for singl P-shape patch antenna

3. P-shaped UWB Antenna Array

2-elemant antenna array was designed in corporate feed structure with P-shaped patch are placed on each side of FR-4 substrate that has dimension (33×70) mm^2 with dielectric constant ε_r=4.3 and height h=1.6mm with optimum distance between elements X=38 mm as shown in Figure 4. Now let us investigate the parametric study as follows.

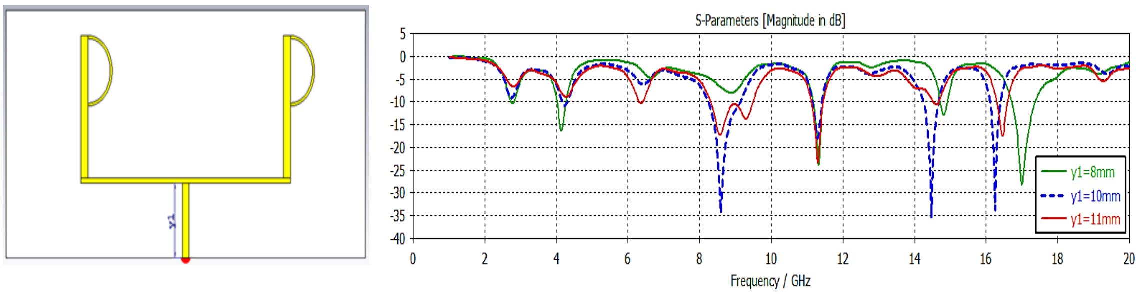


(a) (b)

Figure 4. P-shape antenna array (a) top view (b) bottom view

3.1. Effect of Center Feed Length

Figure 5 (a) shows 2-elements P-shaped antenna array, and Figure 5 (b) shows S_{11} vs. frequency for changing the length of the center feed. It noted that Y1=10 mm give good band width (i.e. S_{11} < -10 dB).

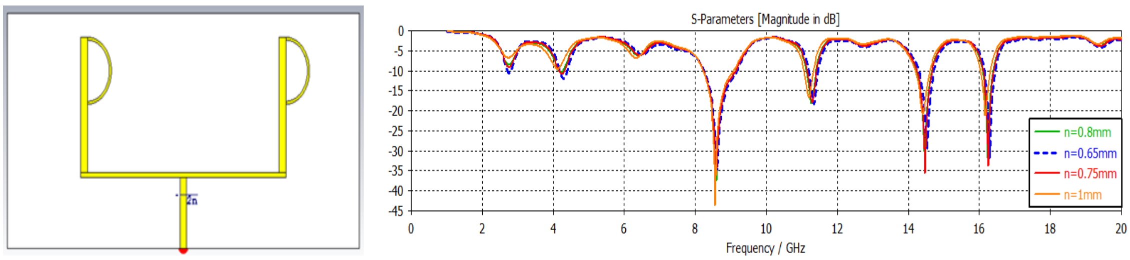


(a) (b)

Figure 5. Effect of center feed length
(a) 2-elements P-shaped antenna array (b) S_{11} vs. frequency

3.2. Effect of Center Feed Width

Figure 6 (a) shows 2-elements P-shaped antenna array, and Figure 6 (b) shows S_{11} vs. frequency for changing the width of center feed, it is observed that n=0.65 mm give good band width (i.e. S_{11} < -10 dB).

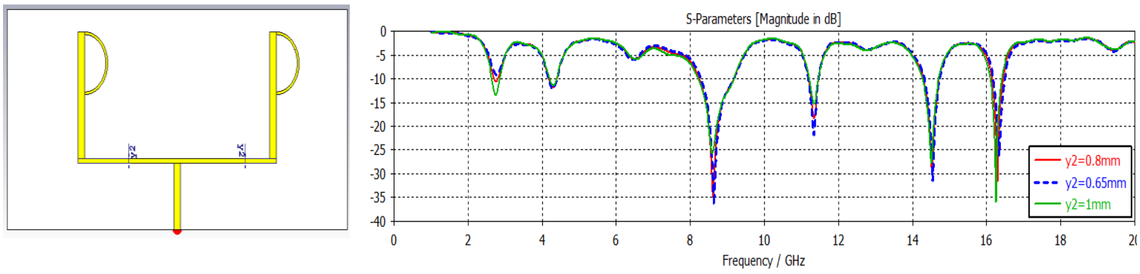


(a) (b)

Figure 6. Effect of center feed width
(a) 2-elements P-shaped antenna array (b) S_{11} vs. frequency

3.3. Effect of Horizontal Combination Feed Width

Figure 7 shows (a) 2-elements P-shaped antenna array, and (b) shows S_{11} vs. frequency for changing the width of horizontal combination feed, it is clear that Y2=0.65 mm give good band width with (i.e. S_{11} < -10 dB).

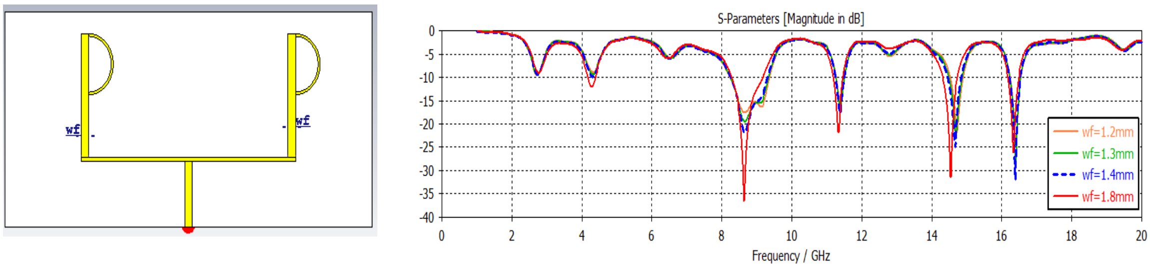


(a) (b)

Figure 7. Effect of horizontal combination feed width
(a) 2-elements P-shaped antenna array (b) S_{11} vs. frequency

3.4. Effect of Elements' Feed Width

Figure 8 shows S_{11} vs. frequency for changing the width of elements feed, it is noted that wf=1.4 mm give good band width (i.e. S_{11} < -10 dB).

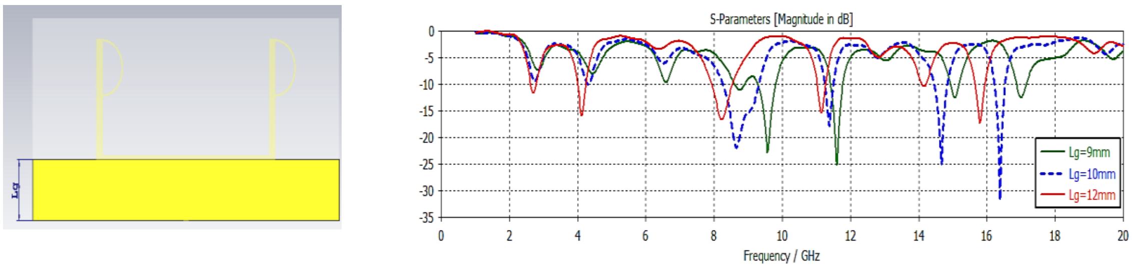


(a) (b)

Figure 8. Effect of elements' feed width (a) 2-elements P-shaped antenna array
(b) S_{11} vs. frequency

3.5. Effect of Ground Length

Figures 9 (a-b) shows S_{11} vs. frequency for changing the length of ground, it is seen that Lg=10 mm give good band width (i.e. S_{11} < -10 dB).



(a) (b)

Figure 9. Effect of ground length (a) 2-elements P-shaped antenna array (b) S_{11} vs. frequency

3.6. Effect of Etching Slots in Ground

The response of the antenna array was enhanced by etching slots in ground plane as shown in Figure 10 and Figure 11 respectivly. Two stair slots are etched at the each sides of ground in the beginning with length X1=8 mm^2 and width of steps X2=1 mm with space between steps S=1.75 mm, than etched two rectangular slots on each side of feeder in ground side with dimension (bt=1×ht=10) mm^2, these changes in ground give quad bands , the first band (8.163-9.379) GHz ,second band (11.279-11.526) GHz, (14.49-14.87) GHz and (16.276-16.58) GHz as shown in Figure 12.

Figure 10. Stair slot in ground plane of 2-element p-shaped antenna array

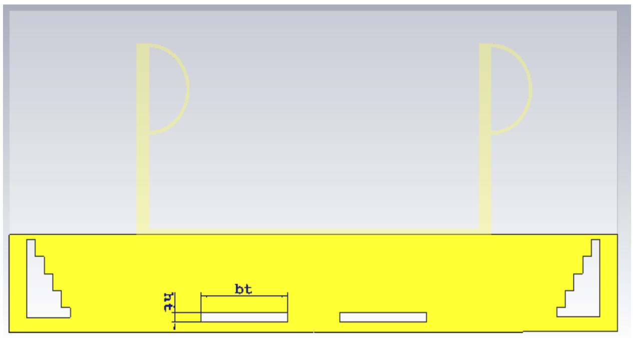


Figure 11. Stair slot and rectangular on each side of ground plane of 2-element P-shaped antenna array

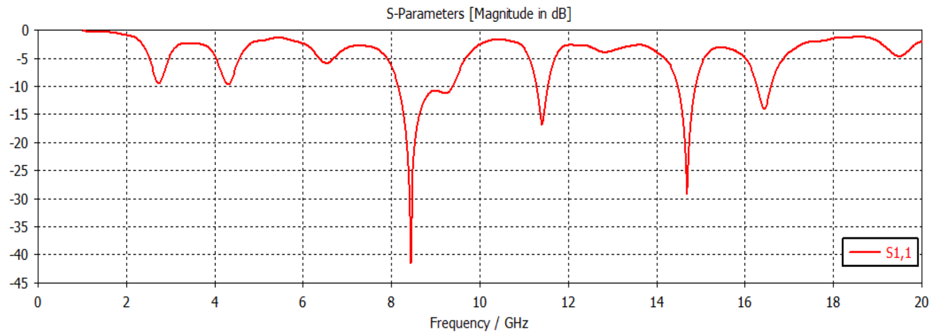


Figure 12. Effect of etching slots in ground

The optimum parameters of the modified antenna array are listed in Table 2. However Figure 13 shows the photograph of the fabricated antenna array using PCB process. Figure 14 shows the comparison between the simulation results and practical results for return loss loss S_{11}.

Table 2. P-shaped Antenna Array Parameters

Parameter	Value(mm)	Parameter	Value(mm)
Ls	33	Y1	10
ws	70	Y2	0.65
Lg	10	m	0
Wg	70	n	0.65
Lf	19	ht	1
Wf	1.4	bt	10
R1	4.6	X1	8
R2	4.3	X2	1
h	1.6	s	1.75

t	0.035

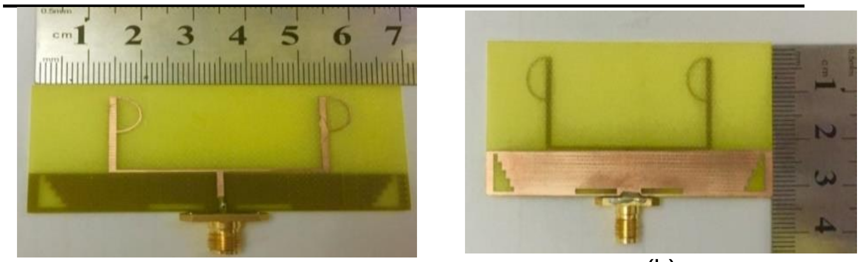


Figure 13. Practical 2-element P-shaped antenna array (a) top view (b) bottom view

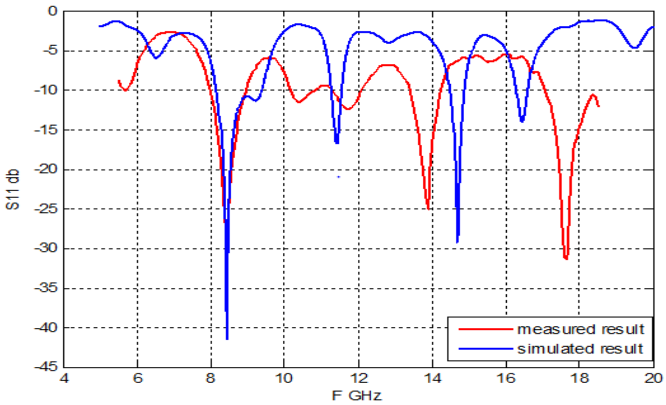


Figure 14. Comparison the measured results and simulated results S_{11} vs. frequency curve

Figure 14 shows aresonable agreement between the simulation and tested results with some shift between bands that is because of the unspecific values of ε_r and possible fabrication error. Also, there is a slight difference concerning the band bandwidth due to the SMA connecter's loss.

The simulation antenna arrays offer good matching for frequencies covering (8.1567-9.3811) GHz, with reflection coefficient of about (-41.553) dB at frequency of (8.429) GHz, also it covers another band (11.279-11.359) GHz, (14.482-14.877) GHz and(16.275-16.593) GHz while the fabrication antenna offers good matching operation for frequencies covering (8.035-8.945) GHz, with reflection coefficient of (-29.778) dB at frequency of (8.425) GHz also offer good matching at bands (10.18-10.33) GHz, (11.285-12.065) GHz, (13.43-14.21), (17.07-18.5) GHz. The gain of the modified antenna array is (5.635-8.305) dBi as shown in Figure 15.

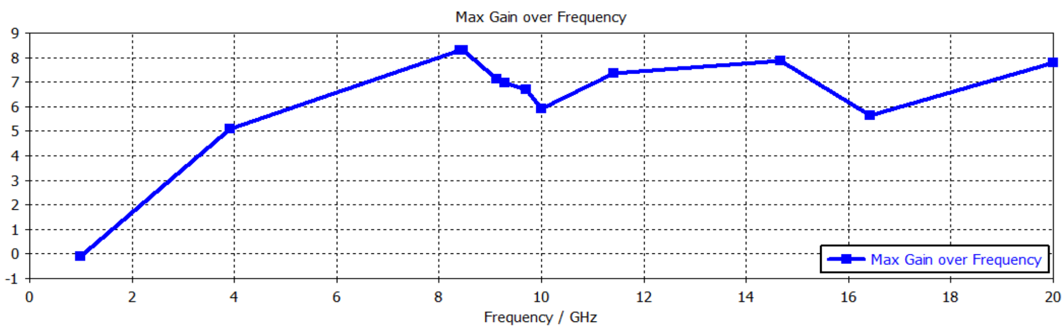
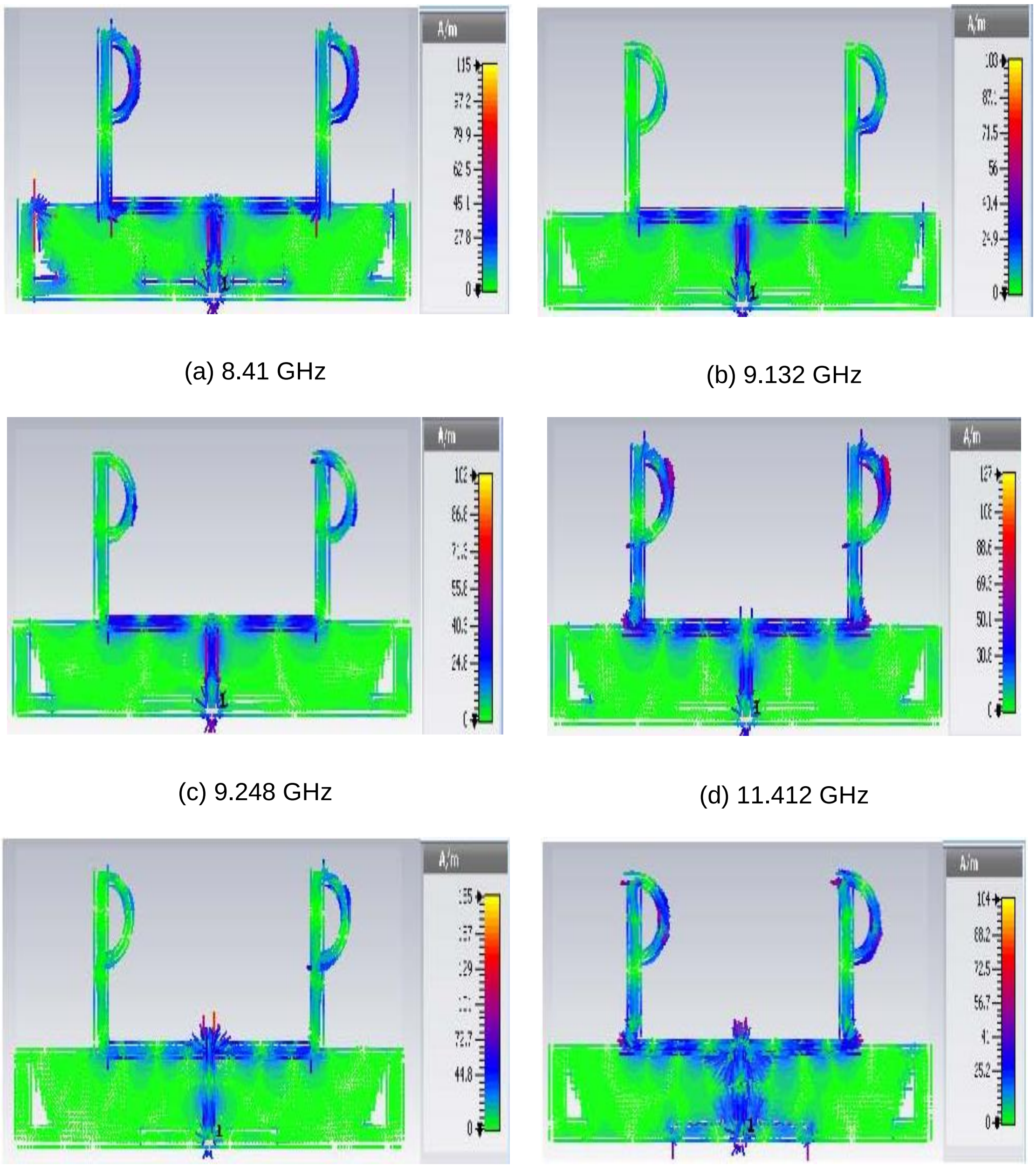


Figure 15. The gain of 2-element P-shaped antenna array

4. Current Distribution and Radiation Patterns

To clarify details about the properties of proposed antenna array, some frequencies are chosen to illustrate the current distribution and radiation patterns. The current distributions of proposed antenna array are shown in Figure 16 at frequencies (8.41, 9.132, 9.248, 11.412, 14.68, and 16.428) GHz respectively and they illustrate maximum currents are generated on antenna array surface. Also the 3D farfield radiation patterns for proposed antenna array has maximum directivities (8.37, 7.16, 7.05, 7.73, 8.01 and 5.83) dBi respectively as shown in Figure 17. The radiation patterns for the proposed antenna array are illustrated in Figure 18 in E-plane and H-plane for previous frequencies. From these figures, it's noted that, bi-directional patterns are radiated form this array antenna.

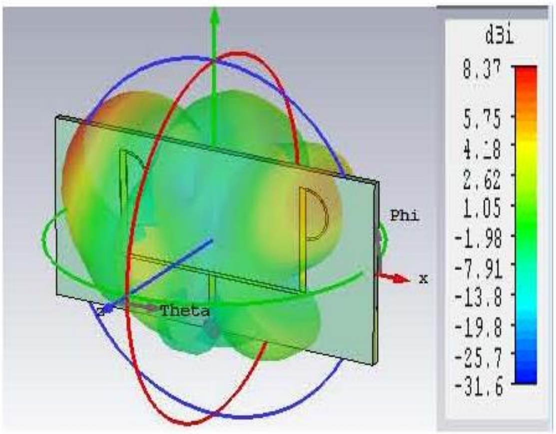


(a) 8.41 GHz (b) 9.132 GHz

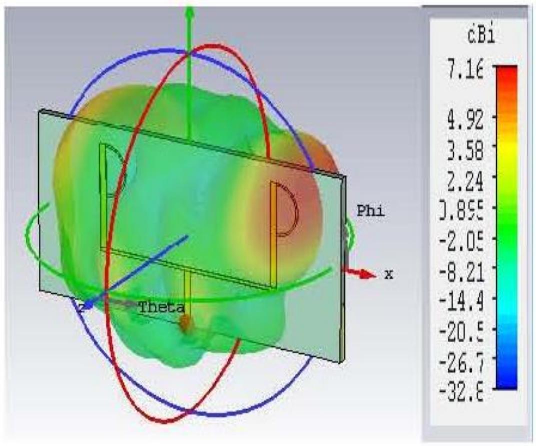
(c) 9.248 GHz (d) 11.412 GHz

(e) 14.68 GHz (f) 16.428 GHz

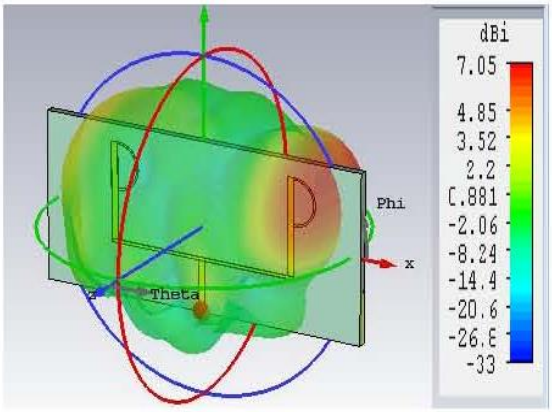
Figure 16. The current distributions of the antenna array for frequencies
(a) 8.41 GHz (b) 9.132 GHz (c) 9.248 GHz (d) 11.412 GHz (e) 14.68 GHz (f) 16.428 GHz



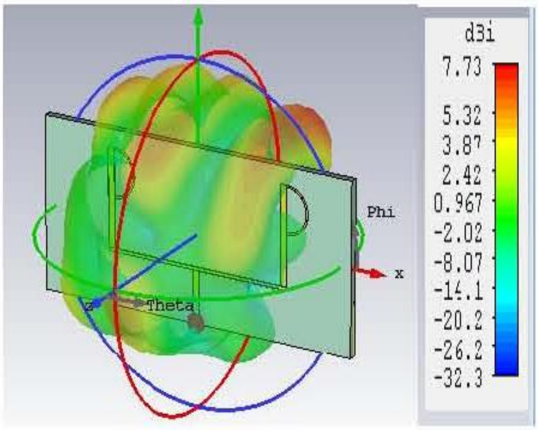
(a) 8.41 GHz



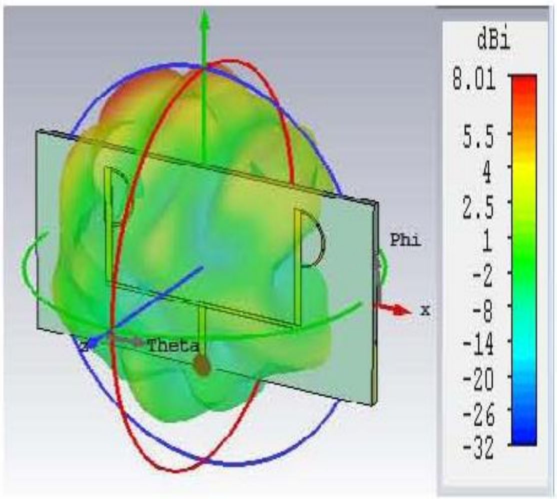
(b) 9.132 GHz



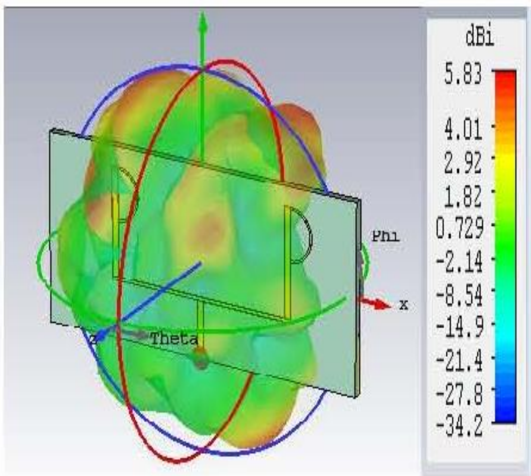
(c) 9.248 GHz



(d) 11.412 GHz

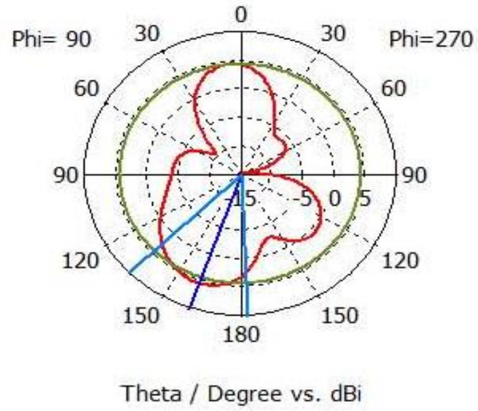


(e) 14.68 GHz

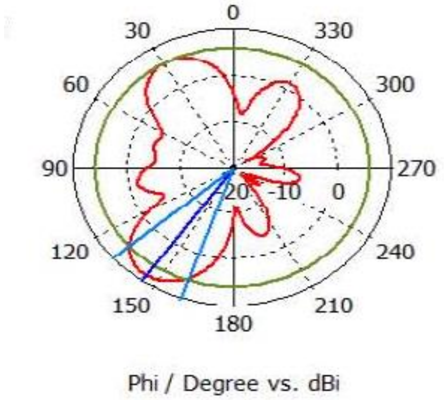


(f) 16.428 GHz

Figure 17. 3D farfield radiation patterns for frequencies
(a) 8.41 GHz (b) 9.132 GHz (c) 9.248 GHz (d) 11.412 GHz (e) 14.68 GHz (f) 16.428 GHz

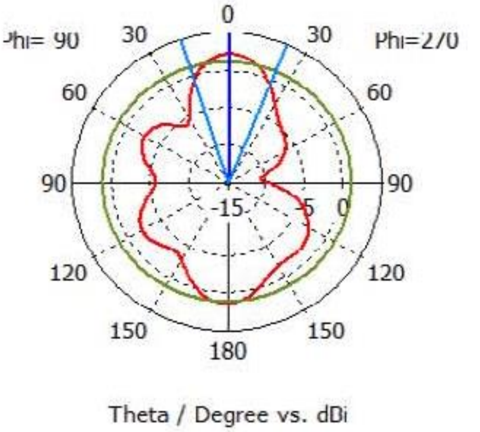


E-Field

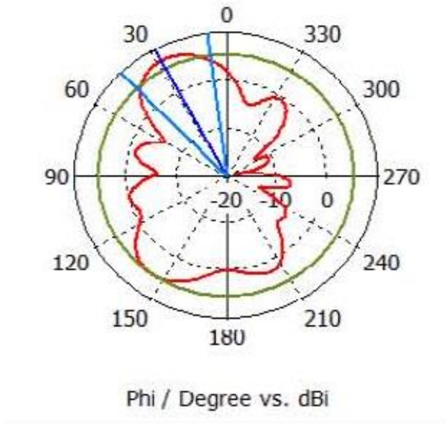


H-field

(a) 8.41 GHz

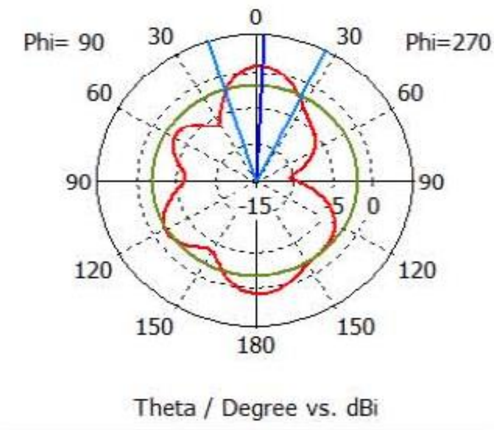


E-Field

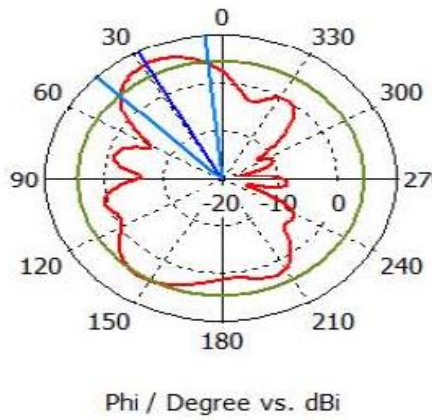


H-field

(b) 9.132 GHz



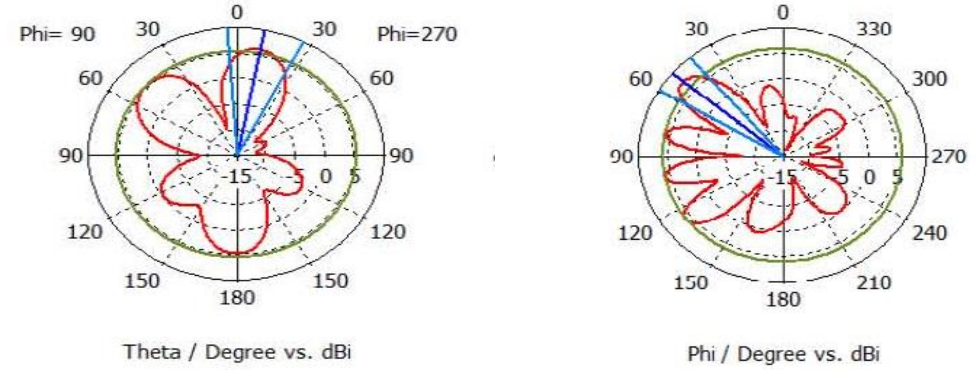
E-Field



H-field

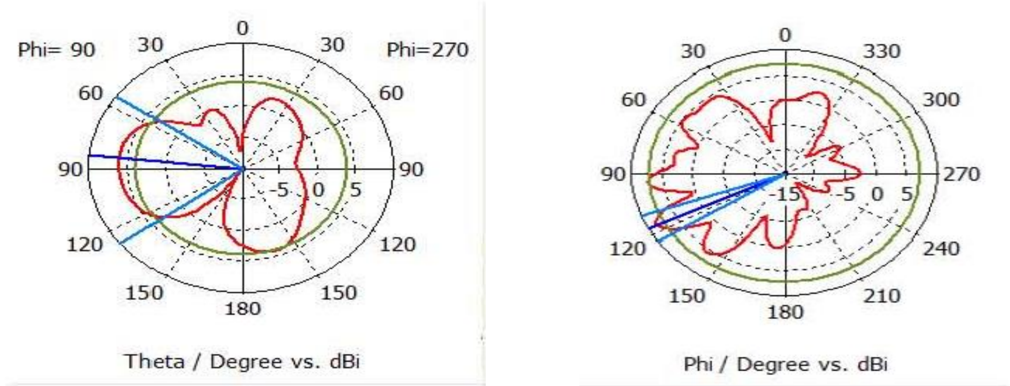
(c) 9.284 GHz

Figure 18. Simulated-radiation patterns for P-shaped antenna array for frequencies (a) 8.41 GHz (b) 9.132 GHz (c) 9.284 GHz



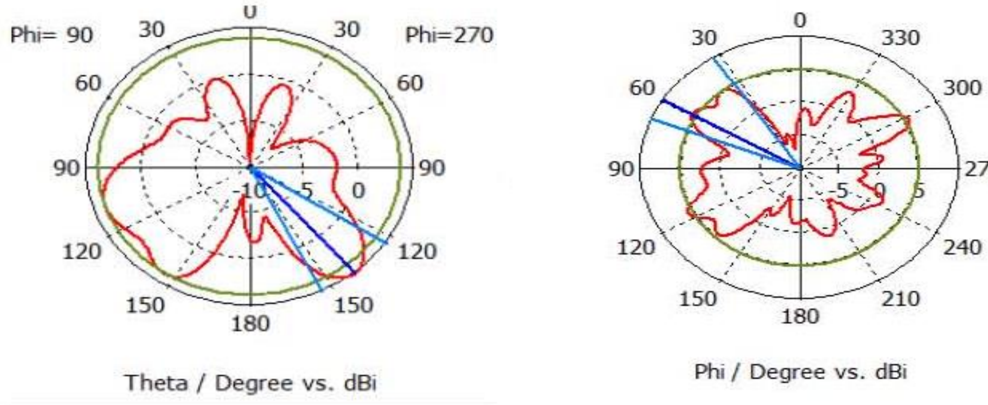
E-Field H-field

(d) 11.412 GHz



E-Field H-Field

(e) 14.68 GHz



E-Field H-Field

(f) 16.428 GHz

Figure 18. Simulated-radiation patterns for P-shaped antenna array for frequencies (d) 11.412 GHz (e) 14.68 GHz (f) 16.428 GHz

5. Conclusion

A P-shaped antenna for wireless communication is proposed and then an array is implemented. However the single P-shaped characteristics were investigated and then the 2-element P-shaped antenna is proposed and modified to enhance the gain. Also it was found that etching slots in the ground plane results in more operating bands in which ($S_{11} < -10dB$) which indicates the suitability of using the P-shaped antenna for many wireless communication proposes (i.e. satellite communication and military application).However the array is fabricated and tested using the VNA device. The size of the antenna array is ($33 \times 70 \times 1.6$) mm^3, with FR-4 substrate. It was noted that there is reasonable agreement between simulation results and tested results. We believe that, the main reason for the error is the unspecific value of ε_r and due to fabrication error.

References

[1] Nikitha Prem EK, Karthikeyan R. Triple Band Notch UWB Antenna Array with EBG Structure. *e IEEE WiSPNET.* 2016.
[2] Ma T G, Jeng S K. A Printed Dipole Antenna with Tapered Slot Feed for Ultra wide-Band Applications. *IEEE Transactions on Antennas and Propegations*. 2015; 53(11).
[3] Ashtankar P S, Dethe C G. U-T Shape Ultra Wide Band Antenna for IEEE802.15.3a Applications'. *International Journal of u- and e- Service, Science and Technology*. 2012; 5(3).
[4] *First Report and Order*. Federal Communications Commission (FCC). 2002.
[5] Sahu G, Choudri T R. A UWB Triangular Shape, Triangular Patch Antenna Array type Antenna for 3G Mobile Communication in India. *TECHNIA*. 2012; 5(1).
[6] Garg R. Microstrip Antenna Design Handbook. Boston: Artech House. 2011.
[7] Otman O, Touhami N A, Aghoutane M, Kchairi A B. A New Design of a Wideband Miniature Antenna Array. *International Journal of Electrical and Computer Engineering (IJECE)*. 2017; 7(4): 1850~1857.
[8] Rafique U, Ali S A. Ultra-Wideband Patch Antenna for K-band Applications. *TELKOMNIKA Indonesian Journal of Electrical Engineering*. 2014; 12(12): 8252-8256.
[9] Huque M T I, Hosain M K, Islam M S, Chowdhury M A. 'Design and performance analysis of microstrip array antennas with optimum Parameters for X-band aplications'. *International Journal of Advanced Computer Science and Applications (IJACSA)*. 2011; 2(4).
[10] Choi W, Kim J M, Bae J H, Pyo C. *High Gain and Broadband Microstrip Array Antenna using Combined Structure of Corporate and Series Feeding*. *IEEE*. 2004.
[11] Levine E, Malamud G, Shtrikman S, Treves D. A Study of Microstrip Array Antennas with the Feed Network. *IEEE Transactions on Antennas and Propegations*. 1989; 31(4).