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Investigate the Performance of Various Shapes of Planar Monopole Antenna on Modified Ground Plane Structures for L frequency Band Applications

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ABSTRACT: In this paper, various shapes of planar monopole antenna on different ground plane structures are presented. It is designed for the 1-2 GHz frequency band for L-band application. A monopole of square, circular, triangular and hexagon shape is mounted vertically on the dielectric of glass epoxy (FR4 lossy substrate) with relative permittivity of 4.3, thickness of 1.6 mm above the ground plane through a single feeding strip. Simulation results such as impedance bandwidth, directivity, gain and radiation pattern are also analyzed and compared. The effect of feeding strip is a critical parameter for the performance of antenna, is studied for various shapes of monopole antenna are investigated. The radiation performance is also shown to be acceptable over a wide range of frequency.

KEYWORDS: Monopole Antenna, Planar Square Monopole Antenna, Planar Circular Monopole Antenna, Planar Triangular Monopole Antenna, Impedance bandwidth.

1 INTRODUCTION

With the growth of applications in wireless communication systems, various antenna designs take greater demand [1-7]. One of the most popular antennas employed in mobile and wireless communication systems is the monopole antenna because of satisfactory radiation characteristics over a wideband is achieved.

Antennas, which can work properly in more than one frequency region either for transmitting or receiving electromagnetic (EM) waves, are termed as Multiband antennas. Such antennas are usually tri-band, penta-band etc. Multi-band antennas are much more complex than the single band antennas in their design, structures and operations [1].

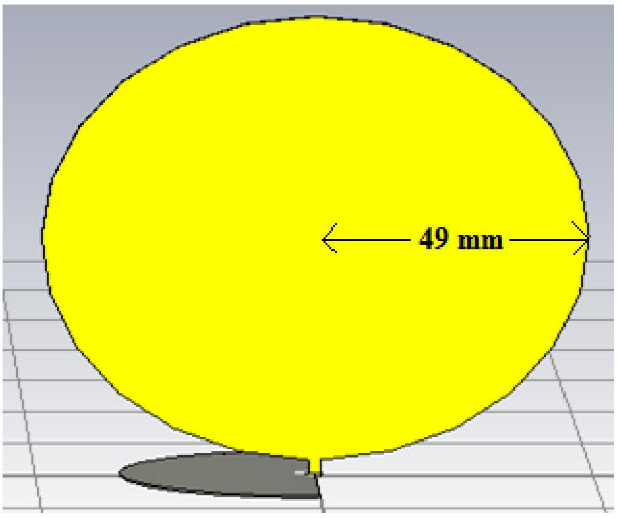
In this paper, several planar such as square, circular, triangular and hexagon shaped monopole antenna with single feeding strip above the modified ground plane structure is designed for single band antenna. Their attractive merits such as simple structure, omni-directional radiation pattern, wide impedance bandwidth, compact size and low cost [2]. The proposed planar monopole antenna is a simple configuration fed by 50Ω SMA connector placed under the ground plane of the antenna [3]. Planar monopole antenna can be optimizing to provide extremely wide impedance bandwidths with acceptable radiation performance. They can be developed to cover several operating frequency bands of wireless communication GSM900: 890-960 MHz, DCS: 1.71-1.88 GHz, Personal Communication System (PCS) 1.85-1.99 GHz, and Universal Mobile Telecommunication System (UMTS 1.92-2.17 GHZ) IMT-2000 [4]-[6].

The designs of the proposed configurations are based upon the monopole antenna structure and the ground plane shapes [7] and parameters of the antenna such as return loss S_{11}, directivity and gain are measured with the help of CST (Computer Simulation Technology) Microwave Studio Software.

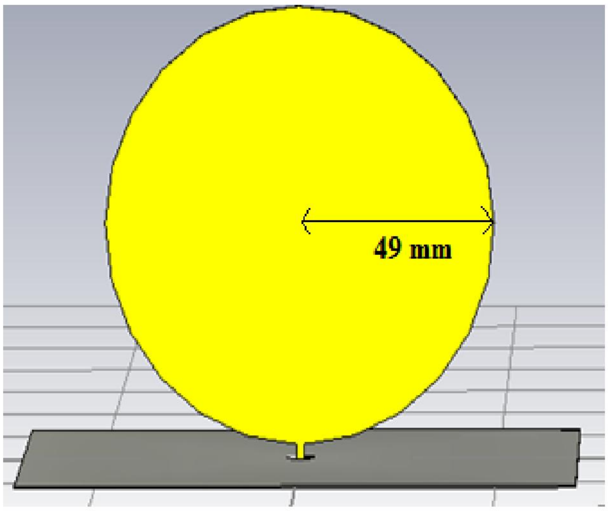
CST MICROWAVE STUDIO is a fully featured software package for electromagnetic analysis and design in the high frequency range. The software contains a transient solver which can obtain the entire broadband frequency behaviour of the simulated device. This solver is very efficient for most kinds of high frequency applications such as connectors, transmission lines, filters, antennas and many more.

2 ANTENNA DESIGN

The proposed figure of the planar circular monopole antenna (PCMA-1) with the half circular ground plane on CST [8]-[20] Microwave Studio software is shown in figure 1(a). The proposed PCMA is vertically mounted above a one sided half circular ground plane of radius 35 mm and in the second design, planar circular monopole antenna (PCMA-2) is vertically mounted with the rectangular ground plane structure of size 140 x 120 mm^2 is shown in figure 1(b). The circular monopole and single feeding strip are integrated together and constructed from a single aluminium plate (1 mm thick sheet is used) for both the design of PCMA. In the design of both PCMA structure, feeding strip has a uniform width of 2 mm and a length of 3.5 mm and is connected to a centre of the lower arc of the circular planar monopole.



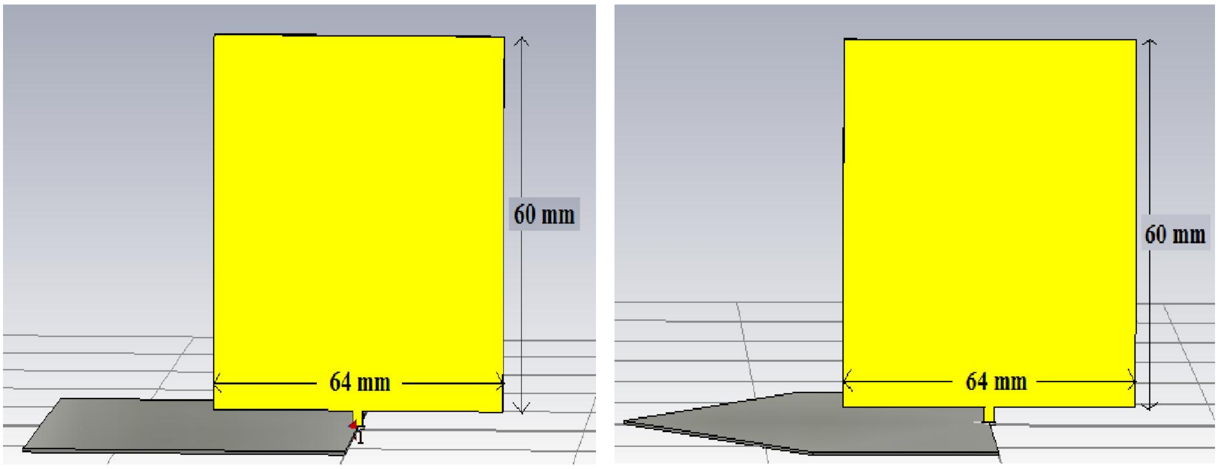
(a)



(b)

Fig. 1. ***Geometry of the proposed planar circular monopole antenna on CST with (a) one sided half circular ground plane (b) rectangular ground plane***

The third and fourth design shows the planar rectangular monopole antenna (PRMA-1) and (PRMA-2) with one sided half rectangular ground plane and one side half hexagon ground plane on CST are shown in figure 2(a) and 2(b) respectively. The size of one sided half rectangular ground plane in the PRMA-1 is 70 x 130 mm^2 and the radius of one side half hexagon ground plane radius in the PRMA-2 is 80 mm. In the design of both PRMA structure, feeding strip has a uniform width of 2 mm and a length of 3 mm and is connected to a centre of the bottom side of the rectangular monopole.



(a) *(b)*

Fig. 2. Geometry of the proposed planar rectangular monopole antenna on CST (a) with one sided half rectangular ground plane (b) one side half hexagon ground plane.

Figure 3 shows geometry of proposed planar equilateral triangular monopole antenna (PETMA) above a one sided half rectangular ground plane of size 90 x 105 mm^2. The geometry of proposed figure of Planar Hexagon Monopole Antenna (PHMA) with rectangular ground plane shape of size 140 x 150 mm^2 on CST software is shown in figure 4. The feeding strip in PETMA and PHMA contains a constant width of 2 mm and length of 4.5 mm to achieve the wide bandwidth and is connected to a centre of the bottom side of the monopole structure.

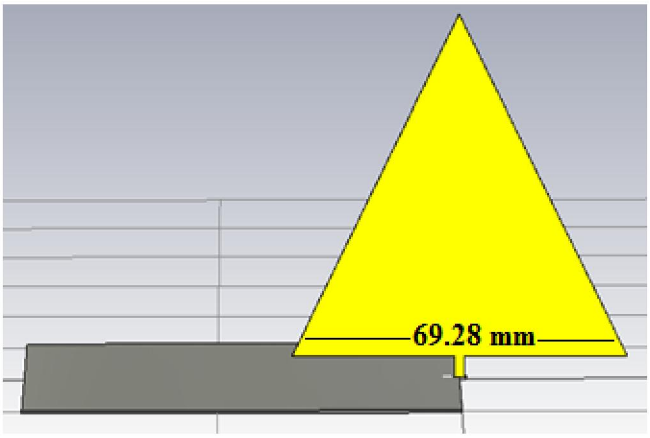


Fig. 3. Geometry of proposed PTMA with one sided half rectangular ground plane on CST

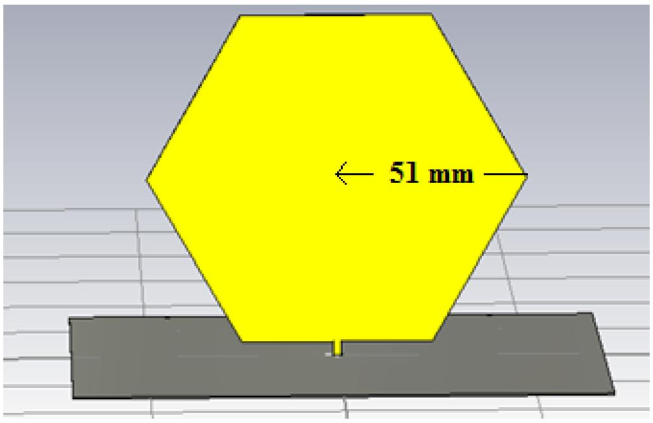


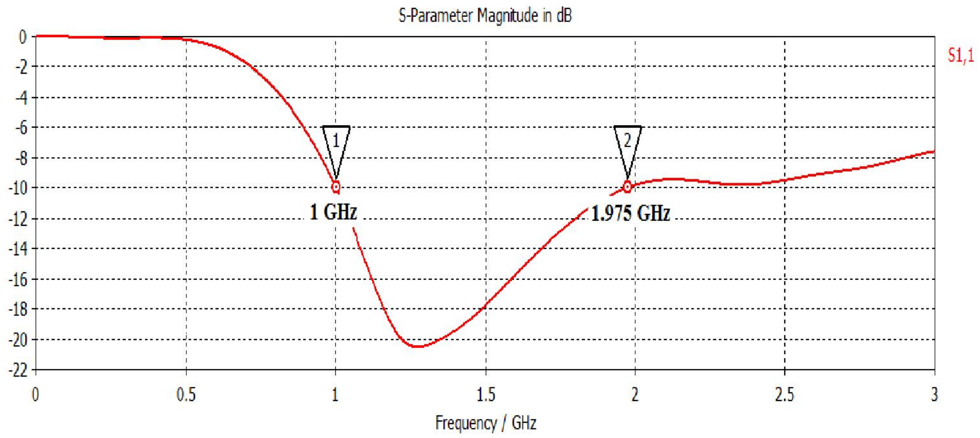
Fig. 4. Geometry of proposed PHMA with rectangular ground plane on CST

3 SIMULATED AND EXPERIMENTAL RESULT'S

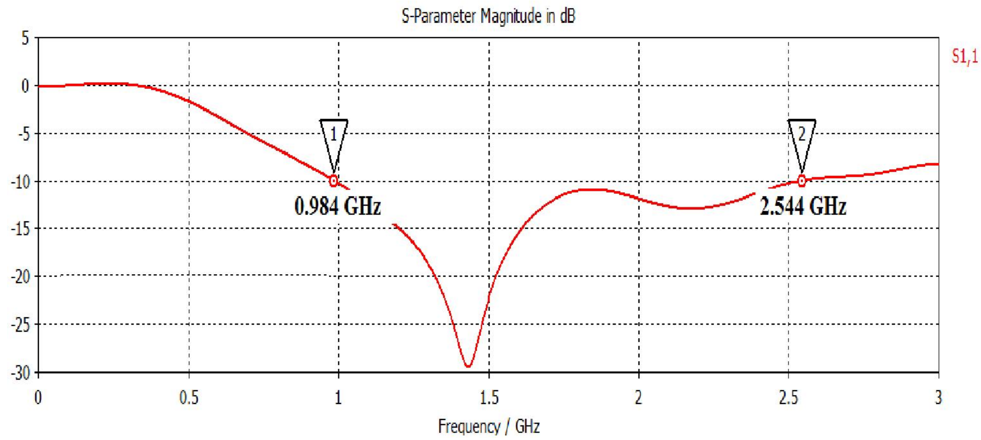
Prototypes of the both proposed PCMA-1 and PCMA-2 with a single feeding strip above the one sided half circular ground plane and rectangular ground plane were simulated and studied. The simulated results are obtained using Computer Simulation Software (CST) Microwave Studio software.

The simulated return loss of PCMA-1 with the one sided half circular ground plane is shown in figure 5(a). The radius of the circular planar monopole is chosen to be 49 mm, which easily makes the obtained impedance bandwidth (10 dB return loss) have a lower frequency (f_L) of 1.0 GHz. Also by selecting the length of feeding strip to be 3.5 mm, the upper frequency (f_U) of the impedance bandwidth is 1.975 GHz and the bandwidth of 975 MHz is achieved.

The simulated return loss for the design of PCMA-2 with the rectangular ground plane is shown in figure 5(b). The radius of circular monopole and feeding strip length are same as the first design to get the wide impedance bandwidth of 1.56 GHz in the frequency range of 0.984 – 2.544 GHz.



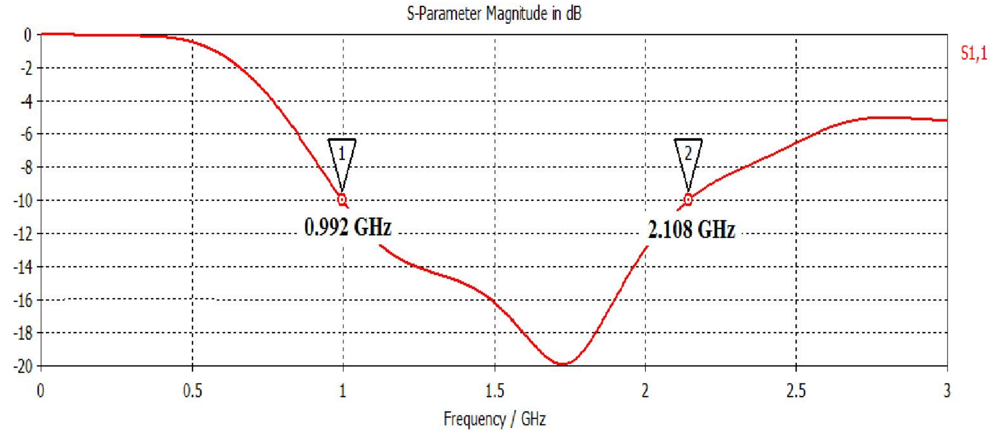
(a)



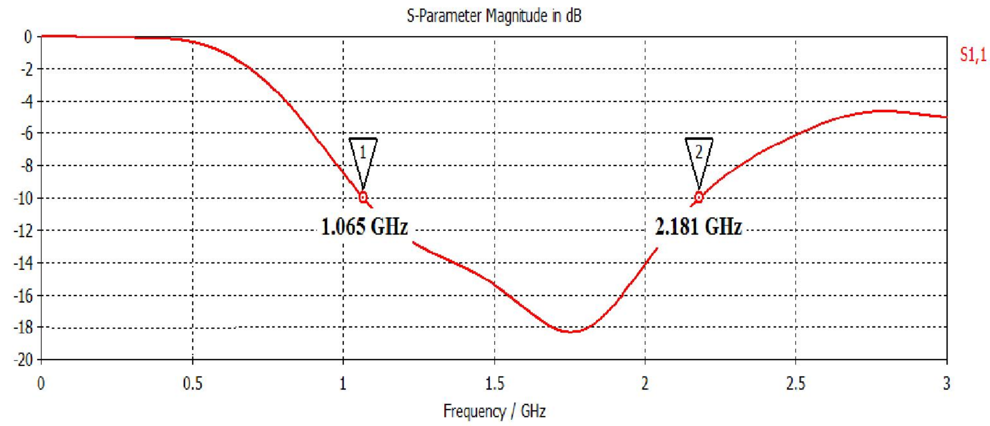
(b)

Fig. 5. Simulated return loss for (a) PCMA-1 and (b) PCMA-2

The simulated return loss for the PRMA-1 with one sided half rectangular ground plane is shown in figure 6(a) and the simulated return loss for the design of PRMA-2 with one sided half hexagon ground plane is shown in figure 6(b). The size of rectangular planar monopole and length of feeding strip in both the design of PRMA-1 and PRMA-2 are set to 64 x 60 mm^2 and 3 mm respectively, to achieve the impedance bandwidth of 1.116 GHz in the frequency range 0.992 - 2.108 and bandwidth of 1.116 GHz in the frequency range of 1.065 - 2.181 GHz respectively.



(a)



(b)

Fig. 6. Simulated return loss for (a) PRMA-1 (b) PRMA-2

The simulated return loss for PETMA with one sided half rectangular ground plane is shown in figure 7. The side of the equilateral triangular planar monopole is 69.28 mm which easily makes the obtained impedance bandwidth of about 1.079 GHz have a lower frequency of 1.025 GHz and upper frequency of 2.104 GHz. The simulated return loss of PHMA with rectangular ground plane is shown in figure 8. The each side of the hexagonal planar monopole is 51 mm which obtained the impedance bandwidth of 1.747 GHz in the frequency range of 0.932 - 2.679 GHz. The feeding strip length of 4.5 mm and width of 2 mm are used for the above PETMA and PHMA design.

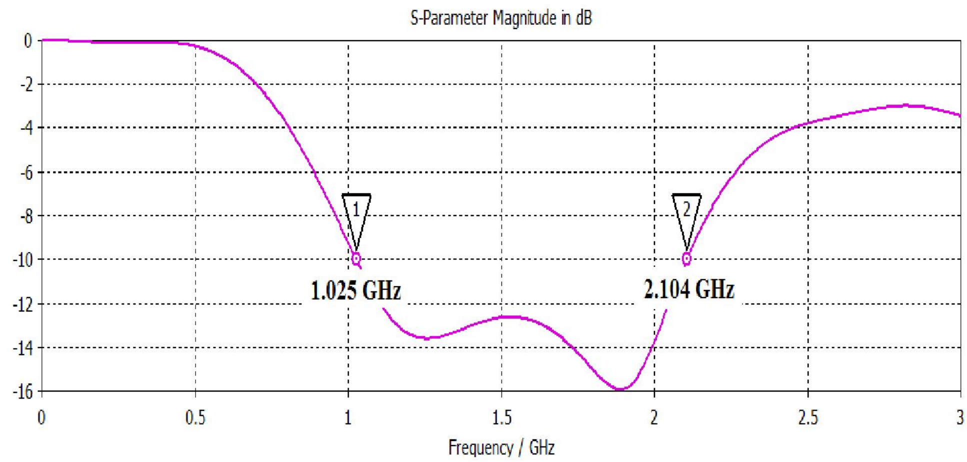


Fig. 7. Simulated result of the proposed PETMA

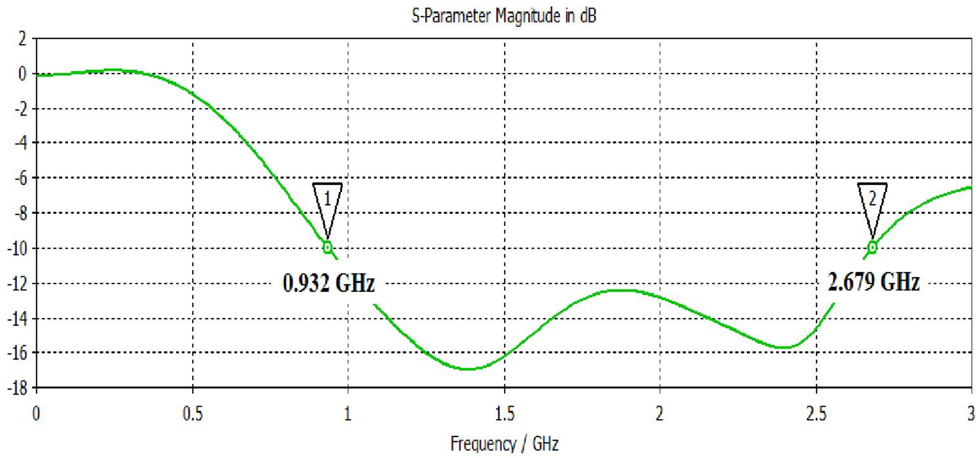


Fig. 8. Simulated result of the proposed PHMA

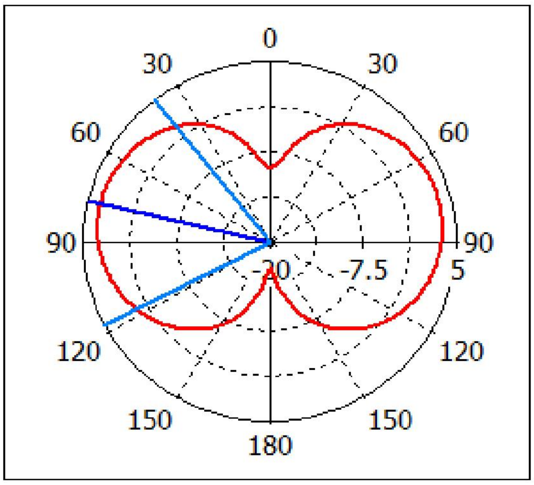
The corresponding simulated data of the various shapes of monopole antenna with different ground planes are listed in table 1 for comparison.

Table 1. Simulated results of the circular, rectangular, triangular and hexagonal planar monopole antenna on different ground planes structure with different lower and upper frequency.

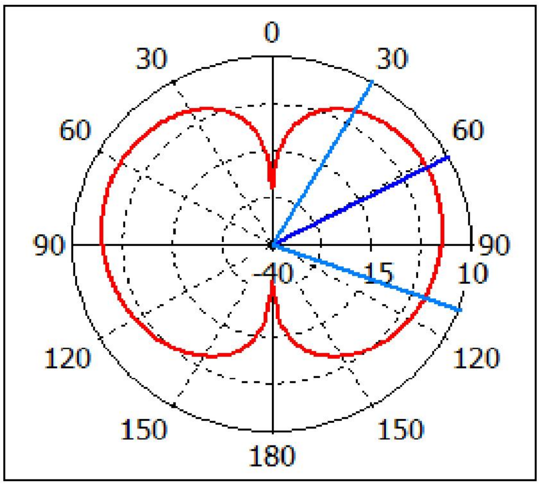
Configuration	Bandwidth (GHz)	Frequency Ratio (f_U/f_L)
PCMA-1	0.975, (1.0-1.975)	1.97
PCMA-2	1.560, (0.984-2.544)	2.58
PRMA-1	1.122,(0.991-2.113)	2.13
PRMA-2	1.116, (1.065-2.181)	2.04
PETMA	1.079, (1.025-2.104)	2.05
PHMA	1.747,(0.932-2.679)	2.87

It is noticed form the data of Table 1, all configurations given above are designed for the L frequency band applications and the bandwidths of PHMA and PCMA-2 are greater than the remaining design of monopole antennas.

Radiation characteristic of all the proposed planar monopole antennas are also analyzed. Simulated radiation pattern for all the cases of monopole antenna are shown in figure 9.



(a)



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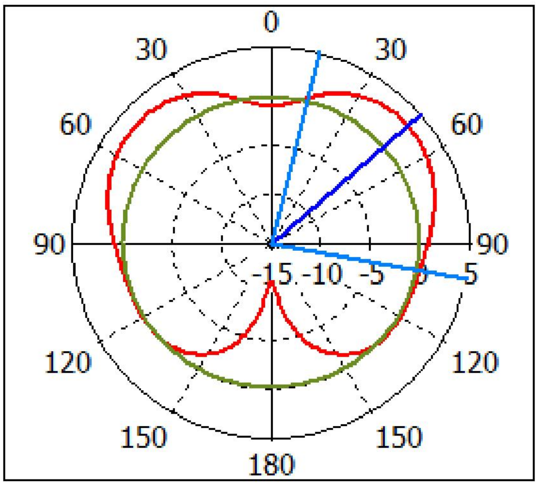

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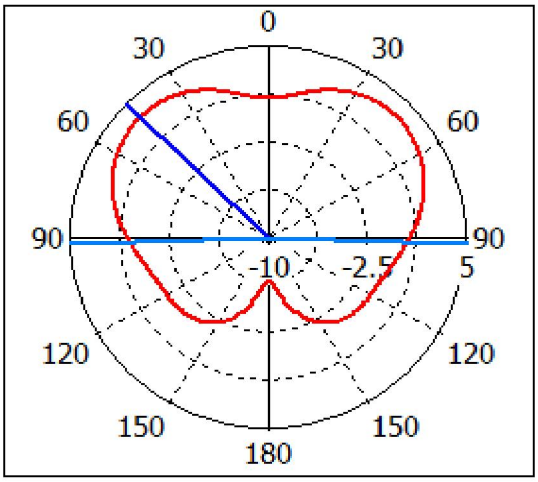

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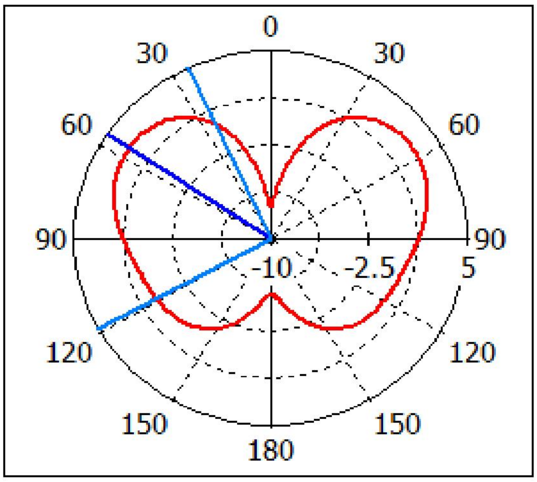

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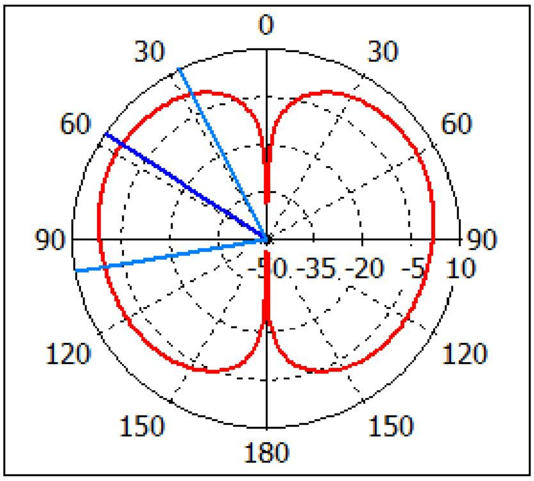

(f)

Fig. 9. Simulated radiation pattern of (a) PCMA-1 at 1.28 GHz (b) PCMA-2 at 1.43 GHz (c) PRMA-1 at 1.6 GHz (d) PRMA-2 at 1.75 GHz (e) PETMA at 1.88 GHz (f) PHMA at 1.38 GHz

The radiation efficiency, directivity and gain of all the proposed monopole antennas at different frequencies are shown in Table 2.

Table 2. Radiation efficiency, Directivity and Gain of all proposed monopole antennas at different frequencies

Configuration	Frequency (GHz)	Radiation Efficiency (%)	Directivity (dBi)	Gain (dB)
PCMA-1	1.28	99.36	3.135	3.158
PCMA-2	1.43	98.92	3.503	3.555
PRMA-1	1.60	99.11	3.190	3.197
PRMA-2	1.75	99.67	3.504	3.489
PETMA	1.88	98.88	3.374	3.325
PHMA	1.38	98.18	3.723	3.643

For the comparison point of view, Figure 10 shows a comparison of the simulated return loss of all the design of planar monopole antennas. It is clearly shown in figure 10 and from the data of table 1 that the response and bandwidth of PCMA-2 is better than remaining proposed monopole antenna designs.

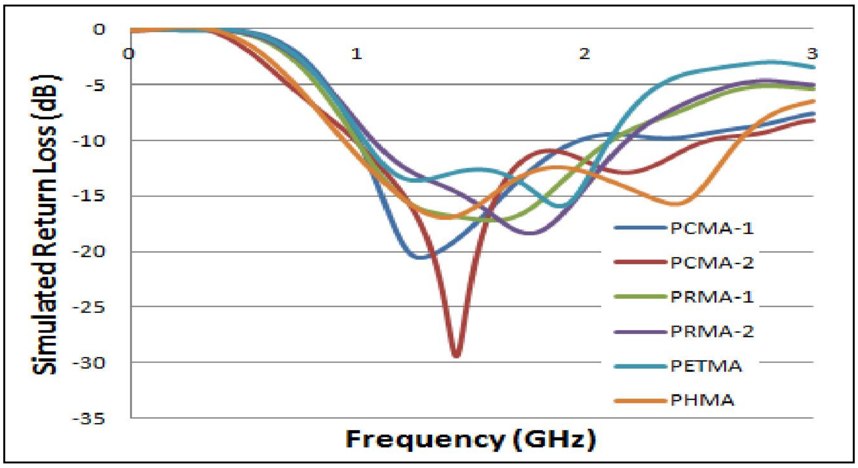

Fig. 10. Comparison of simulated return loss of the all proposed monopole antennas

The antenna gain of all the design of proposed planar monopole antenna are analyzed in the frequency range 0 – 3 GHz. For frequencies upto about 3 GHz, it is seen that the antenna gain of proposed PCMA-1, PRMA-1, PRMA-2 and PETMA monotonically increases with the increases of frecuencies from about 2 to 4.8 dB, 1.6 to 5.5 dB, 1.6 to 6.0, 1.8 to 6.0 respectively. The antenna gain of proposed PCMA-2 and PHMA upto 2.2 GHz frequency is also monotonically increases from about 1.5 to 6.5 dB and 1.4 to 6.3 dB respectively but for higher frequency portion of 2.2 – 3 GHz, the antenna gain decreases from about 6.5 to 5.3 dB and 6.3 to 5.0 dB respectively with the increase of frequency. The antenna gain with frequency in the frequency range 0-3 GHz is also plotted in figure 11 for comparison.

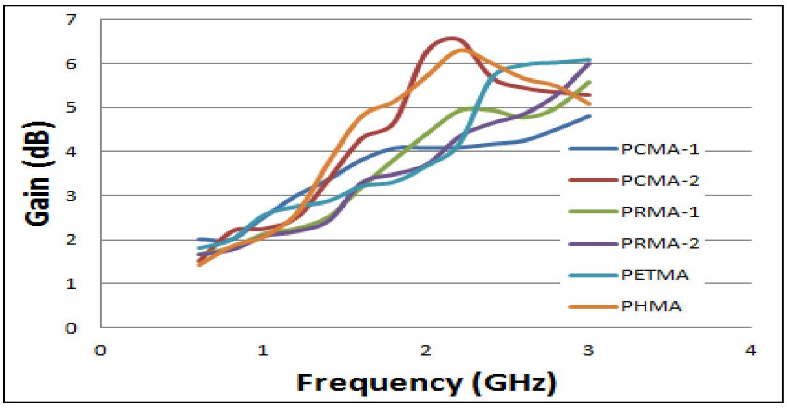

Fig. 11. Comparison of the antenna gain with frequency of all the proposed planar monopole antennas

The lengths of feeding strip, which is the gap between the monopole structure and the ground plane are studied. The corresponding simulated data are listed in table 3 to table 8 of all the design of monopole antennas for comparison, having all the remaining parameters of the proposed antennas are same as design of PCMA-1.

The value of feeding strip length varies from 3 to 4.5 mm for the PCMA-1 is analysed and corresponding simulated data are listed in table 3 with respective simulated return loss as shown in figure 12 which is clearly shows that the response (return loss) of antenna and antenna bandwidth are the function of feeding strip. The antenna bandwidth is decreases with the increment in feeding strip length. The antenna efficiency is also given as per the repsponse of PCMA-1 with variation in feeding strip length. The antenna efficiency is also given for each case of PCMA-1 as per the variation in feeding strip length.

Table 3. Simulated results of the proposed PCMA-1 as a function of feeding strip

Feeding Strip (mm)	Simulated Frequency (GHz)		Bandwidth (GHz)	Antenna Efficiency (%)
	f_L	f_U		
3	1.018	2.663	1.645	99.16
3.5	1.000	1.975	0.975	99.64
4	0.990	1.970	0.980	99.66
4.5	0.970	1.818	0.848	99.70

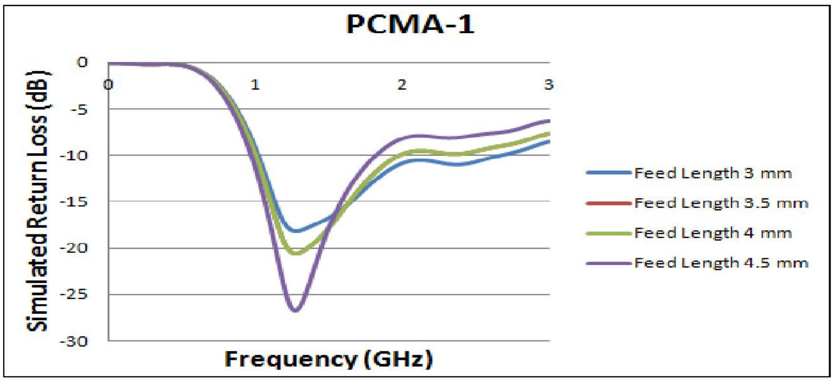

Fig. 12. Simulated return loss of the proposed PCMA-1 as a function of feeding strip

The simulated return loss of the proposed PCMA-2 with the variation in feeding strip varies from 2.5 to 4 mm is shown in figure 13 and the corresponding data (simulated results) is also listed in table 4. All the remaining parameters of the proposed antenna are constant for comparison. The data of the table 3 clearly shows that antenna bandwidth is monotonically decreases with the increment in length of feeding strip. The antenna efficiency is also given as per the repsponse of PCMA-2 with variation in feeding strip length.

Table 4. Simulated results of the proposed PCMA-2 as a function of feeding strip

Feeding Strip (mm)	Simulated Frequency (GHz)		Bandwidth (GHz)	Antenna Efficiency (%)
	f_L	f_U		
2.5	0.929	2.828	1.899	99.53
3	0.955	2.701	1.746	99.67
3.5	0.984	2.544	1.560	98.90
4	1.023	2.480	1.457	99.38

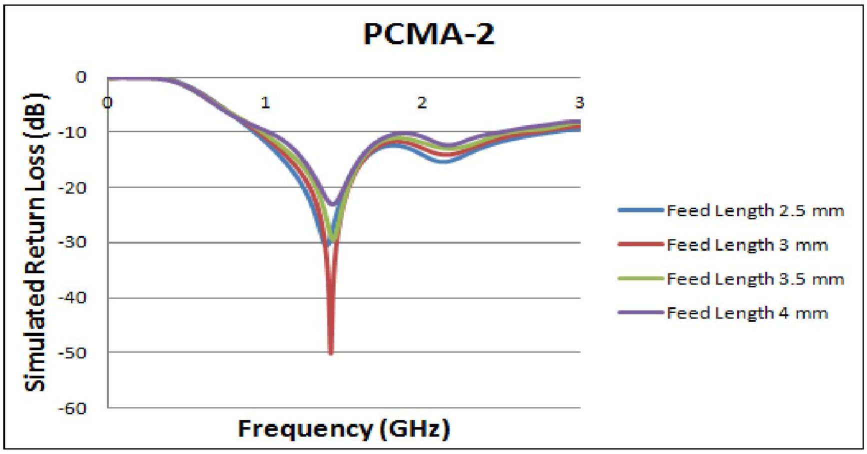

Fig. 13. Simulated return loss of the proposed PCMA-2 as a function of feeding strip

The value of feeding strip length varies from 2.5 to 5 mm for the PRMA-1 is analysed and corresponding simulated data are listed in table 5 and their respective simulated return loss is shown in figure 14 which is clearly shows that the response (return loss) of antenna and antenna bandwidth are the function of feeding strip. The data of the table 3 clearly shows that antenna bandwidth is monotonically increases with the increment in length of feeding strip up to 4 mm and after that if feeding strip length is further increased then antenna of bandwidth is decreases.

Table 5. Simulated results of the proposed PRMA-1 as a function of feeding strip

Feeding Strip (mm)	Simulated Frequency (GHz)		Bandwidth (GHz)	Antenna Efficiency (%)
	f_L	f_U		
2.5	0.991	2.024	1.033	97.79
3	0.992	2.108	1.116	98.26
3.5	0.996	2.143	1.147	98.30
4	1.004	2.156	1.152	99.01
4.5	1.035	2.130	1.095	99.42
5	1.099	2.115	1.016	99.59

The simulated return loss of the proposed PRMA-2 with the variation in feeding strip length varies from 2 to 4.5 mm is shown in figure 15 and the corresponding data (simulated results) is also listed in table 6. All the remaining parameters of the proposed antenna are same as design of PRMA-2 for comparison. The data of the table 3 clearly shows that antenna bandwidth is monotonically increases with the increment in length of feeding strip up to 4 mm and after that if feeding strip length is further increased then antenna of bandwidth is decreases.

Table 6. Simulated results of the proposed PRMA-2 as a function of feeding strip

Feeding Strip (mm)	Simulated Frequency (GHz)		Bandwidth (GHz)	Antenna Efficiency (%)
	f_L	f_U		
2	1.042	1.894	0.852	98.66
2.5	1.053	2.114	1.061	96.35
3	1.065	2.181	1.116	98.2
3.5	1.087	2.210	1.123	99.02
4	1.135	2.218	1.083	99.49
4.5	1.299	2.209	0.910	99.91

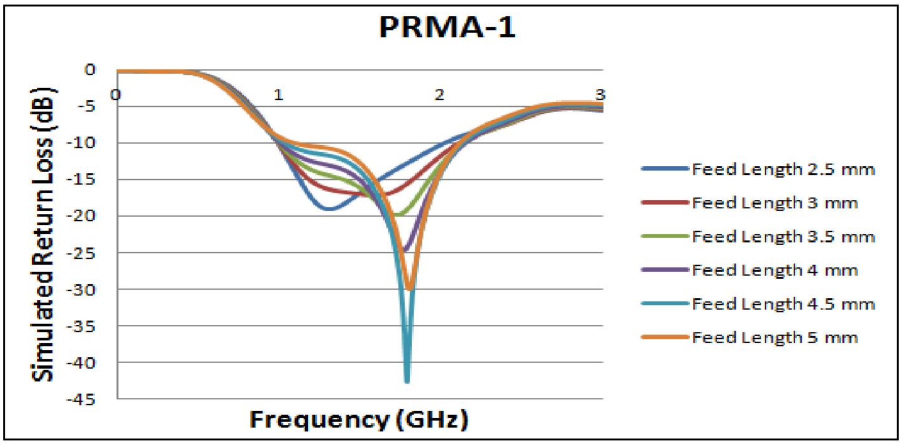

Fig. 14. Simulated return loss of the proposed PRMA-1 as a function of feeding strip

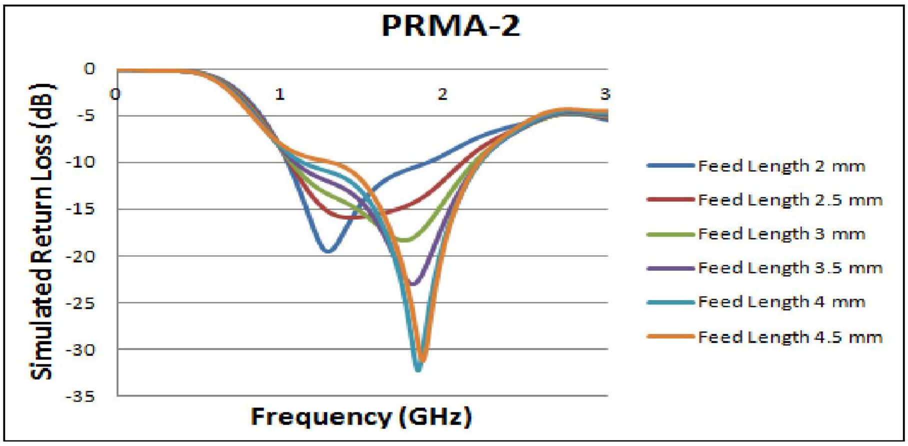

Fig. 15. Simulated return loss of the proposed PRMA-2 as a function of feeding strip

The effects of feeding strip length on the impedance bandwidth of PETMA are studied in table 7 and corresponding simulated return loss is shown in figure 16. For the feeding strip length varies from 3 to 4.5 mm, the antenna bandwidth is monotonically increases with the increment of the length of feeding strip.

Table 7. Simulated results of the proposed PETMA as a function of feeding strip

Feeding Strip (mm)	Simulated Frequency (GHz)		Bandwidth (GHz)	Antenna Efficiency (%)
	f_L	f_U		
3	1.119	2.065	0.946	99.09
3.5	1.076	2.091	1.015	98.65
4	1.049	2.102	1.053	97.74
4.5	1.025	2.104	1.079	96.34

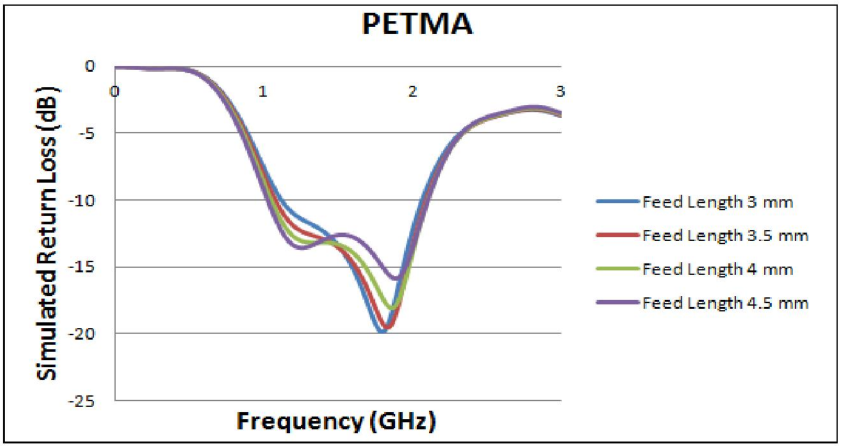

Fig. 16. Simulated return loss of the proposed PETMA as a function of feeding strip

Table 8. Simulated results of the proposed PHMA as a function of feeding strip

Feeding Strip (mm)	Simulated Frequency (GHz)		Bandwidth (GHz)	Antenna Efficiency (%)
	f_L	f_U		
3.5	0.886	2.680	1.794	97.49
4	0.906	2.687	1.781	94.79
4.5	0.939	2.679	1.740	96.21
5	0.960	2.670	1.710	98.06
5.5	0.968	2.657	1.689	98.96
6	1.026	2.622	1.596	99.54

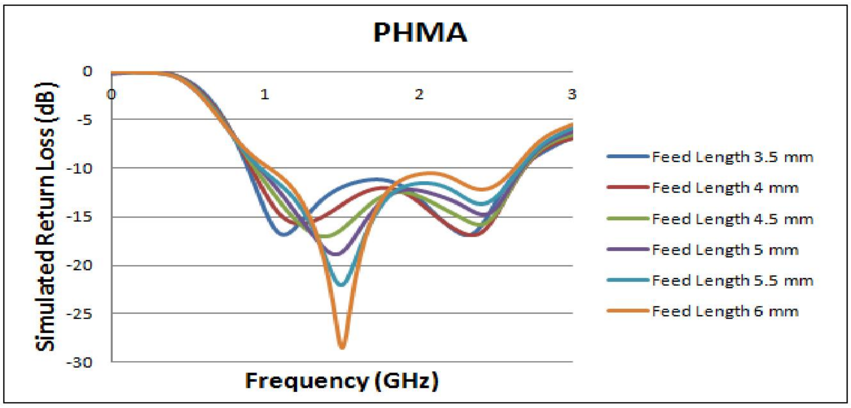

Fig. 17. Simulated return loss of the proposed PHMA as a function of feeding strip

The simulated return loss of the PHMA with the variation of feeding strip varies from 3.5 to 6 mm is shown in figure 17. The corresponding bandwidth (simulated results) is also listed in table 8. It is clearly seen that the antenna bandwidth is monotonically decreases with the increment of the length of feeding strip.

4 CONCLUSION

New configurations of planar circular, square, equilateral triangular and hexagon monopole antenna on the modified ground plane shapes using single feeding strip has been investigated. These proposed antennas can be easily constructed using the aluminum sheet and achieved the bandwidth of 1 GHz and much more in all the design and each cases of monopole antenna structure which is applicable for the L-frequency Band. It is also investigated that feed gap is a frequency dependent parameter which effects the bandwidth of the antenna (antenna bandwidth in each design is either increases or decreases as feeding strip length increases). In each design of proposed planar monopole antenna, the antenna gain is also investigated that the antenna gain is also a frequency dependent parameter (as frequency increases, the antenna gain is increases). Among all these configurations, the PCMA-2 and PHMA were reported maximum bandwidth.

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