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Design of CPW-fed Printed Rectangular Monopole Antenna for Wideband Dual-Frequency Applications

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ABSTRACT: A printed rectangular monopole antenna (PRMA) with coplanar waveguide (CPW)-fed is designed for wideband dual frequency application. A proposed monopole antenna which has a size of 31.9 x 33 mm^2, is fabricated to work on a substrate (FR4 lossy) that has the relative permittivity (ε_r) of 4.4 and a thickness of 1.6 mm with CPW-fed in the frequency range of 6 - 16 GHz. Simulation results such as impedance bandwidth are presented and discussed. Simulation results have been verified with good agreement. The parameters which affect the performance of the antenna characteristics are investigated in this paper.

KEYWORDS: Printed rectangular monopole antenna, Wideband antenna, Coplanar waveguide fed, Impedance bandwidth, Return Loss.

1 INTRODUCTION

In the era of modern wireless communication systems, dualband or multiband antennas with omni-directional radiation characteristics play a vital role. Among the printed monopole antennas of various shapes, rectangular monopole antenna is simple in geometry and CPW-fed technique [1] is used for transmission line i.e. transmitting or receiving the electromagnetic (EM) waves.

The design of relatively compact, planar monopole antennas based on the microstrip structures has been reported to meet the bandwidth requirement. Indeed, compared to the classical monopole antennas, the planar monopole antennas are of a significantly wider bandwidth and have similar radiation characteristics. A planar rectangular monopole antenna (PRMA) fed by a coplanar waveguide (CPW) is proposed to promise the aforementioned impedance bandwidth together with satisfactory radiation characteristics through the dual band. The CPW-fed PRMA exploits the CPW configuration to permit easy integration with the monolithic microwave integrated circuits.

A simple structure, dual or multiband operation, and wide bandwidth for use in the modern wireless communication system are the requirement for increasing the information transfer. Several antenna designs such as the planar inverted-F antennas [2], the aperture stacked patch antenna [3], the meander-line chip antennas [4], and the planar monopole antennas [5] have been designed in the last few years to solve this problem. But, such kinds of antennas need a large size of ground plane, which is printed on the different side of the substrate from the radiating plane, and a via-hole connection is always necessary for feeding the signal which increases the manufacture difficulty and cost.

Recently, due to its many attractive features such as wide bandwidth, low cross polarization, uniplanar nature and easy integration with active devices or monolithic microwave integrated circuits, the coplanar waveguide (CPW)-fed antenna has been used a alternative to conventional antennas for wireless communication systems [6-9].

In this paper, a rectangular monopole antenna fed by a CPW transmission line is designed for obtaining wideband dual-frequency operation which is operate in the range of 6.9 – 7.7 GHz and 12.6 - 14.5 GHz frequency bands. The proposed design wide bandwidths cover the C and Ku bands according to IEEE standard frequency spectrum. The Ku frequency band is wide used for maritime civil and military navigation radars applications like airborne radars for performing the roles of interceptor, fighter, and attack of enemy fighters and of ground targets.

The parameters of the antenna such as return loss, radiation efficiency, directivity and gain are determined using CST (Computer Simulation Technology) Microwave Studio software [10-12]. CST MICROWAVE STUDIO is a fully featured software package for electromagnetic analysis and design in the high frequency range. The software contains transient solver which best fit their particular applications and provide the entire broadband frequency behaviour of the simulated device from only one calculation run. 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 geometry of proposed wideband dual frequency PRMA with CPW-fed is shown in fig 1. In this design, PRMA with feeding line and ground planes are all printed on the same side of glass epoxy dielectric substrate of thickness (h) 1.6 mm with a relative permittivity ($€_r$) of 4.4 while the other side of dielectric substrate is without any metallization. A singe rectangular strip line of width Ws and two equal ground planes are used as CPW-fed transmission line. Two equal finite ground planes, each with dimensions of length Lg and width Wg are placed symmetrically on each side of the strip line. The rectangular monopole is connected centrally at the end of the CPW feed line. The space (d) between the rectangular monopole and the edge of the ground plane dominates the resonant mode of the upper band while gap (g) between the strip line and coplanar ground planes vary the impedance bandwidth of upper band. By properly selecting the antenna's geometric parameters, wideband and dual-frequency operation is achieved and even small size of antenna is also obtained.

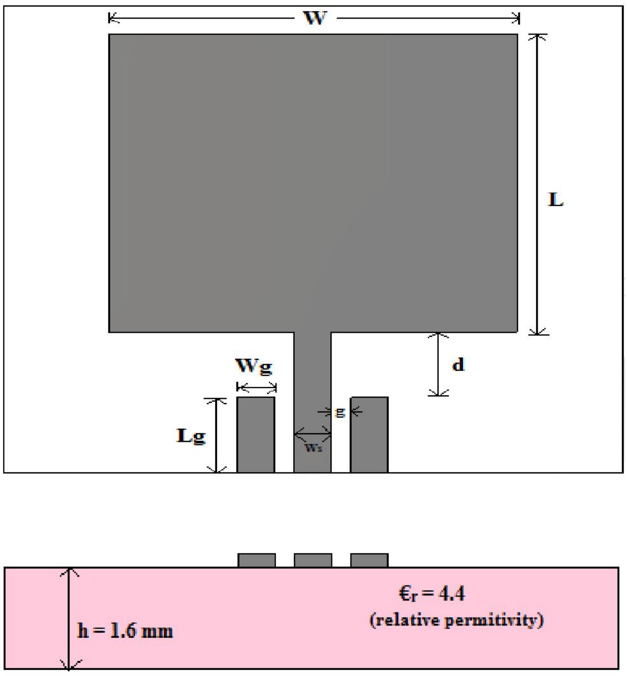


Fig. 1. Geometry of the proposed CPW-fed PRMA for wideband dual frequency operation (All dimensions in mm)

The geometric parameters were adjusted carefully and finally the antenna dimensions were obtained is shown in Table 1.

Table 1. Dimensions of CPW-fed PRMA

Parameter	Dimension	Parameter	Dimension
Lg	8.1 mm	Ws	3 mm
Wg	3 mm	d	7 mm
L	31.9 mm	g	1.6 mm
W	33 mm		

In addition, due to the simulation results show that both the gap distance (g) space (d) have a significant effect on the impedance bandwidth of the proposed antenna.

3 SIMULATED RESULTS

Fig 2 shows the simulated return loss against frequency in the range of 6 – 16 GHz for the proposed wideband dual frequency CPW-fed rectangular monopole antenna. The simulated result is obtained using the CST Microwave Studio software. After analysing the result, it is clearly seen that two resonant modes at about 7.3 and 13.4 GHz are excited with good impedance. The lower resonant band obtain a bandwidth of 0.75 GHz in the range from 6.96 to 7.71 GHz with respect to a resonant frequency of 7.3 GHz and upper resonant band achieves a bandwidth of 1.83 GHz in the range from 12.67 to 14.5 GHz with respect to a resonant frequency of 13.4 GHz.

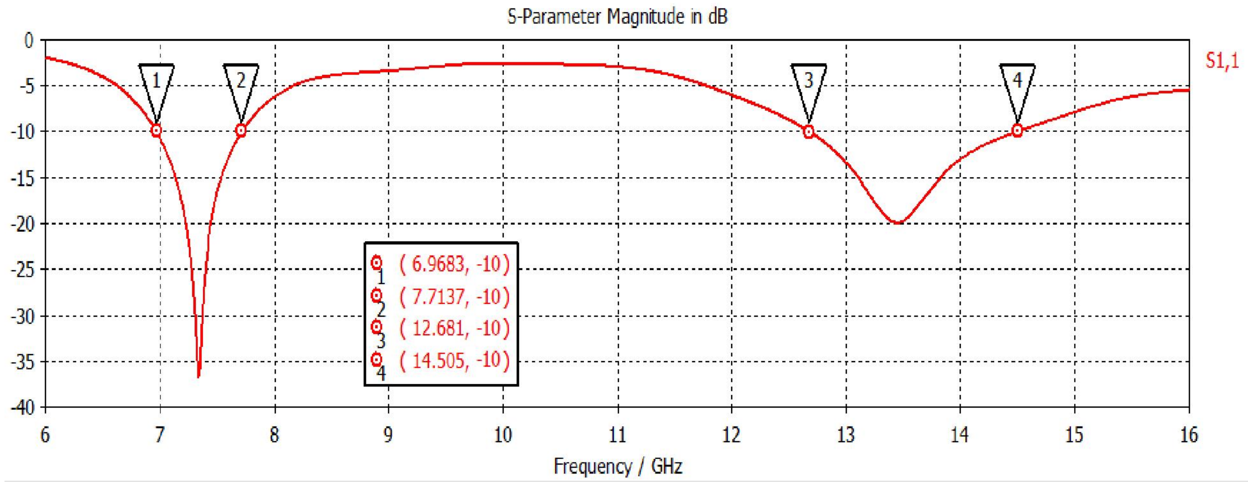
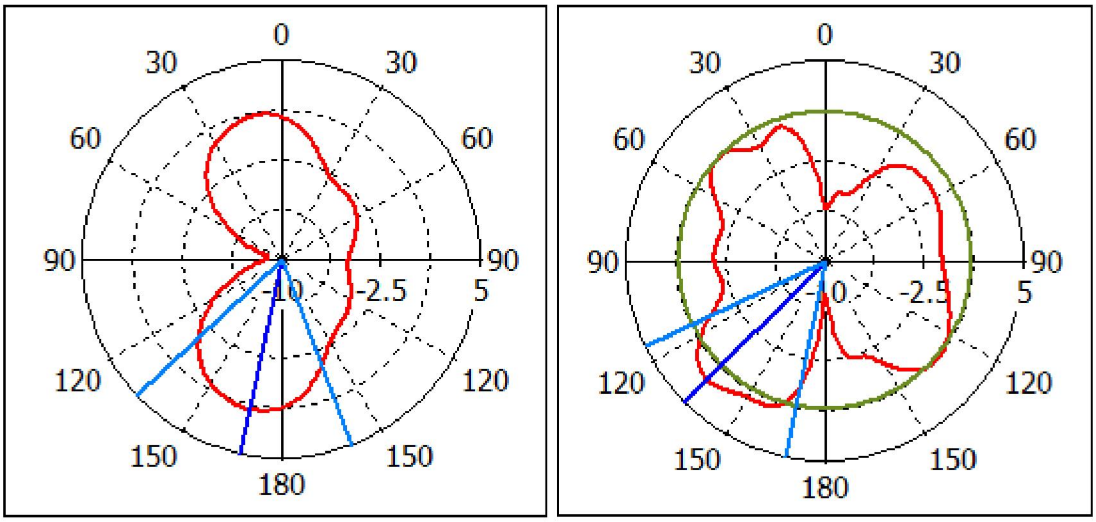


Fig. 2. Simulated return loss of the proposed CPW-fed PRMA.

The simulated radiation patterns of the proposed CPW-fed PRMA at resonant frequencies of 7.3 and 13.4GHz for lower and upper bands are shown in Fig 3. The radiation efficiency, directivity and gain at both lower and upper frequency of 7.3 and 13.4 GHz are 83.33%, 2.908 dBi, 3.693 dB and 84.65%, 4.871 dBi, 4.148 dB respectively.



(a) At 7.3 GHz ***(b) At 13.4 GHz.***

Fig. 3. Simulated radiation pattern of the proposed CPW-fed PRMA (a) at 7.3 GHz and (b) at 13.4 GHz

An important feature of the proposed antenna is the capability of impedance matching at both resonant frequencies using a single CPW feed line. For this, the coupling effect between the feed line and the ground planes is investigated. Fig. 4 shows the simulated return loss of the proposed antenna with different gap width (g) and the corresponding data for comparison is shown in Table 2 with all the remaining parameters of the proposed antenna are same as the design shown in fig 1. As seen in Fig. 4, the gap width has a significant effect on the upper band impedance bandwidth of the proposed antenna as compare to lower band bandwidth. The upper band bandwidth is monotonically increases with the decrement in gap width from about 1.35 to 2.23 GHz with respect to simultaneously increment in resonant frequencies.

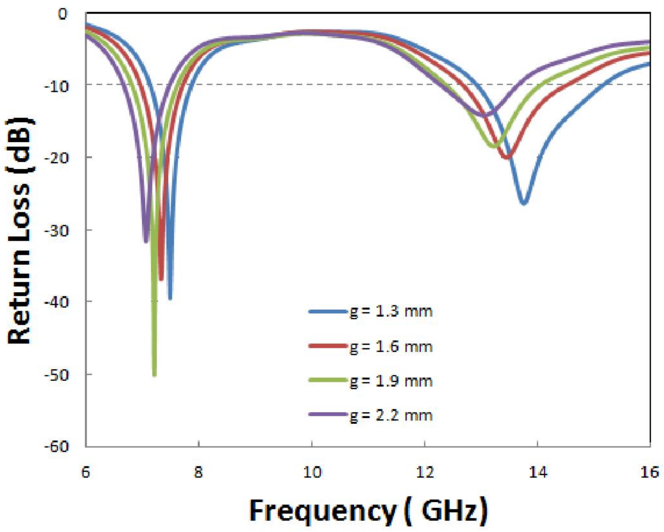


Fig. 4. Simulated return loss of the proposed CPW-fed PRMA with various gap widths.

Table 2. Simulated bandwidths of proposed CPW-fed PRMA as a function of gap width.

Gap width ‘g’ (mm)	Bandwidth (GHz)	Resonant frequency (GHz)
1.3	0.73, (7.13-7.86) 2.23, (12.92-15.15)	7.5 13.7
1.6	0.75, (6.96-7.71) 1.83, (12.67-14.50)	7.3 13.4
1.9	0.8, (6.81-7.61) 1.66, (12.38-14.04)	7.2 13.2
2.2	0.8, (6.67-7.47) 1.35, (12.29-13.64)	7 13

Also the effect of the space (d) between the rectangular monopole patch and the edge of the ground plane of the proposed CPW-fed PRMA for the impedance bandwidths is studied. Here, the two cases arise for the impedance bandwidth analysis. In the first case, the dimensions of both the rectangular monopole patch and the ground plane are fixed but the space between them is varied and in another case, the space between them is varied according to the change of the ground plane length but dimensions of rectangular monopole patch is fixed. In both the cases, the remaining parameters of the proposed antenna are same as the design shown in fig 1.

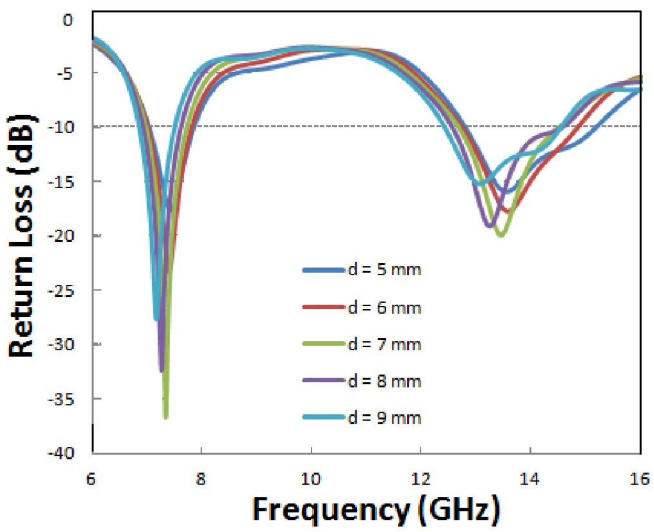


Fig. 5. Simulated return loss of the proposed CPW-fed PRMA as a function of space between monopole antenna and ground.

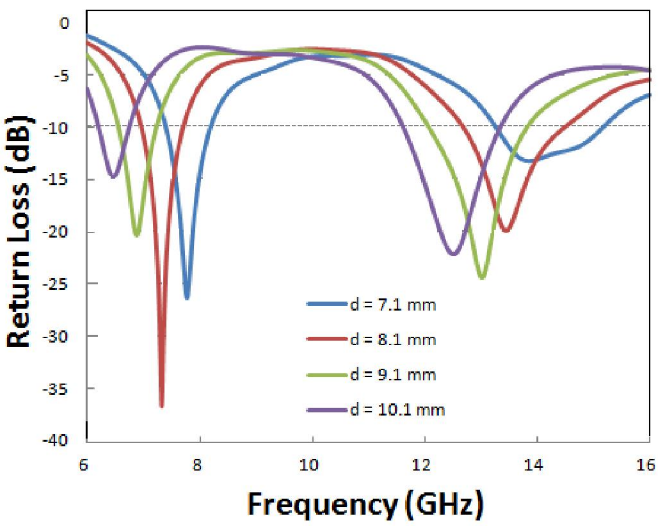


Fig. 6. Simulated return loss of the proposed CPW-fed PRMA as a function of space between monopole antenna and ground plane with respect to the ground plane length.

The simulated return loss of the proposed CPW-fed PRMA with the variation in space between the rectangular monopole and ground plane is shown in fig 5 and their corresponding simulated data are shown in table 3. It is observed from the table 4 that the space (s) has a large impact on the upper band impedance bandwidth, while the lower band almost keeps unchanged.

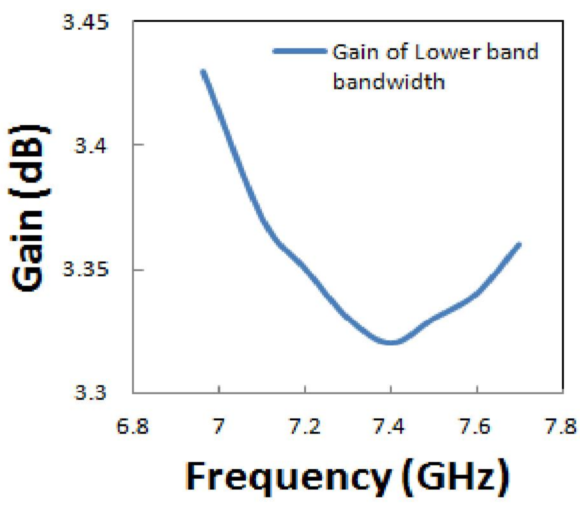
Similarly the simulated return loss of the proposed CPW-fed PRMA with the variation in space between the rectangular monopole and ground plane with respect to change of ground plane length is shown in fig 6 and table 4 lists the corresponding obtained simulated bandwidths for d varying from 7.1 to 11.1 mm for comparison. It is clearly seen in fig 5 that both upper and lower bands of bandwidth and their respective resonant frequencies is varied by the change of the space (s) with respect to the ground plane length. The lower and upper band bandwidths and their respective resonant frequencies are decreases with increase the distance of space (s).

Table 3. Table 3. Simulated bandwidths of proposed CPW-fed PRMA as a function of 'd'

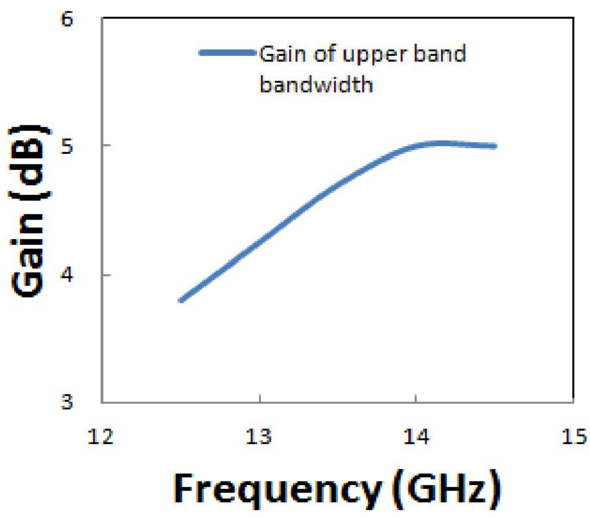
'd' (mm)	Bandwidth (GHz)	Resonant frequency (GHz)
5	0.81, (7.02-7.83) 2.36, (12.80-15.16)	7.4 13.5
6	0.80, (7.00-7.80) 2.10, (12.74-14.84)	7.4 13.6
7	0.75, (6.96-7.71) 1.83, (12.67-14.50)	7.3 13.4
8	0.69, (6.91-7.60) 1.99, (12.56-14.55)	7.2 13.2
9	0.65, (6.84-7.49) 2.12, (12.42-14.54)	7.1 13

Table 4. Simulated bandwidths of proposed CPW-fed PRMA as a function of 'd' with respect to the ground plane length.

'd' (mm)	Bandwidth (GHz)	Resonant frequency (GHz)
7.1	0.79, (7.40-8.19) 1.91, (13.26-15.17)	7.8 13.9
8.1	0.75, (6.96-7.71) 1.83, (12.67-14.50)	7.3 13.4
9.1	0.67, (6.56-7.23) 1.75, (12.07-13.82)	6.9 13
10.1	0.55, (6.20-6.75) 1.73, (11.61-13.34)	6.5 12.5



(a)



(b)

Fig. 7. Measured antenna gain for frequencies across (a) the lower band, (b) the upper band of the proposed CPW-fed rectangular monopole antenna.

The antenna gain (dB) of the proposed CPW-fed PRMA across the two bands is shown in Fig 7. For the lower band, the maximum antenna gain of about 3.43 dB is observed and for the upper band, the antenna gain is 5.0 dB. The VSWR (Voltage Standing Wave Ratio) and the efficiency (%) of proposed antenna against the frequency are shown in fig 8.

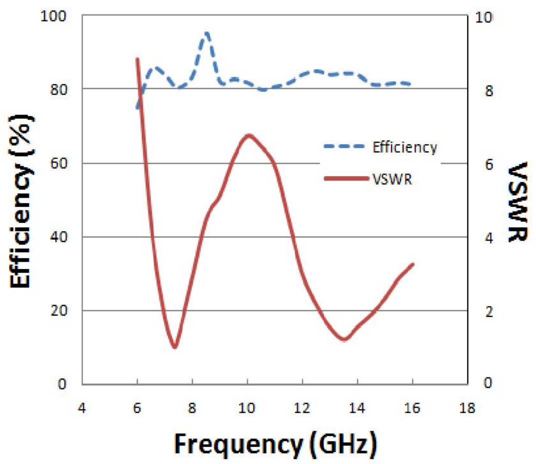


Fig. 8. VSWR and efficiency curve of the proposed CPW-fed PRMA.

4 CONCLUSION

A single-layer rectangular printed monopole antenna based on CPW-fed technology on the FR4 lossy substrate for obtaining two separate wide operating bands has been presented, with simulation results. Good antenna performances such as the wide impedance band-widths, monopole-like radiation patterns, and good antenna gains for the operating frequencies across the two bands have been obtained. The proposed CPW-fed monopole antenna has a very simple structure, which makes the design simpler and fabrication easier, and is very suitable for applications in the access points of wireless communications. It is also investigated that both gap ‘g’ (distance between the single strip and the coplanar ground plane) and spacing ‘d’ (distance between the patch and edge of the ground plane) is a frequency dependent parameter which effects the bandwidth of the antenna.

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