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DESIGN OF CIRCULAR PATCH ANTENNA WITH STAIRS ANDSLITS FOR WIRELESS APPLICATION

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ABSTARCT

Present days most of the equipment needs tiny and comfortable for easy usage. In this paper a compact circular patch antenna designed with CPW feeding with feed without contact with the radiating patch, known as capacitive loading, which is penetrated inside the patch is presented. Antenna without stairs and slits exhibits 62.7% bandwidth (4.7GHz-9GHz).And in modified proposed design, stairs and slits are incorporated in the radiating patch exhibits dual band for WiMAX (3.3 GHz-3.7GHz) and WLAN (5.725-5.825GHz) applications. In addition to this direct short range communication (DSRC) frequency range also achieved.

Keywords: capacitive loading, CPW feeding, stairs and slits, radiation pattern, WLAN, WiMAX, DSRC.

1. INTRODUCTION

In modern days compact antenna structures are very much in need because of their tiny size. Microstrip patch antennas has been extensively used nowadays because of its light weight and compact size. Co planar waveguide (CPW) method is chosen because of its ease of fabrication and simple to assemble. In this communication circular patch antenna that is well suited for worldwide interoperability for microwave access (WiMAX) and wireless local area network (WLAN) applications are proposed. This small communication terminals leads to great demand in integrating various services to collaborate with each other. Coplanar waveguide (CPW) transmission lines have been widely used as feeding networks with slot antennas. This CPW design has many characteristics such as low radiation leakage, less dispersion, little dependence of characteristic impedance on the substrate height, and unipolar configuration. They also allow easy mounting and integration with other microwave integrated circuits and RF devices. The main advantage of the CPW fed antenna is it provides easy impedance matching which results good bandwidth improvement. With the rapid development of the modern wireless communication, worldwide interoperability for microwave access (WiMAX) covering 3.3-3.7GHz and wireless local area network which operates in the frequency band 5.150-5.825GHz have been widely used in portable devices. A dual band double-T monopole antenna have been reported in [1].Antennas with open slots for wireless applications are reported in [2]-[4].Some monopole antennas for multiband applications such as U-shape [5], T-shape [6],fork shaped [7,8],trident shaped [9]have been reported. Printed slot antenna used in multiband operation design is relatively less in open literature. These antenna designs mentioned above can achieve dual or multiple band property, they are somewhat larger in size, which are not perfectly practical for small communication terminals

Antenna design has turned and focused on multiband and small simple structures. In this paper, circular patch antenna with feed is penetrated inside the radiating patch is proposed and it is not in contact with circular radiating patch, known as capacitive loading. Impedance matching is achieved by adjusting the feed width and gap between the ground and feed strip. In the proposed design, circular patch antenna exhibits wide band width of 62.7%,and in latter modified proposed design stairs and slits has been incorporated on the radiating patch with good impedance bandwidths at 3.5GHz/5.8GHz.There exits a another frequency band 5.850GHz-5.925GHz for DSRC based on 802.11p also achieved. In the latter antenna design because of stairs and slits its cost also effectively reduced.

2. ANTENNA DESIGN

Figure-1 depicts the configuration of capacitive loading antenna structure without stairs and slits. The antenna is fabricated on the FR4 substrate of thickness(h) 1.6mm,with relative dielectric constant (ϵ_r) of 4.4.It has dimension 25mmx25mmx1.6mm.Circular patch has radius(R) 7mm and feed strip length (FL) and width (FW)are 15.6mm and 3mm respectively. Feed strip is not in contact with radiating patch is known as capacitive loading. Antenna is fed with CPW feeding, with feed length FL=15.6mm,feed width FW=3mm,ground length GL= 8.5mm,ground width GW=10.7mm,spacing S between ground and feed strip is 0.3mm and radius R of the radiating patch is 7mm.The gap between the radiating patch and feed strip denoted as g maintained as 0.3mm.

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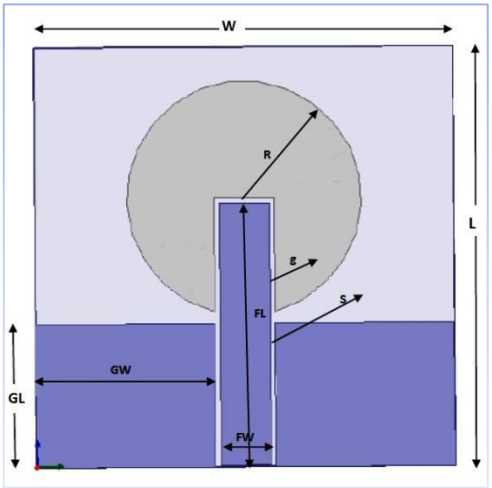

Figure-1. Base antenna.

$$r_{eff} = r\sqrt{1 + \frac{2h}{\pi r \varepsilon_r}\left(ln\frac{\pi r}{2h} + 1.7726\right)} \quad (1)$$

$$f_{nm} = \frac{\chi_{nm}}{\sqrt{\varepsilon_r}}\frac{c}{2\pi r_e} \quad (2)$$

Effective radius (r_{eff}) the circular patch antenna is calculated from [10] and the equation (1) as 7.17mm, and the radiating frequency is calculated from equation (2) as 5.84 GHz.

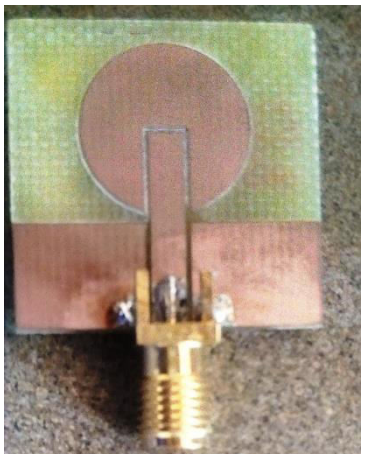

Figure-2. Fabricated base antenna.

Fabricated antenna shown in Figure-2.It exhibits the return loss below -10 dB between the range of 4.5GHz and 9GHz, which shows band width of 62.7%.VSWR also maintains below 2 within that range. Measurement are made with ANRITSU combinational analyzer MS 2073C and simulation has carried out using HFSS. S11 characteristics are shown in Figure-3, There are almost similar results between measured and simulation. Gain and radiation pattern variations at frequency 8GHz shown in Figure-4 and Figure-5.

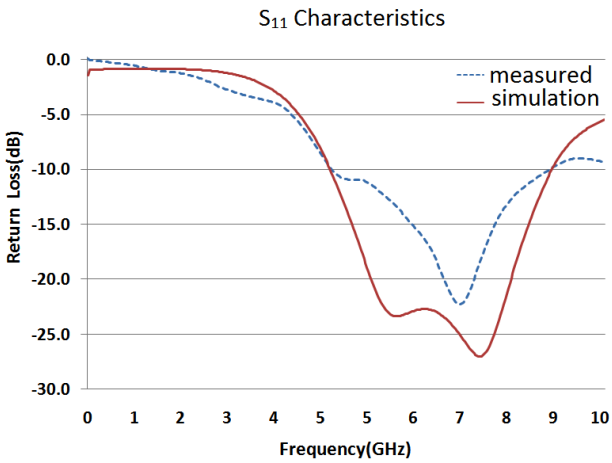

Figure-3. Return loss characteristics of base antenna without stairs and slits.

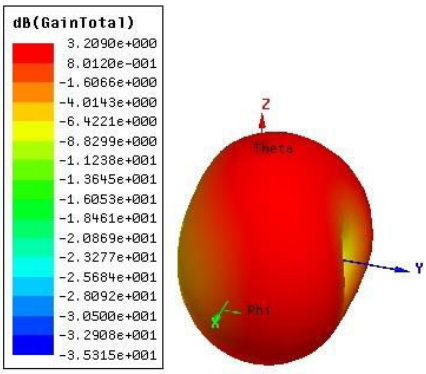

Figure-4. Gain variation at 8GHz.

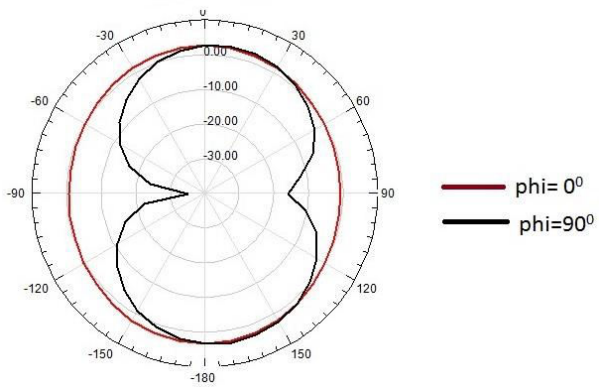

Figure-5. Radiation pattern at 8GHz.

3. ANTENNA WITH STAIRS AND SLITS

Proposed antenna with inclusion of stairs and slits is shown in Figure-6. Dimensions of antenna are slightly increased as 25mm x 28mmx1.6mm.Antenna is again fed with CPW feed having feed strip length FL=17.6mm, ground length GL is slightly decreased to 6.7mm, ground width GW=10.7mm, spacing S between the ground and feed strip is 0.3mm. Radiating circular patch radius R is slightly increased to 8.2mm.Gap 'g_1' between the feed

strip and radiating patch is 0.4mm and on the top side gap 'g_2' is 0.3mm.

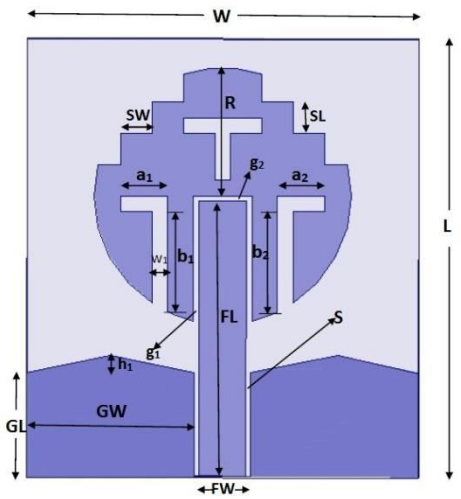

Figure-6. Proposed antenna.

Top of ground on either side is changed to triangle shape with height h_1=1mm.Circular radiating patch is incorporated with stairs on either side of the top and inverted 'L' shape slits and 'T' shape slot is created symmetrically. T shape dimensions are maintained constant and symmetrical with respect to vertical axis. Stair width SW and stair length SL is same and is equal to 2mm.Slot and slit on the radiating patch has common width w_1=1mm.The length b_1 and b_2 of the L shape is same and is equal to 6.5mm.The length a_1 and a_2 of the L shape is same and equal to 3mm.Dimensions of the proposed and fabricated antenna are shown in Table-1.Fabricated antenna is shown in Figure-7.Two bands exhibited with 10dB return loss are about 3.3-3.9GHz and 5.6GHz -6.9GHz corresponding to 16% and 20.8% respectively.

Table-1. Dimensions of proposed antenna.

Parameter	Value	Parameter	Value
W	25mm	g_1	0.4mm
L	28mm	g_2	0.3mm
H	1.6mm	a_1	3mm
GW	10.7mm	b_1	6.5mm
GL	6.7mm	a_2	3mm
FW	3mm	b_2	6.5mm
FL	17.6mm	R	8.2mm
h_1	1mm	SW	2mm
w_1	1mm	SL	2mm

Figure-7. Fabrication of proposed antenna.

In the antenna design the horizontal part a_1 having slit dimension 3mm, and vertical part b_1 having dimension 6.5mm of the inverted L slit which is on either side of circular radiating patch with the same dimensions a_2 and b_2.

The resonant frequencies roughly approximated by

$$f_1 = \frac{c}{\sqrt{\epsilon_{eff}}\,(6.5)\,(\frac{a_1}{2}+b_1)} \quad (3)$$

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} \quad (4)$$

$$f_2 = \frac{c}{\sqrt{\epsilon_{eff}}\,\frac{6.5}{1.78}\,(\frac{a_1}{2}+b_1)} \quad (5)$$

4. PARAMETRIC VARIATION

To further examine the effect of the slits on the proposed antenna, the frequency response of $|S_{11}|$ for the proposed antenna with different lengths of slits is analyzed and presented in Figure-8.When the slit horizontal dimensions of inverted L shape a_1 and a_2 are increased by 1mm they were changed to 4mm.With these modification,f_1 and f_2 is calculated as 3.30GHz and 5.88GHz respectively with the help of equations (3) and (5).Horizontal dimension a_1 and a_2 of the inverted L slit on either side of the feed strip located on the radiating patch is varied shown in Figure-9.The center frequency of working band of the antenna moves towards right side. Return loss variations for different slit lengths shown in Figure-9.

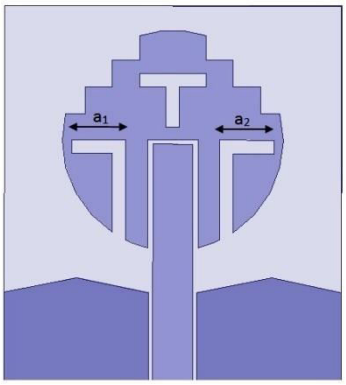

Figure-8. Variation of horizontal slit length a_1 and a_2.

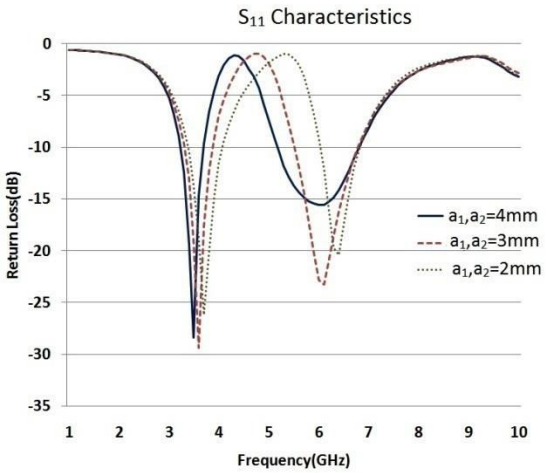

Figure-9. Return loss characteristics of slit length a_1 and a_2 variation.

Table-2. Horizontal slit variation.

Horizontal slit (b_1 and b_2=6.5mm)	Simulated frequencies	Calculated frequencies
a_1,a_2=4mm	3.5GHz, 6GHz	3.3GHz, 5.88GHz
a_1,a_2=3mm	3.6GHz, 6.1GHz	3.51GHz, 6.24GHz
a_1,a_2=2mm	3.7GHz, 6.4GHz	3.74GHz, 6.67GHz

It is observed that when vertical dimension of the slit denoted as b_1 and b_2 of the proposed antenna is varied the return loss characteristics where S_{11} is less than -10 dB is exits with in the wireless band region. These variations are shown in Figure-11.Center frequency is increases with decrease of slit length accordingly.

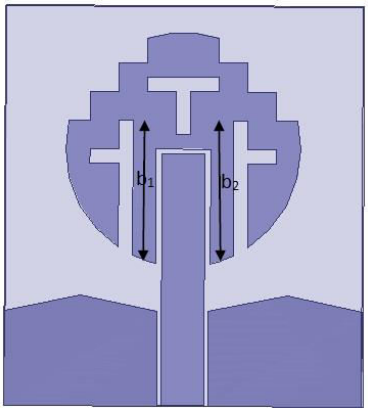

Figure-10. Variation of vertical slit length b_1 and b_2.

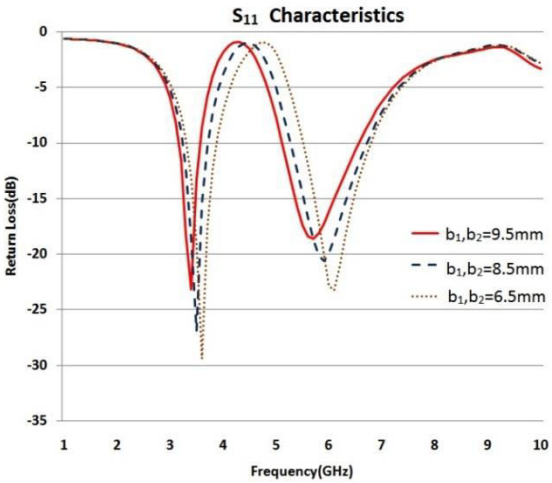

Figure-11. Return loss characteristics of slit length b_1 and b_2 variation.

By varying the horizontal slit dimensions of the proposed antenna dual band exhibited over range of frequencies. The dual inverted L shaped slits introduces the resonant mode at 3.5GHz and at 5.8GHz.simulated and calculated frequencies of the proposed antenna compared in the Table-2. Resonant frequency is calculated from the formula mentioned above in equation (3) and (5).

5. RESULTS AND DISCUSSIONS

With a_1 =3mm and b_1=6.5mm for the proposed antenna shown in Figure-6, relative dielectric constant ϵ_r= 4.4mm and c is the velocity of light in free space. Antenna dimensions a_1 and a_2 are equal, and b_1 and b_2 are equal. The above mentioned formula in equation (3) and (5) is valid only for the variation of horizontal slit dimension a_1 and a_2. From the equation (3) and (5) f_1 is calculated as 3.51GHz and f_2 is calculated as 6.24GHz. Referring to these results, the antenna can satisfy WiMAX band of 3.5GHz and WLAN band of 5.8GHz.The simulated and measured reflection coefficient ($|S_{11}|$) of the proposed stairs and slit antenna are illustrated in Figure-12.In addition to his dedicated short range communication (DSRC) systems operating in 5.850GHz-5.925GHz of IEEE 802.11p used for vehicle to vehicle (V2V)

communication. Reasonable agreements between the simulation and measurement results are attained. Some slight discrepancies between them may be attributed to measurement errors, inaccuracies in the fabrication process, and the impact of the SMA connector.

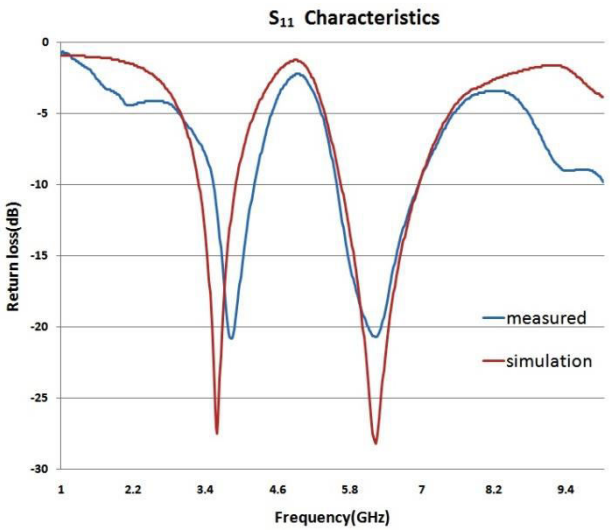

Figure-12. Return loss characteristics of proposed antenna.

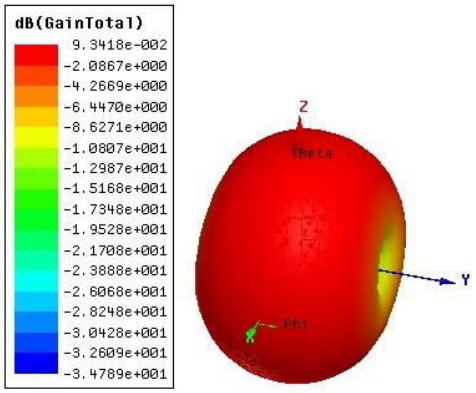

Figure-13. Gain variation at 3.6GHz.

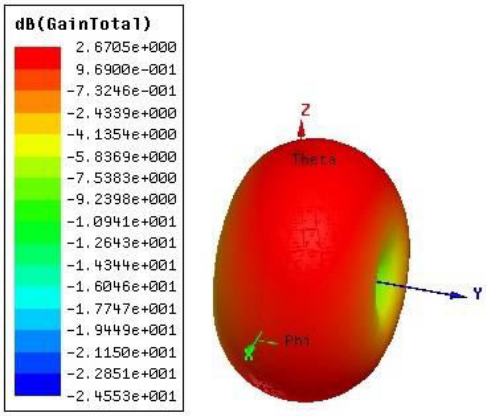

Figure-14. Gain variation at 5.8GHz.

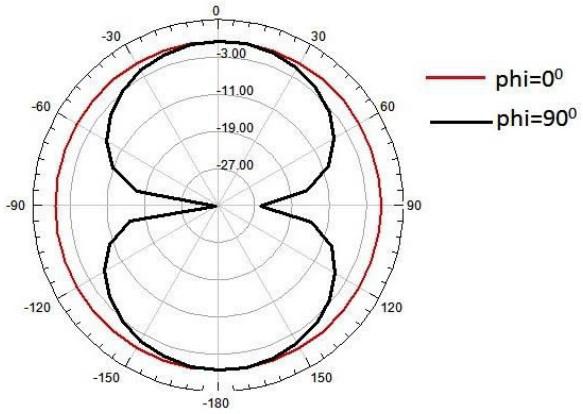

Figure-15. Radiation pattern at 3.6GHz.

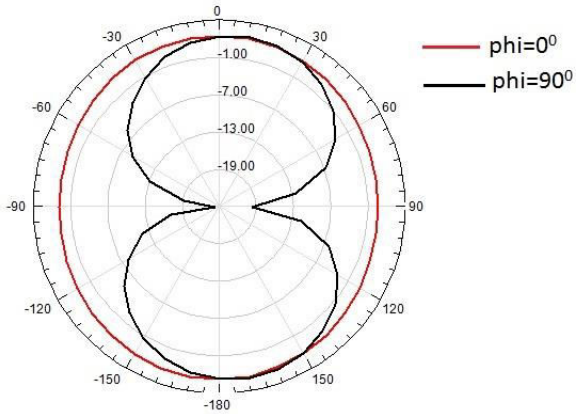

Figure-16. Radiation pattern at 5.8GHz.

6. CONCLUSIONS

Gain and radiation patterns variations are shown from Figure-13 to Figure-16.It is observed that gain is maintained positive over these bands. The radiation pattern indicates that omni directional in H-plane and dipole pattern in E-plane in the working bands. it is observed that antenna exhibits frequency range of 4.7GHz and 9 GHz. As per the IEEE 802.11a WLAN operation between 5.150GHz to 5.825GHz. And antenna also can be used for ITU 8GHz band operating at 7.725GHz - 8.275GHz,then is also can be used other short-range wireless communication. The proposed antenna which stairs and slits exhibits WiMAX band of 3.5GHz and WLAN band of 5.8GHz and DSRC band (5.9 GHz)for V2V communication.

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