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A Circularly Polarized Multi Band Stub Loaded Slot Antenna For GPS / WiMAX / WLAN System

Satya Prakash Sinha[1], Kapil Bhushan[2]

PG Student, Dept. of ECE, SRMSCET, Bareilly, UP, India[1]

Assistant Professor, Dept. of ECE, SRMSCET, Bareilly, UP, India [2]

ABSTRACT: In this paper, A single feed low profile and easy to fabricate circularly polarized slot antenna for four frequency band i.e. Global Positioning System, (GPS), World Wide interoperability microwave access (WiMAX) and Wireless Local Area Network (WLAN) has been developed. A CP multi band stub loaded antenna is designed and studied using Ansoft HFSS V 14.0 designer on the substrate of 3.5 relative permittivity, height of 0.8 mm and delta factor of 0.004. For Quad frequency band, three stubs, which works as monopole, included in the design. The antenna consists of a rectangular slot with the area of 48 X 18 mm^2, a T-shaped feed patch, an inverted T-shaped stub, and two E-shaped. Each stub is responsible for the individual frequency band. The simulated results like return loss, VSWR, radiation pattern, peak gain and efficiency are presented. The methodology of using the design for all the frequency bands are mentioned in the paper. At last the parametric study on different methods to achieve circular polarization of antenna is also discussed.

KEYWORDS: Slot Antenna, HFSS, Open Stub, Monopole, Multi band Return Loss, Radiation Pattern

I. INTRODUCTION

WITH rapid development of wireless communication system, an antenna became inseparable from a transmission line and to radiate more efficiently, its matching with the transmission line needs more attention. In microwave frequencies, circular polarization is able to reduce multipath effects. It also allows a more flexible reciprocal orientation between the transmitting and the receiving antennas. Because of these reasons, CP antennas are often preferred in satellite communication, Global Positioning System (GPS), and radar system. Till now many kinds of circularly polarized (CP) antennas have been studied. In general, based on feeding structure, the CP antenna may be divided into single and hybrid feeding. A single-feeding CP antenna provides simple structure, easy manufacture, and advantage in array with small size. However, it has narrow axial ratio bandwidth. Hybrid feeding gives complex structure, difficult manufacture, and increased antenna size, but it provides wide axial ratio bandwidth. Thus, in the design of CP antenna, a tradeoff of characteristics between two feeding methods is required. Moreover, a number of dual band CP antennas have been studied A Dual band Circularly polarized with deformed monopole [1] and A Dual band omni directional CP Antenna [2] is fed by coplanar waveguide, A Dual band CP micro strip antenna with small freq. ratio [3] and Dual band CP stub loaded micro strip patch antenna for GPS application [4] is fed by probe feeding, A novel dual feed slot coupling feeding technique for circularly polarized patch array [5] is fed by probe fed Another factor of the paper is slot, the slot antenna having the advantages of compact size, wide bandwidth and easy integration with other devices, which enables him a good candidate for the multiband antennas. With the help of stub in the slot, the monopole [1], [4] tuned to the resonant frequency.

In CP antenna, axial ratio bandwidth is the most important factor in design since it is the most limiting factor for operation. The gain, LHCP and RHCP are the another factor to analyze the design precisely. Therefore, many kinds of CP antennas have been studied to obtain wide axial ratio bandwidth [1]–[5]. Recently, CP antennas to obtain wide axial ratio bandwidth using single feeding have been studied to improve disadvantages of hybrid feeding, e.g., large antenna size and complex structure. Cross aperture coupled micro strip antenna [1] was proposed and analyzed, but it still has narrow axial ratio bandwidth (4.6%), wide gain bandwidth (16.7% for 3-dB), and antenna gain (8 dBi) at a

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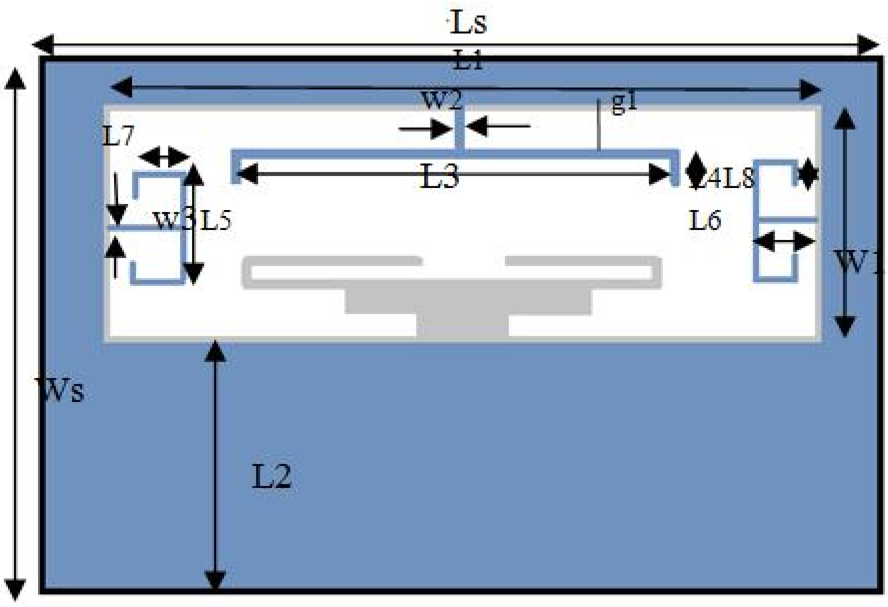
centre frequency of 2.45 GHz. Another improvement was suggested by Ko Han Lu [2], where array of 2X2, 4X4 and 8X8 CP antenna was introduced. However, it achieved 15.3, 21 and 25.4 dBic gain with aperture efficiency of 67%, 63% and 48% at 11, 11.6 and 12.4 GHz frequency respectively. The 3 dB gain bandwidth is 14% with a maximum gain of 25.4 dBic at 11.7 GHz. Therefore, not only wide axial ratio and impedance bandwidth, but also other enhanced characteristics, e.g., high gain, flat-gain bandwidth, and similar radiation patterns in operating frequencies are needed in CP antenna for practical wireless communication system. The design [3] uses the slot and monopole to emphasize on the smaller frequency ratios. Another paper [4] uses the stub with slot in micro strip patch antenna for dual band operation for the L1 and L2 bands of GPS application. It uses the cross slot structure which results in 6.46 and 6.78 dB respectively and it antenna efficiency is about 98%. Dual feed technique is another method to obtain the circularly polarize signal, the paper [5], operating for two frequencies of WiMAX 3.3 -3.8 GHz with 14 % bandwidth and axial ratio < 1.35 dB at broadside and less than 2.25 db at 3.55 GHz along any direction of antenna main beam.

So, the analysis of previous papers describes that along with multiband, optimum performance of a circularly polarized antenna is a new scope to enhance the wireless communication effectively. With this goal, this paper is drafted to ensure the better communication facility with the multi band operation. By keeping in view of the advantages of slot antenna [1] - [5], monopole is used to choose the operating frequency.

This paper present the design of a four band slot antenna for GPS/WiMAX/WLAN systems. The antenna consists of a T-shaped feed patch, a rectangular slot, an inverted T- shaped stub and two E- shaped stubs to generated four frequency bands at about 1.575, 2.45, 3.5 and 5.4 GHz for the GPS, IEEE 802.11b & g, WiMAX, and IEEE 802.11 a systems respectively. In this proposed four band antenna, we use the harmonics of the T- shaped feed to generate two frequency bands, and the double folded stub in the T-shaped feed patch used to tune the two harmonic resonant frequency independently. The gain of the antenna in the four frequency bands are much higher than those of dual band stub loaded CP antenna[4]. The proposed multiband CP antenna is studied and designed using ANSYS HFSS version 14 designer. The methodology used to design the antenna for other frequency band is also proposed. The results on reflection coefficient S11, radiation pattern, realized peak gain, and efficiency are presented. The effects of the cover used in the wireless devices are also investigated.

II. ANTENNA DESIGN



(a)

W1

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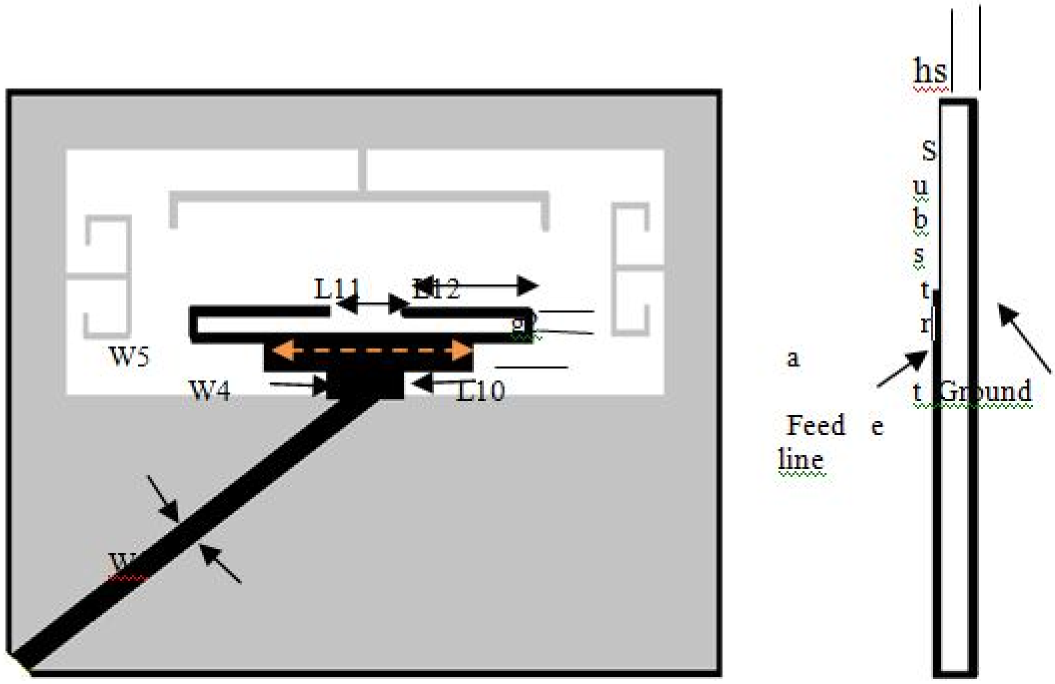

(b) (c)

Fig 1. Geometry of antenna: (a) top view , (b) bottom view, and (c) side view

Figure 1 shows the fabrication of the designed quad -band circularly polarized antenna. It is printed on a substrate with a dimension of $Ls \times Ws$ =56 × 44 mm^2, a relative permittivity εr= 3.5 and a loss tangent tan θ = 0.004. The antenna is fed by a 50Ω micro strip fed line of feed width, Wf 1.76 mm. On the top side of substrate a rectangular slot with the size L1 ×W1 =48 × 18mm^2 which houses with an inverted T-shaped stub and two E-shaped stubs on the left hand and right hand sides of the slot. The stub used in the slot behaves as the monopole radiator, these monopoles are folded to make the size compact at each shaped stub but due to folding techniques, the input impedance of these monopoles are increases sharply, approximately four times, to counter the high input impedance, another monopoles are connected in reverse direction. The dual folded strip monopole antenna is derived from a single folded strip monopole antenna by modifying it with an additional arm placed at the appropriate location. Note that when an additional arm is top loaded to quarter wave monopole then total effective length of the folded strip required to fix the resonant frequency at 2.45 GHZ is $0.627\lambda_d$.

In case of two different length of branched folded arms in a double folded monopole antenna, the two branched folded arms offers a dual resonance characteristics due to different meandered current paths excited in the radiating structure. The longer arm l of the folded monopole excites a lower resonance of the dual frequency response and shorter arm excites the higher frequency. But for the lower frequency shorter arm of the monopole increases the inductive reactance as the length of the arm 2 is approximately quarter wavelength of the shorter ann. Thus the capacitive impedance due the coupling between the ground plane and horizontal strip of the arm l is minimized and antenna exhibits bandwidth enhancement in the lower order mode. But for the second resonant mode arm l length is half wavelength order of the second resonant frequency hence arm 1 adds more capacitive reactance to the input impedance of the second resonant frequency. Thus for second mode degradation in bandwidth is observed So, the individual monopole resonates at different frequencies depends on the length of the monopole. In this design, both the monopoles are of equal length, hence they resonates at same frequency. The computed field distribution indicates that the folded arm must be loaded at a height of approximately quarter wavelength (which corresponds to E minimum) to avoid the radiation from the bend edges. When the loading height is greater or less than the quarter wavelength there may be radiation from the bend edges of the folded monopole. -This will affect the radiation characteristics considerably. Hence loading height is selected according to the frequency requirements.

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A step is used in the lower side of the T-shaped feed patch on both the LH and the RH sides for better impedance matching. The antenna can generate four frequency bands at about 1.575, 2.45, 3.5, and 5.4 GHz, denoted here as bands 1, 2, 3, and 4, respectively, for different wireless standards. The rectangular slot and the inverted T-shaped stub together generate band 1 at about 1.575 GHz for the GPS system. The two E-shaped stubs operating as monopole radiators generate band 2 at about 2.45 GHz for the IEEE 802.11b&g WLAN systems. The T-shaped feed patch and inverted T-shaped stub generate band 3 at about 3.5 GHz for the WiMAX system. The T-shaped feed patch in the higher mode generates band 4 at about 5.4 GHz for the IEEE 802.11a WLAN system. The final dimensions of the designs are given in table I, which is used to fabricate the antenna shown in fig. 2 for measurement.

TABLE I
DIMENSIONS OF THE PROPOSED ANTENNA (MM)

L1	L2	L3	L4	L5	L6	L7	L8	L9
48	21.6	29	3.3	12	5.5	4	1.3	2
L10	L11	L12	g1	g2	W1	W2	W3	W4
2	4	11.5	2	0.4	18	1	0.5	3.6
W5	Wf	Ws	hs	Ls				
15	1.76	44	0.8	56				

In the antenna layout shown in Fig I, the feed line is placed diagonally on the large ground plane, to create dual or circularly polarize signal, having the advantage of simple structure over the dual feed or hybrid feeding.

III. STUDIES OF ANTENNA

The four most popular feed techniques used are the microstrip line, coaxial probe (both contacting schemes), aperture coupling and proximity coupling (both non contacting schemes). This design uses single feed with edge or microstrip line feed technique to generate the circular polarize signal Since the different radiating elements of the multi band stub loaded circularly polarized antenna oscillates for the different frequency, so the change in their dimensions affect the particular resonant frequency of the antenna.

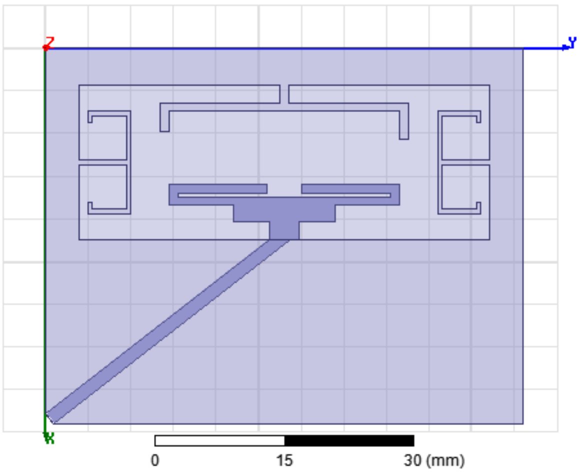

Fig III prototype antenna

Fig III depicts the geometrical view of the proposed antenna on ansoft designer HFSS based on the dimensions given in the table I. The upper and lower side of the proposed antenna is depicted on the same design. The resonant frequency generated by the slot dimensions are in conjunction with T-shaped feed patch and other monopoles. So, starting from initial step, the resonant frequency generated by the slot dimensions are given as

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$$f = \frac{C}{2(L1 + W1) * \sqrt{\epsilon_{eff}}}$$

Where L1 and W1 are length and the width of the slot dimensions given in the fig III. Later on, the different length of monopole decides the respective harmonic frequency. The length of the different monopole can be calculated by the following formula

$$f_r = \frac{C}{4L\sqrt{\epsilon_{eff}}}$$

where

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2}$$

Fig IV depicts the return loss of the proposed design, which describes that the proposed multiband antenna has four frequency bands (with S11 < -10 dB),

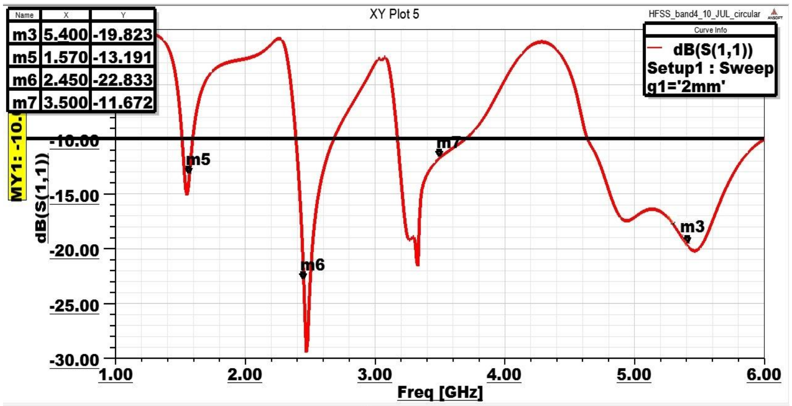

Fig. IV Return loss of the proposed antenna

i.e. 1.562-1.588 GHz for the GPS system, 2.368–2.56 GHz for the IEEE 802.11b&g WLAN systems, 3.19–3.732 GHz for the WiMAX system, and 4.86–6.00 GHz for the IEEE 802.11a WLAN system.

Although the GPS system employs circularly polarized signal with a frequency band from 1570 to 1590 MHz, and most commercially wireless devices employs linearly polarized antennas to receive the GPS signal, which lead to a 3-dB power loss, but in this design the CP antenna not only saves the 3 dB power, but also improves for the other frequency band. The geometry of the antenna shown in fig I has various factors such as L1, L3-L10, W1, W5 and g1 which affect the frequency bands [6]. Results have showed that we can set the frequency bands in the order of bands 1,2, 3 and 4 using the following parameters[6].

Band 1 :Using g1 (the gap between the inverted T -shaped stub and the upper edge of the slot) .
Band 2 :Using L6 (the height of the E-shaped stub) .
Band 3 :Using L3 (the length o f the inverted T -shaped stub)and W5 (width of the T -shaped feed patch).
Band 4 :Usin g L12 (the length of the double-folded stub in the T -shaped feed patch) .

The T shaped feed patch is twisted 48^0 left from the centre position to meet the corner of the designed antenna. Due to twisted, the feed patch splits into two components at perpendicular to each other.

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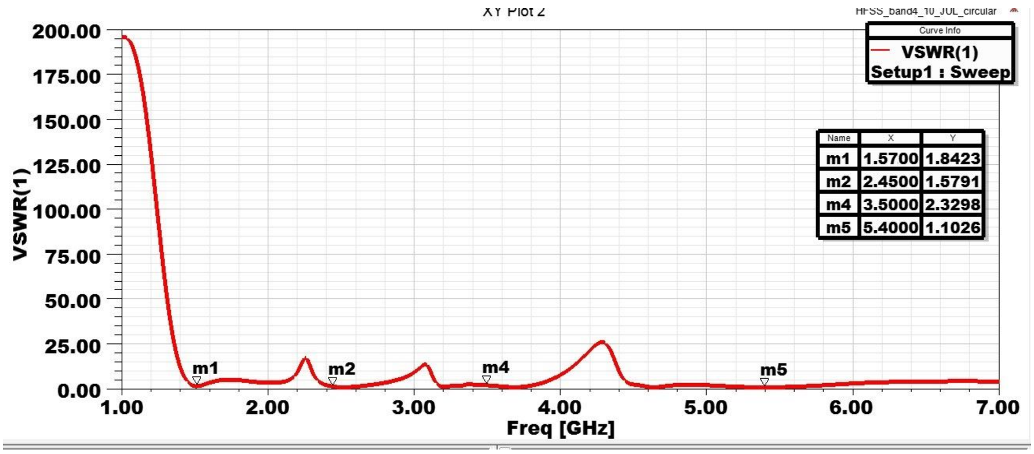
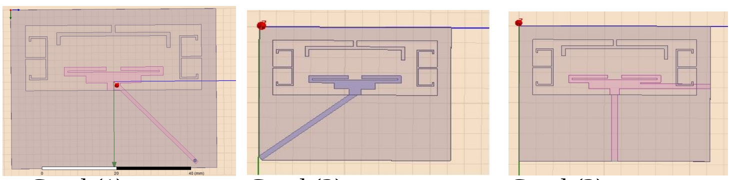


Fig V. VSWR of the proposed antenna

Fig V depicts the VSWR of the proposed antenna. Out of four selecting band, three bands having VSWR between 1 and 2, which is preferable for any design of antenna.

To study the effects of different feeding techniques on the frequency bands of the proposed multiband antenna, computer simulation on S11 is carried out in three different conditions: 1) Coax or probe feed is being used for single feed techniques, 2) Single fed technique using micro strip feed 3) Dual feed technique. In this proposed antenna design, the edge fed technique is used. Table II gives the comparative study of the different conditions.



Cond (1) Cond (2) Cond (3)

Fig VI Different conditions of feeding

Cond (1) is the state where the T shaped feed patch is twisted 450 right from the centre and the probe feed technique is used. Later on the width of the T shaped feed patch is reduced to the 1.00 mm to match the input impedance. Cond (2) is the proposed antenna design state where the T shaped feed patch is rotated 480 left from the centre and the length of the feed is increased due to the length changes from L2 to L2 cosθ. Cond (3) is the state where dual feed techniqueis used. Equal length of feed with equal width is used to feed the signal at orthogonal.

TABLE II
COMPARATIVE STUDY OF THREE CP CONDITIONS

Para (dB)	Freq. (GHz)	Cond1	Cond2	Cond3
S11	1.575	-0.002	-13.191	-6.349
	2.45	-0.002	-22.833	-5.979
	3.5	-0.004	-11.672	-23.40
	5.4	-0.005	-19.823	-11.10
VSWR	1.575	2224.6	1.8423	2.856
	2.45	1913.7	1.5791	3.019
	3.5	1746.3	2.3298	1.149
	5.4	1666.4	1.1026	1.772

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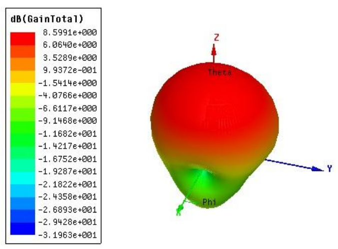
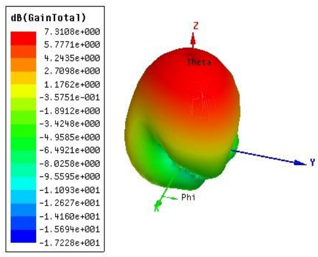
Based on the simulated result of the different designed CP antenna, their comparative study tabulated as above in table II. The table clearly indicate that the condition 2 is the better option out of three. Cond (1) shows the worst S11 and VSWR out of the three. Certainly the position of probe feeding affecting most the performance of the design, so the selection of the location of probe feed is important and the result of the cond 1 can be improve by selecting the another location of the feed. Cond (3) is somehow showing the better return loss at 3.5 and 5.4 GHz frequency, while at frequency 1.575 and 2.45 GHz, the return loss needs some more improvement and the VSWR of the Cond3 design is close to the ideal case.

IV. SIMULATION AND MEASUREMENT RESULTS

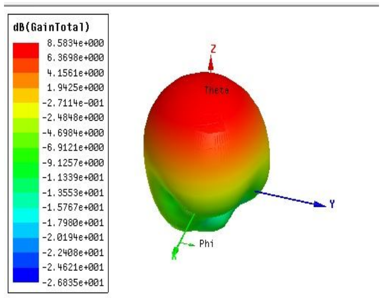
The proposed multiband antenna has been studied using computer simulation with the aid of Ansoft HFSS version 14.0 software. Keeping in mind the above comparative results, this paper followed the second condition. After design and simulation, some of the results depicted below. Fig VII describes the polar plot of the antenna at four different frequencies.



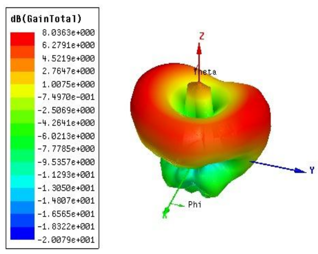
(a) 1.575 GHz



(b) 2.45 GHz



(c) 3.5 GHz



(d) 5.4 GHz

Fig VII polar plot at different frequencies

Fig VIII depicts the polarization of the designed antenna in terms of LHCP and RHCP at all operating frequecies. AT θ = 0 Deg the gain should be maximum. The same has been described in the diagram.

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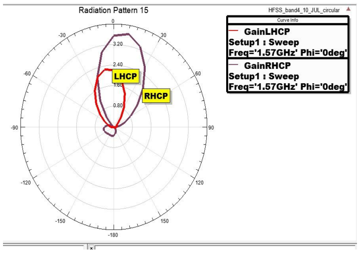
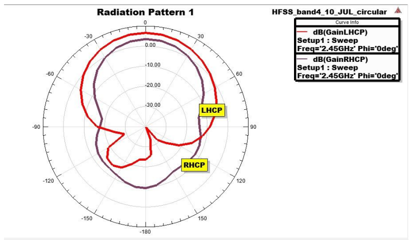
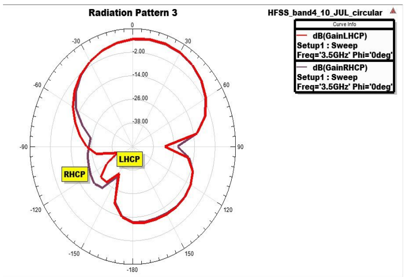


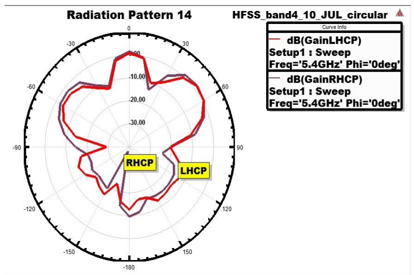
(a) 1.575 GHz



(b) 2.45 GHz



(c) 3.5 GHz



(d) 5.4 GHz

Fig VIII Polarisation at different frequencies

Another result of axial ratio is depicted below. Fig IX explain the axial ratio of the proposed antenna which at all the frequency bands. The proposed design shows the axial ratio of 2.064 db, 2.53 db, 0.65 db and 0.8773 dB at band 1,2,3 and 4 respectively.

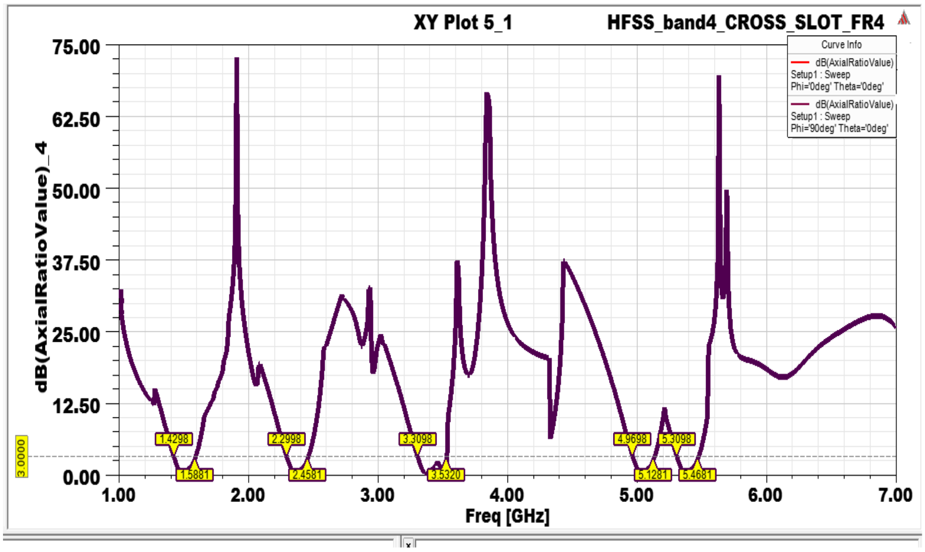


Fig IX Axial ratio of the proposed antenna

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V. CONCLUSION

In theproposed design, the antenna achieves the better gain along with narrow bandwidth at 1.575 GHz, which is used for GPS which will further improve the quality of the service and provides wide bandwidth at 3.5 and 5.4 GHz WiMAX frequency band. The frequency band 3.5 GHz, part of S band, is being used by weather Radar, Surface ship Radar and some communication satellites, while 5.4 GHz of WiMAX frequency band is known for the high speed broadband solution. Since the integration of multiple communication standard into a single device is always the desire of the new invention, its not only reduces the number of devices to operate simultaneously but also include the easy handling and continuous monitoring at all frequencies. Now a weather observer need not to carry the weather radar, data communication device and GPS separately, a ship radar operator can continuously observe the weather and location of the ship simultaneously. Since the integrated antenna needs to be compact in size, higher in gain and smaller in VSWR. The proposed antenna fulfilling all those criteria. The bandwidth of the proposed antenna is 880 MHz, which is wide enough, so it can be widely used for the other applications falling within the frequency range.

REFERENCES

[1]Hyungrak Kim, Byoung Moo Lee, and Young Joong Yoon, "A Single-Feeding Circularly Polarized Microstrip Antenna With the Effect of Hybrid Feeding," IEEE antennas and wireless propagation letters, Vol. 2, 2003

[2]Ko Han Lu and The-Nan Chang , "Circularly Polarized Array Antenna With Corporate-Feed Network and Series-Feed Elements", IEEE Transactions on Antennas and Propagation, Vol. 53, no. 10, Oct 2005

[3]Roberto Caso, Alice Buffi, Marcos Rodriguez Pino, Paolo Nepa, and Giuliano Manara,"A Novel Dual-Feed Slot-Coupling Feeding Technique for Circularly Polarized Patch Arrays", IEEE Antennas and wireless propagation letters, vol. 9, 2010

[4]Adam Narbudowicz, Xiu LongBao, and Max J. Ammann, "Dual- Band Omnidirectional Circularly Polarized Antenna" ,IEEE transactions on Antennas and Propagation, vol. 61, no. 1, January 2013

[5]W. Liao and Q.-X. Chu, "Dual-band circularly polarized microstrip antenna with small frequency ratio",*Progress In Electromagnetics Research Letters, Vol. 15, 145{152, 2010*

[6]Huan Zhang*, Yong Chang Jiao, Wei Long Liang, and Liang Lu , " Dual-band Circularly Polarized Deformed Monopole Antenna", Progress In Electromagnetics Research C, Vol. 54, 117–124, 2014

[7]Roberto Caso, Alice Buffi, Marcos Rodriguez Pino, Paolo Nepa,and Giuliano Manara, , "A Novel Dual-Feed Slot-Coupling Feeding Technique for Circularly Polarized Patch Arrays", IEEE antennas and wireless propagation letters, vol. 9, 2010