Advanced Research in Electrical and Electronic Engineering
p-ISSN: 2349-5804; e-ISSN: 2349-5812 Volume 4, Issue 5, October-December, 2017, pp. 245-249

http://www.krishisanskriti.org/Publication.html

Circular Polarized Monopole Antenna for K Band Application

Reshmi Dhara[1], Madhurima Sarkar[2], Tarun Kumar Dey[3] and Sanjay Kumar Jana[4]

[1,4]National Institute of Technology Sikkim
[2]Northern India Engineering College, Delhi
[3]Supreme Knowledge Foundations group of Institution, Hooghly.
E-mail: [1]reshmidhara@yahoo.co.in, [2]madhurima.1385@gmail.com, [3]tarunkumardey57@yahoo.com, [4]skjiit@gmail.com

Abstract—*A CPW-fed circularly-polarized monopole antenna with bandwidth enhancement has been presented in this paper. The circularly polarized characteristic has been achieved by a C-shaped monopole. To realize the circular polarization a new structure including two semicircles and a spring were etched on ground. The proposed antenna has a very small size 0.8 cubic mm which cover of* $20 \times 20\, mm^2$. *The antenna obtained simulated impedance bandwidth (IBW) 13.8208 GHz- 25.7488 GHz (11.928 GHz i.e. 60.23 %, at centre frequency 19.7848 GHz) with axial ratio bandwidth (ARBW) 721.6 MHz (23.3255 GHz – 24.0471 GHz i.e. 3.05 %, at centre frequency 23.668 GHz) for microwave 'K' band application. The peak gain of the antenna is 4.1164 dBi.*

Keywords*: Circular polarization, impedance bandwidth, axial ratio, K band.*

1. INTRODUCTION

With recent ongoing progress in the next generation wireless communications, there is an inevitable demand for wireless antennas which support high data rate capacity. In recent years, compact circularly polarized (CP) antennas is becoming more attractive in various applications such as short range wireless communication, satellite positioning, radar and sensing, and radio frequency identification (RFID). As the CP antennas do not affected by multipath and transceiver's orientations, those have several important advantages over linearly polarized antennas. On the other hand, In order to overcome polarization mismatch between transmitter and receiver, circular polarization (CP) is becoming popular in wireless communications to enhance system performance. The features can be realized when two orthogonal modes with equal amplitude and in phase quadrature are excited. Owing to features such as wide impedance bandwidth, low profile, low cost of manufacturing, and easy integration with monolithic integrated circuits attract more attention in wireless systems. On the other words, the main challenge in design of wideband CP antennas is broadening of 3 dB axial ratio (AR) while keeping a compact and low profile design. In recent years, various shapes and designs of CP slot antennas have been developed to overcome the narrow impedance and axial-ratio bandwidths (ARBWs) [1]–[10]. The circularly polarized square slot antenna can provide broad impedance and axial-ratio bandwidths. Also, the right-hand CP and the left-hand CP can be achieved simultaneously with various techniques in these antennas [1]–[10]. Some of the techniques has been used to design these kinds of antennas with broad CP bandwidth and broad AR include the following. A Circularly Polarized (CP) microstrip patch array [1] working at Ku band and in particular between 16.9-17.2GHz is based on a sequential rotation of four linearly polarized rectangular patches and appropriate phase shifts provided by a corporate feed network. A microstrip fed Spidron fractal patch [2] is used on a single substrate for Ku band application to achieve dual CP IBW 8.7 % and 6.6% with ARBW 2.96 % and 1.68 % respectively. Recent reports include for CP [3] have been using open ended slot at left end of the antenna. The impedance bandwidth of 7000 MHz (2.0-9.0 GHz) and IBW range of 5.1-5.8GHz has been achieved. Another technique a single fed wideband circularly polarized slot antenna [4] is designed for multiband applications. The achieved IBW and ARBW were 60.4% and 26.1% respectively. The designed antenna [5] was L strip fed proximity coupled circular microstrip antenna where the radiating patch is loaded by a cross slot of unequal arm's length. The circular polarization has been achieved by cutting an asymmetric slot cut on circular radiating patch to produce orthogonal modes, measured IBW of 51.8% and ARBW of 8.43% (AR<3dB). Another technique for CNSS dual-band applications, the designed antenna [6] comprises a small circular patch with embedded four spiral square slots around the boundary and a narrow slot in the center. It is observed that the lower (1615MHz) and upper (2498MHz) resonance frequencies are controlled by the circular patch and the spiral slots. The CP operation is mainly achieved by the narrow slot. The IBW are 3.5 % and 5.9% with ARBW are 0.87 % and 1.12% respectively. In [7] CP antenna obtained IBW 35 % and

ARBW 30% only for lower (L and S) band. Another CP performance only for short range communication [8] is obtained by CPW feed, IBW 51.4% and ARBW is 48.8 %. A new wideband circularly polarized square slot antenna (CPSSA) with a coplanar waveguide (CPW) feed [9] the measured IBW and ARBW are 52% and 25% respectively only for S band communication. Another circularly polarized characteristic is achieved by a C-shaped monopole [10]. To enhance the bandwidth of the antenna, a rectangle stub is adopted on the ground. The demonstrated antenna exhibits the impedance bandwidth of 1650 MHz (2.89-4.54GHz), while the AR bandwidth is 1060 MHz (3.12-4.18 GHz) only for WiMAX application.

As cited above, till now the IBW achieved is not very large for high frequency Ku-K band communication and ARBW is also very small. In this paper we report enhanced IBW compared to earlier reports for Ku-K band communication. The measured ARBW is also high compared to earlier reports. In this design a C shaped patched with a CPW ground is used. In order to increase IBW two semicircle are etched from CPW ground. But ARBW is not significantly increase. In order to increase circular polarization a spring is etched from CPW ground. By using this technique the achievable IBW is 11.928 GHz with ARBW is 721.6 MHz.

2. ANTENNA DESIGN

The optimized dimension (in mm) of the proposed antenna in Fig. 1 is illustrated. The antenna structure is consist of a C shaped monopole, a square strip grounded patch, two semicircle slots with 1.7 mm radius etched from the ground plane and a spring of 0.4 mm width is also etched from ground. The proposed CP antenna is fed by a 50 Ω CPW feed-line with width of 1.5 mm printed on FR4 substrate with thickness of 0.8 with ε_r = 4.4 and $\tan\delta = 0.02$. The gap between feed-line and ground plane is 0.3 mm. The overall dimension is $20 \times 20 \times 0.8\, mm^3$. To obtain CP operation by tuning the length of the C arms and the gap width between the microstrip line and CPW feed ground. The optimal dimensions of the designed antenna are specified in Table I. P_3, P_4, P_5, P_6, Y_f , P_{11} (width of the spring) are the key parameters to designed of this antenna.

To explain the CP performance of the antenna, the evolution of the antenna structure is depicted in Fig. 2. Five antennas have been discussed here. At step 1 a ground plane have taken on bottom side of the substrate but IBW is very low. In order to increase compactness a square slot is etched from ground at step 2, which increase IBW compare to step 1. At step 3 in state of ground plane on opposite side of substrate take CPW feed ground which increase IBW slightly. At this step, the antenna's AR bandwidth is enhanced but does not possess broadband CP characteristics.

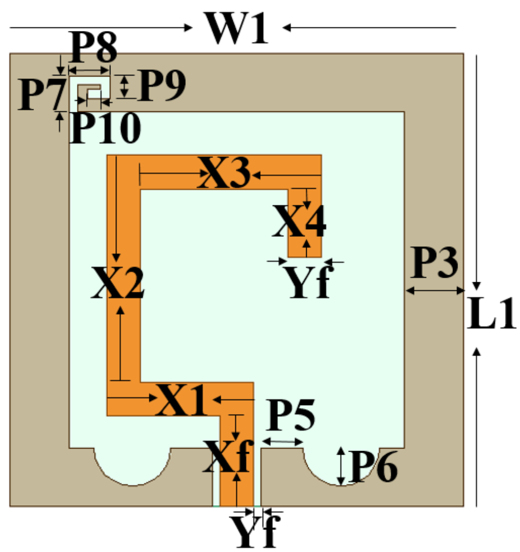
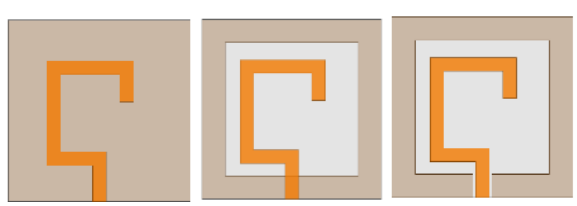


Fig. 1 Optimized dimension of the proposed antenna

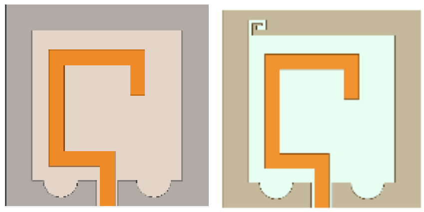
Table I: Optimal dimension of the proposed antenna

Parameter	Value (mm)	Parameter	Value (mm)	Parameter	Value (mm)
W_1	20	L_1	20	H	0.8
X_f	4	Y_f	1.5	X_1	5
X_2	10	X_3	8	X_4	3
P_3	2.6	P_4	0.3	P_5	4.6
P_6	1.7	P_7	1.7	P_8	1.4
P_9	0.6	P_{10}	0.6	P_{11}	0.4

The C shaped radiator patch, which plays the key role in the frequency bandwidth improvement , is truncated with two triangular notches for decreasing the effect of abrupt discontinuity in the connection point between the CPW feed line and the C shaped patch, as shown in step 3. A step 4 etching the semicircles in the lower both side of the CPW feed line from the ground plane. Hence, the good impedance characteristics will be obtained. In other words, a balance between vertical and horizontal electrical currents on the C shaped patch will be achieved and the impedance bandwidth and CP performance of the modified patch will be bettered. A last step i.e. 5 to significantly improve impedance bandwidth and CP performance of the proposed antenna, a spring is etched from CPW feed ground. Which shows that the C-shaped with microstrip line feeding can not only enhance the impedance bandwidth, but also generate two orthogonal modes with 90 phase difference and achieve CP radiation.



Step. 1 **Step. 2** **Step. 3**

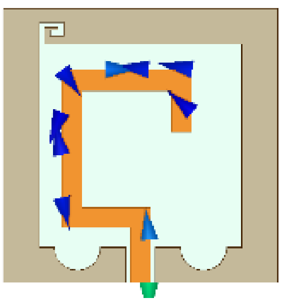


Step. 4 **Step. 5**

Fig. 2 Five improve structure of proposed antenna.

In order to understand the working principle of the proposed antenna, the surface current distribution is analyzed. Fig. 2 shows the simulated surface current distribution at 20 GHz for phases of 0°, 90°, 180° and 270° respectively.

From Fig. 3, it can be seen that the predominant surface current turns in clockwise direction as time increases,



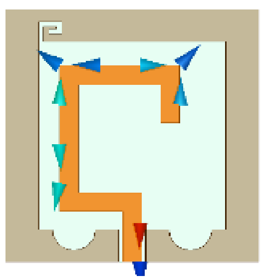
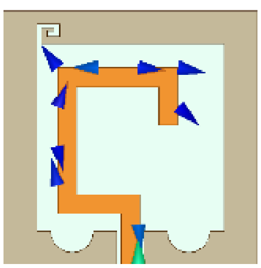


Fig. 3a **Fig. 3b**



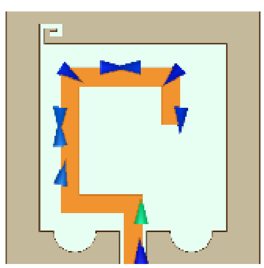


Fig.3c **Fig.3d**

Fig. 3: Simulated surface current distribution at 5.5GHz for four time instants. (a) 0°. (b) 90°. (c) 180°. (d) 270°.

Thus the polarization sense is left hand circularly polarization (LHRP). When the C-shaped monopole is inverted, opposite CP radiation can be obtained.

3. RESULT AND DISCUSSION

The simulation was performed using HFSS 13. The antenna has resonances at 17.144 GHz, 19.3 GHz and 24.62 GHz and the wide band performance has been obtained by merging these resonances.

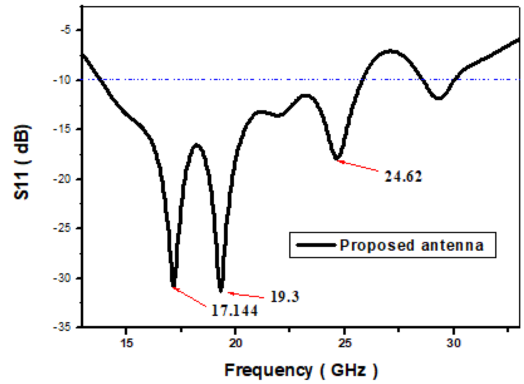


Fig. 4 Simulated return loss of proposed antenna.

The -10dB impedance bandwidth (IBW) of the measured return loss reached to 11.928 GHz, which covered the frequency from 13.8208 GHz to 25.7488 GHz. A wide band from 13.8208 GHz to 25.7488 GHz with the center at 19.7848 GHz shown at fig.4. There are three subsections: A) Study of the impedance band width and resonant modes. The simulated return loss of the proposed antenna has been discussed. B) Analysis of the axial ratio. C) Illustration of the simulated radiation pattern and gain. Fig. 4 shows the simulated return loss of the proposed antenna at 11.927 GHz or approximately 60.23% with respect to center the frequency at 19.7848 GHz.

Fig. 5 shows comparisons of simulated return loss improvement of the proposed antenna. According to Fig. 5, the proposed antenna performs satisfactorily over a wide bandwidth due to the three resonant modes which are influenced and excited by the above criteria.

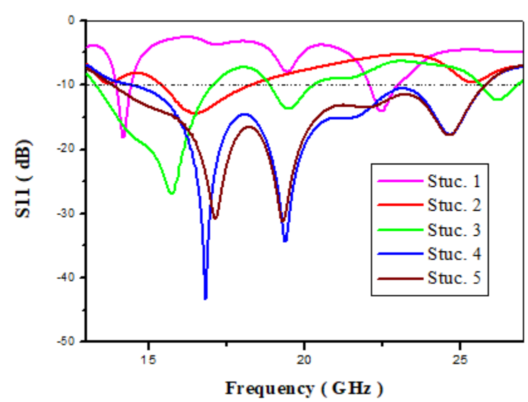


Fig. 5 Simulated S_{11} for Struc. 1, Stuc. 2, Stuc. 3,Stuc. 4, Stuc. 5.

The simulated AR results of the broadside direction versus frequency has been shown in Fig.6. The measured 3dB ARBW reach 721.6 MHz i.e. 3.05 % with respect to center frequency of 23.668 GHz(23.3255 GHz – 24.0471 GHz) which one is within‘K’ band (18 GHz- 26.5 GHz). This total simulated bandcan be used for FCC application mention below.

The frequency 23.55-23.6 GHz, Federal agencies use this band for fixed and mobile low-capacity microwave point-to-point communications systems for voice, data, and video at various government facilities and laboratories, test ranges, and air traffic control facilities. The National Science Foundation and the National Aeronautics and Space Administration use this band for the radio astronomy research of various spectral-lines and continuum measurements.

The frequency 23.6-24 GHz, the National Aeronautics and Space Administration (NASA) and the National Oceanographic and Atmospheric Administration (NOAA) use this band for passive sensing of the Earth from space using microwave radiometers to obtain data on water vapor, liquid water content, and as an associated channel for atmospheric sounding. This band is used in conjunction with passive sensing bands around 6.7, 10.6, 18.7 and 36 GHz to obtain several important climatologically parameters. The National Science Foundation and NASA use this band for the radio astronomy research of various spectral lines and continuum measurements. Observations of three major ammonia lines are performed in this band that help deduce the temperature of interstellar mediums. NASA supports radio astronomy observations in the 23.6- 24 GHz band with its deep space station receiver.

The frequency 24-24.05 GHz, the National Science Foundation uses this band for the radio astronomy research of various spectral-lines and continuum measurements [12-14].

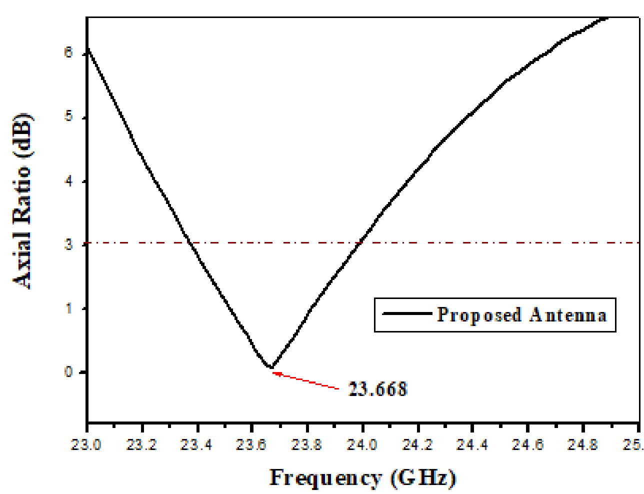


Fig. 6 Simulated Axial ratio bandwidth for proposed antenna

The peak gain, depicted in Fig. 7, is almost 4.1164 dBi at 23.164 GHz which is good for wireless communication.

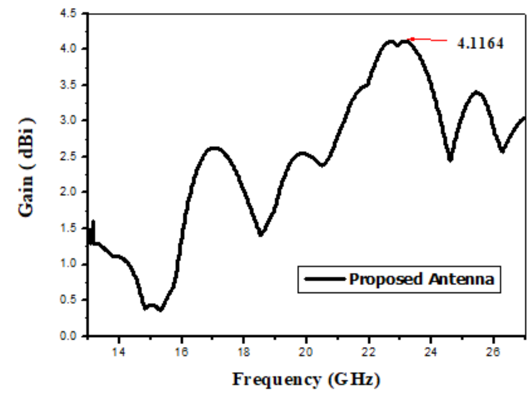
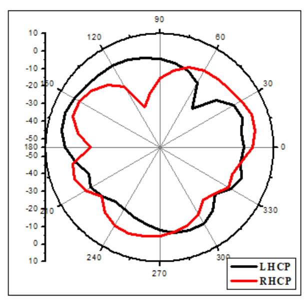


Fig. 7 Simulated gain plot of the proposed antenna.

Figures 8a and Fig. 8b are plots of the radiation pattern of the proposed antenna at 0^0 (in the XZ plane) and 90^0 (in the YZ plane) have shown for LHCP and RHCP at the frequency of 23.668 GHz. The observations in Fig. 8a and Fig. 8b show good LHCP and RHCP.



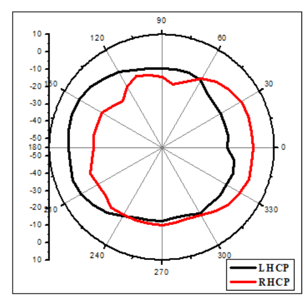


Fig. 8a **Fig. 8b**

Fig. 8a Simulated radiation pattern for the proposed antenna at 0^0 (XZ plane) for LHCP and RHCP at frequency 23.668 GHz.

Fig.8b Simulated radiation pattern for the proposed antenna at 90^0 (XZ plane) for LHCP and RHCP at frequency 23.668 GHz.

4. CONCLUSION

A CP Monopole antenna with bandwidth enhancement for ‘K’ band application has been proposed in this paper. By splitting the fundamental resonant mode into two near-degenerate modes of the C-shaped monopole, the CP characteristic has been obtained. In order to enhance the bandwidth of the antenna, two semi hexagonal slots and a spring were etched from CPW ground. Improvement in the impedance bandwidth and AR bandwidth of the antenna were observed. A good radiation performance has been achieved. The antenna simulated is of low cost and simple structure; thus suitable for practical wireless communication systems.

5. ACKNOWLEDGMENTS

We thank Dr. Taraknath Kundu, Head the Department of the Chemistry and Biotechnology, National Institute of Technology Sikkim and Dr. Tarun Kr. Dey, Dean of SKFGI for assistance with correcting manuscript in appropriate format, and for comments that greatly improved the manuscript.

REFERENCES

[1] Ferré, R., Mira, F., Luzi, G., Mateu, J. and Kalialakis, C., 2017, March. A Ku band circularly polarized 2× 2 microstrip antenna array for remote sensing applications. In *Applied Computational Electromagnetics Society Symposium-Italy (ACES), 2017 International* (pp. 1-2). IEEE.

[2] Thi, T.N., Hwang, K.C. and Kim, H.B., 2013. Dual-band circularly-polarised Spidron fractal microstrip patch antenna for Ku-band satellite communication applications. *Electronics Letters*, *49*(7), pp.444-445.

[3] Vishwakarma, N., Dwivedi, P.K. and Chauhan, R.K., 2016, July. CPW fed open ended slot antenna. In *Power Electronics, Intelligent Control and Energy Systems (ICPEICES), IEEE International Conference on* (pp. 1-3). IEEE.

[4] Kwame, O.G., Ellis, M.S. and John, K.J., 2013, December. A wideband single fed circularly polarized slot antenna for multi-band applications. In *Instrumentation and Measurement, Sensor Network and Automation (IMSNA), 2013 2nd International Symposium on* (pp. 620-623). IEEE.

[5] Singh, D.K., Kanaujia, B.K., Dwari, S. and Pandey, G.P., 2013, December. L-strip fed circularly polarised microstrip antenna with cross slots. In *Microwave and Photonics (ICMAP), 2013 International Conference on* (pp. 1-4). IEEE.

[6] Pan, Z.K., Chu, Q.X. and Lin, W., 2011, December. Compact circularly-polarized antenna with spiral slots for CNSS dual-band applications. In *Microwave Conference Proceedings (APMC), 2011 Asia-Pacific* (pp. 825-828). IEEE.

[7] Sze, J.Y. and Chen, W.H., 2011. Axial-ratio-bandwidth enhancement of a microstrip-line-fed circularly polarized annular-ring slot antenna. *IEEE transactions on antennas and propagation*, *59*(7), pp.2450-2456.

[8] Sze, J.Y., Hsu, C.I., Chen, Z.W. and Chang, C.C., 2010. Broadband CPW-fed circularly polarized square slot antenna with lightening-shaped feedline and inverted-L grounded strips. *IEEE Transactions on Antennas and Propagation*, *58*(3), pp.973-977.

[9] Sze, J.Y. and Chang, C.C., 2008. Circularly polarized square slot antenna with a pair of inverted-L grounded strips. *IEEE Antennas and Wireless Propagation Letters*, *7*, pp.149-151.

[10] Xing, Y., Zhang, R., Han, L., Ma, R. and Zhang, W., 2016, June. Circularly polarized monopole antenna with bandwidth enhancement. In *Microwave and Millimeter Wave Technology (ICMMT), 2016 IEEE International Conference on* (Vol. 1, pp. 220-222). IEEE.

[11] Constantine, A.B., 2005. Antenna theory: analysis and design. *MICROSTRIP ANTENNAS, third edition, John wiley& sons*.

[12] Federal Spectrum Use Summary , 30 MHz – 3000 GHz , *National Telecommunications And Information Administration Office Of Spectrum Management* , June 21, 2010.

[13] *5G Americas White Paper* on 5G Spectrum Recommendations-April 2017.

[14] FCC FACT SHEET, Exploring Flexible Use in Mid-Band Spectrum Between 3.7 GHz and 24 GHz, Notice of Inquiry, *GN Docket No. 17-183*, July 13, 2017.