Design and Characterization of a Ring Shaped Circular Polarized Microstrip Patch Antenna for X Band Applications

Conference Paper · December 2022

DOI: 10.1109/ICECTE57896.2022.10114542

3 authors:

Md. Farhad Hossain
Chittagong University of Engineering & Technology

Debprosad Das
Chittagong University of Engineering & Technology

Md. Azad Hossain
Chittagong University of Engineering & Technology

Design and Characterization of a Ring Shaped Circular Polarized Microstrip Patch Antenna for X Band Applications

Md. Farhad Hossain
Dept. of Electronics and Telecommunication Engineering
Chittagong University of Engineering and Technology
Chattogram, Bangladesh
farhad.hossain@cuet.ac.bd

Debprosad Das
Dept. of Electronics and Telecommunication Engineering
Chittagong University of Engineering and Technology
Chattogram, Bangladesh
u19mete024p@student.cuet.ac.bd

Md. Azad Hossain
Dept. of Electronics and Telecommunication Engineering
Chittagong University of Engineering and Technology
Chattogram, Bangladesh
azad@cuet.ac.bd

***Abstract*—A ring-shaped patch antenna with a 50-ohm feed was designed, to produce a circular polarized antenna for X band applications. The proposed microstrip antenna is of a ring shaped patch with a microstrip line along the diameter of the ring patch. The ring patch produces two orthogonal degenerative modes which makes circular polarization possible with a single feed. Outside the ring patch a stub is placed along the microstrip line for impedance matching purpose. Varying feed position from the center along the length of the microstip line is considered to tune the antenna in desired frequency. This ring shaped patch with microstrip line is placed on a Teflon substrate with a dielectric constant of 2.15 and a substrate height of 0.8 mm. The patch and ground plane uses copper with 0.018 mm of thickness. The return loss of the designed structure shows excellent impedance matching with values of -65.564 dB at the resonant frequency.**

***Index Terms*—Circular Polarization, Ring-Shaped, Microstrip Patch Antenna**

I. Introduction

Circularly polarized microstrip antennas (CMPAs) is widely used in recent past due to its ideal properties of reducing multipath distortion and improving polarization mismatch when compared to linear polarization [1]. It also gets rid of the need for exact alignment of the sending and receiving antennas, which explains the electromagnetic effects of the ionosphere [2]. Additionally, it has the superiority of low cost, low profile and simple integration, which have become incredibly popular throughout time in satellite and mobile communication [3]. Also, the same goes for radio-frequency identification (RFID) devices, like credit card, passenger pass card in train or bus, which employ CP to enable communication with RFID regardless of the card orientation [4].

Circular polarization is practically accomplished when two orthogonal modes are induced with a 90° phase difference between them. There are two categories of methods for producing circular polarization in microstrip antennas: single feeding point and two (or four) feeding point methods. The fundamental idea behind this feeding technique is the ability to divide the excited mode into two orthogonal ones. The structure's slight asymmetry, which results in a little difference in frequency between the two resonances, allows for the 90° shift. These two resonant modes can be generated with equal amplitudes and a 90° phase difference, resulting in circularly polarized radiation, whenever one of the patch elements is quarter of a wave length ahead of the other patch on the same side [5].

One method for obtaining a CP antenna is to truncate a corner of a rectangular patch. In order to radiate energy in all planes, including horizontal, vertical, and oblique ones, the patch was sliced orthogonally. Additionally, the ability to induce CP rotation can be improved by introducing an angled or diagonal slot at the radiating patch's center [6], [7]. In [8] a rectangular microstrip antenna having circular polarization by specifying a single point feed with the feed point either along the x-axis or along the patch's diagonal line is presented. In a rectangular or square patch, [9] addresses trimming off a pair of patch corners for CP. [10] depict a patch-edged antenna with slits or spur lines. An example of a trapezoidal-shaped slot antenna with a CPW line is shown in [11]. There are other methods that achieve circular polarization with two excitation locations by using two different feeds, one for each mode. The patches are provided in this case with the same amplitude and 90° out of phase using an external polarizer [12]. There are further approaches, such merging the first two. [13] provides a patch with slots and double feeding as an illustration. Four feeding stations are another widely used technique [14]. Using four feeding sites, two distinct frequencies can yield circular or sequential polarization.

Circularly polarized microstrip antennas with a single feed are often more compact than those with multiple feeds. Single

979-8-3503-2054-1/22/$31.00 ©2022 IEEE

feed CPMA features a simple, low-cost production architecture with a compact footprint. Also, uses of X band frequency microstrip antennas have been an interest for antenna researchers [15]–[18]. In this study, a ring shape patch with a microstrip line patch along the center of the ring is used to propose a CPMA for X band frequency. On the patch, the feed point is placed where the input impedance is 50 ohms at resonant frequency. As a result, finding the feed point is done through trial and error.

II. Design of the Antenna

A. Structure of the Antenna

On a Teflon glass fiber substrate with a relative dielectric constant of 2.15, the proposed antenna is constructed. The substrate has a thickness of 0.8 mm. Copper, which is utilized as a ground plane conductor and radiating plane with a thickness of 0.018 mm. Fig. 1 depicts the ring-shaped antenna's whole construction. The size of the ground plane is 20 × 20 mm^2. The outer ring is constructed at 7.7 mm from the center at the top of the substrate, then the inner ring is formed at 1.2 mm from the outer ring, which forms the ring-shaped of a 1.2 mm width. A rectangular microstrip patch line of 1.2 mm is added with the ring. This rectangular patch has a length of 16.6 mm, on both side of the ring, the patch line extended about 0.6 mm. A 50-ohm feed is inserted into the center of patch line. The described values are presented in Table I.

B. Basic Operation of the Antenna

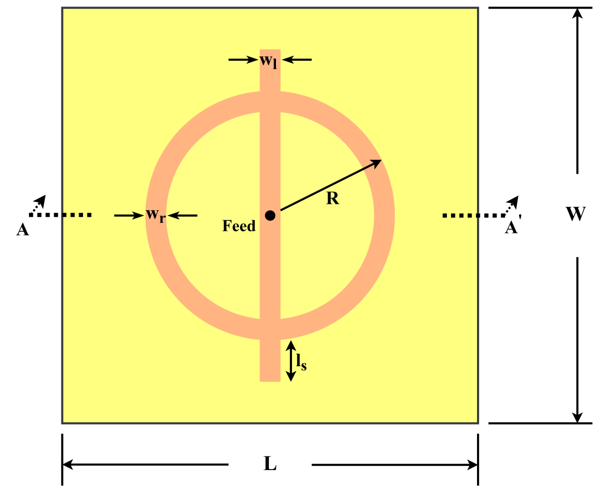
During operation the microstrip line propagates the input signal towards both ends of the line. The signal travels from the line to the ring shape patch as the ring patch and microstrip line are interconnected. The ring patch is then excited in higher order modes because of two wavelength circumference of the ring. The two semicircular ring patch on either side of the microstrip line acts as two individual antennas in the opposite phase which produces two orthogonal degenerative modes resulting in circular polarization.

III. Results and Discussion

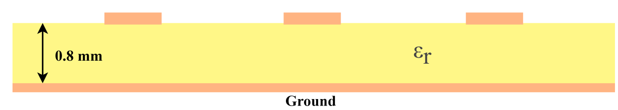
The simulation started by designing the ring-shaped patch. The feed point is first inserted at the center of the patch with no stub at either ends of the patch, which shows a return loss of -25.046 dB at 10 GHz. To tune the designed further, a series of simulation is done by increasing stub length along the microstrip line on both sides of the ring patch. For a stub length of 0.6 mm from the edge of outer ring patch, return loss of -39.980 dB at resonant frequency of 9.88 GHz is obtained. Fig. 2 Shows the simulated return loss of the proposed antenna for several stub lengths while keeping input feed position at center.

TABLE I: Design Parameters of the proposed ring shape antenna

Parameter	Value
Substrate	Teflon Glass Fiber
Relative dielectric constant, ϵ_r	2.15
Substrate height	0.8 mm
Copper thickness (ground, patch)	0.018 mm
Ground dimension, L×W	20 × 20 mm^2
Outer ring radius, R	7.7 mm
Ring width, w_r	1.2 mm
Microstrip line width, w_l	1.2 mm
Stub length, l_s	0.6 mm
Microstrip line length	16.6 mm
Feed Impedance	50 Ω



(a) Top view



(b) Cross-sectional view along AA'

Fig. 1: Design structure of the proposed ring-shaped patch antenna. w_l = 1.2 mm, w_r = 1.2 mm, l_s = 0.6 mm, R = 7.7 mm, L = W = 20 mm.

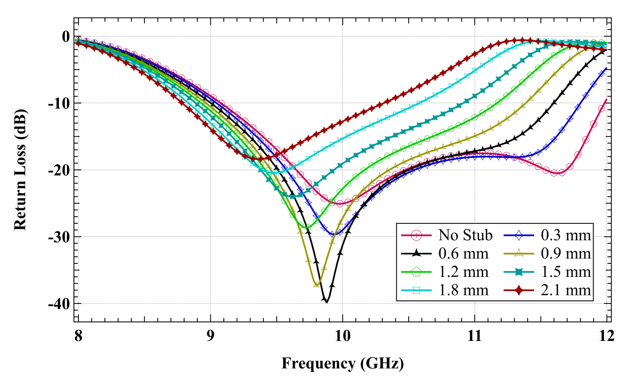


Fig. 2: Simulated Return loss with respect to frequency for different stub length when feed at center position for the proposed antenna.

For further tuning while keeping the stub length at 0.6 mm, feed position is varied from the center along the microstrip line. Return loss of -48.86 dB achieved at resonant frequency of 9.96 GHz, at the feed position of 1 mm below from center. Further increasing the feed point distance from center, at 1.5 mm distance, the desired tune frequency of 10 GHz found with a return loss of -44.81 dB. And at that resonance frequency of 10 GHz the bandwidth percentage is found is found to be 25.4 %. Fig. 3 Shows the simulated return loss of the proposed antenna for several feed positions while keeping stub length at 0.6 mm from the edge of the ring patch.

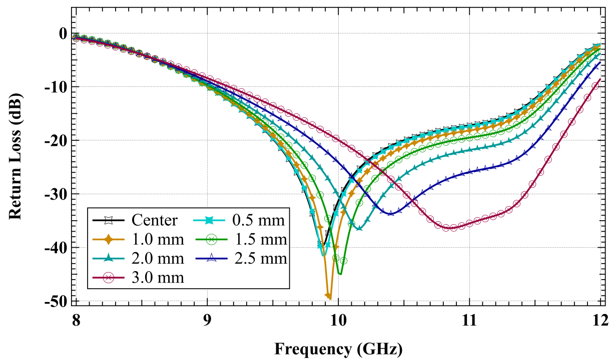


Fig. 3: Simulated Return loss with respect to frequency for different feed position when stub length is 0.6 mm from the edge of the ring patch.

Fig. 4 presents the optimized return loss (RL) of the proposed antenna. This proposed structure has a return loss of -65.564 dB at 9.960 GHz when the feed point is at 1.2 mm down from the center and has a stub length of 0.6 mm, indicates good impedance matching. And operating range of the antenna (RL $<$ -10 dB) is from 9 GHz to 11.64 GHz.

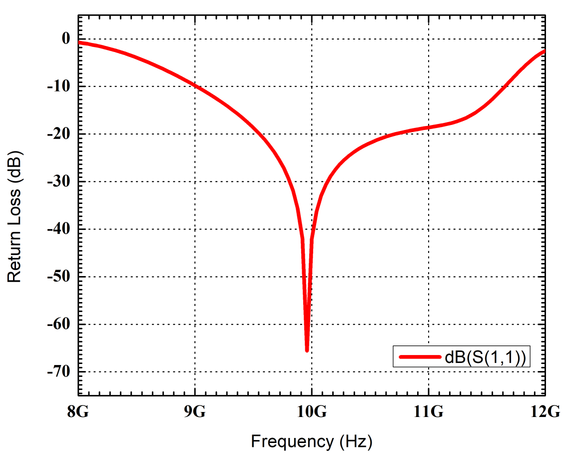


Fig. 4: Optimized return loss of the proposed designed antenna.

Fig. 5 depicts the antenna's input impedance as simulated using ADS. At 10 GHz, an impedance locus dipping is observed, indicating that two resonant modes are activated at relatively near frequencies. As a result, it appears that the current design's fundamental mode is divided up into two almost degenerate resonant modes. This results the antenna to be radiated in a circular polarized manner. Fig. 6 shows the

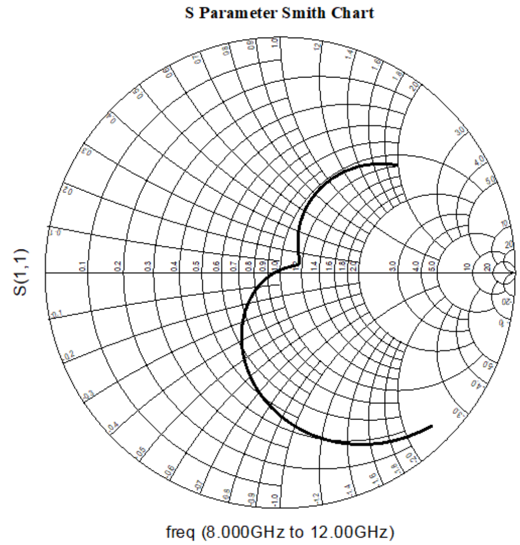


Fig. 5: Input impedance of the ring-shaped antenna.

current distribution of the proposed antenna at 10 GHz using ADS software. Utilizing the ideal design parameter values, the surface current distribution of the proposed array antenna is derived.

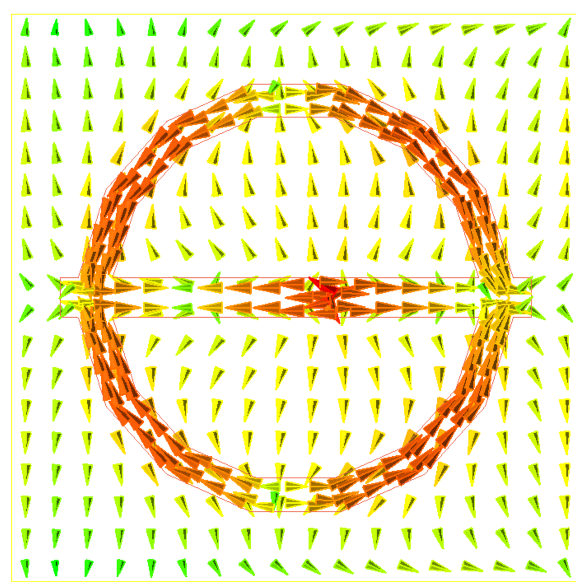


Fig. 6: Current Distribution of the ring-shaped antenna.

Fig. 7 shows the directivity versus frequency curve of the proposed antenna. It is clear from the plot that the designed antenna has a maximum directivity of 5.212 dBi in S band frequency range. The antenna also shows a maximum gain of 5 dBi in the S band frequency range.

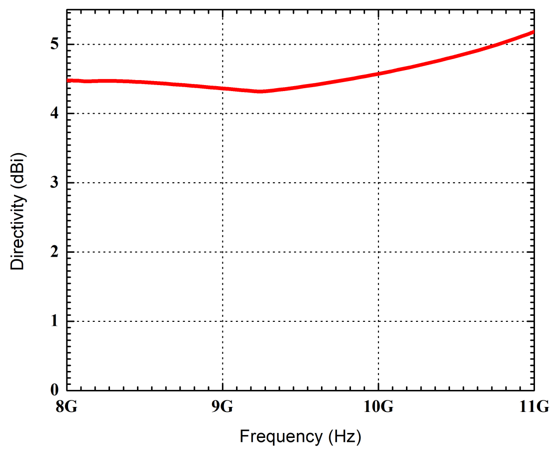


Fig. 7: Directivity of the proposed ring-shaped microstrip patch antenna.

Fig. 8 shows the radiation pattern of the proposed ring shape microstrip patch antenna.

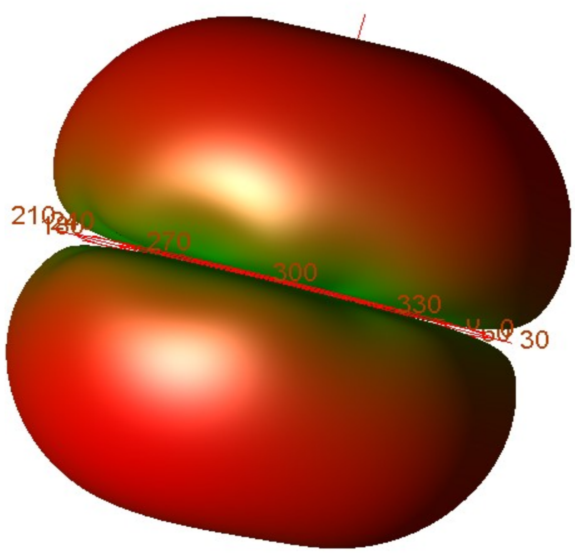


Fig. 8: Simulated 3D radiation pattern of the proposed ring-shaped microstrip patch antenna.

IV. Conclusion

A 10 GHz ring shape microstrip antenna for circular polarization is designed in this work, also the characteristics of the antenna also discussed. The designed antenna shows good impedance matching and Circular Polarization. The return loss of the antenna at resonance frequency 10 GHz is -44.813 dB, with an operating range (<-10 dB) of 9.04 GHz to 11.68 GHz. Which also illustrated from VSWR ($<$ 2) is 8.97 GHz to 11.65 GHz. This design utilizes the ring-shaped patch and a patch line, along with several stub lengths and feed positions. This compact sized circular polarized antenna with enhanced bandwidth make this much suitable for wireless applications.

References

[1] J.-W. Baik, K.-J. Lee, W.-S. Yoon, T.-H. Lee, and Y.-S. Kim, "Novel circularly polarized printed crossed dipole array with broad axial ratio bandwidth," in *2008 38th European Microwave Conference*. IEEE, 2008, pp. 401–403.

[2] B. Y. Toh, R. Cahill, and V. F. Fusco, "Understanding and measuring circular polarization," *IEEE Transactions on Education*, vol. 46, no. 3, pp. 313–318, 2003.

[3] X. Chen, G. Fu, S.-X. Gong, Y.-L. Yan, and W. Zhao, "Circularly polarized stacked annular-ring microstrip antenna with integrated feeding network for uhf rfid readers," *IEEE Antennas and Wireless Propagation Letters*, vol. 9, pp. 542–545, 2010.

[4] J. Garcia, A. Arriola, F. Casado, X. Chen, J. Sancho, and D. Valderas, "Coverage and read range comparison of linearly and circularly polarised radio frequency identification ultra-high frequency tag antennas," *IET microwaves, antennas & propagation*, vol. 6, no. 9, pp. 1070–1078, 2012.

[5] K.-L. Wong, "Compact and broadband microstrip antennas, jon wiley & sons," *Inc, New York*, 2002.

[6] K. Fujita, K. Yoshitomi, K. Yoshida, and H. Kanaya, "A circularly polarized planar antenna on flexible substrate for ultra-wideband high-band applications," *AEU-International Journal of Electronics and Communications*, vol. 69, no. 9, pp. 1381–1386, 2015.

[7] B. Kunooru, S. V. Nandigama, S. S. Rani, and D. RamaKrishna, "Analysis of lhcp and rhcp for microstrip patch antenna," in *2019 International Conference on Communication and Signal Processing (ICCSP)*. IEEE, 2019, pp. 0045–0049.

[8] M. Haneishi and S. Yoshida, "A design method of circularly polarized rectangular microstrip antenna by one-point feed," *Electronics and Communications in Japan (Part I: Communications)*, vol. 64, no. 4, pp. 46–54, 1981.

[9] W. S. Chen, C.-K. Wu, and K. L. Wong, "Single-feed square-ring microstrip antenna with truncated corners for compact circular polarisation operation," *Electronics Letters*, vol. 34, no. 11, pp. 1045–1046, 1998.

[10] H.-M. Chen and K.-L. Wong, "On the circular polarization operation of annular-ring microstrip antennas," *IEEE transactions on Antennas and Propagation*, vol. 47, no. 8, pp. 1289–1292, 1999.

[11] R. R. Krishna and R. Kumar, "Design of ultra wideband trapezoidal shape slot antenna with circular polarization," *AEU-international journal of electronics and communications*, vol. 67, no. 12, pp. 1038–1047, 2013.

[12] E. A. Hajlaoui and H. Trabelsi, "Improvement of circularly polarized slot-patch antenna parameters by using electromagnetic band gap structures," *Journal of Microwaves, Optoelectronics and Electromagnetic Applications*, vol. 15, pp. 428–440, 2016.

[13] A. Siblini, B. Jecko, and E. Arnaud, "Multimode reconfigurable nanosatellite antenna for pdtm application," in *2017 11th European Conference on Antennas and Propagation (EUCAP)*. IEEE, 2017, pp. 542–545.

[14] A. Siblini, H. Abou Taam, B. Jecko, M. Rammal, and A. Bellion, "Pixel and patch comparison circular polarization: For arma new agile circularly polarized approach," in *2017 Sensors Networks Smart and Emerging Technologies (SENSET)*. IEEE, 2017, pp. 1–4.

[15] Q. Chen, H. Zhang, X. Zhang, M. Jin, and W. Wang, "An x band dual-polarized shared aperture antenna using waveguide and microstrip antennas," in *2018 IEEE Asia-Pacific Conference on Antennas and Propagation (APCAP)*. IEEE, 2018, pp. 106–107.

[16] M. A. Rahman, Q. D. Hossain, M. A. Hossain, E. Nishiyama, and I. Toyoda, "Design of an x-band microstrip array antenna for circular polarization," in *8th International Conference on Electrical and Computer Engineering*. IEEE, 2014, pp. 184–187.

[17] M. A. Rahman, E. Nishiyama, M. A. Hossain, Q. D. Hossain, and I. Toyoda, "A microstrip antenna with circular polarization switching capability for x-band applications," in *2016 International Symposium on Antennas and Propagation (ISAP)*. IEEE, 2016, pp. 820–821.

[18] H. R. Gajera, K. Dutta, S. Poornima, S. Chandramma *et al.*, "Dual-band design of microstrip patch antenna with copper ring superstrate for x-band applications," in *2020 IEEE 1st International Conference for Convergence in Engineering (ICCE)*. IEEE, 2020, pp. 371–373.