URSI AP-RASC 2019, New Delhi, India, 09 - 15 March 2019

Wideband Circularly Polarized Microstrip Antenna with Enhanced Beamwidth

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Abstract

Circularly polarized microstrip antennas have inherent narrow axial ratio bandwidth and beamwidth is close to 90º. The axial ratio (AR) bandwidth can be increased by using a U-slot. In this paper, a U-slot loaded microstrip patch antenna is mounted on a conical ground to increase the AR beamwidth. This results in simultaneous increase in both the AR bandwidth and the AR beamwidth which as per the author's knowledge is rare to achieve. The AR bandwidth obtained is 2.18% and the AR beamwidth is around 140º. The half power beamwidth (HPBW) is also around 130º.

1. Introduction

In electronic warfare the airborne systems are in a moving trajectory along with a rotational motion. As the position of the antennas in such a system is constantly changing, circular polarization is required to mitigate the effects of polarization mismatch occurring in communicating with such a system.

Although circular polarization can be achieved by various kinds of antennas, microstrip antennas are advantageous due to their low profile and conformability to various surfaces.

Circularly polarized (CP) microstrip antennas can broadly be classified into two groups- single feed and dual feed. Circular polarization can be achieved in single feed antennas by adding some perturbation in the form of corner truncations [1] or slots [2]. These antennas exhibit a narrow axial ratio bandwidth [3]. Dual feed antennas on the other hand can provide a comparatively higher axial ratio bandwidth at the expense of additional feed network [4].

Attempts have been made to increase the axial ratio bandwidth by using thicker substrates [5]. Addition of a U-slot in the patch and feeding it with an L shaped probe resulted in increase of axial ratio bandwidth [6]. Aperture coupled feed can also be used to further increase the axial ratio bandwidth [7].

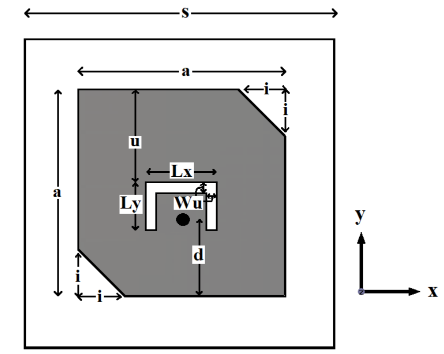
Microstrip antennas have a typical HPBW of around 90º. For warfare applications, a wide beamwidth may be required. Reducing the dimensions of the ground plane resulted in increase of HPBW in linearly polarized rectangular [8] and circular [9] patch antennas. Further increase in HPBW can be obtained by using shaped ground planes. A circularly polarized corner truncated square microstrip patch antenna was mounted on a three-dimensional square ground structure in [10]. The HPBW obtained in the left hand circularly polarized (LHCP) radiation was around 110º and the axial ratio bandwidth was 1.5%. A corner truncated microstrip patch antenna was enclosed by a folded conducting wall which covered all sides of the substrate and also some part of the patch in [11]. The overall structure was thin as there was no extension on the backside of the antenna. The HPBW was 106º and 104º in the two planes with a CP bandwidth of 1.9%. This work was further extended in [12] where in addition to the folded conducting wall, a pyramidal ground plane was also used. This resulted in a HPBW of around 130º with an axial ratio bandwidth of 0.76%. A corner truncated microstrip patch antenna with additional perturbation in all the four edges was placed upon a conical ground along with a rectangular metal sheet at the bottom in [13]. The left hand circularly polarized (LHCP) HPBW achieved was around 152º although the axial ratio beamwidth was 89º.

All the reported works have used the corner truncated microstrip patch antenna in which the axial ratio bandwidth was less than 2%. Also the AR beamwidth was not mentioned in many of these works. In this work, for the first time a U-slot loaded corner truncated microstrip antenna is chosen as the radiating element and it is placed on a conical ground structure by which not only a wide beamwidth CP radiation is achieved but also a greater axial ratio bandwidth has been obtained.

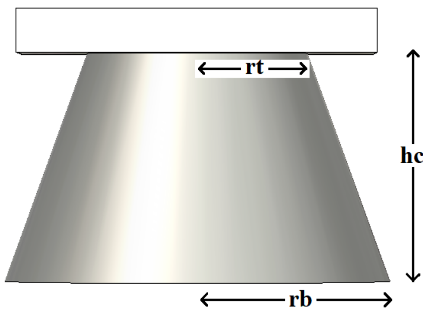
2. Antenna Design

A corner truncated microstrip patch antenna as shown in fig. 1a is simulated on an Arlon AD 250 substrate with permittivity (ε_r) =2.5, tan δ = 0.0018 at 10 GHz and substrate thickness of 1.524mm. The dimensions are chosen such that the center frequency of the operating band lies at 9 GHz. The patch antenna is placed symmetrically on a solid conical ground structure whose configuration is shown in fig. 1b below. A cylindrical region has been hollowed out of the structure for inserting a coaxial connector to feed the antenna. Upon varying only the parameters of the cone, it is found that an increase in HPBW does not essentially imply an increase in AR beamwidth. Our aim is to maximize the AR beamwidth, as in some cases it may be important than HPBW e.g. projectiles in electronic warfare.

Finally the parameters of the patch antenna and the cone are varied to obtain the maximum overlap between HPBW and AR beamwidth. The dimensions are a=9.37mm, i=1.8mm, d=4.2mm, Lx=3.2mm, Ly=2.6mm, Wu=0.4mm u=3.9mm and s=13.37mm. The dimensions of the cone are rt=5mm, rb=8mm and hc=10mm.The feed is placed at the position (0, -a/2+d).



(a)



(b)

Figure 1. a) Microstrip Patch Antenna (MPA) and (b) MPA with conical ground

3. Results

The microstrip antenna described in the last section (shown in fig. 1b) produces RHCP radiation. Fig. 2 shows the variation of axial ratio with frequency. The axial ratio bandwidth obtained is 197 MHz.

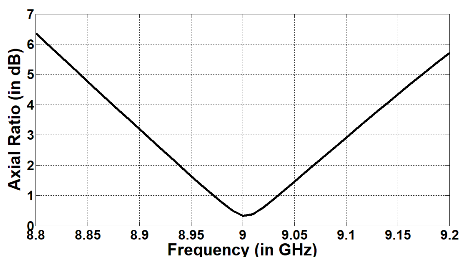
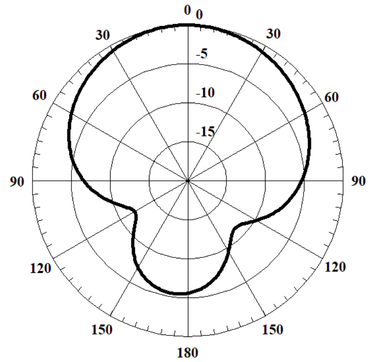
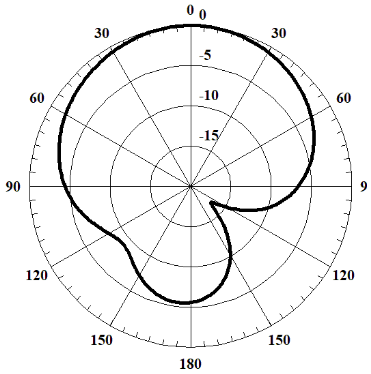


Figure 2. Axial Ratio vs. Frequency

The simulations have been done using CST Studio Suite [14]. Normalized gain of the microstrip patch antenna along with the conical ground is shown in fig.3 below.



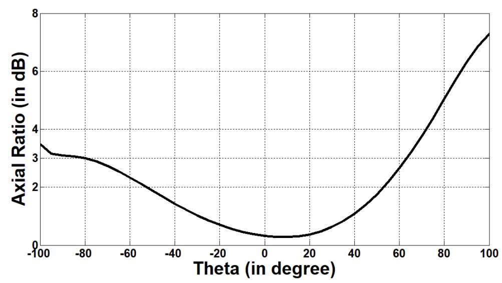
(a)



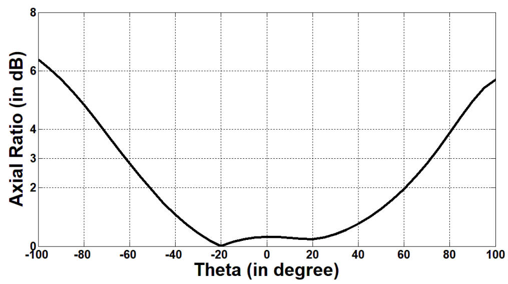
(b)

Figure 3. Normalized gain in the (a) phi=0° plane and (b) phi=90° plane

Angular variation of axial ratio in both ϕ=0° and ϕ=90° planes are shown in fig. 4 below.



(a)



(b)

Figure 4. Axial Ratio vs. theta in the (a) phi=0° plane and (b) phi=90° plane

Variation of S_{11} with frequency is shown in fig. 5 below. The impedance bandwidth obtained is 858 MHz.

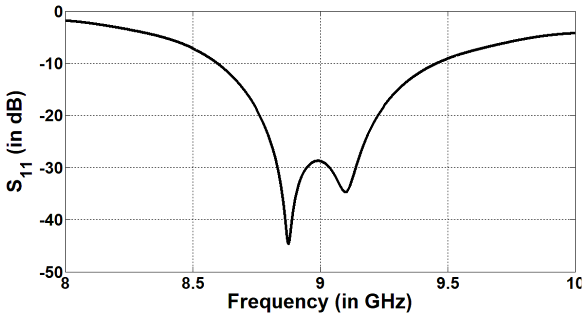


Figure 5.S_{11} vs. frequency

The results are summarized in Table 1 below. Usable beamwidth is defined as the range of angles (θ) which are common to both the HPBW and axial ratio beamwidth.

Table 1. Simulated values of the various parameters of the antenna

PARAMETER	VALUE
AR Bandwidth (GHz)	8.906 – 9.103 (2.18%)
AR Beamwidth (ϕ=0º)	-80º – 63º (143º)
AR Beamwidth (ϕ=90º)	-61º – 71º (132º)
HPBW (ϕ=0º)	-63º – 65º (128º)
HPBW (ϕ=90º)	-74º – 63º (137º)
Usable Beamwidth (ϕ=0º)	-63º – 63º (126º)
Usable Beamwidth (ϕ=90º)	-61º – 63º (124º)
Impedance Bandwidth (GHz)	8.597 – 9.455 (9.5%)
Gain (dB)	4.27

It can be observed that the usable beamwidth is around 125º.

Table 2. Comparison of our work with other reported works

	HPBW		**AR Beamwidth**		**AR Band width**	**Size**
	ϕ=0º	**ϕ=90º**	**ϕ=0º**	**ϕ=90º**		
[10]	113º	113º	-	-	1.5%	0.63 λ_o
[11]	106º	104º	-	-	1.9%	0.04 λ_o
[12]	131º	132º	-	-	0.76%	0.12 λ_o
[13]	152º	152º	110º	89º	-	0.24 λ_o
Our Work	128º	137º	143º	132º	2.18%	0.3 λ_o

It can be observed that the proposed work has a higher AR bandwidth due to the addition of the U-slot.

5. Conclusion

A U-slot loaded microstip antenna was mounted on a conical ground to obtain a wide beamwidth circularly polarized radiation. The HPBW increased by about 40º as compared to a regular microstrip patch antenna. The proposed antenna can be utilized for electronic warfare applications.

6. Acknowledgements

Suman Pradhan would like to thank CSIR for financial support vide file no. 09/096(0923) 2018 EMR-I. The authors would like to thank ARDE, DRDO for giving us an opportunity to work under a sponsored project.

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