Bandwidth Enhancement of Single-feed Circularly Polarized Equilateral Triangular Microstrip Antenna

Sara Sadat Karimabadi[1], **Yalda Mohsenzadeh**[1]
Amir Reza Attari[1], **and S. Mahdi Moghadasi**[1,2]

[1]Electrical Engineering Department, Ferdowsi University of Mashhad, Iran
[2]Communications and Computer Research Center, Ferdowsi University of Mashhad, Iran

Abstract— This paper presents a novel method of increasing impedance and axial ratio (AR) bandwidth of a single feed circularly polarized tip-truncated equilateral triangular microstrip antenna (ETMSA). Tip-truncated ETMSA has been previously introduced in the literature; in this new method by cutting a small equilateral triangular slot near the modified vertex, the impedance and AR bandwidths are increased more than two times.

1. INTRODUCTION

The main advantage of single-feed circularly polarized microstrip antennas is their simple structures that do not require an external polarizer [1]. Conventional designs of single-feed microstrip antennas for circular polarization (CP) are usually achieved by truncating patch corners of a square patch, using nearly square or nearly circular patches, cutting a diagonal slot in the square or circular patches, protruding or inserting a pair of symmetric perturbation elements at the boundary of a circular patch [1, 2]. Presently, typical designs of circularly polarized triangular microstrip antennas are using a nearly equilateral-triangular patch or an equilateral-triangular patch with a slit inserted at the patch edge [3].

On the other hand, the main weakness of an ordinary microstrip antenna is its narrow bandwidth. There are several ways to overcome this problem. A well known way is based on the introduction of an additional stacked [4, 5] or coupled patch [6, 7]. This makes the configuration more complex. As a consequence the array becomes more costly in production especially in the case of stacked patches. Also the dimension of the array increases. An alternative way consists in the use of specially shaped patches with slits [8, 9] and the rectangular patches with slot [10]. We have considered the slotted tip-truncated equilateral triangular patch because it has a smaller patch size at a given frequency, as compared to square and circular microstrip antennas, and has a good CP operation.

It is shown that by embedding a small equilateral triangular slot near the modified vertex of a tip-truncated equilateral triangular microstrip antenna, an impedance and AR bandwidth enhancement of about two times can be achieved. In the following section, details of the proposed CP designs of slotted triangular microstrip antennas are described and simulation results of the CP performance are presented.

2. ANTENNA CONFIGURATION

The geometry of the present antenna is consisting of a tip-truncated equilateral triangular patch [11] which yields circularly polarization (Fig. 1). The triangular patch with side length of L is printed on a substrate of thickness h and dielectric constant ε_r. By cutting a small equilateral triangular slot of side length b at the triangular patch in the height of h_1 from the bottom side of the patch (Fig. 2), AR bandwidth is improved more than two times.

Also, by further selecting a proper slot length and feeding the patch at a suitable position, two near-degenerate orthogonal resonant modes of equal amplitudes and 90° phase difference, and therefore a CP operation can be obtained. As depicted in Fig. 2, for the feed position at point B, a right-hand CP operation is obtained and by feeding the patch at point A (the mirror image of point B with respect to the centerline of the triangular patch) a left-hand CP is achieved.

3. SIMULATION RESULTS

In this section, simulation results are presented for the geometry shown in Fig. 2. As it will be shown, by using this geometry the AR bandwidth of antenna is increased in comparison to the geometry shown in Fig. 1. First, consider the tip-truncated triangular patch with parameters given in Fig. 1.

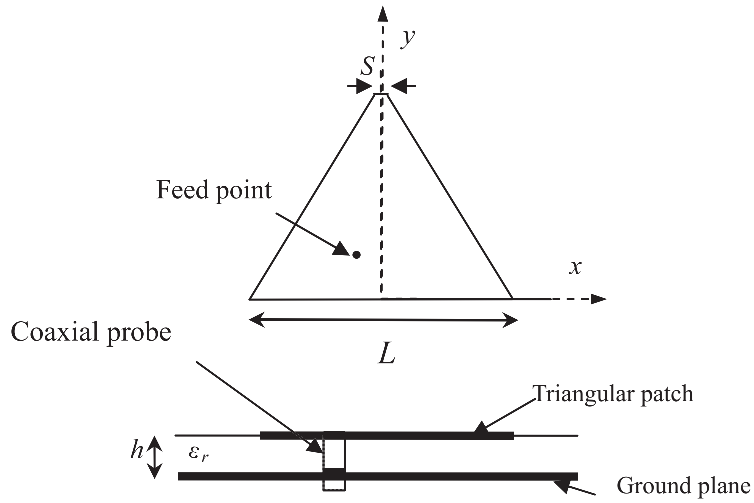


Figure 1: Geometry of circularly polarized tip-truncated equilateral triangular microstrip antenna. ($L = 36$ mm, $S = 2$ mm, $x_f = -3$ mm, $y_f = 7$ mm, $h = 1.52$ mm, $\varepsilon_r = 3.5$, $\tan\delta = 0.00018$)

It is found that by adjusting the inserted slit length (S) to be 2 mm, the CP operation can be obtained. Now, by cutting an equilateral triangular slot with dimensions shown in Fig. 2, a broadband CP operation is achieved. The simulated axial ratio versus frequency is presented in Fig. 3(b). The center frequency, defined as the frequency with a minimum axial ratio, is at 2.895 GHz and the CP bandwidth, determined from -3 dB axial ratio, is about 16.2834 MHz. For comparison, the results are also listed in Table 1 in which the proposed antenna is compared with the reference antenna shown in Fig. 1. The radiation patterns in two orthogonal planes are also computed. Fig. 4 plots the radiation patterns of proposed antenna at 2.895 MHz. As shown in this figure, a good left-hand CP operation is obtained.

Table 1: Comparison between the proposed antenna (with parameters given in Fig. 2) and the reference antenna (with parameters given in Fig. 1).

	Center frequency	Bandwidth VSWR < 2	CP Bandwidth AR $< -3dB$
Proposed antenna	2.895 GHZ	121.1303 MHZ	16.2834 MHZ
Reference antenna	2.902 GHZ	55.99 MHZ	7.7 MHZ

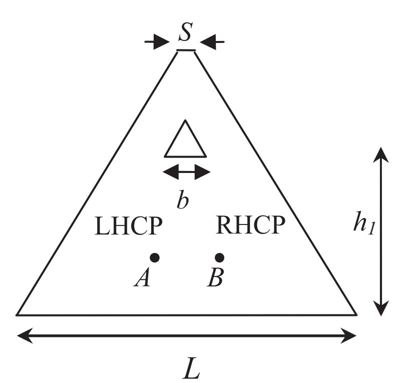
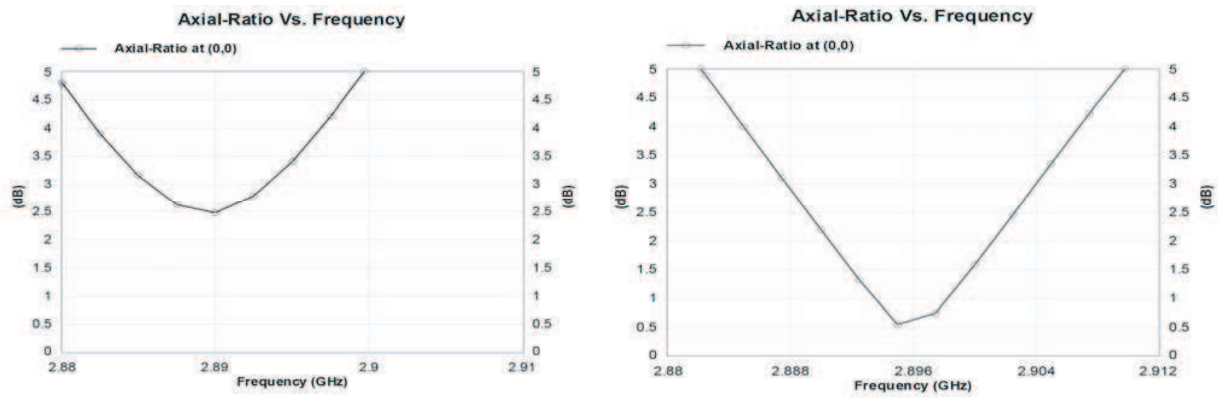


Figure 2: Geometry of the proposed antenna structure for increasing the axial ratio bandwidth. ($b = 4.8$ mm, $h_1 = 22$ mm, $x_f = -3$ mm, $y_f = 7$ mm)

From the simulation result listed in Table 2, it is seen that AR and VSWR bandwidth of proposed antenna decrease with decreasing the slot size. Also, the center frequency for CP operation



(a) (b)

Figure 3: Simulated axial ratio of (a) reference antenna given in Fig. 1 and (b) proposed antenna shown in Fig. 2.

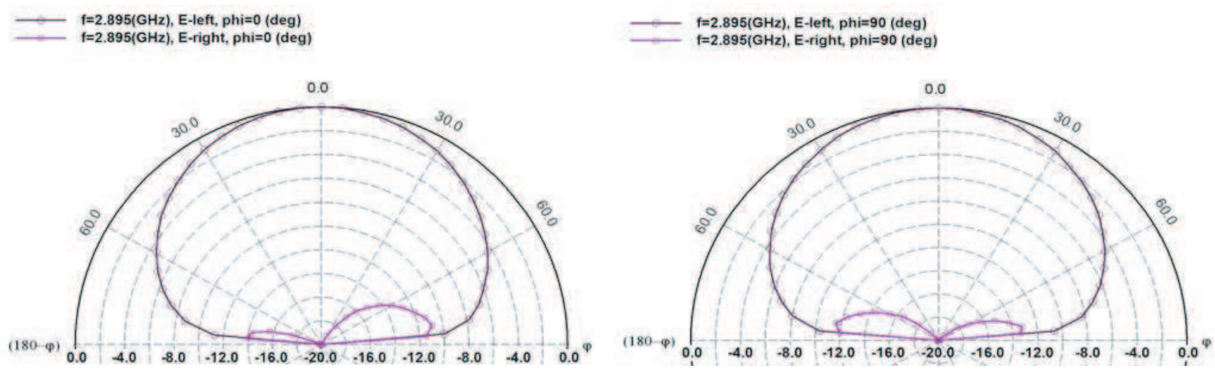


Figure 4: Simulated radiation pattern of proposed antenna in two orthogonal planes at $f = 2.895$ GHz.

of antenna decreases with decreasing h_1. In all these simulations other parameters of proposed antenna, were taken constant.

Table 2: Result of the proposed circularly polarized triangular microstrip antenna with various length and position of the triangular slot (Antenna parameters given in Fig. 1).

b (mm)	Center frequency (GHZ)	VSWR BW (MHZ)	AR BW (MHZ)
5	2.89	72.7122	16.2072
4.8	2.895	71.1303	16.2834
4.6	2.898	68.6034	16.1381
4.4	2.901	66.8675	15.83

h_1 (mm)	Center frequency (GHZ)	VSWR BW (MHZ)	AR BW (MHZ)
22.2	2.9	71.8508	16.2892
22	2.895	71.1303	16.2834
21.8	2.89	69.6429	16.324
21.6	2.884	68.4913	16.0849

4. CONCLUSIONS

A new design of single-feed circularly polarized microstrip antenna using slotted tip-truncated equilateral triangular patch has been proposed. The proposed structure has been simulated by using the IE3D software. The optimum feed position has been determined for good impedance matching. In comparison with an ordinary tip-truncated equilateral triangular patch, the AR bandwidth of our proposed structure is improved more than two times.

REFERENCES

1. Kumar, G. and K. P. Ray, *Broadband Microstrip Antennas*, Artech House, 2003.
2. Sharma, P. C. and K. C. Gupta, "Analysis and optimized design of single feed circularly polarized microstrip antennas," *IEEE Transactions on Antennas and Propagation*, Vol. 31, 949–955, 1983.
3. Lu, J. H., C. L. Tang, and K. L. Wong, "Circular polarization design of a single-feed equilateral-triangular microstrip antenna," *Electron Letters*, Vol. 34, 319–321, 1998.
4. Lee, R. Q., K. F. Lee, and J. Bobinchak, "Characteristics of a two-layer electromagnetically coupled rectangular patch antenna," *Electronic Letters*, Vol. 23, No. 20, 1070–1072, 1987.
5. Croq, F. and D. M. Pozar, "Millimeter-wave design of wide-band aperture-coupled stacked microstrip antennas," *IEEE Transactions on Antennas and Propagation*, Vol. 39, No. 12, 1770–1776, 1991.
6. Kumar, G. and K. C. Gupta, "Directly coupled multiple resonator wide-band microstrip antenna," *IEEE Transactions on Antennas and Propagation*, Vol. 33, No. 6, 588–593, 1985.
7. Celenet, M. and L. Shafai, "Wideband single layer microstrip antenna for array applications," *Electronic Letters*, Vol. 35, No. 16, 1292–1293, 1999.
8. Yang, F., X. X. Zhang, and Y. Samii, "Wide-band E-shaped patch antennas for wireless communications," *IEEE Transactions on Antennas and Propagation*, Vol. 49, No. 7, 1094–1100, 2001.
9. Wong, K. L. and W. H. Hsu, "A broad-band rectangular patch antennas with a pair of wide slits," *IEEE Transactions on Antennas and Propagation*, Vol. 49, No. 9, 1345–1347, 2001.
10. Huynh, T. and K. F. Lee, "Single-layer single patch wideband microstrip antennas," *Electronic Letters*, Vol. 31, No. 16, 1310–1312, 1995.
11. Tang, C. L., J. H. Lu, and K. L. Wong, "Circularly polarized equilateral triangular microstrip antenna with truncated tip," *Electronic Letters*, Vol. 34, 1277–1278, 1998.