MINIATURIZATION OF MICROSTRIP ANTENNA USING A 3-DIMENSIONAL AND T-SHAPED SLIT STRUCTURE

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1. Introduction

The microstrip patch antennas (MPAs) are widely applied because of their low volume, low weight and thin profile characteristics. These MPA's characteristics are particularly interesting for high-performance aircraft, spacecraft, satellite, missile and mobile communication applications because they are easily installed on flat or gently curved surfaces [1, 2]. Also, at present time, the miniaturization of the antenna size is one of the most important factors in case of antenna design and fabrication. There are many types of small sized MPAs such as the slit, shorting pin, super-strate-loaded [1, 2] and 3-dimensional structure [3, 4, 5, 6, 7].

This paper describes the fabricated antenna properties of the miniaturized 3-dimensional circularly polarized MPA (CPMPA) operating at a center frequency 1.575 GHz which four corners are depressed and four sides are cut out T-shaped slit. First, the properties of the general single-feed CPMPA and CPMPA with four T-shaped slits (T-CPMPA) are summarized. Second, a method for diminishing the size of T-CPMPA using 3-dimensional four-corner-depressed structure of the patch is discussed and the newly suggested antenna is fabricated. Finally, the fabricated antenna's experimental results are showed.

2. T-CPMPA properties at 1.575 GHz

The general structure of single-feed CPMPA operating at a frequency of 1.575 GHz is shown in Fig. 1 (a). The single feeding method is used to simplify the fabrication of the antenna because the dual-feed CPMPA is required an external power divider with quadrature phase difference to generate the two orthogonal modes. The size of the patch printed on foam material with dielectric constant ε_r = 1.06 is 76 mm × 83 mm and the height is 8.5 mm [3]. The measured return loss is −10.1 dB and the bandwidth is 85 MHz (5.4 %).

A useful way to decline the resonant frequency of the general CPMPA is to increase the total path length of the surface current by modifying the patch. Using the decline of the resonant frequency, the miniaturization of the antenna is achieved by recurring to the original resonant frequency through the decrease of the resonant length of the patch in CPMPA. In this case, it is one of the effective methods that cut the patch to the T-shaped slit [4]. Fig. 1 (b) shows the T- CPMPA where the size (length × width) of the patch printed on foam material with ε_r = 1.06 is 57 mm × 57 mm (square) and the height is 8.5 mm. A square patch with a single feed along the diagonal is one of the simplest MSA configurations to generate circular polarization. When this square is diagonally fed at the one point shown in Fig. 1 (b), right hand circular polarization

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(RHCP) is obtained where the two orthogonal modes are controlled by the T-shaped slit length variation. The measured return loss is −10.5 dB, the gain is 3.4 dBd, and the axial ratio is 2.79 dB from 1.571 GHz to 1.579 GHz.

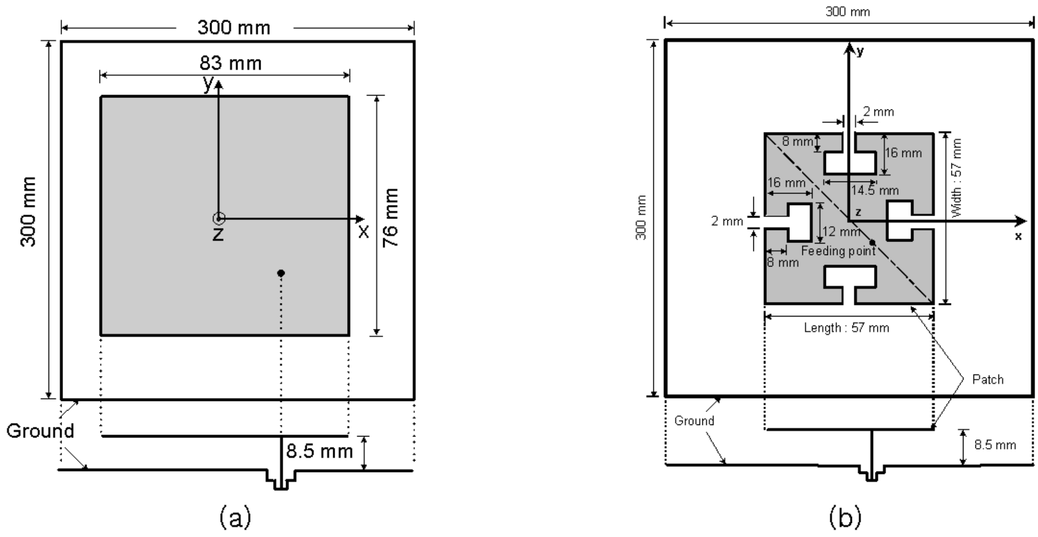

Fig. 1 The structure of (a) general CPMPA and (b) T-CPMPA with a height 8.5 mm

3. 3-dimensional T-CPMPA

To miniaturize the antenna, the decline of the resonant frequency of the T-CPMPA with a height 8.5 mm is observed through the four-corner-depressed length increasing simultaneously from 2 mm to 16 mm as shown in Fig. 2 where the outer dimensions of T-CPMPA and the size of the T-shaped slit are kept constant during the depressing the patch. In this case the resonant frequency decreases from 1.575 GHz to 1.095 GHz as shown in Fig. 3. As an increase of the four-corner-depressed length, the resonant frequency of the T-CPMPA is lowered. This effect is based on the inward perturbation on the radiating edges where the electric field is strong [3, 8] as well as the increase of the surface current path length as a result of 3-dimensional four-corner-depressed structure of the patch.

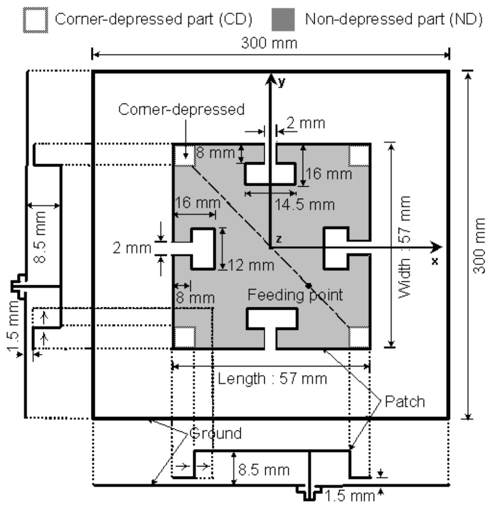

Fig. 2 Four-corner-depressed T-CPMPA

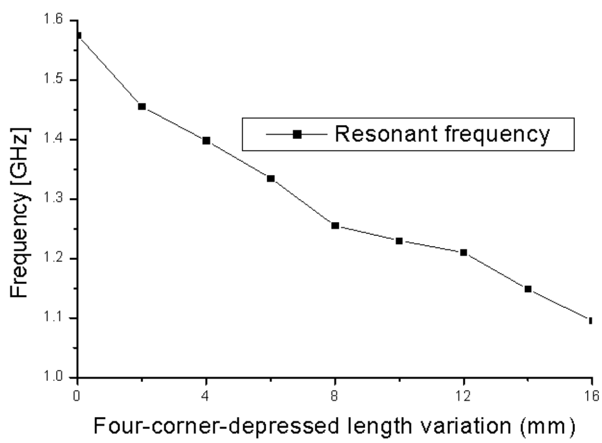

Fig. 3 Resonant frequency variation vs. four-corner-depressed length variation

4. Results

Using the deformation of the patch that depresses the four corners of the T-CPMPA, the miniaturization of antenna is achieved by recurring to the original resonant frequency through the decrease of the resonant length of the patch in T-CPMPA. Fig. 4 shows the properties of the newly suggested 3-dimensional T-CPMPA. This antenna's structure is a compact configuration as compared with the general CPMPA and T-CDMPA. The 3-dimensional T-CPMPA is fabricated in foam material with ε_r = 1.06 and height = 8.5 mm. The fabricated antenna size (42 mm × 42 mm) is reduced to 72 % and 45.7 % as compared with the size of the general CPMPA (76 mm × 83 mm) and T-CPMPA (57 mm × 57 mm) respectively. The measured return loss is −11.7 dB and the axial ratio is 1.99 dB from 1.565 GHz to 1.575 GHz. The gain is 1.4 dBd and the half power beam width (HPBW) in the z-x plane (x-axis pol.) and z-y plane (y-axis pol.) are 94° and 101° respectively. The experimental results are summarized in Table 1.

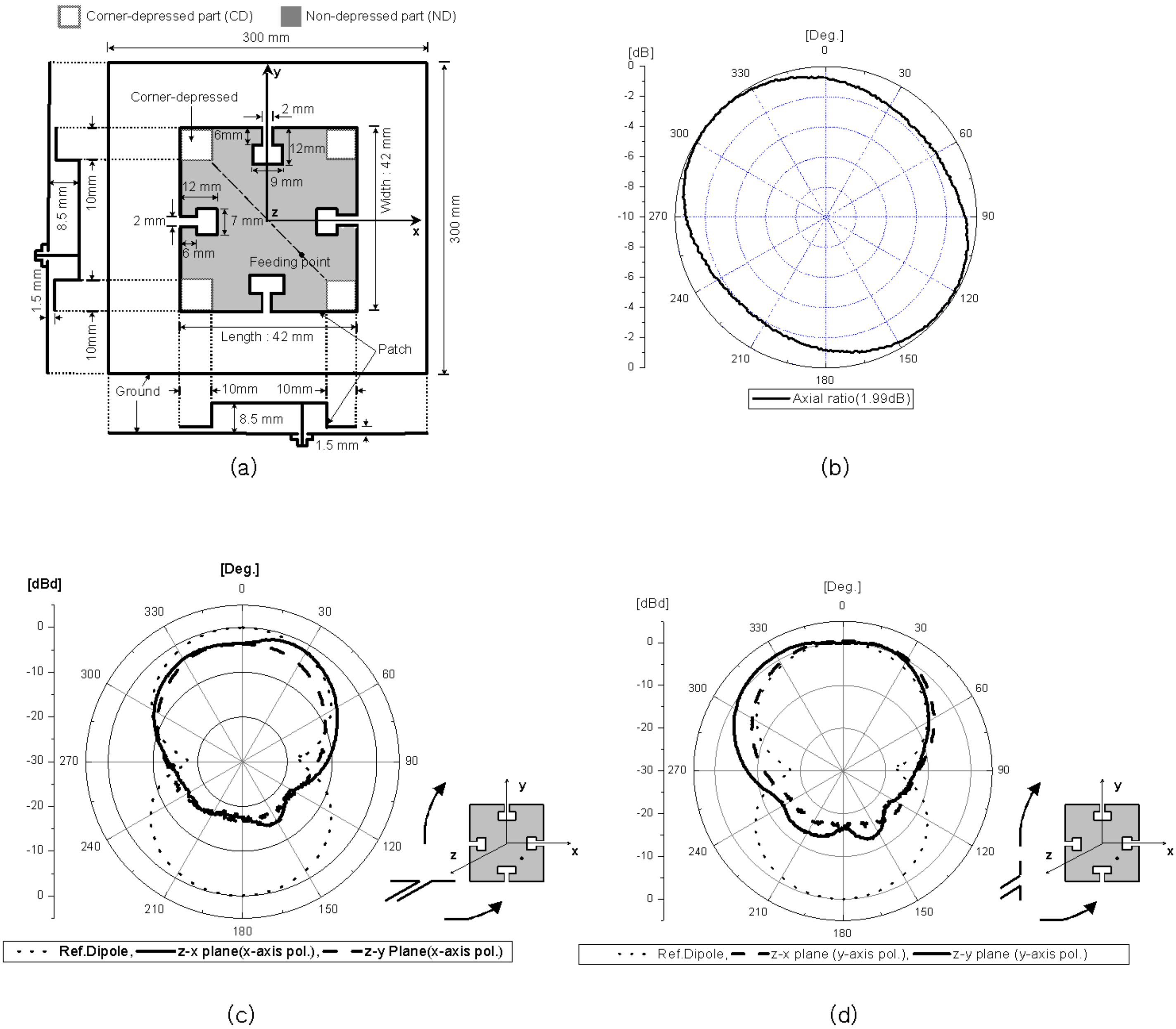

Fig. 4 The properties of the 3-dimensional T-CPMPA (a) structure (b) axial ratio (c) radiation patterns of the x-axis polarization and (d) radiation patterns of the y-axis polarization

5. Conclusions

A highly miniaturized 3-dimensional T-CPMPA operating at a center frequency 1.575 GHz is designed and fabricated using the reduction of the resonant frequency of the general single-feed CPMPA. This newly suggested 3-dimensional T-CPMPA is reduced to 72 % and 45.7 % as compared with that of the general CPMPA and T-CPMPA respectively. Through this result, it is confirmed that the 3-dimensional T-CPMPA has the advantage of miniaturization of the CPMPA.

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Table 1. The measured characteristics of the general CPMPA, T-CPMPA, and 3-dimensional T-CPMPA

(ND : Non-depressed part, CD : Corner-depressed part)

		General CPMPA	T-CPMPA	3-dimensional T-CPMPA
Substrate height of ND/CD [mm]		8.5 / 0	8.5 / 0	8.5 / 1.5
Return loss [dB]		-10.1	-10.5	-11.7
-10dB return loss bandwidth [MHz]		85 (5.4 %)	56 (3.6 %)	53 (3.4 %)
Gain(Max.) [dBd]		4.2	3.4	1.4
-3dB beamwidth [Deg.]	z-x plane (x-axis pol.)	56.2	62	94
	z-y plane (y-axis pol.)	66.2	91	101
Axial ratio [dB]		2.8	2.79	1.99
ARBW within 3 dB [MHz]		25 (1.6 %)	8 (0.51 %)	2 dB ARBW 10 (0.63 %)
Patch size [mm×mm] (Percentage of reduction in patch size)		76 × 83 (Ref.)	57 × 57 (52.6 %↓)	42 × 42 (72 %↓)