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OMNIDIRECTIONAL BROADBAND STEP-SHAPED METAL-PLATE MONOPOLE ANTENNA

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1. Introduction

Planar metal-plate monopole antennas have the attractive feature of very wide impedance bandwidth [1]-[8]. However, for higher operating frequencies in the very wide impedance bandwidth obtained, omnidirectional or near-omnidirectional radiation patterns (defined here for gain variations less than 3 dBi in the azimuthal plane) usually cannot be achieved [4]. This is because, for achieving a very wide impedance bandwidth, the planar metal-plate monopole is usually designed to be with a large width, which is usually comparable to or larger than a quarter-wavelength of the higher operating frequencies in the impedance bandwidth. In this case, due to the path-length difference caused by the large monopole width, the antenna's radiated fields contributed from the excited surface currents near the two side edges of the planar monopole will be destructive in the direction parallel to the planar monopole. On the other hand, the radiated fields in the direction normal to the planar monopole in general have no path-length difference and will be constructive. This behavior will lead to an elliptical radiation pattern in the azimuthal plane.

To overcome the problem of poor omnidirectional radiation characteristics for higher operating frequencies for the conventional planar monopole antenna, we propose a novel broadband step-shaped metal-plate monopole antenna. It is expected that, when the side lengths or widths of the cross-sectional area of the proposed step-shaped monopole are the same in two orthogonal directions [see Fig. 1], the maximum path-length difference of the antenna's radiated fields (contributed from the excited surface currents near the two side edges of the planar monopole) in the azimuthal plane can be considerably reduced. This suggests that good or near-omnidirectional radiation characteristics over a much wider impedance bandwidth can be obtained for the proposed antenna than for a corresponding planar monopole antenna (that is, the proposed antenna unfolded into a planar metal-plate structure). Experimental and simulation results of the proposed antenna are presented and discussed.

2. Antenna Design

Fig. 1(a) shows the geometry of the proposed broadband step-shaped metal-plate monopole antenna mounted on a ground plane (size 100 × 100 mm^2). The proposed antenna is excited through a feeding post of length h connected to the center of the monopole's lower edge. The feeding post is then connected to a 50 Ω SMA connector through a via-hole in the center of the ground plane. The step-shaped metal-plate monopole has a cross-sectional view shown in Fig. 1(b), and can be easily achieved from bending a planar metal plate (a 0.2 mm brass sheet was used in this study) of dimensions $L \times W$ shown in Fig. 1(c).

Note that, as shown in Fig. 1(b), the cross-sectional area has two side lengths of W_2 and $2W_1$ in the x and y directions, respectively. By comparing the step-shaped monopole to the planar monopole in Fig. 1(c), it is clearly to see that the possible maximum path-length difference of the antenna's radiated fields in the x direction is reduced from W (= $2W_1 + W_2$) to W_2. Thus, by choosing $2W_1 = W_2$ (square cross-sectional area for the proposed antenna), the possible maximum path-length difference in the x direction can be reduced by about one half for the proposed antenna. In addition, with $2W_1 = W_2$, the antenna's radiated fields in the x and y directions will be expected to have about the same amplitude, thereby causing much improved omnidirectional radiation characteristics in the azimuthal plane for higher operating frequencies for the proposed antenna here.

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3. Experimental Results and Discussion

Fig. 2 shows the measured and simulated return loss for the proposed antenna with $L = 24$ mm, $W = 20$ mm, $W_1 = 5$ mm, $W_2 = 10$ mm, $h = 2$ mm. In this case the cross-sectional area of the proposed antenna has two equal side lengths (10 mm), which is only one half of the corresponding planar monopole antenna ($W_1 = 0$, $W_2 = 20$ mm). The simulated results are obtained using Ansoft simulation software HFSS (High Frequency Structure Simulator), and good agreement between the measured data and simulated results is obtained. From the measured data, a very wide impedance bandwidth, defined by 2:1 VSWR, of frequency ratio about 1:3 (2180–6590 MHz) is obtained for the proposed antenna, which is about the same as that of a corresponding planar monopole antenna.

Fig. 3 plots the measured radiation patterns at 3000 MHz. In this case good omnidirectional radiation is obtained, and the measured antenna gain variations in the azimuthal plane (x–y plane) are less than 1.0 dBi. Fig. 4 plots the measured radiation patterns at 6000 MHz. Good omnidirectional radiation with gain variations in the azimuthal plane less than 2.2 dBi is achieved. The antenna gain for frequencies across the impedance bandwidth is in a range of about 2.8–5.5 dBi.

Fig. 5 presents the measured maximum gain variations in the azimuthal plane against frequencies for the proposed antenna and a corresponding planar monopole antenna ($W_1 = 0$, $W_2 = 20$ mm). For both antennas, the maximum gain variations increase monotonically with an increase in the operating frequency, and it is clearly seen that the proposed step-shaped monopole antenna has better omnidirectional radiation characteristic. For the operating frequency less than about 6.6 GHz, the maximum gain variation in the azimuthal plane is less than 3 dBi for the proposed monopole antenna. On the other hand, the corresponding planar monopole antenna shows a smaller frequency range (less than about 5.3 GHz) for achieving gain variations in the azimuthal plane less than 3 dBi. Further related experimental and simulation results will be discussed in the presentation.

4. Conclusion

A novel step-shaped metal-plate monopole antenna for achieving improved omnidirectional radiation across a very wide bandwidth has been proposed. The proposed monopole antenna has a simple structure and is easy to construct. Prototypes of the proposed antenna have been successfully implemented. Results indicate that, when the cross-sectional area of the step-shaped monopole is with equal side-lengths in two orthogonal directions, good omnidirectional radiation (gain variations less than 3 dBi in the azimuthal plane) for frequencies across a very wide bandwidth of frequency ratio about 1:3 (about 2.2 to 6.6 GHz in this study) have been achieved.

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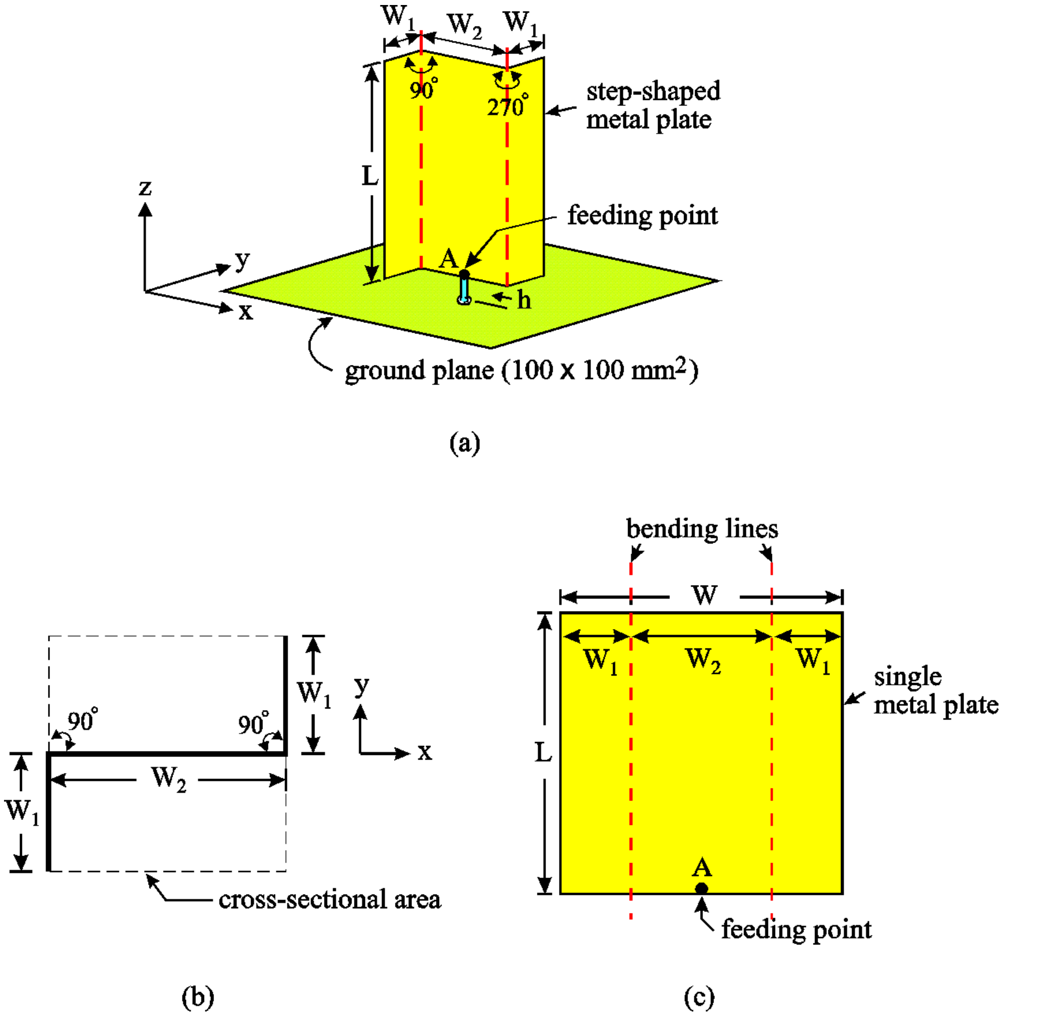

Fig. 1 (a) Geometry of the proposed broadband step-shaped metal-plate monopole antenna. (b) Cross-sectional view of the metal-plate monopole in (a). (c) The step-shaped metal-plate monopole unfolded into a planar structure.

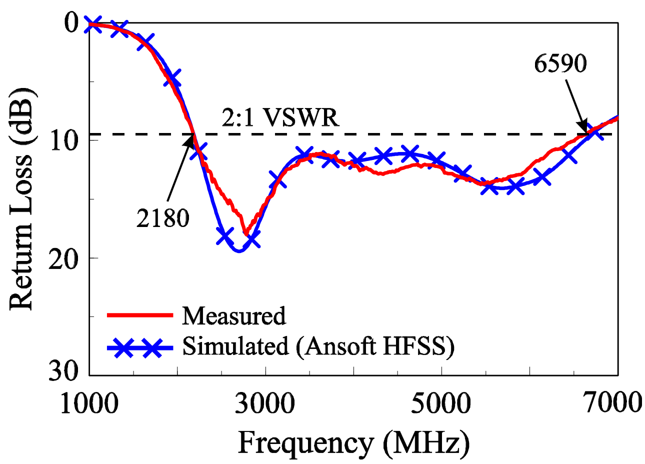

Fig. 2 Measured and simulated return loss for the proposed antenna with $L = 24$ mm, $W = 20$ mm, $W_1 = 5$ mm, $W_2 = 10$ mm, $h = 2$ mm.

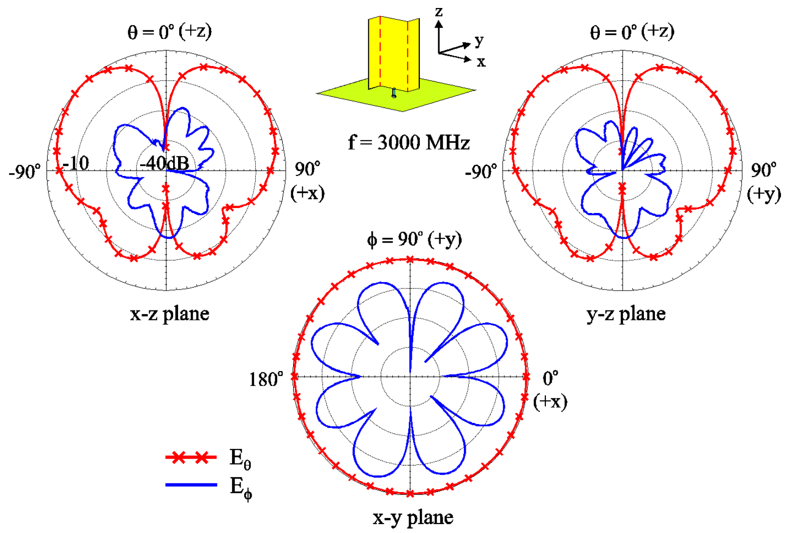

Fig. 3 Measured radiation patterns at 3000 MHz for the proposed antenna.

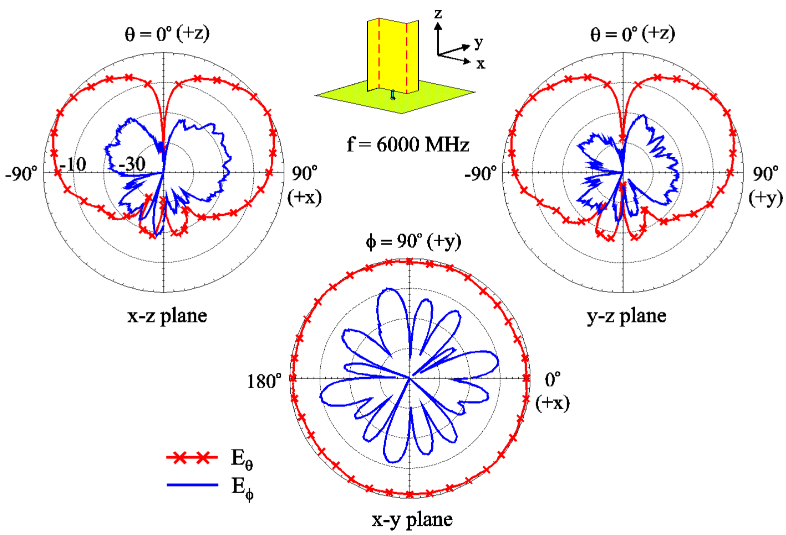

Fig. 4 Measured radiation patterns at 6000 MHz for the proposed antenna.

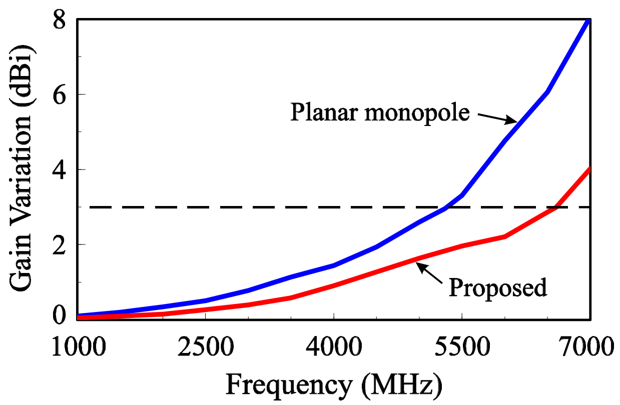

Fig. 5 Measured maximum gain variations in the azimuthal plane against frequencies for the proposed and a corresponding planar monopole antenna.