Open-Ended Rampart Slot Array Antenna Fed by a CPW

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***Abstract*—An open-ended rampart slot array antenna fed by a coplanar waveguide is designed and compared to the short-ended one. Experimental results show that a lower operating frequency band and better radiation characteristics of the antenna, such as higher in-band peak gains and lower H-plane sidelobe and cross-polarization levels, can be achieved by opening the rampart slotline terminations instead of shorting them.**

***Index Terms*—Coplanar waveguides, planar arrays, slot arrays, slotline.**

I. Introduction

Due to the low profile, light weight, and high directivity, planar antenna arrays have been used in microwave and millimeter-wave applications, such as the wireless local area network (WLAN) access points, for many years. Many planar antenna arrays have been designed by using the microstrip-line feeds, however, relatively fewer works so far have used the coplanar waveguide (CPW) as feed lines [1]–[5]. The CPW has gained more and more popularity since it has many advantages over the microstrip-line, such as lower radiation loss, less dispersion, and easier integration with active and passive devices. Moreover, using apertures as radiating elements in the CPW-fed planar antenna arrays will make the structure uniplanar and facilitate the input impedance matching [5]. In an effort to incorporate the CPW line to feed the slot array, a rampart slot array fed by the CPW was designed recently [6], where the end slot of the array is terminated by a short. To investigate this design further, an open-ended rampart slot array fed by a CPW is proposed. Comparing to the short-ended one presented in [6], this antenna has higher in-band peak gains, a lower operating frequency band, and lower sidelobe and cross-polarization levels in the H-plane pattern.

II. Antenna Design

The geometry of the CPW-fed open-ended rampart slot array antenna with six radiating elements is shown in Fig. 1. This antenna has a simple structure with only one layer of dielectric substrate and metallization. A pair of shunt rampart slotlines is etched on the conducting plane and placed in the direction transverse to the feeding CPW. The rampart slotline pair is terminated by open-circuits, where both the ground plane and the substrate

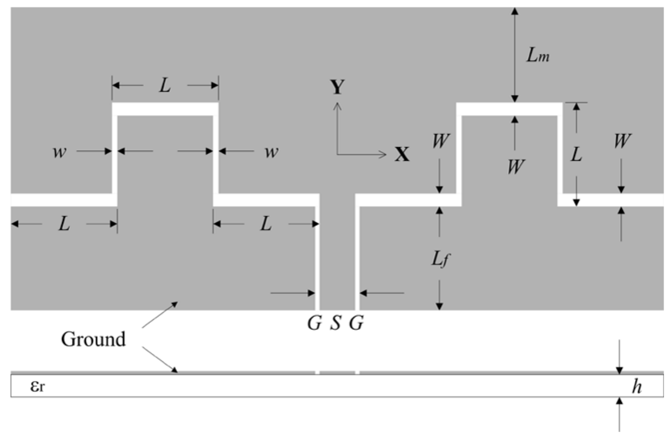

Fig. 1. Geometry of six-element open-ended rampart slot array antenna fed by a CPW.

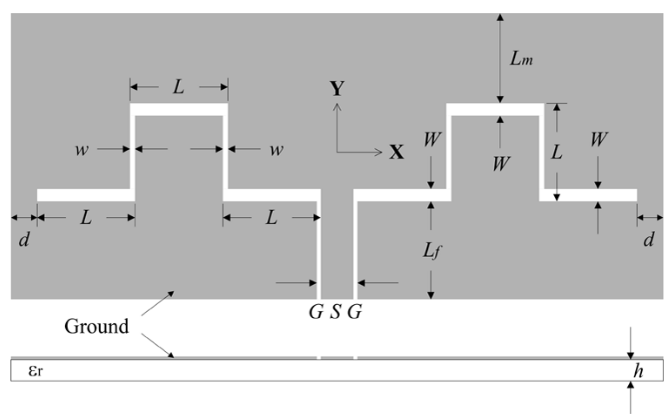

Fig. 2. Geometry of six-element short-ended rampart slot array antenna fed by a CPW.

are truncated. All vertical and horizontal slotline sections are of the same length L, which is approximately a half guided-wavelength $\lambda_g/2$ at the slotline resonance. The vertical slotline sections serve as the feeding network, while the in-phase-excited horizontal sections are the radiators or the array elements. The antenna gain is thus increased by this simple array arrangement. For comparison, the rampart slotline pair with shorted ends is shown in Fig. 2. It is known that, at the shorted ends, the incident and reflected surface magnetic currents (or equivalently, the electric fields) will add out-of-phase to possess local minima, while in our proposed design, the incident and reflected surface magnetic currents will add in-phase at the open ends to have local maxima. Considering that the far-field radiation integral behaves like a Fourier transform of the antenna's surface currents, the above differences in magnetic currents near the far

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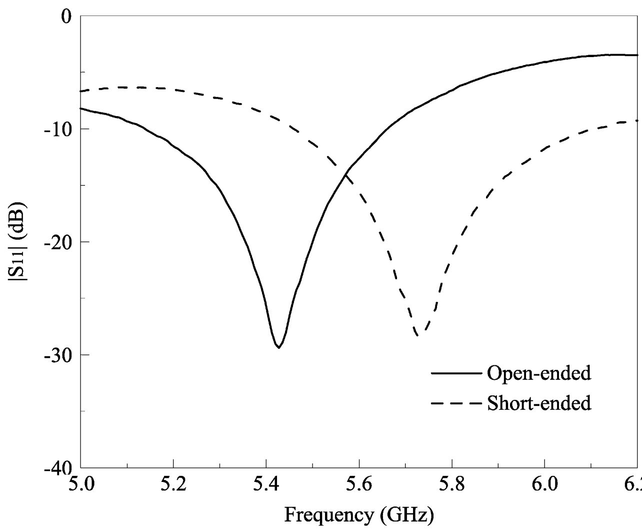

Fig. 3. Measured input return losses of the prototype antennas.

ends of the antenna will make the proposed open-ended rampart slot array result in higher antenna gains as compared to the short-ended one with the same number of array elements.

To demonstrate the advantages of the open-ended design over the short-ended one, the lengths of the slotline sections L of both the open- and short-ended rampart slot arrays are chosen to be the same, and, for the short-ended design, the distance between the substrate edge and the end point of the rampart slotline d is minimized to reduce the substrate size to be approximately equal to that of the open-ended one. Note that, throughout the design process, the effects of the finite ground plane and substrate have been taken into account by employing the package software HFSS from Ansoft Corporation, which is a three-dimensional full-wave simulator using the finite element method. In both cases, the widths of the vertical and horizontal slotline sections, w and W, respectively, are two key parameters for obtaining an input impedance match. In general, the peak antenna gain can be improved by increasing W, while the H-plane (x-z plane) cross-polarization level can be suppressed by decreasing w. However, their suitable values depend on the input matching condition. In the following input matched designs, W for the open-ended case is much larger than that for the short-ended one, while w for both cases are approximately the same. It should be noted that, although the width of each horizontal slotline section W may vary from each other according to the required aperture field distribution, it will result in a complicated design. For simplicity, in each of the following experiments, W is kept constant for a uniformly excited array.

III. Experimental Results

Both the open- and short-ended rampart slot array antennas are designed with six radiating elements, and the two test pieces are fabricated on the FR-4 substrate with dielectric constant $\varepsilon_r = 4.3$, loss tangent $\tan\delta = 0.02$, and thickness $h = 1.6$ mm. In both designs, the CPW feedlines are of the same length $L_f = 24.4$ mm, and the widths of the strip and slot of the 50-Ω CPW feedline, S and G, are chosen to be 3.0 and 0.3 mm, respectively. Also, the lengths of the slotline sections L and the upper margins of the substrate L_m for both prototype antennas are the same, and they are 19.0 and 16.6 mm, respectively. To separately optimize the two designs, $W = 2.0$ and 0.9 mm and $w = 0.6$ and 0.7 mm, respectively, for the open- and short-ended prototype antennas. In the short-ended array, d is determined to be 0.9 mm to simultaneously minimize the substrate size and achieve a better input match, thus its substrate size (60.0×116.0 mm^2) is approximately equal to that of the open-ended one (60.0×114.6 mm^2).

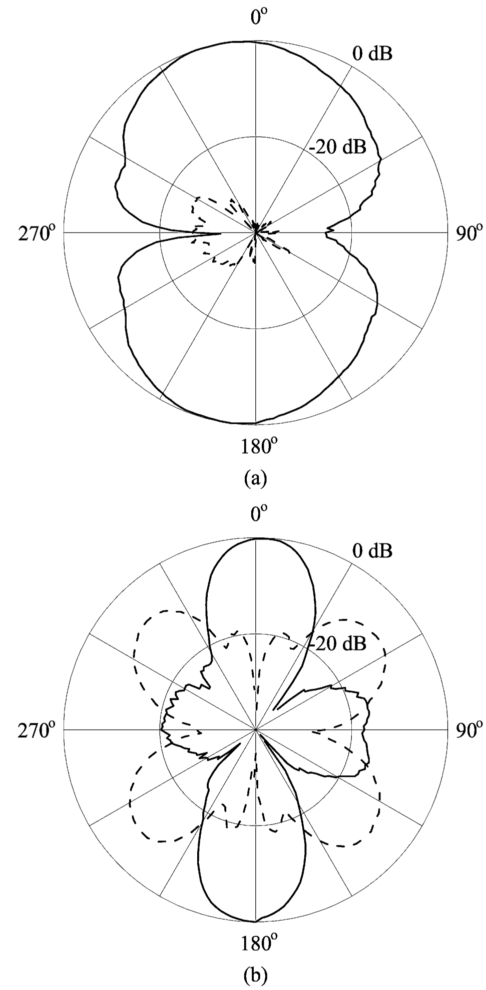

Fig. 4. Radiation patterns of the open-ended prototype antenna measured at 5.42 GHz. (a) E-plane pattern. (b) H-plane pattern. Solid line: copolarization; dashed line: cross-polarization.

Measured input return losses of the two prototype antennas are shown and compared in Fig. 3. The measured input impedance bandwidths (return loss >10 dB) of the open- and short-ended prototype antennas are 9.6% (5.14–5.66 GHz) and 11.1% (5.46–6.10 GHz), respectively, and the resonant frequency of the open-ended design (5.42 GHz) is lower than that of the short-ended one (5.72 GHz). The radiation patterns of the two prototype antennas measured at their corresponding resonant frequencies are shown in Figs. 4 and 5, respectively. Since the terminations of the rampart slotlines influence mainly the field distributions along the x-axis, the difference between the measured E-plane (y-z plane) patterns in Figs. 4(a) and 5(a) is therefore negligible. However, as shown in Figs. 4(b) and 5(b), the H-plane sidelobe and cross-polarization levels of the

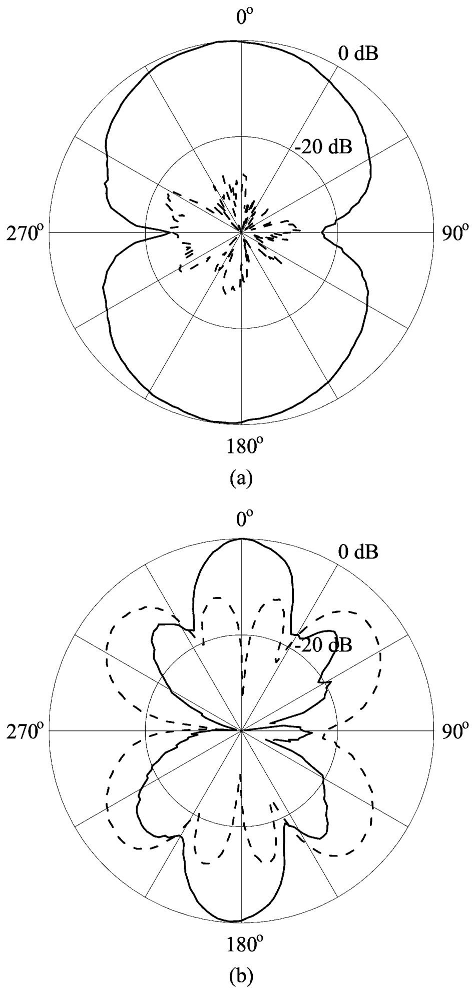

Fig. 5. Radiation patterns of the short-ended prototype antenna measured at 5.72 GHz. (a) E-plane pattern. (b) H-plane pattern. Solid line: copolarization; dashed line: cross-polarization.

open-ended prototype antenna are at least 5 dB and 3 dB lower than those of the short-ended one, respectively. Concerning the pattern only around the mainbeam, the suppression of H-plane cross-polarization of the open-ended design is more significant, and an 8 dB reduction is obtained. The peak gains of the two prototype antennas are measured within their operating bands and illustrated in Fig. 6. The in-band peak gains of the short-ended case range between 8.2–6.5 dBi, while those of the open-ended case are about 1–2 dB higher and in the range between 9.0–8.2 dBi.

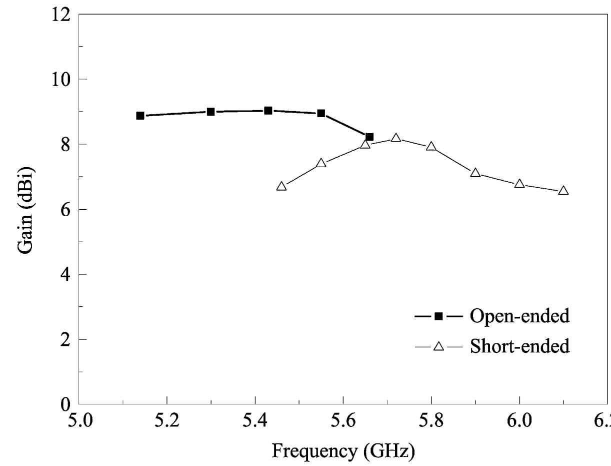

Fig. 6. Measured in-band peak gains of the prototype antennas.

IV. Conclusion

An open-ended rampart slot array antenna fed by a CPW has been presented to have higher in-band peak gains and a lower operating frequency band as compared to those of the short-ended one. Through the 6-element test pieces, lower sidelobe and cross-polarization levels in the H-plane pattern have been observed in the open-ended case. The measured input impedance bandwidth of the open-ended prototype antenna is 9.6% (5.14–5.66 GHz), and the in-band peak gains range between 9.0–8.2 dBi. These characteristics and the simple and uniplanar configuration make the proposed open-ended design suitable in many wireless applications, such as the WLAN access points.

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