A Compact E-Shaped Patch Antenna With Corrugated Wings

Yuehe Ge, Karu P. Esselle, and Trevor S. Bird

***Abstract*—A compact E-shaped microstrip patch antenna, which is significantly smaller than previous E-shaped patch antennas, is presented. The reduction in area is achieved by introducing corrugations into the two side wings of the E-shaped patch. The new technique is demonstrated by designing a 5–6 GHz corrugated E-shaped patch antenna that is 25% smaller than a conventional design. Despite the small size, the bandwidth of the corrugated antenna is as broad as the conventional antenna.**

***Index Terms*—Broadband antennas, microstrip antennas, wireless LAN.**

I. Introduction

E-shaped microstrip patch antennas have been developed in the past for broadband applications, including 2 GHz wireless communication systems [1], [2], and some designs have achieved 10 dB return loss bandwidth of over 30%. Recently, the authors investigated the application of the E-shaped patch antenna to wireless local area networks (WLAN) operating in the 5–6 GHz band [3], and successfully developed several antennas suitable for high-speed (IEEE 802.11a, 54 Mb/s) WLANs and other similar wireless communication systems [4]. These include a single E-shaped patch antenna, diversity antenna pair and a polarisation diversity antenna pair. The antennas and diversity configurations were designed to suit wireless network adaptor cards for notebook computers in the PC (also known as CardBus or PCMCIA) format. It was demonstrated that the two IEEE 802.11a bands (5.15–5.35 GHz and 5.725–5.825 GHz) could be covered by an E-shaped patch antenna that is only 3.5 mm high, highlighting the possibility of accommodating the antenna inside a standard PC card that is only 5 mm thick, without increasing the card thickness at the antenna end (as done in some commercial designs).

However, during these investigations we also found that, in order to mount two E-shaped antennas in a single PC card, for example for diversity, one had to make the antenna end of the card wider than the standard width of a PC card (54 mm) unless antenna performance figures such as return loss and mutual coupling are compromised. This was primarily because the area taken by each E-shaped patch antenna is too large—about 32 mm × 23.6 mm and two of them cannot be separated enough within a 54 mm space to reduce mutual coupling to acceptable levels. Hence, there was a need to develop an antenna that uses less area than a standard E-shaped patch but has similar performance figures for the same antenna height. From the previous investigations we also found that reducing the width of the three wings of the E-shaped antenna deteriorates the return loss. Therefore, we investigated alternative techniques to reduce the antenna size.

In this paper, a modified E-shaped patch antenna is presented to address these requirements. This E-shaped patch antenna has less area but still covers the WLAN frequency bands that are of practical interest. In the new antenna, corrugations have been placed in the two side-wings to reduce the width of the side-wings without significantly reducing the "metal" area of the antenna.

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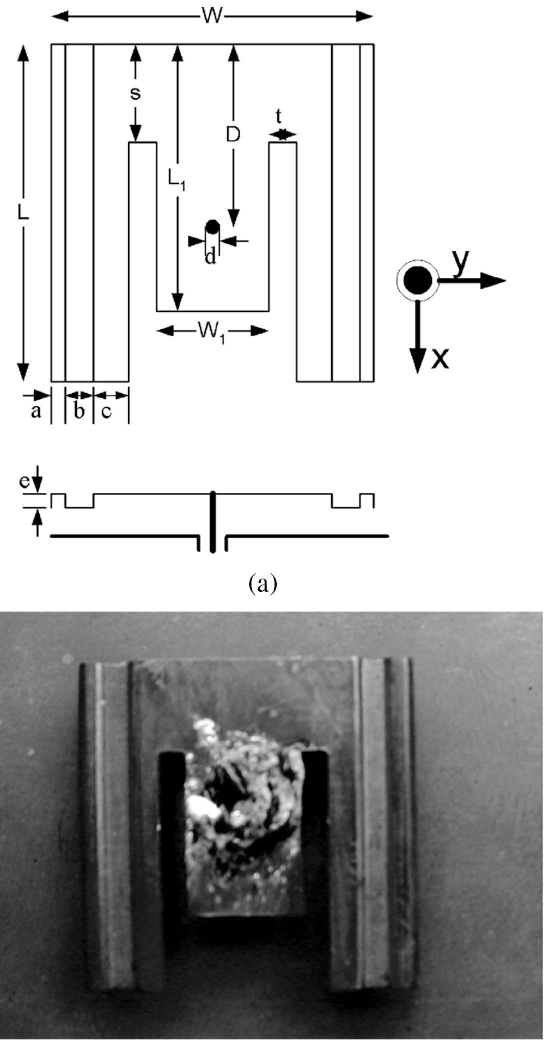

(a)

(b)

Fig. 1. Geometry of the corrugated E-shaped patch. (a) Configuration and (b) prototype.

II. Antenna Configuration and Design Process

The geometry of an E-shaped patch antenna with corrugated wings is shown in Fig. 1(a). A photograph of a fabricated corrugated E-patch antenna is also given in Fig. 1(b) to illustrate the 3-D configuration. The main difference between this antenna and those given in [3] is the corrugation of the wings, shown better in the cross-sectional view in Fig. 1(a). In order to maintain the same overall height as before, the corrugations are bent towards the ground plane rather than away from the ground plane. Due to corrugation, the width of each of the two side-wings is reduced, but the total metal area of each wing remains the same as before. The antenna is fabricated by cutting the E-shape out of a single metal sheet and pressing it to form the corrugations. The space between the patch and the ground plane may be filled by air, a foam material, or a combination, for additional mechanical stability. As with previous E-shaped patch antennas, the antenna is fed by a coaxial probe [1]–[4].

To demonstrate the size reduction, we designed an example E-shaped patch antenna with corrugated wings to achieve *a minimum* 10 dB return loss in the 5 to 6 GHz frequency band. Our design process started with the parameters of a 3.5 mm high conventional E-shaped patch antenna, previously designed for the same frequency range [3]. For any

TABLE I
PARAMETERS OF THE INITIAL E-SHAPED PATCH ANTENNA DESIGN (IN mm)

L	W	W1	a+b+c	L_1	D	s	t	e
23.6	32.0	8.0	8.5	18.4	11.4	6.8	3.5	0.0

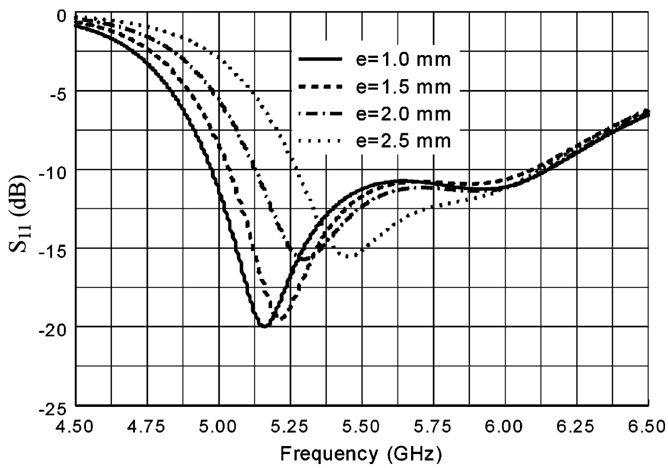

Fig. 2. Simulated reflection coefficient (S_{11}) with variation of the corrugation depth e.

TABLE II
PARAMETERS OF THE CORRUGATED E-SHAPED PATCH ANTENNA DESIGN (IN mm)

L	W	W1	a	b	c	L_1	D	s	t	e
23.6	24.0	8.0	1.5	2.0	2.5	18.4	10.9	6.8	2.0	1.0

other application or frequency range, such initial parameters can be obtained by following the process outlined in [3]. The initial parameters of our design are given in Table I. Then, 1.0, 1.5, 2.0, and 2.5 mm corrugations were introduced and the wing widths were reduced accordingly. Using Ansoft HFSS software, the new configuration was analysed iteratively and the parameters a, b, c, e, t and D were adjusted until an acceptable return loss was obtained over the frequency band.

It should be noted, in order to maintain similar performance, the total area of a corrugated side wing should be almost the same as that of planar side wing of a conventional planar E-patch antenna. Therefore, the parameter $(a+b+c+3e)$ of corrugated E-patch should be approximately equal to $(a+b+c)$ of its corresponding planar counterpart. Increasing the parameter e will result in the reduction of the width of the corrugated E-patch. However, we found from the simulations that the large value of e will lead to narrow bandwidth and the deterioration of the return loss in the working band. The reason is that a large e effectively reduces of the height of the E-patch. Fig. 2 shows the simulated return loss for $e = 1.0$ mm, 1.5, 2.0, and 2.5 mm. It can be seen that the return loss in 5–6 GHz frequency band deteriorates and the -10 dB bandwidth becomes narrower when e is changed from 1.0–2.5 mm. During this design process, we also noted that the length parameters L and L_1 could not be changed much because they essentially determine the two resonance frequencies of the antenna. Hence, the area reduction has to come from width (i.e., parameters a, b, c, t, etc.). In fact, using the initial parameters in Table I, after the corrugations were introduced, minor tuning the parameters L_1, D, and s gave good results.

Our HFSS analyses also included a finite ground plane of $60 \times 60\ \mathrm{mm}^2$ and a standard SMA connector with an inner diameter of 1.3 mm and an outer diameter of 4.1 mm. The probe location was along the centerline of the patch, to maintain symmetry of the antenna. The

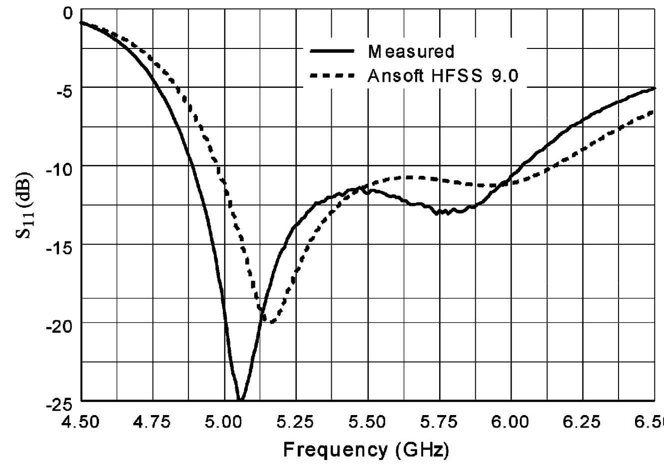

Fig. 3. Reflection coefficient (S_{11}) of the example corrugated E-shaped patch (Table II).

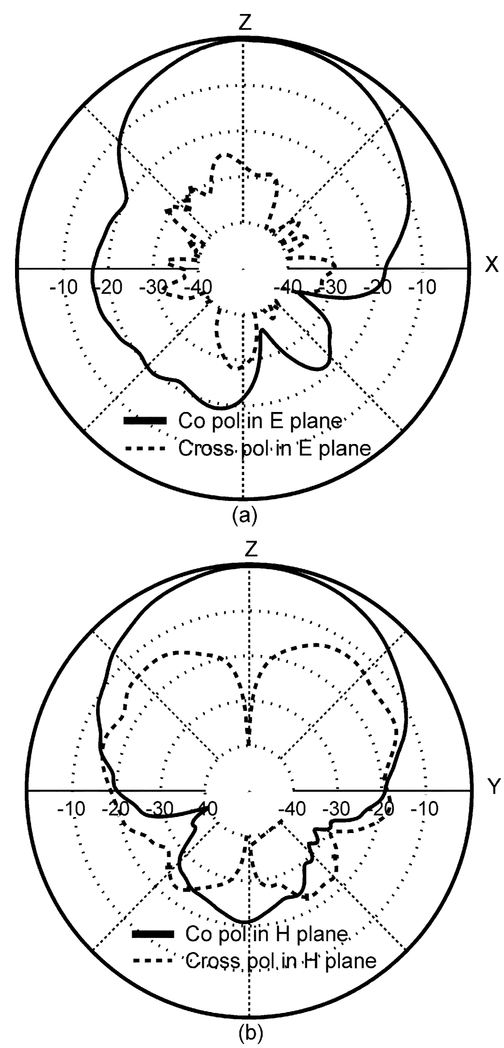

Fig. 4. Measured radiation patterns of the corrugated E-shaped patch at 5.25 GHz. (a) E-plane and (b) H-plane.

parameters thus obtained for the final design of the E-shaped patch antenna with corrugated wings are listed in Table II. In this design, the parameter e is taken as 1.0 mm because of the need for broad bandwidth, good return loss and the ease of fabrication for small e.

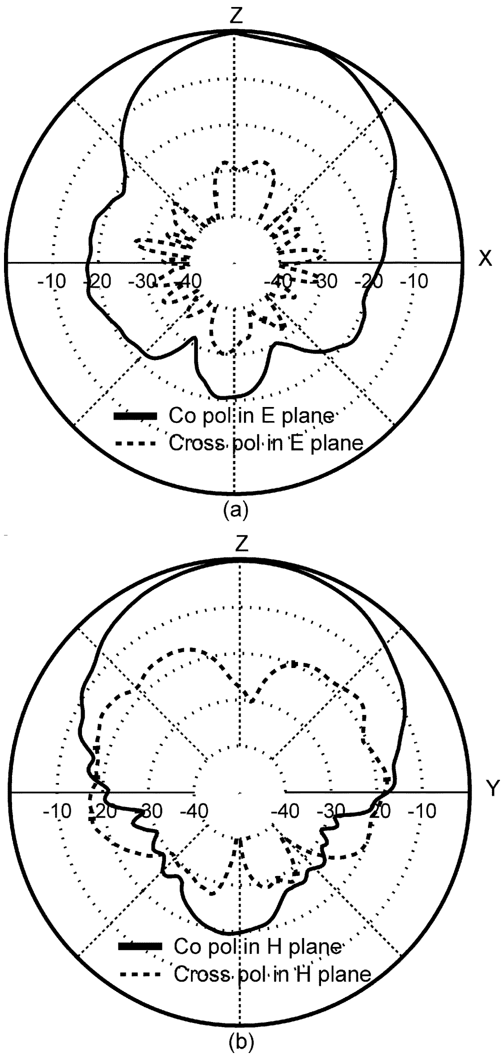

Fig. 5. Measured radiation patterns of the corrugated E-shaped patch at 5.78 GHz. (a) E-plane and (b) H-plane.

III. Results

An E-shaped patch antenna with corrugated wings that is described by the parameters given in Table II was fabricated and its return loss and radiation patterns were measured. The overall height of the antenna was 3.5 mm. Fig. 3 shows the theoretical (HFSS) and measured input reflection coefficient magnitude of the new antenna. This experimental antenna has a 10 dB return loss bandwidth from 4.89–6.04 GHz, which covers not only the two popular bands used for IEEE 802.11a (5.15–5.35 GHz and 5.725–5.825 GHz) systems in USA and Europe but also the 4.9–5.1 GHz band that has been proposed for IEEE 802.11j systems in Japan, etc. Although the measured bandwidth shows a small shift compared with what was predicted theoretically, the agreement between measured and theoretical results is reasonable for most practical purposes. For comparison, the measured bandwidth of a 3.5 mm high, conventional (therefore much wider—32 mm) probe-fed E-shaped patch antenna is 4.9–6.0 GHz on a ground plane of the same size [3].

Fig. 4 and 5 show the measured E- (ZY-plane) and H- (ZX-plane) plane radiation patterns at the mid frequencies of the two commonly used IEEE 802.11a bands, i.e., 5.25 and 5.78 GHz, respectively. These patterns are similar to those of the conventional E-shaped patch antennas [3], [4]. Note that the rear lobe and nulls are due to the finite-sized ground plane. The gains of the corrugated E-shaped antenna and its planar counterpart were measured over the frequency band 5.0–6.0 GHz and are plotted in Fig. 6. Gain was measured by comparison with a standard gain horn in our spherical near-field range. Although the surface area of the corrugated one is reduced about 25%, the gain is comparable with the planar antenna over the bandwidth.

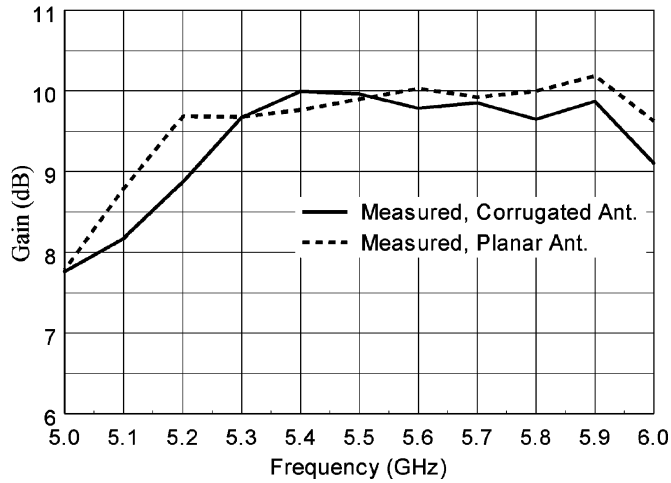

Fig. 6. Measured gain of the proposed antenna.

IV. Conclusion

By introducing corrugations parallel to the length dimension of an E-shaped patch antenna, the antenna width can be reduced significantly, while maintaining the same overall thickness and performance of the antenna. An example application of this technique to a triple-band WLAN antenna resulted in a reduction in area of 25%, without degrading the antenna bandwidth. This size reduction technique is effective as long as the corrugations are not too deep. That is because the currents in the corrugated antenna flow on the same metal area, as in the planar counterpart. When corrugations are too deep, the antenna height is effectively reduced and the performance deteriorates.

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