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# A SIMPLE BROADBAND PRINTED ANTENNA

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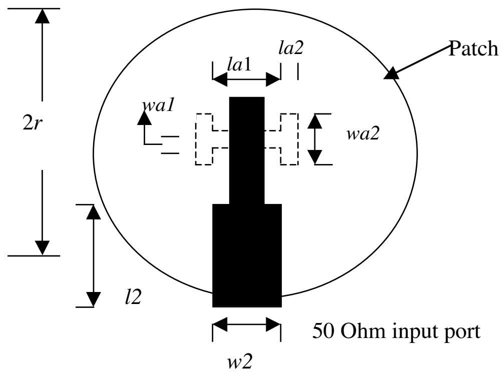
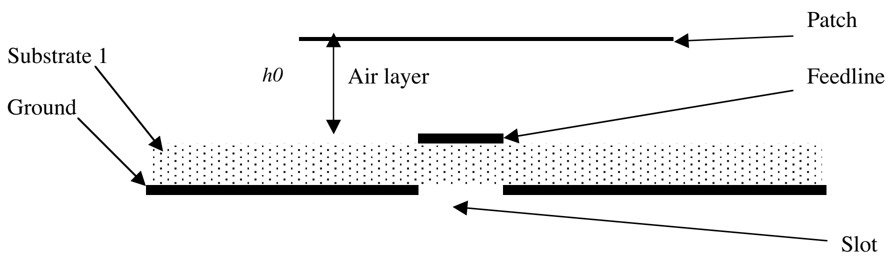
**Abstract**—This paper presents a simple broadband proximity-coupled microstrip patch antenna. A circular patch is used as the main radiator, and an H-shaped shot is cut in the ground plane below the feed line. A stepped-width microstrip line is used to feed the patch through proximity coupling. By using a single patch, the prototype antenna achieves an impedance bandwidth of 26%. Low cross-polar levels below $-20\,\text{dB}$ are observed in both $E$- and $H$-planes. The broadband antenna is planar, small size, simple in structure, low in cost, and easy to be fabricated, thus attractive for practical applications.

## 1. INTRODUCTION

Microstrip antennas offer the attractive advantages of low cost, low profile, light weight, easy fabrication and easy integration with circuits. Small bandwidth is probably the most serious disadvantage of microstrip antenna. During the recent years, the capacity issue for wireless communication applications is not easily solved, with the expansion in mobile communication systems and the number of people using their services. Much effort has been devoted to the bandwidth enhancement of microstrip patch antennas, and many techniques have been proposed. These techniques include the use of impedance matching network [1, 2], multiple resonators arranged in co-planar or stacked structure [3–9], the reactive loading using U-shaped slot [10], lossy materials [11], the capacitively probe-fed structure [7, 12], the L-probe feeding [13, 14], a combined use of both U-slot loaded patch and L-probe feeding [15], and a three-dimensional transition microstrip feed line [16]. In most cases, a thick foam substrate is required [10, 12–16]. A few results of a rectangular patch antenna with an H-shaped



(a) Top view



(b) Side view

**Figure 1.** Configuration of the antenna.

slot in the ground plane are given in [17]. The antenna has a simple configuration, and a bandwidth of 21% is reported [17].

The purpose of this paper is to present a detailed study of an improved design, which combines the techniques in [1, 2] and [17]. Better performances can be achieved by the new design, as confirmed by both simulations and experiments.

## 2. ANTENNA CONFIGURATION

Figure 1 shows the configuration of the broadband antenna proposed. The antenna consists of an air layer having a thickness of $h_0$, and a dielectric substrate layer 1 having a permittivity of $\varepsilon_{r1}$ and a thickness of $h_1$. The air layer is realized by using the plastic spacers. Instead of using a rectangular patch as in [17], here we use a circular patch, which has a radius of $r$. Due to the existence of a thick air layer, the coupling between the feedline and the patch is weak. To enhance the EM coupling between the patch and the feedline, a slot is cut in the ground plane under the feedline. The slot could have the shape of a narrow rectangle, be of U-shaped, or be realized as the H-slot [18, 19]. Here the H-shaped slot is used, which is defined by parameters $la1$, $la2$, $wa1$ and $wa2$. The slot is located in the center of the patch. The feed line is a stepped-width microstrip line defined by $w_1, l_1, w_2$ and $l_2$, where $w_2$ corresponds to the width of a 50 Ohm line. This stepped-width microstrip line is used as a kind of impedance matching network for further broadening the antenna bandwidth [1, 2].

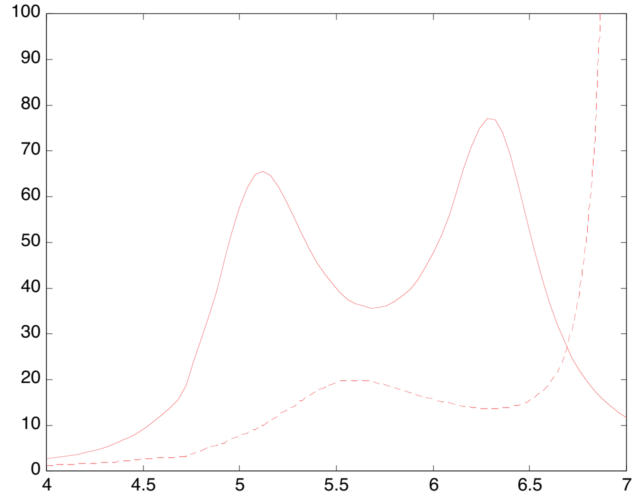
## 3. RESULTS AND DISCUSSION

For easy fabrication of the metallic patch, a FR4 substrate is used, where the metal on one side is completely removed while the other side carries the patch facing the feedline below. This is a kind of inverted structure, where the substrate above the patch could act as a radome for protection. The FR4 substrate (thickness of 1.6 mm and permittivity of 4.4) is also used for substrate 1.

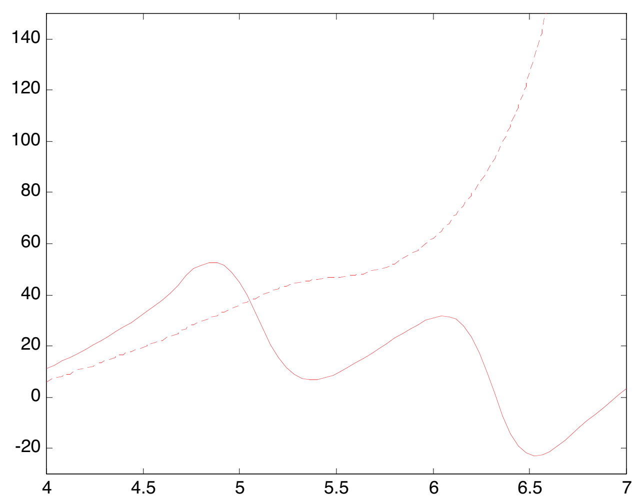
A parametric study of the antenna is done first, and the simulation is carried out by using the software *Ensemble* from Ansoft Corporation. Figure 2 gives a comparison between the input impedance results of the antennas with and without the slot cut in the ground. Both the real part (input resistance $R$) and imaginary part (input reactance $X$) are given. We can see that the input resistance of the antenna without the slot is very small ($< 20$ Ohm) in the frequency range between 4.0–6.5 GHz, which means the patch is weakly coupled by the feed line due to the air layer. In this case, the input matching is poor. A dramatic increase of the input resistance is noticed after a slot is cut in the ground plane, which means the increase of the coupling between the feed line and the patch. Two resonances are clearly observed around 5.1 GHz and 6.3 GHz, respectively.

The equivalent circuit of the antenna is given in Figure 3, consisting of two resonant circuits. One resonance is due to the patch (i.e., parallel $R_1L_1C_1$ resonant circuit), and the other resonance is due to the series combination of the slot ($L_2$) and the open stub ($C_2$). $R_2$ is due to the loss from both the slot and the open stub. The broadband operation of the antenna is due to this double resonance. However, to reduce the backward radiation, we need to keep the slot length away from its resonant length, so a compromise between the backward radiation and bandwidth has to be made in the design.

Figure 4 gives the input impedance results of the antenna with different slot length $la1$. When $la1$ is increased, both the lower and the upper resonance are shifted down to lower frequency band. During the process, the amplitude of the lower resonance is increased, while




(a)




(b)

**Figure 2.** Impedance results of the antennas with (solid line) and without slot (dashed line). Parameters: $r = 8.5\,\mathrm{mm}$, $h_0 = 3.2\,\mathrm{mm}$, and $w_1 = 2\,\mathrm{mm}$, $l_1 = 7.6\,\mathrm{mm}$, $w_2 = 3\,\mathrm{mm}$ and $l_2 = 2.5\,\mathrm{mm}$; Slot parameters: $la1 = 6\,\mathrm{mm}$, $la2 = 1\,\mathrm{mm}$, $wa1 = 1\,\mathrm{mm}$, $wa2 = 4.4\,\mathrm{mm}$.

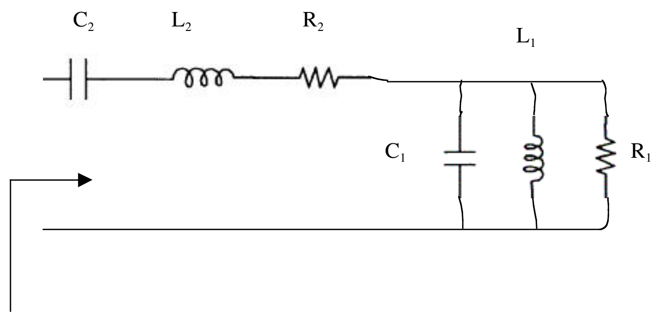
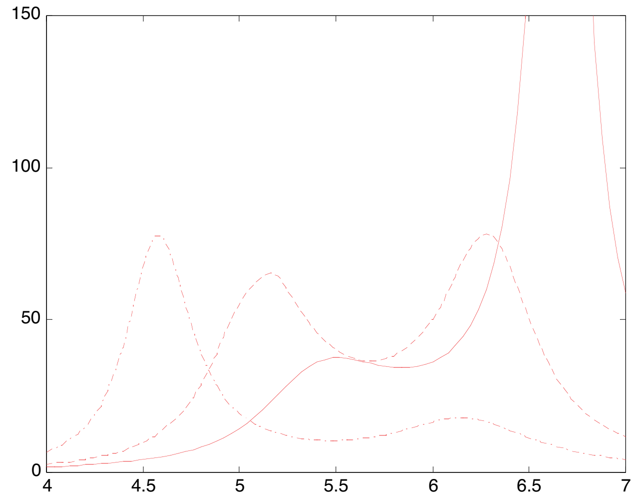



**Figure 3.** Equivalent circuit of the antenna.

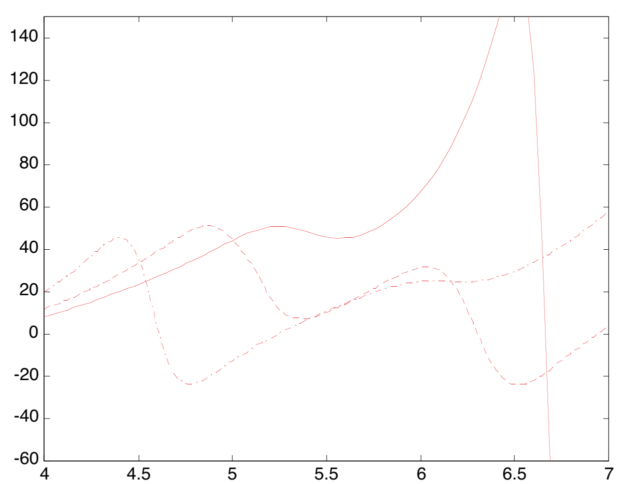
the amplitude of the upper resonance is decreased. To achieve the impedance matching within a broad bandwidth, the amplitudes of both the lower resonance and the upper resonance should be close to 50 Ohm, which means a compromise of the value of $la1$ needs to be found. Similar tendency of input resistance variation is observed while the value of $la2$ is increased, as we can see from Figures 5. Amongst the three parameters $la1$, $la2$ and $wa2$, it seems that the antenna impedance is the most sensitive to the variation of $la2$, which may be due to the large value of $wa2$ used here (4.4 mm). Figure 6 gives the input impedance results of the antenna with different air layer thickness $h_0$. As we can see, the input impedance varies significantly with the changing of $h_0$. The double resonances are moved closer to each other, while $h_0$ is increased from 2 mm to 3.5 mm, and finally merged into a single resonance when $h_0$ is 5 mm. Thus, an appropriate choice of $h_0$ is very important for achieving a broadband width.

To demonstrate the concept in Fig. 1, a prototype antenna is designed. The design parameters for the prototype antenna are: $r = 8.5$ mm, $h_0 = 3.2$ mm, $la1 = 6$ mm, $la2 = 1$ mm, $wa1 = 1$ mm, $wa2 = 4.4$ mm, $w_1 = 2$ mm, $l_1 = 7.6$ mm, $w_2 = 2$ mm and $l_2 = 2.5$ mm. The measured results of return loss are given in Fig. 7. The return loss is below $-10$ dB in the frequency range of 5.12–6.65 GHz, which corresponds to an impedance bandwidth of 26%.

The measured results of the radiation patterns at 5.5 GHz are given in Figure 8. As we can see, the cross-polar levels are below $-20$ dB in both $E$ and $H$ planes. The backward radiation is below $-15$ dB. The backward radiation is lower compared to the case of traditional aperture-coupled antenna, where the open-end microstrip feed line contributes to backward radiation. Here the radiation of open-end microstrip feed line is utilized to produce the desired radiation at the boresight, thus improving the backward radiation performance as




(a)




(b)

**Figure 4.** Input impedance results of the antenna with different $la1$ (solid line: $la1 = 3\,\text{mm}$, dashed dot: $la1 = 9\,\text{mm}$). Other parameters: $r = 8.5\,\text{mm}$, $h_0 = 3.2\,\text{mm}$, $la2 = 1\,\text{mm}$, $wa1 = 1\,\text{mm}$, $wa2 = 4.4\,\text{mm}$, $w_1 = 2\,\text{mm}$, $l_1 = 7.6\,\text{mm}$, $w_2 = 3\,\text{mm}$ and $l_2 = 2.5\,\text{mm}$.

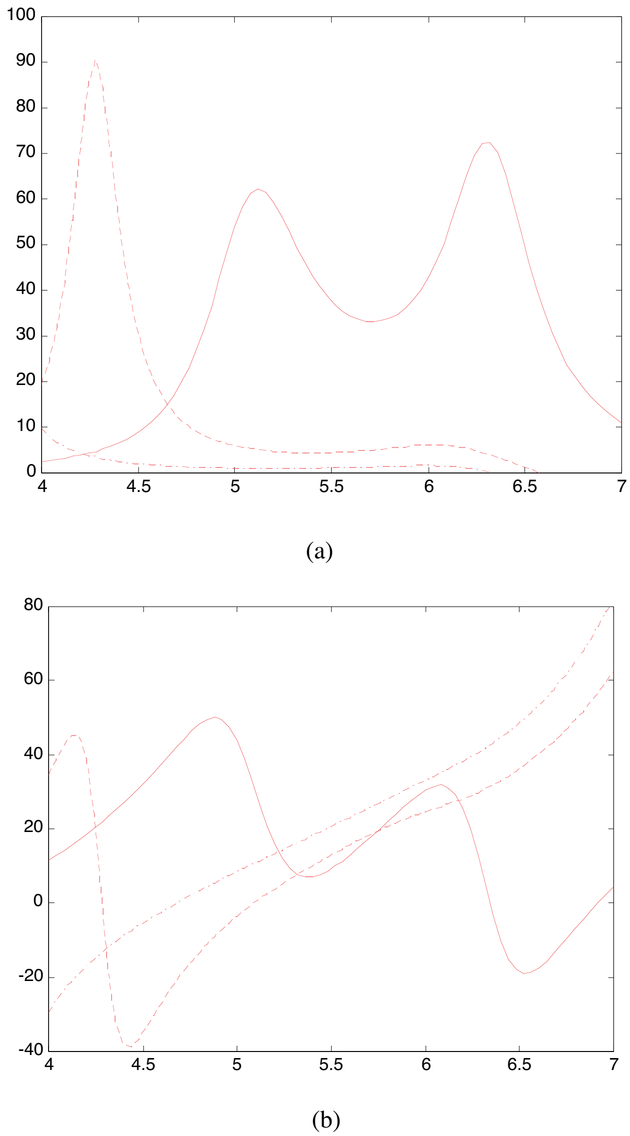
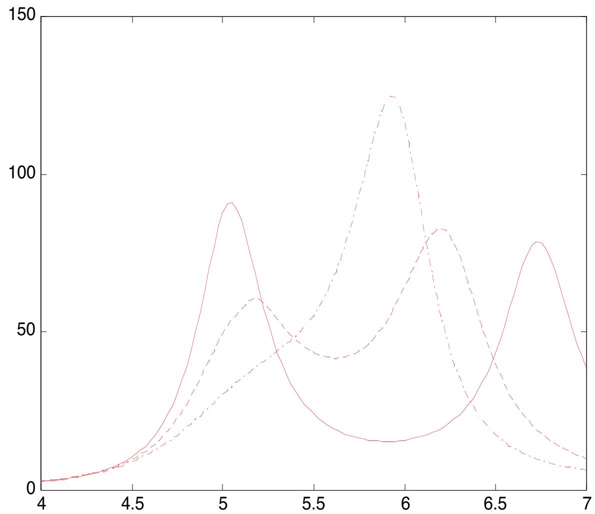
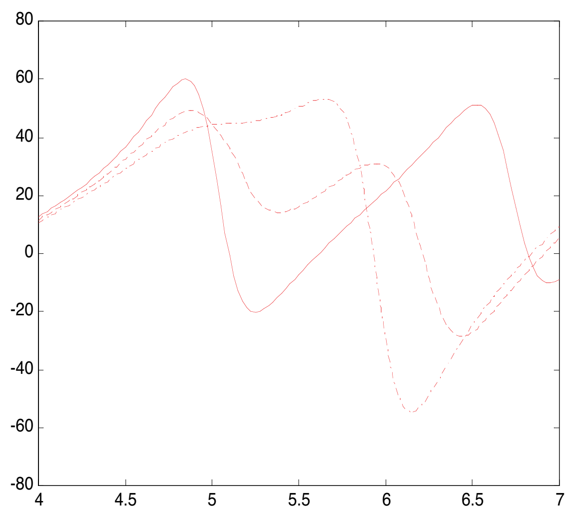



**Figure 5.** Input impedance results of the antenna with different $la2$ (solid line: $la2 = 1\,\text{mm}$, dashed: $la2 = 3\,\text{mm}$; dash dot: $la2 = 5\,\text{mm}$). Other parameters: $r = 8.5\,\text{mm}$, $h_0 = 3.2\,\text{mm}$, $la1 = 6\,\text{mm}$, $wa1 = 1\,\text{mm}$, $wa2 = 4.4\,\text{mm}$, $w_1 = 2\,\text{mm}$, $l_1 = 7.6\,\text{mm}$, $w_2 = 3\,\text{mm}$ and $l_2 = 2.5\,\text{mm}$.




(a) Input resistance R




(b) Input reactance X

**Figure 6.** Input impedance results of the antenna with different $h_0$ (solid line: $h_0 = 2\,\text{mm}$, dashed: $h_0 = 3.5\,\text{mm}$; dash dot: $h_0 = 5\,\text{mm}$). Other parameters: $r = 8.5\,\text{mm}$, $la1 = 6\,\text{mm}$, $la2 = 1\,\text{mm}$, $wa1 = 1\,\text{mm}$, $wa2 = 4.4\,\text{mm}$, $w_1 = 2\,\text{mm}$, $l_1 = 7.6\,\text{mm}$, $w_2 = 3\,\text{mm}$ and $l_2 = 2.5\,\text{mm}$.

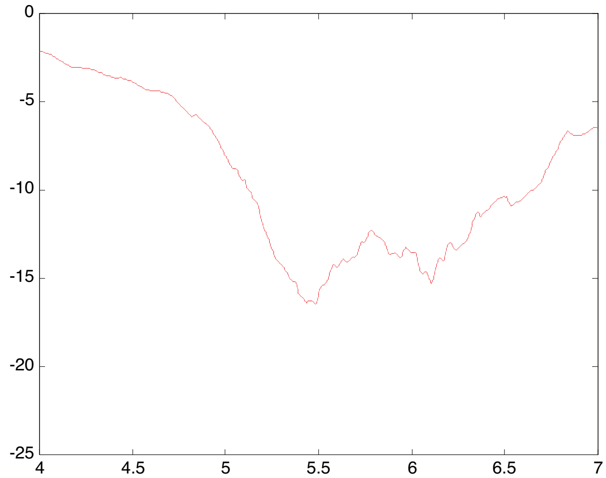



**Figure 7.** Measured return loss of the antenna.

well as antenna efficiency. Radiation patterns are also measured at several other frequencies, and it is observed that the radiation patterns are stable across the bandwidth.

## 4. CONCLUSIONS

A simple broadband antenna is proposed. By using only one patch, the designed antenna achieves a bandwidth of 26%. Good broadside radiation patterns are observed, and the cross-polar levels are below $-20$ dB at both $E$- and $H$-panes. Compared to previous broadband designs using traditional aperture-coupled antenna [4], the proposed broadband antenna has a simpler structure, and lower backward radiation and higher radiation efficiency. The antenna is planar, small size, simple in structure and easy to be fabricated, thus promising for applications in mobile communication systems. The proposed antenna is also suitable for application in the array antenna design.

## ACKNOWLEDGMENT

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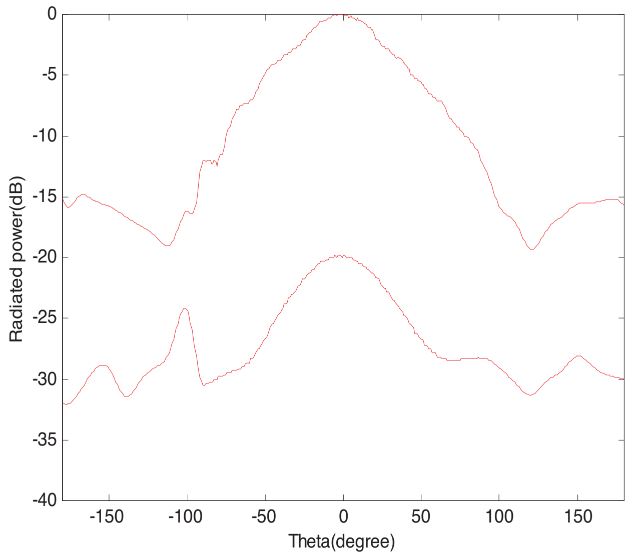
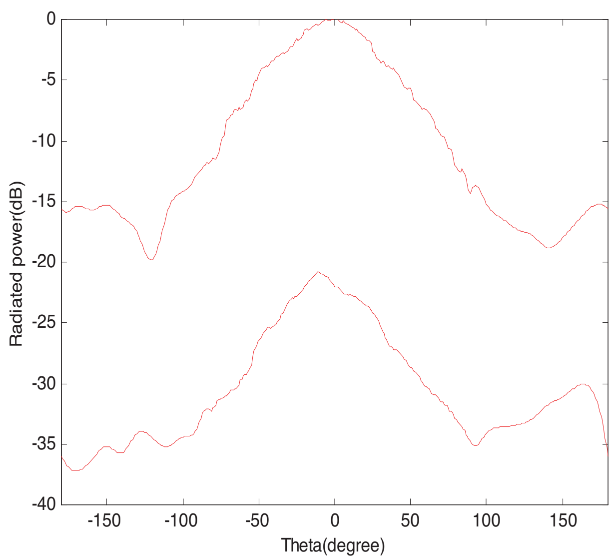



(a) *E* plane




(b) *H* plane

**Figure 8.** Radiation patterns at 5.5 GHz (solid: co-polar; dashed: cross-polar).

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