A Probe-Fed Patch Antenna with a Step-Shaped Ground Plane for WLAN Access Point

Fa-Shian Chang [1], Saou-Wen Su[2], Jui-Hung Chou[2], Chia-Hung Lu [3] and Hong-Twu Chen[3]
[1] Department of Electronics, R.O.C. Cheng Shiu University, Feng-Shan 83347, Taiwan
[2]Network Access Strategic Business Unit, Lite-On Technology Corp., Taipei 23585, Taiwan
[3]Department of Physics, R.O.C. Military Academy, Feng-Shan 83059, Taiwan

1. Introduction

Many patch antennas utilizing thick air substrates have been developed and studied to achieve impedance bandwidth exceeding 10% defined by 2:1 VSWR or 5% by 1.5:1 VSWR for broadband operation [1-6]. Among these researches, a short probe pin of the probe feed is mostly employed in conjunction with various matching mechanism. That is because for patch antenna with such thick air substrate, using a long probe pin can cause large inductance, which makes it very difficult to well match the antenna to impedance bandwidth within VSWR of 2. In addition to the use of a short probe pin, the matching mechanism in these studies also demonstrates some modification to the structure of the antenna feed. These designs include the use of a bevel-feed transition [1], a cylinder-feed transition [2], a T-shaped probe feed [3], an L-shaped probe feed [4], an edge-fed patch with an L-shaped ground [5], a ridge-shaped ground [6], and so forth. In this paper, we introduce a new design of a probe-fed patch antenna capable of broadband operation. The antenna is backed by a step-shaped ground plane and can be fed by a long probe pin at one of the patch radiating edges. Simply by tuning the probe-pin length, good impedance matching over frequency band with 1.5:1-VSWR bandwidth of about 6% can be obtained. Several design prototypes have been built, and a design example aimed for operation in the 2.4 GHz (2400-2484 MHz) WLAN band has been implemented too. The proposed antenna is designed for access-point applications in the WLAN environment. Details of the antenna design are described, and experiment results are discussed.

2. Antenna Design

Fig. 1(a) shows the geometry, in detail, of the proposed antenna for operation in the 2.4 GHz band. The radiating patch is in the shape of a rectangle with the dimensions 54 mm (L) × 60 mm (W) and has a small bent portion (4 mm in length) at one of the patch radiating edges. The antenna ground plane is bent three times into a step-shaped structure and consists of four portions: two horizontal plates, one vertical plate, and one inclined plate, all with the same width of 80 mm. The angle between the inclined (5 mm in length) and horizontal (60 mm in length) plates is 135°. In the center of the inclined plate below a via hole is located a 50-Ω SMA connector of the probe feed. In this case, the probe pin (length d) of the probe feed is inclined at an angle of 45° [see Fig. 1(b)]. The radiating patch is edge-fed by this inclined probe feed, and the probe pin is coplanar with the patch bent portion. The thickness of the air substrate is set to be 10 mm in this study, which is about 0.08 times the free-space wavelength at 2442 MHz, the center frequency of the 2.4-GHz WLAN band.

3. Results and Discussion

Fig. 2 shows the measured return loss for the design prototype of various probe-pin lengths (*d*). It is first seen that with *d* equal to 8 mm, good impedance bandwidth defined by 1.5:1 VSWR (14 dB return loss) can be obtained and reaches 140 MHz (2370-2510 MHz), easily covering the 2.4 GHz band. The sum of *d* and *L* (patch length) also corresponds to a half wavelength of the center operating frequency at 2442 MHz targeted in this study. In addition, compared with a short probe pin, usually 2% wavelength of the center operating frequency, used for broadband patch antenna designs [1-6], the probe pin of 8 mm here is relatively long and about 6.5% wavelength at 2442 MHz. Notice that when the probe-pin length *d* changes from 5 to 9 mm, the thickness of the air substrate slightly increases from 8 to 11 mm. In general, with an increase in *d*, the antenna operating frequency moves to lower frequencies, which behavior is the same as that a thicker substrate can result in a lower frequency band as reported in [5]. Fig. 3 and Fig. 4 gives the measured and simulated radiation patterns of the *E*-plane (*x*-*z* cut) and *H*-plane (*y*-*z* cut) at 2442 MHz for the constructed prototype studied in Fig. 2 with probe-pin length *d* = 8 mm. Measurements at other frequencies in the 2.4 GHz band were also taken, and the results were similar radiation patterns as those plotted here. In the *x*-*z* cut was seen cross-polarization radiation below about –20 dB in the *E*-plane patterns for the frequencies over the 2.4 GHz band; as for *H*-plane patterns in the *y*-*z* cut, the cross-polarization radiation is below about –15 dB. The measured peak antenna gain is presented in Fig. 5, and the peak-gain level is seen to be about 8 dBi.

4. Conclusions

A patch antenna fed by an inclined probe pin with a step-shaped ground plane has been proposed, and several prototypes have been studied. The impedance matching with VSWR below 1.5 of the antenna for WLAN operation in the 2.4 GHz band can easily be obtained. The measured results show that although a long probe pin is in use, large probe inductance is well compensated for additional capacitive coupling arising between the vertical and inclined plates of the ground and the patch bent portion. The proposed patch antenna along with good radiation characteristics is suitable for WLAN access-point antennas, especially for the use in panel antennas.

References

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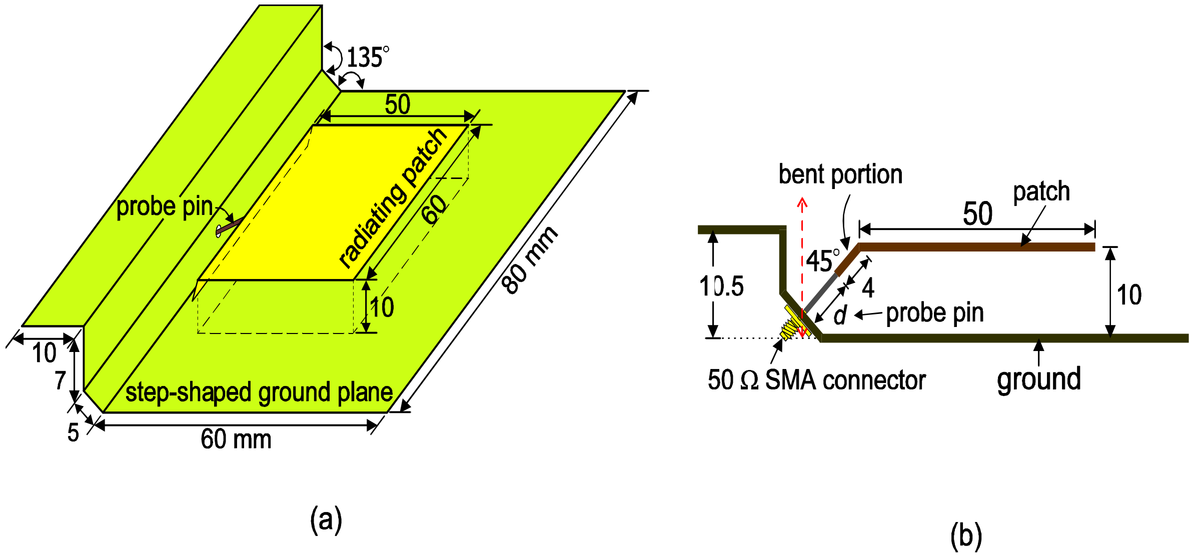

Figure 1: (a) Geometry of the proposed antenna. (b) Side view of the proposed antenna.

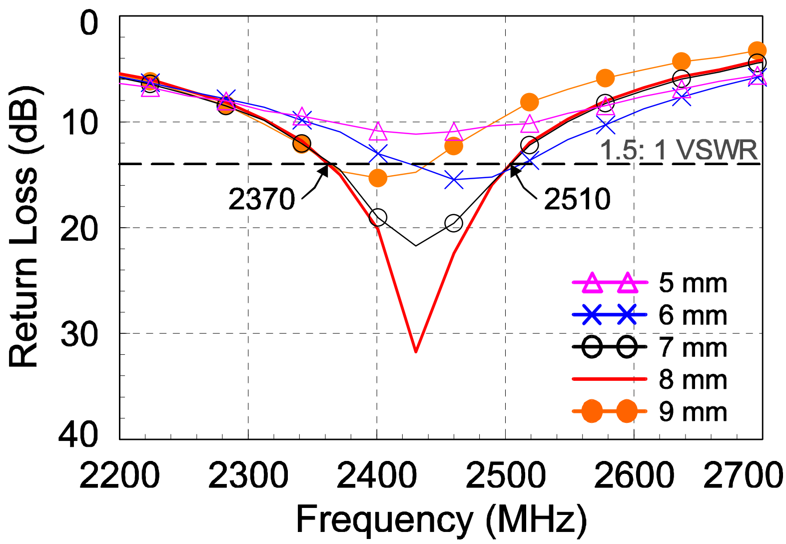

Figure 2: Measured return loss for the design prototype of various probe-pin lengths.

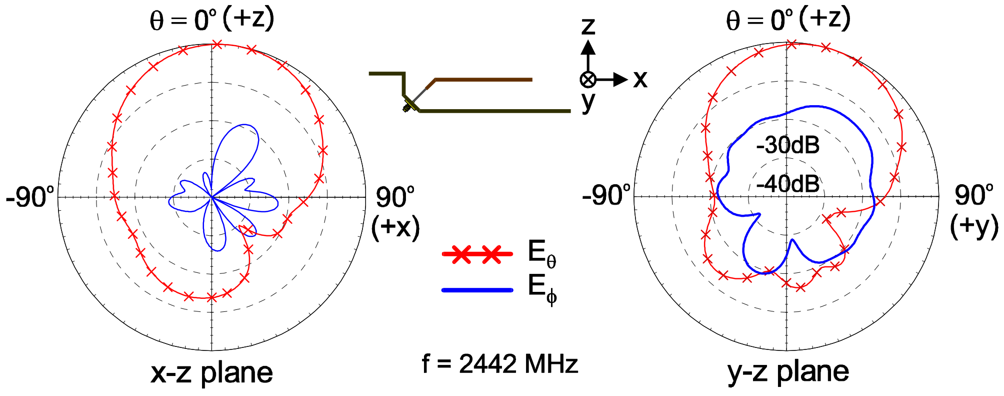

Figure 3: Measured radiation patterns at 2450 MHz for the proposed antenna studied in Fig. 2 with the length of the probe pin equal to 8 mm.

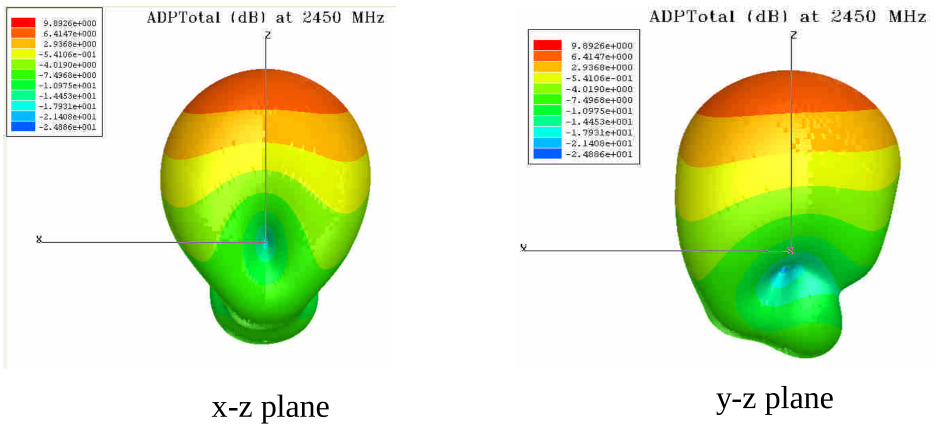

Figure 4: Simulated radiation patterns at 2450 MHz for the proposed antenna.

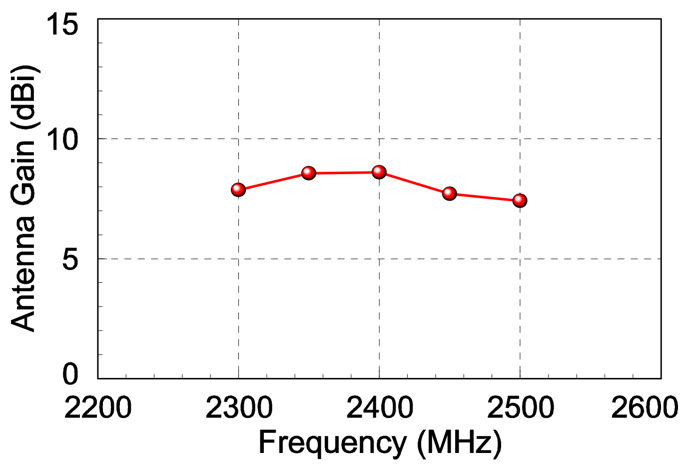

Figure 5: Measured peak antenna gain against frequency.