Bandwidth Enhancement Technique for Quarter-Wave Patch Antennas

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***Abstract*—A novel technique that improves the performance of a conventional quarter-wave patch antenna is proposed. Two different geometries (U-slot and L-slit) are being investigated experimentally. With the inclusion of a folded inner small patch, we achieve impedance bandwidths of 53% and 45% of a voltage standing wave ratio less than 2 for the U-slot and L-slit, respectively. Radiation patterns are stable across the whole operating frequency bands.**

***Index Terms*—Patch antenna, wideband antenna.**

I. Introduction

MICROSTRIP antenna is commonly used in small antenna design because of its low profile. The U-slot and the L-slit are two common geometries employed in designing such type of antenna with dual-band operation [1]. With the presence of a shorting wall, the resonant length of a rectangular patch antenna can be reduced by half, but the impedance bandwidth is usually not more than 10% [2]. Certain techniques for enhancing the bandwidth of planar antennas have already been developed, e.g., parasitic patch either in stacked or coplanar geometries, U-slot patch [3], L-probe coupling [4], aperture coupling and increasing the thickness of the antenna. In this paper, a novel simple alternative for enhancing the impedance bandwidth of a conventional quarter-wave patch antenna is proposed. It is a folded patch antenna design with a shorting wall. The U-slot and L-slit geometries are being tested and the U-slot one has an impedance bandwidth (VSWR $\leq$2) of 53%, 25% higher than that of the 28% bandwidth U-slot patch antenna reported in [5] with the same patch size but a thinner profile.

II. Antenna Design and Structure

It is known that increasing the thickness of the patch antenna will increase the impedance bandwidth. However, the thicker the substrate of the antenna, the longer the coaxial probe will be used and, thus, more probe inductance will be introduced [6], which limits the impedance bandwidth. Consequently, a patch antenna design that can counteract or reduce the probe inductance will enlarge the impedance bandwidth.

For the proposed antennas, the inner portions of the U-slot and L-slit patches are folded downward from the outer patches as shown in Fig. 1 with square ground planes 30.48 cm $\times$ 30.48 cm and 8 cm $\times$ 8 cm, respectively. They center on the ground planes and resemble the original U-slot and L-slit patches when viewed from the top. With this special design,

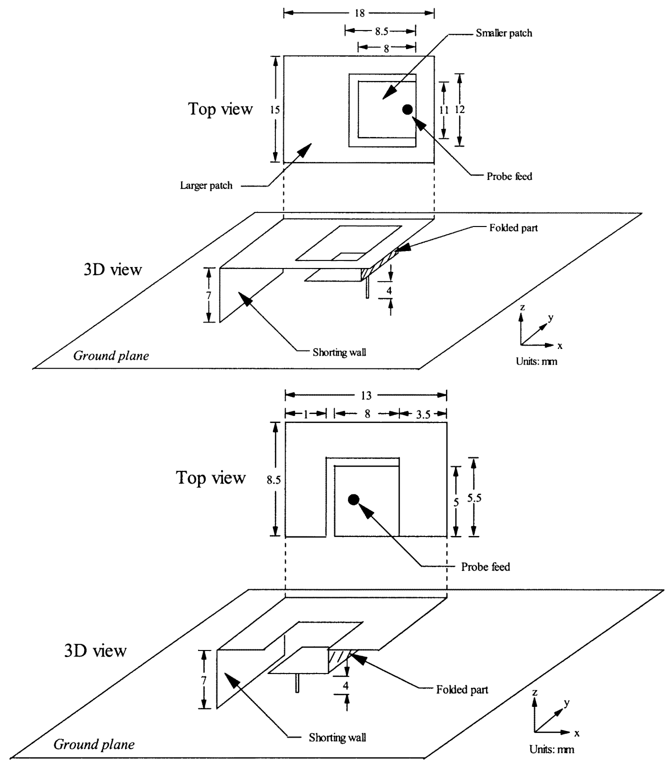

Fig. 1. Configurations of the proposed U-slot (top) and L-slit (bottom) quarter-wave patch antennas with folded patch design.

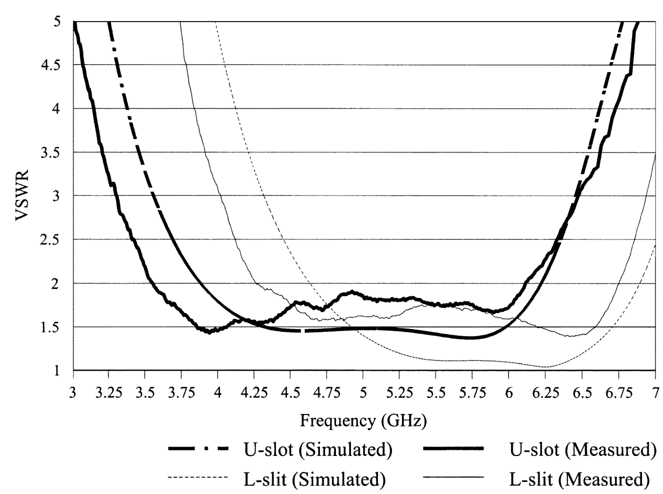

Fig. 2. Simulated and measured VSWR of the proposed U-slot and L-slit antennas.

Manuscript received April 11, 2003; revised June 2, 2003. This work was supported by the Hong Kong Research Grant Council, Grant 9040452.

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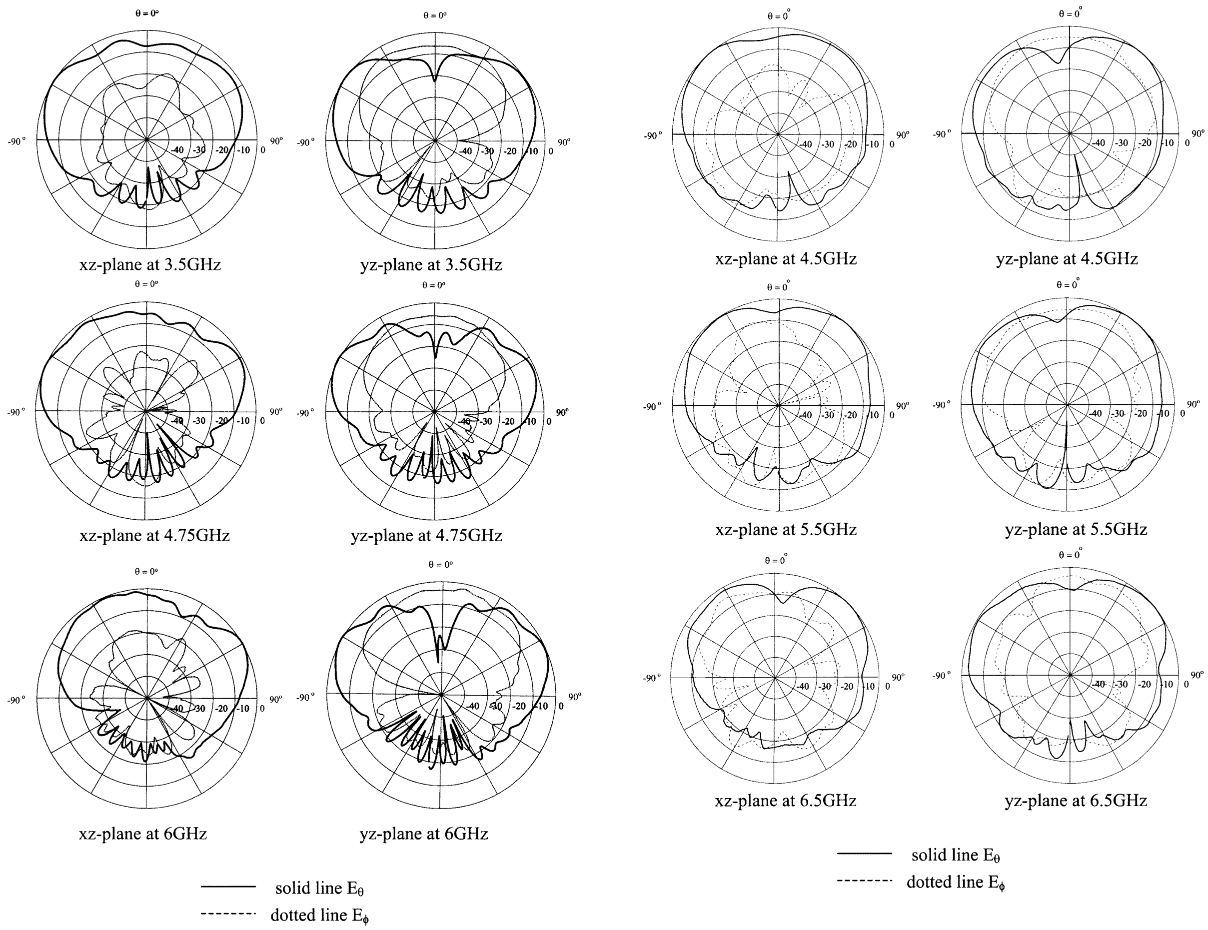
Digital Object Identifier 10.1109/LAWP.2003.816636



(a) (b)

Fig. 3. (a) Measured radiation patterns of the proposed U-slot antenna at 3.5, 4.75, and 6 GHz. (b) Measured radiation patterns of the proposed L-slit antenna at 4.5, 5.5, and 6.5 GHz.

only a short coaxial probe is required, lowering the probe inductance. The substrates and materials of the proposed antennas are air and 0.2-mm copper sheet and shorting walls are used to reduce the overall size to nearly a quarter wavelength of the center operating frequency.

III. Simulation and Measured Results

The simulated and measured voltage standing wave ratios (VSWRs) of the U-slot and L-slit geometries are given in Fig. 2. The measured impedance bandwidths (VSWR $\leq$2) are 53.54% from 3.57 GHz to 6.18 GHz, and 45.12% from 4.265 GHz to 6.75 GHz. They agree well with the simulated results performed by IE3D Version 9.2 [7]. To discretize the structure, a cell size of $\lambda/20$ is being used. In addition, to reduce the simulation time, an infinite ground plane is used to model the structure. This is accurate enough because the ground plane is much larger than the radiating patch. The small frequency shift may be mainly due to fabrication tolerance. The radiation patterns are observed to be stable across the whole operating frequency bands and the patterns at 3.5, 4.75, and 6 GHz for the U-slot geometry are given in Fig. 3(a), while the patterns at 4.5, 5.5, and 6.5 GHz for the L-slit geometry are given in Fig. 3(b). Fig. 4 shows the variation of the measured gain with frequency. The gain difference between the U-slot and L-slit geometries is mainly due to the different sizes of the ground planes.

We have also investigated effects on the impedance bandwidth by varying the height of the smaller patch above the ground plane (U-slot geometry). Basically, such wide impedance bandwidth is a combination of two nulls in the reflection coefficient. When the height of the smaller patch is increased (equals to the length of the coaxial probe), the length difference between the smaller patch (including the folded part) and the larger patch on the top is also increased. We also find that two nulls are being obtained in the reflection coefficient when the height of the smaller patch is higher than 4 mm. The optimal design is at 4 mm with a wide bandwidth and stable radiation pattern across the band as depicted in Fig. 3(a). When the height is 5 mm, a wide bandwidth is also achieved but the radiation pattern varies substantially across the bandwidth.

IV. Conclusion

A novel technique for enhancing bandwidth of quarter-wave patch antennas is successfully demonstrated in this paper. With the folded inner small patch technique, both U-slot and L-slit geometries are proved to have impedance bandwidth improvement substantially. For the U-slot geometry, the overall projec-

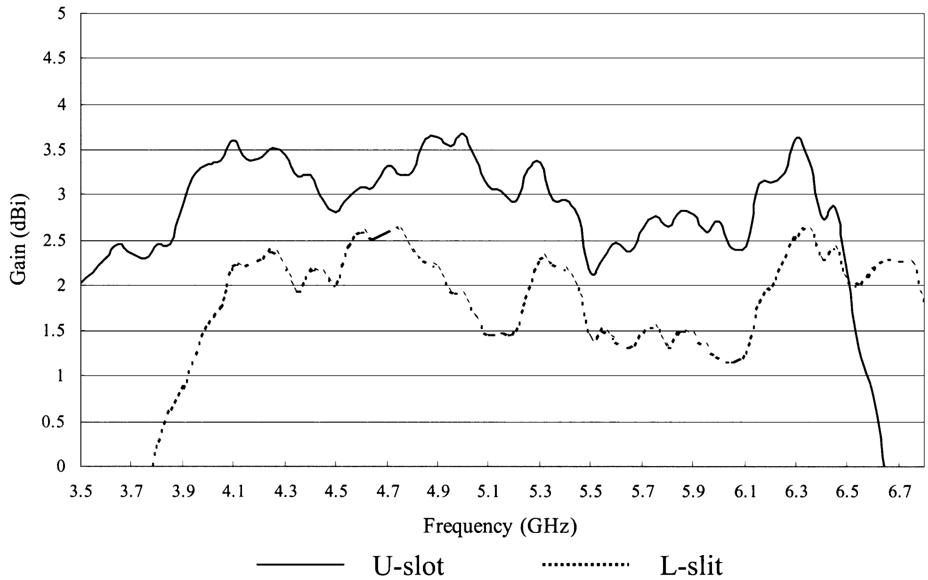


Fig. 4. Measured antenna gain of the proposed U-slot and L-slit antennas.

tion size and the ground plane size of the antenna remain unchanged and the antenna profile reduces from 9 to 7 mm when compared to the original U-slot design [5] but the impedance bandwidth can be increased dramatically from 28% to 53%.

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