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Max Ammann

*Technological University Dublin, max.ammann@tudublin.ie*

Zhi Ning Chen

*National University of Singapore*

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## A Wide-Band Shorted Planar Monopole With Bevel

M. J. Ammann and Zhi Ning Chen

**Abstract**—A new wide-band shorted planar monopole with a bevel is presented. The numerical simulations and measurements demonstrate that the impedance bandwidth of a wide-band planar square monopole is shown to increase dramatically by combining bevelling and a shorting technique. The radiation pattern stability is also discussed.

**Index Terms**—Planar monopole antenna, ultra-wideband, wide-band antenna.

### I. INTRODUCTION

Ultra-wide-band antennas are becoming very attractive for future software defined and reconfigurable wireless systems. The wide-band antenna is simpler than dual-band or triple-band designs of narrow-band elements, which tend to get complicated and may be prone to proximity detuning in some circumstances. Also, some systems may demand more than triple-band operation. Ultra-wide-band (UWB) antennas are an attractive alternative in these cases. Moreover, ultra wideband is an emerging new technology for broad-band internet access and public safety applications, employing the spectrum in the region of 1.9 to 10.6 GHz at extremely low power levels.

The planar monopole antenna was first reported in 1976 by Dubost and Zisler [1] and planar disc antennas have been recently studied [2]. The dependency of the impedance bandwidth on feedgap separation has been analyzed [3] and the method of moments (MoM) employing a wire-grid and finite-gap voltage-feed has been shown to approximate the antenna behavior. Simple formulae have been proposed to determine the lower edge frequency for various planar geometries [3]–[5]. The bandwidth has been increased by adding a shorting post [6] and the use of planar bow-tie geometries have also been examined [4]. The use of parasitic elements has also been investigated [7], [8] and the effect of employing various bevel angles on one or both sides of the feeding probe has been shown to significantly increase the impedance bandwidth [9].

In this paper, the proposed antenna can cover frequencies from 800 MHz to greater than 10.5 GHz. Included in this range of frequencies are GSM, PCS, IMT-2000, DECT, the 2.4 GHz, and 5.8 GHz ISM bands, U-NII, and the recent UWB technologies.

### II. SQUARE PLANAR MONOPOLE ANTENNAS

The simple square planar monopole has been shown to have an impedance bandwidth (2:1 VSWR) of 75–100% [3] and the addition of a shorting post increases this to about 350% [5], which represents an impedance bandwidth ratio of 3.5:1. However, although an impedance bandwidth ratio of up to 3.5:1 is feasible with this element, future systems may demand more, up to 10:1. The addition of a bevel on one side of the shorted planar monopole as shown in Fig. 1 increases the bandwidth dramatically. An impedance bandwidth ratio of 10:1 for a 3:1 VSWR is achievable. Trimming the square edge near the groundplane yielding trapezoidal and pentagonal shapes, has been shown to increase the upper edge frequency significantly [5].

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M. J. Ammann is with the School of Electronic and Communications Engineering, Dublin Institute of Technology, Dublin 8, Ireland.

Z. N. Chen is with the Center for Wireless Communications, National University of Singapore, TeleTech Park, 117674 Singapore.

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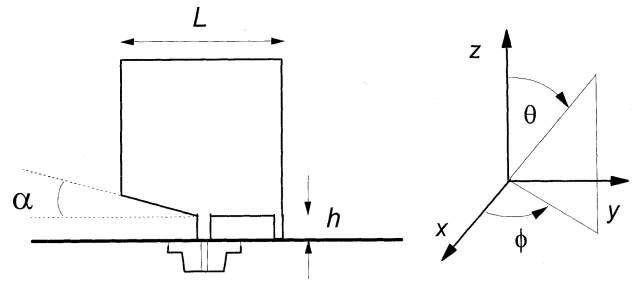


Fig. 1. A square planar monopole with bevel and shorting post is fed using an SMA connector, through a 200-mm square groundplane.

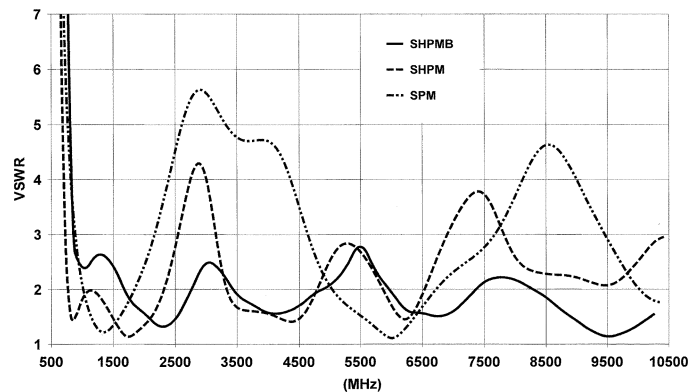


Fig. 2. MoM simulated VSWR for the SPM, SHPM, and SHPMB.

The introduction of a bevel increases the upper-edge frequency, and control of this frequency is possible by adjusting the bevel angle [9]. Increasing the angle of the bevel raises the upper-edge frequency until the bevel angle reaches about  $40^\circ$ . Cutting slots in each side of the planar element also reduce the lower-edge frequency slightly.

The antenna is constructed using 0.2-mm-thick copper sheet on a 200-mm-square groundplane and a SMA connector. The square dimension,  $L$ , is 60 mm, the shorting strip is 2-mm-wide and the feedgap is 1.2 mm. The square geometry is beveled on the side opposite the shorting strip and the bevel angle  $\alpha$  was varied from  $0^\circ$  to  $40^\circ$  in  $10^\circ$  steps.

### III. IMPEDANCE AND PATTERN BANDWIDTH

The variation of VSWR with frequency was simulated by the MoM using a finite-gap voltage-feed and a wire-grid technique with piecewise sinusoidal basis functions. The simulated results are compared to experimental work. The simulated swept VSWR for the square planar monopole with and without shorting strip and bevel is shown in Fig. 2. The shorting strip reduces the lower-edge frequency and the bevel raises the upper-edge frequency significantly. The plot shows the effect of introducing the bevel and shorting strip on the impedance bandwidth. The feedgaps are optimized for maximum bandwidth in each case. Simulated 3:1 VSWR impedance bandwidths are 890–2250 MHz for the simple planar monopole (SPM), 730–2500 MHz for the shorted planar monopole (SHPM) and 850 MHz to >10.5 GHz for the shorted planar monopole with bevel (SHPMB).

Experimentally, swept VSWR plots (0.5–10.5 GHz) are shown for the simple planar beveled monopole with bevel angles of  $\alpha = 0^\circ$  to  $\alpha = 40^\circ$  in Fig. 3(a). It can be seen that the VSWR variation with frequency is reduced by the addition of the bevel. Fig. 3 (b) displays

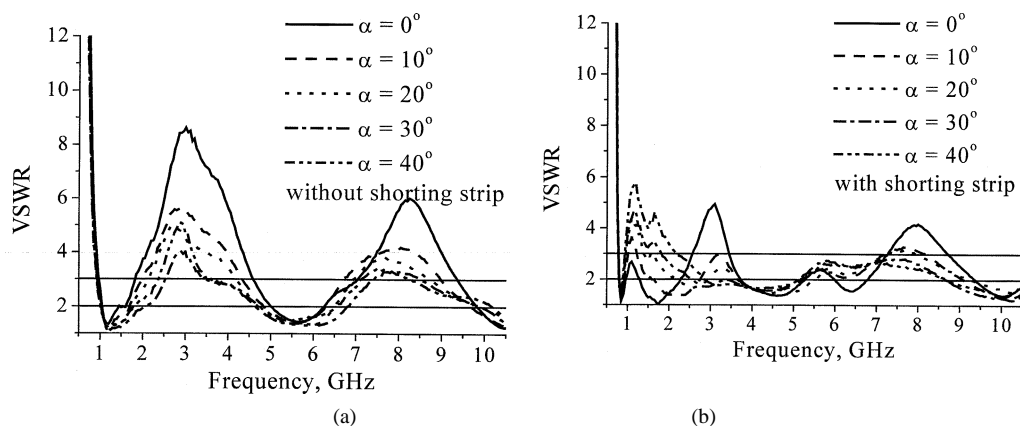


Fig. 3 (a). Measured VSWR for the 60-mm-square simple planar monopole for  $\alpha = 0^\circ$  to  $\alpha = 40^\circ$ . (b) Measured VSWR for the 60-mm-square shorted planar monopole for  $\alpha = 0^\circ$  to  $\alpha = 40^\circ$ .

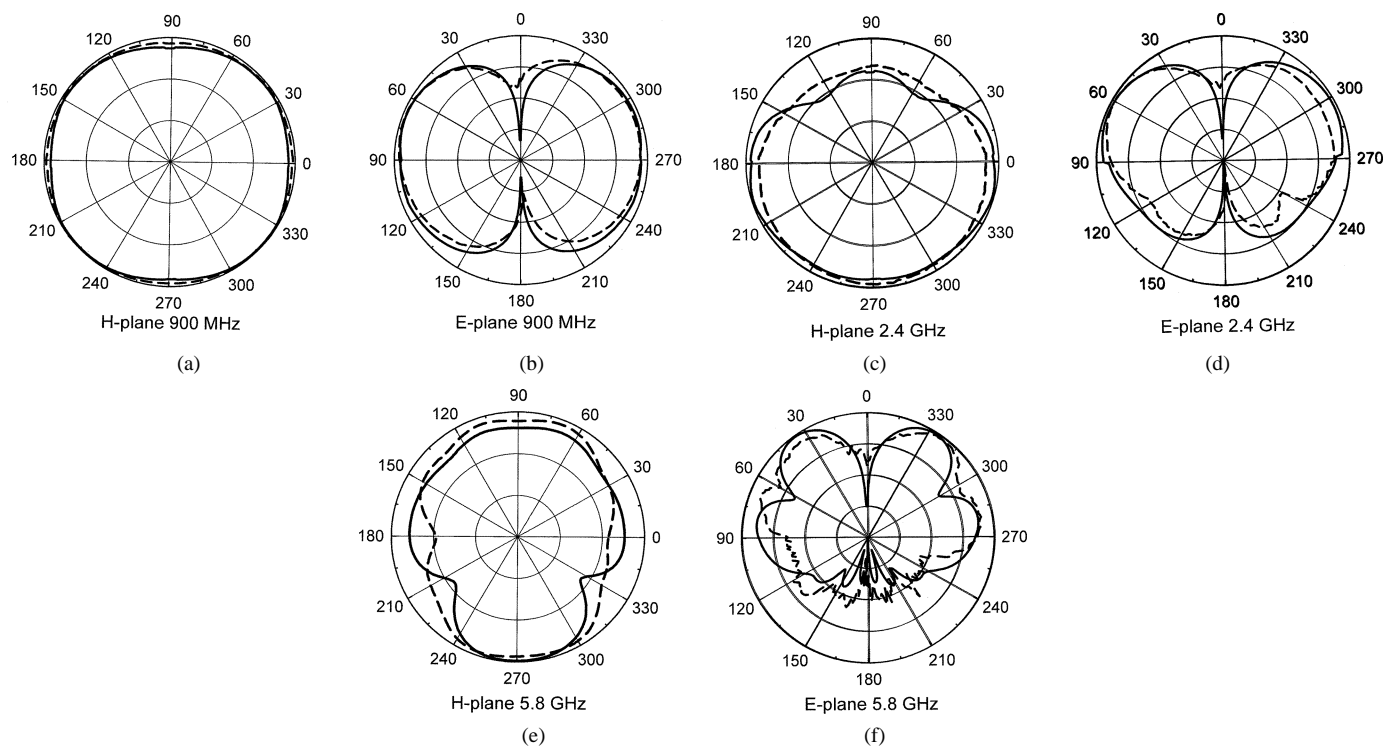


Fig. 4. The radiation patterns [simulated (solid) and measured (dashed)] of  $E_\theta$ -components in the H plane ( $\phi, \theta = 0^\circ$ ) and E plane ( $\theta, \phi = 0^\circ$ ) at 900 MHz, 2.4, and 5.8 GHz. (10 dB/div).

the VSWR for the planar element with both bevel and shorting strip. It can be observed that the VSWR remains below 3:1 over most of the frequency range when  $\alpha = 10^\circ$  and  $20^\circ$ . The bevel tends to increase the VSWR slightly at the lower frequencies but reduces the VSWR significantly at higher frequencies. For  $\alpha = 10^\circ$ , the lower- and upper-edge frequencies (3:1 VSWR) are 790 MHz and >10.5 GHz, respectively. The VSWR is slightly greater than 3:1 only in the regions from 1.05–1.22 GHz and from 7.5–8.2 GHz.

The measured radiation patterns shown in Fig. 4 are generally in good agreement with simulated data by MoM combined with the uniform theory of diffraction (UTD). The plots indicate nearly omnidirectional patterns in the H plane and typical monopole patterns in the E plane cuts at the lower frequencies. The plots are given at 900 MHz, 2.4, and 5.8 GHz. The UTD ray paths included singly and doubly reflected fields, singly diffracted fields (normal diffracted and slope diffracted), the reflected-diffracted and diffracted-reflected fields.

#### IV. CONCLUSION

A wide-band planar monopole employing two broad-banding techniques has been investigated experimentally and numerically, and is shown to yield an impedance bandwidth ratio of more than 10:1 for VSWR=3:1. The typical monopole radiation patterns have also been seen over the broad bandwidth.

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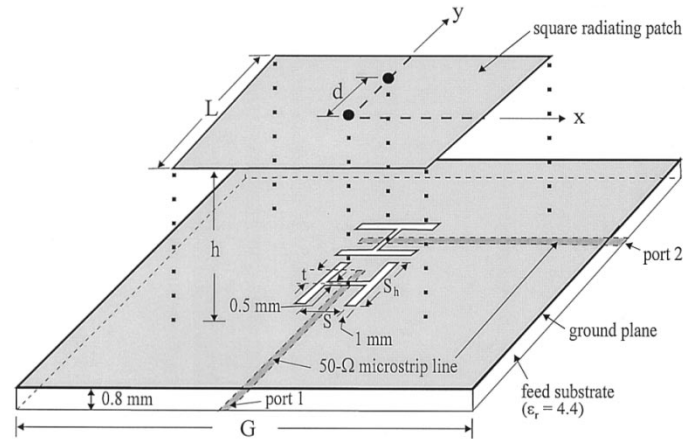


Fig. 1. Geometry of a broad-band dual-polarized aperture-coupled patch antenna with a finite ground plane.

## Finite Ground Plane Effects on Broad-Band Dual Polarized Patch Antenna Properties

Kin-Lu Wong and Tzung-Wern Chiou

**Abstract**—Effects of finite ground plane on isolation and radiation properties of a broad-band dual-polarized aperture-coupled patch antenna are experimentally investigated. The dual-polarized patch antenna has a thick air substrate for broad-band operation ( $>16\%$  for both polarizations) and is excited by microstrip lines through two H-shaped coupling slots. Results show that by selecting suitable ground-plane dimensions, isolation between the two feeding ports can be greatly enhanced by about 10 dB, and the cross-polarization level in the E and H planes can also be improved by about 10 and 5 dB, respectively. Also, the impedance bandwidth increases with decreasing ground-plane dimensions.

**Index Terms**—Dual polarization, finite ground plane, patch antenna.

### I. INTRODUCTION

For practical applications, microstrip patch antennas are with a finite ground plane. Effects of finite ground plane dimensions on the radiation and impedance characteristics of microstrip patch antennas have also been investigated [1]–[5]. However, for finite ground plane effects on isolation and radiation properties of a dual-polarized microstrip patch antenna, related studies are not available in the open literature. Since dual-polarized microstrip patch antennas are very suitable for applications in wireless communications systems that demand frequency reuse or polarization diversity, related information of the finite ground plane effects will be very helpful for antenna engineers in practical designs. In this communication, we present an experimental study of finite ground plane effects on various properties of a broad-band dual-polarized aperture-coupled patch antenna. The isolation between the two feeding ports, cross-polarization level (XPL) in principal planes, impedance bandwidth, and antenna gain as a function of the ground plane dimensions are experimentally investigated.

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The authors are with the Department of Electrical Engineering, National Sun Yat-Sen University, Kaohsiung, Taiwan 804, Republic of China.  
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TABLE I

DUAL-POLARIZED PROPERTIES AS A FUNCTION OF GROUND PLANE DIMENSIONS;  $L = 58$  mm,  $h = 13.6$  mm,  $d = 19$  mm,  $S = 18$  mm,  $t = 5.0$  mm,  $S_h = 16$  mm.  $\lambda_0$  IS THE FREE-SPACE WAVELENGTH AT THE DESIGNED CENTER FREQUENCY 1800 MHz ( $f_c$ ). THE RESULTS SHOWN ARE FOR PORT-1 EXCITATION. THE IMPEDANCE BANDWIDTH (BW) IS DETERMINED FROM 10-dB RETURN LOSS. THE ISOLATION GIVEN IS THE MAXIMUM VALUE OF  $S_{21}$  ACROSS ENTIRE IMPEDANCE BANDWIDTH

$L$ mm	$G$ mm	Impedance BW	Isolation dB	XPL at $f_c$		Gain at $f_c$ dBi
				E-plane	H-plane	
58 ( $0.35\lambda_0$ )	150 ( $0.90\lambda_0$ )	16.7% (300 MHz)	-35.3	32.5	19.5	7.6
	100 ( $0.60\lambda_0$ )	17.4% (314 MHz)	-35.5	34.3	20.0	7.1
	90 ( $0.54\lambda_0$ )	18.5% (333 MHz)	-34.2	28.3	16.2	6.9
	80 ( $0.48\lambda_0$ )	18.7% (336 MHz)	-29.1	25.5	15.5	6.5
	75 ( $0.45\lambda_0$ )	21.3% (384 MHz)	-26.0	25.0	15.4	5.5

### II. ANTENNA CONFIGURATION

Fig. 1 shows the geometry of a broad-band dual-polarized aperture-coupled patch antenna. The antenna's ground plane has dimensions of  $G \times G$ . The square radiating patch has a side length of  $L$ . For obtaining broad-band operation, a thick air substrate (thickness  $h$ ) was used between the square patch and the ground plane of a grounded substrate (feed substrate; its thickness and relative permittivity in this communication were 0.8 mm and 4.4, respectively). Plastic posts (not shown in the figure) were used to support the square patch above the ground plane. Two identical H-shaped coupling slots, whose central arm and two side arms have dimensions of  $S \times 0.5$  mm and  $S_h \times 1$  mm, respectively, were used to couple the electromagnetic energy from the 50- $\Omega$  microstrip feed lines to the square patch for dual linear polarizations. The microstrip feed lines were printed on the feed substrate and had a tuning stub length of  $t$ . Also note that the H-shaped coupling slot of port 1 is centered below the square patch (in the  $z$ -axis), and the central arm of the other H-shaped coupling slot for port 2 is arranged along the direction of the microstrip feed line of port 1, with the center of the coupling slot having a distance of  $d$  away from the central axis ( $z$ -axis). This arrangement in the two H-shaped coupling slots can result in optimal isolation between the two feeding ports. In the experiments, the IE3D simulation software was also used for obtaining the initial promising parameters for the communication, and final parameters were determined from experiments.