Design of Small-Size Wide-Bandwidth Microstrip-Patch Antennas

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Abstract

Several designs for small-size wide-bandwidth microstrip antennas are examined through simulation and experiment. Designs are presented based on two wideband patch antennas: the U-slot patch antenna, and the L-probe-fed patch antenna. Several techniques are utilized to reduce the resonant length of these wideband microstrip-patch antennas: increasing the dielectric constant of the microwave substrate material, the addition of a shorting wall between the conducting patch and the ground plane, and the addition of a shorting pin between the conducting patch and the ground plane. Simulation and experimental results confirm that the size of the antennas can be reduced by as much as 94%, while maintaining impedance bandwidths in excess of 20%.

Keywords: Microstrip antennas; broadband antenna; miniature antenna; antenna pattern measurements

1. Introduction

The major disadvantage of the microstrip-patch antenna is its inherently narrow impedance bandwidth of only a couple of percent. Much intensive research has been done in recent years to develop bandwidth-enhancement techniques. These techniques include the utilization of thick substrates with a low dielectric constant [1], and stacked or co-planar parasitic patches [2]. The use of an electronically thick substrate only results in limited success, because a large inductance is introduced by the increased length of the probe feed, resulting in a maximum bandwidth of less than 10% of the resonant frequency. By using stacked patches, bandwidths of 10%-20% can be obtained, but this design has the disadvantage of added complexity of fabrication. To counteract the inductance introduced when using a thick substrate, capacitance can be introduced by adding a concentric annular gap around the probe feed, resulting in 16% bandwidth [3].

More recently, the addition of a U-shaped slot [4, 5, 6] and the use of an L-shaped probe [7, 8] have both been shown to provide bandwidths in excess of 30%. The U-slot patch antenna consists of a probe-fed rectangular patch with a U-shaped slot, as seen in Figure 1. The U slot introduces a capacitance, allowing the use of a thick substrate ($\sim 0.1\lambda_0$), and induces a second resonance near the main resonance of the patch, producing a wideband frequency response. The rectangular U-slot patch antenna has an average gain of 7 dBi and good pattern characteristics. The operation of the L-probe-fed patch, seen in Figure 2, is similar to that of the U-slot patch, with the L probe introducing capacitance, allowing the use of a thick substrate and inducing an additional resonance near the main resonance of the patch. The average gain of the L-probe-fed rectangular patch is 7.5 dBi, with good pattern characteristics.

The resonant length of the microstrip-patch antenna is approximately $\lambda_0/2$, which is too large for many applications. Several techniques are available to decrease the resonant length of the patch, including the use of a substrate material with a high dielectric constant [9], the addition of a shorting wall [10], the addition of a shorting pin [11], and the planar inverted-F antenna [12]. The resonant frequency of the patch antenna is inversely proportional to $\sqrt{\varepsilon_r}$: thus, increasing the dielectric constant of the substrate will decrease the resonant length of the patch. However, this technique decreases the already narrow impedance bandwidth of the patch antenna. It has been shown that by placing a shorting wall along the null in the electric field across the center of the patch, the resonant length can be reduced by a factor of two ($\sim \lambda_0/4$), reducing the area occupied by the patch by a factor of four, if the aspect ratio is kept the same. Another technique to reduce the resonant length is adding a shorting pin in close proximity to the probe feed. The shorting pin is capacitively coupled to the resonant circuit of the patch, effectively increasing the permittivity of the substrate. It has been shown that a suitably placed

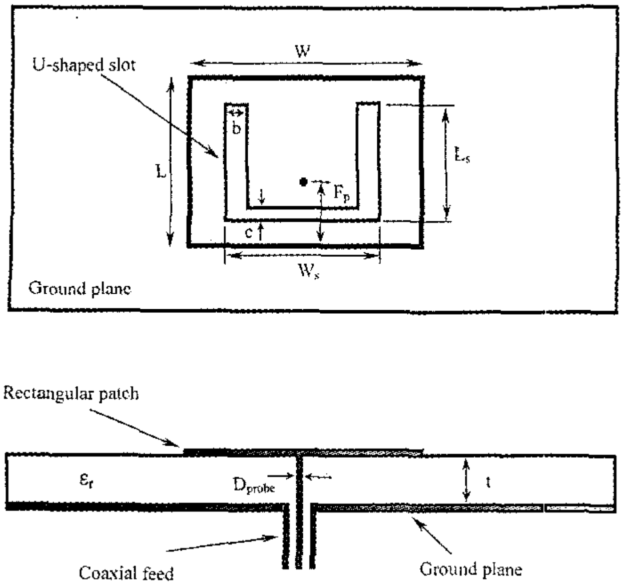

Figure 1. The basic geometry of the U-slot patch antenna.

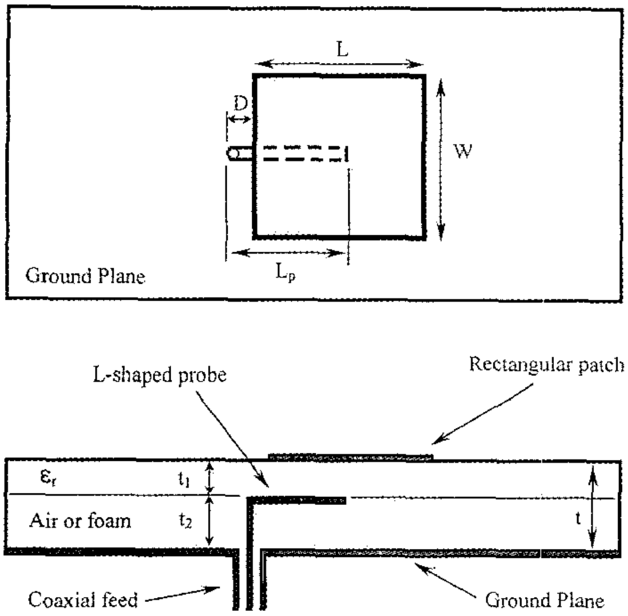

Figure 2. The basic geometry of the L-probe-fed patch antenna.

Table 1a. 900 MHz U-slot patches.

ε_r	Patch Dimensions (cm)	Thickness (cm)	Normalized Area*	BW
1.0	21.97×12.45	$2.69\,(0.08\lambda_0)$	1	42%
2.33	12.40×8.96	$2.76\,(0.08\lambda_0)$	0.41	26.5%
4.0	9.29×6.71	$2.40\,(0.07\lambda_0)$	0.23	22.1%

*Normalized with respect to the U-slot patch with $\varepsilon_r = 1.0$, area (21.97 cm × 12.45 cm = 273.53 cm^2) from [4].

Table 1b. Design parameters for 900 MHz U-slot patches on a microwave substrate (all dimensions in cm).

	$\varepsilon_r = 1.0$	$\varepsilon_r = 2.33$	$\varepsilon_r = 4.0$
W	$21.97\,(0.659\lambda_0)$	$12.40\,(0.372\lambda_0)$	$9.29\,(0.279\lambda_0)$
L	$12.45\,(0.374\lambda_0)$	$8.96\,(0.269\lambda_0)$	$6.71\,(0.201\lambda_0)$
W_s	6.86	4.82	3.61
L_s	8.22	6.20	4.65
b	1.94	1.38	1.03
c	0.89	0.69	0.52
F_p	6.22	4.48	3.36
t	$2.69\,(0.081\lambda_o)$	$2.76\,(0.083\lambda_o)$	$2.40\,(0.072\lambda_o)$
D_{probe}	0.30	0.34	0.17

Table 2a. 900 MHz L-probe patches.

ε_r	Patch Dimensions (cm)	Thickness (cm)	Normalized Area*	BW
1.0	15.83×13.19	$3.483\,(0.1\lambda_0)$	0.763	40%
2.32	12.43×10.36	$4.06\,(0.12\lambda_0)$	0.47	40.6%
4.2	9.75×8.12	$3.90\,(0.12\lambda_0)$	0.29	38.3%

*Normalized with respect to the U-slot patch with $\varepsilon_r = 1.0$, area (21.97 cm × 12.45 cm = 273.53 cm^2) from [4].

Table 2b. Design parameters for 900 MHz L-probe patches (all dimensions in cm).

	$\varepsilon_r = 1.0$	$\varepsilon_r = 2.32$	$\varepsilon_r = 4.2$
W	$15.83\,(0.475\lambda_0)$	$12.43\,(0.373\lambda_0)$	$9.75\,(0.293\lambda_0)$
L	$13.19\,(0.396\lambda_0)$	$10.36\,(0.311\lambda_0)$	$8.12\,(0.244\lambda_0)$
L_p	5.54	4.35	3.41
D	1.06	8.28	6.50
t_1	–	1.28	1.72
t_2	–	2.78	2.18
$t = t_1 + t_2$	$3.48\,(0.104\lambda_0)$	$4.06\,(0.122\lambda_0)$	$3.90\,(0.117\lambda_0)$
D_{probe}	0.53	0.41	0.33

shorting pin can reduce the resonant length by a factor of three, and the area of the patch by a factor of nine.

In this paper, several designs for small-size wide-bandwidth patch antennas are presented. These designs are based on the wideband U-slot and L-probe patch antennas, and utilize the size-reduction techniques discussed previously. Simulation results, obtained using Ansoft *Ensemble 6.0*, and measurement results of several of the simulated antennas are presented.

2. Simulation Results

2.1 U-Slot Patch Antenna on a Microwave Substrate

In the literature, wideband U-slot patch antennas are usually designed on foam or air substrates, resulting in patches with a resonant length of $0.5\lambda_0$. To decrease the resonant length, simulation results of these patch antennas on three types of microwave substrate were obtained, as shown in Figure 1. All three antennas were designed for a center frequency of 900 MHz. The patch dimensions, thickness, normalized area, and bandwidth are shown for the U-slot patch in Table 1a. As the dielectric constant of the substrate material was increased from 1.0 to 4.0, the area of the patch was decreased by 77%, and the bandwidth was decreased from 42% to 22%, still a substantial bandwidth. The substrate thickness decreased from $0.8\lambda_0$ to $0.7\lambda_0$. The design parameters for these antennas are shown in Table 1b. It is seen that the resonant length, L, of the antenna was reduced from $0.374\lambda_0$ to $0.201\lambda_0$ as ε_r increased.

2.2 L-Probe-Fed Patch Antenna on a Microwave Substrate

The design of the L-probe-fed patch antenna requires that the horizontal arm of the feed probe be embedded within the substrate material, making it quite difficult to use any materials other than foam or air for the substrate. To realize the goal of reducing the resonant length of the L-probe patch, a two-layer configuration was conceived, as shown in Figure 2. By placing a microwave substrate in the region between the conducting patch and the L probe, and foam or air between the ground plane and the L probe, the size-reduction properties of the microwave substrate can be utilized, without increasing the difficulty of fabrication, since the horizontal arm of the L probe lies in the air or foam layer. Table 2a shows the simulation results obtained for three different values of ε_r, designed at a center frequency of 900 MHz. It is seen that as ε_r was increased from 1.0 to 4.2, the size reduction was similar to that of the U-slot patches, but the bandwidth was significantly larger, as was the substrate thickness. Table 2b shows the design parameters for these antennas. As ε_r was increased, the resonant length of the patch decreased from $0.396\lambda_0$ to $0.244\lambda_0$.

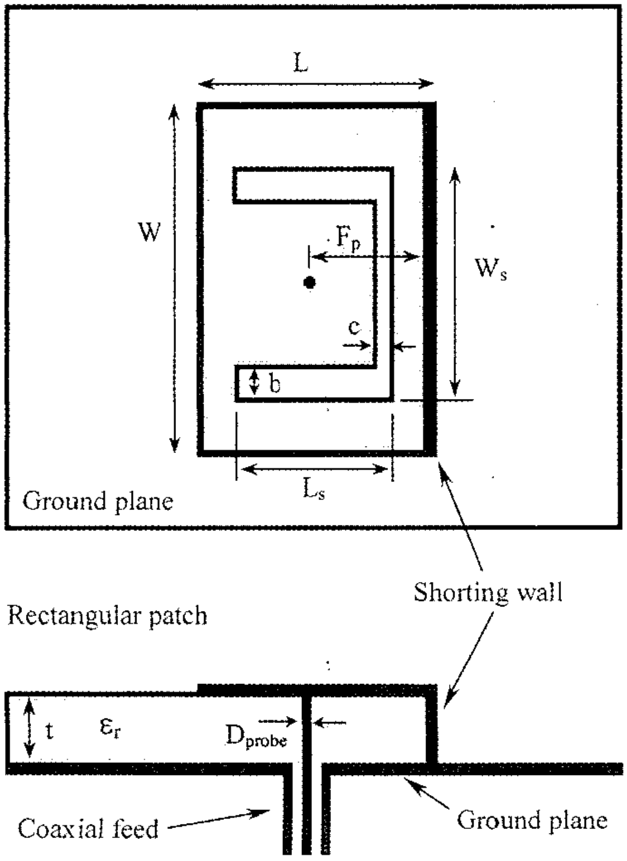

Figure 3. The geometry of the U-slot patch antenna with a shorting wall on a microwave substrate.

Table 3a. 900 MHz U-slot patches with shorting walls.

ε_r	Patch Dimensions (cm)	Thickness (cm)	Normalized Area*	BW
1.0	8.135 × 8.135	2.71 ($0.081\lambda_0$)	0.242	22.7%
2.33	5.71 × 5.71	3.02 ($0.091\lambda_0$)	0.119	22.6%
4.0	3.97 × 3.97	3.62 ($0.109\lambda_0$)	0.058	27.9%

*Normalized with respect to the U-slot patch with $\varepsilon_r = 1.0$, area (21.97 cm × 12.45 cm = 273.53 cm^2) from [4].

Table 3b. Design parameters for 900 MHz U-slot patches on a microwave substrate with a shorting wall (all dimensions in cm).

	$\varepsilon_r = 1.0$	$\varepsilon_r = 2.33$	$\varepsilon_r = 4.0$
W	8.14 ($0.244\lambda_0$)	5.71 ($0.171\lambda_0$)	3.97 ($0.119\lambda_0$)
L	8.14 ($0.244\lambda_0$)	5.71 ($0.171\lambda_0$)	3.97 ($0.119\lambda_0$)
W_s	4.88	3.43	2.38
L_s	7.05	4.95	3.44
b	0.54	0.38	0.27
c	1.08	0.76	0.53
d	0.54	0.38	0.27
F_p	2.71	1.90	0.14
t	2.71 ($0.081\lambda_0$)	3.02 ($0.091\lambda_0$)	3.62 ($0.109\lambda_0$)
D_{probe}	0.27	0.25	0.28

2.3 U-Slot Patch Antenna with a Shorting Wall on a Microwave Substrate

To further reduce the size of the U-slot patch antenna on a microwave substrate, a shorting wall was introduced, as shown in Figure 3. Table 3a shows the simulation results obtained for three different values of ε_r, designed at a center frequency of 900 MHz. The addition of a shorting wall reduced the area of the patch as much as 94%, while maintaining a bandwidth in excess of 20%. The design parameters for these antennas are presented in Table 3b. The resonant length of the patch, L, was reduced from approximately $0.24\lambda_0$ to $0.12\lambda_0$.

2.4 L-Probe-Fed Patch Antenna with a Shorting Wall on a Microwave Substrate

A shorting wall was added to the L-probe-fed patch antenna on a microwave substrate to further reduce the area of the patch, as

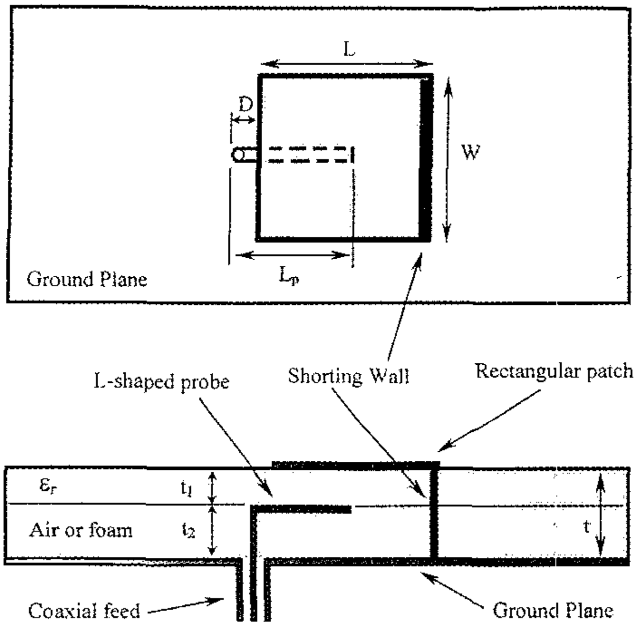

Figure 4. The geometry of the L-probe-fed patch antenna with a shorting wall on a microwave substrate.

Table 4a. 900 MHz L-probe patches with shorting walls.

ε_r	Patch Dimensions (cm)	Thickness (cm)	Normalized Area*	BW
1.0	17.0×6.82	$4.26\ (0.128\lambda_0)$	0.424	29.6%
2.33	11.3×4.52	$3.61\ (0.108\lambda_0)$	0.187	45.1%
4.0	7.92×3.17	$3.65\ (0.11\lambda_0)$	0.092	36.2%

*Normalized with respect to the U-slot patch with $\varepsilon_r = 1.0$, area (21.97 cm × 12.45 cm = 273.53 cm^2) from [4].

Table 4b. Design parameters for 900 MHz L-probe patches with shorting walls (all dimensions in cm).

	$\varepsilon_r = 1.0$	$\varepsilon_r = 2.33$	$\varepsilon_r = 4.0$
W	$17.0\ (0.510\lambda_0)$	$11.3\ (0.339\lambda_0)$	$7.92\ (0.238\lambda_0)$
L	$6.82\ (0.205\lambda_0)$	$4.52\ (0.136\lambda_0)$	$3.17\ (0.095\lambda_0)$
L_p	6.53	4.33	3.04
D	1.14	0.75	0.53
t_1	-	1.17	1.40
t_2	-	2.45	2.24
$t = t_1 + t_2$	$4.29\ (0.128\lambda_0)$	$3.61\ (0.108\lambda_0)$	$3.65\ (0.110\lambda_0)$
D_{probe}	0.38	0.38	0.26

seen in Figure 4. Table 4a shows the simulation results for three such patch antennas, designed for a center frequency of 900 MHz. The patch area was reduced by as much as 90%, while maintaining a bandwidth of approximately 30%. The design parameters for these antennas are shown in Table 4b. It is seen that the resonant length of the patch, L, was reduced from $0.21\lambda_0$ to $0.1\lambda_0$. It should be noted that the aspect ratio of the patch, W/L, must be greater than two, or else these antennas do not exhibit wideband performance.

2.5 U-Slot Patch Antenna with a Shorting Pin

The geometry of the U-slot patch antenna with a shorting pin is shown in Figure 5. Four such antennas were designed for a center frequency of 900 MHz: two with an air substrate ($\varepsilon_r = 1.0$), and two with microwave substrates. Table 5a shows the simulation results obtained, and Table 5b gives the various design parameters. For the case of an air substrate, two sets of results were obtained.

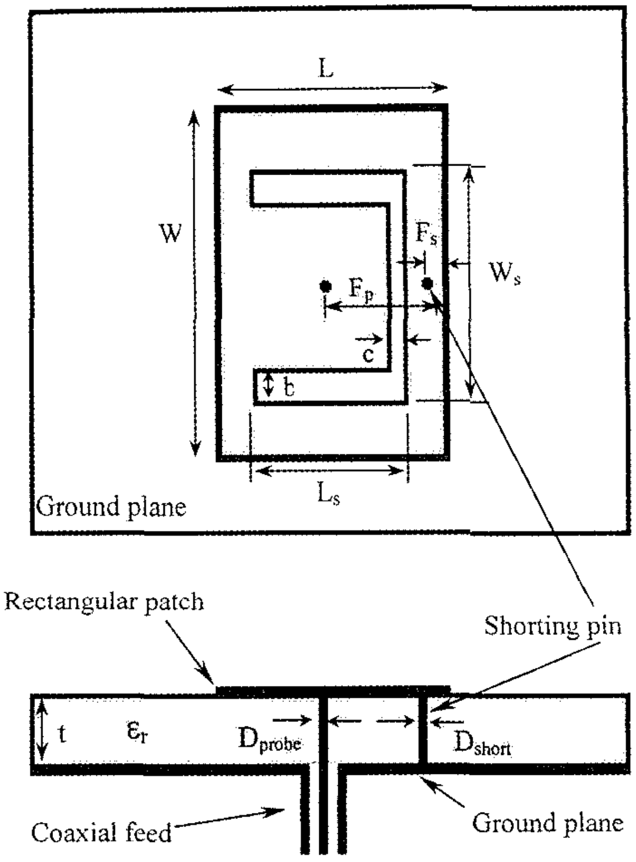

Figure 5. The geometry of the U-slot patch antenna with a shorting pin.

Table 5a. 900 MHz U-slot patches with shorting pins.

ε_r	Patch Dimensions (cm)	Thickness (cm)	Normalized Area*	BW
1.0 (1)	8.4×7.0	$2.8\ (0.084\lambda_0)$	0.21	30%
1.0 (1)	5.33×3.9	$3.3\ (0.099\lambda_0)$	0.056	15%
3.27	2.84×2.08	$3.6\ (0.108\lambda_0)$	0.022	10%
4.5	2.84×2.08	$3.3\ (0.099\lambda_0)$	0.022	11%

*Normalized with respect to the U-slot patch with $\varepsilon_r = 1.0$, area (21.97 cm × 12.45 cm = 273.53 cm^2) from [4].

Table 5b. Design parameters for 900 MHz U-slot patches with shorting pin (all dimensions in cm).

	$\varepsilon_r = 1.0$ (1)	$\varepsilon_r = 1.0$ (2)	$\varepsilon_r = 3.27$	$\varepsilon_r = 4.5$
W	8.4 ($0.252\lambda_0$)	5.33 ($0.016\lambda_0$)	2.84 ($0.0085\lambda_0$)	2.84 ($0.0085\lambda_0$)
L	7.0 ($0.210\lambda_0$)	3.9 ($0.012\lambda_0$)	2.08 ($0.0062\lambda_0$)	2.08 ($0.0062\lambda_0$)
W_s	7.47	1.8	0.96	0.96
L_s	4.67	2.93	1.22	1.22
b	2.1	0.65	0.17	0.17
c	0.47	0.32	0.17	0.17
F_p	6.8	3.6	1.98	1.88
F_s	0.47	0.075	0.34	0.245
d_p	0.47	0.3	0.2	0.4
d_s	0.93	0.15	0.68	0.49
h	2.8 ($0.084\lambda_0$)	3.3 ($0.099\lambda_0$)	3.6 ($0.108\lambda_0$)	3.3 ($0.099\lambda_0$)

Table 6a. Two-layer L-probe measurement results.

ε_r	Patch Dimensions (mm)	Thickness (mm)	f_0 (GHz)	Normalized f_0	BW	Gain
1.0	15.0 × 13.0	6.0 ($0.15\lambda_0$)	7.66	1.0	36%	6.5 dBi
2.32	15.0 × 13.0	6.58 ($0.14\lambda_0$)	6.3	0.82	36%	4.5 dBi

Table 6b. Design parameters for L-probe patches (all dimensions in mm).

	$\varepsilon_r = 1.0$	$\varepsilon_r = 2.32$
W	15.0 ($0.383\lambda_0$)	15.0 ($0.315\lambda_0$)
L	13.0 ($0.332\lambda_0$)	13.0 ($0.273\lambda_0$)
L_p	7.0	7.6
D	3.0	3.0
t_1	–	5.0
t_2	–	1.58
$t = t_1 + t_2$	6.0 ($0.15\lambda_0$)	6.58 ($0.14\lambda_0$)
d_{probe}	1.0	1.0

In Case 1, the patch area was 21% of the regular U-slot patch, and the impedance was 30%. In Case 2, the patch area was only 5.6% of the regular U-slot patch, and the impedance bandwidth was 15%. It should be pointed out that in Figure 5, the shorting pin and the feed are placed at opposite sides of the patch. If the pin is placed close to the feed, which is the case for the rectangular patch (with no U-slot) [11], the antenna fails to function properly.

3. Measurement Results

3.1 L-Probe-Fed Patch Antenna on a Microwave Substrate

Two L-probe-fed patch antennas were fabricated and tested. One was a single-layer geometry, with all foam substrate, and the other was a two-layer configuration, as shown in Figure 2, with $\varepsilon_r = 2.32$. These antennas were designed to operate at a higher frequency (instead of 900 MHz), to suit the equipment capabilities in our laboratory. The dimensions of both patches were the same: 15 mm × 13 mm. The measurement results obtained from these two antennas are presented in Table 6a, and the design parameters are presented in Table 6b. It is seen that by replacing the top layer of foam with a microwave substrate with $\varepsilon_r = 2.32$, there was an 18% decrease in frequency, yet the bandwidth remained 36%. However, there was a 2 dBi decrease in gain when a microwave substrate was used. For both antennas, wideband performance was maintained by using a total substrate thickness of $0.14\lambda_0$ - $0.15\lambda_0$. The measured and simulated VSWR curves and the measured gain curve are shown in Figure 6. While not matching exactly, the measured and simulated VSWR were in qualitative agreement. The measured E-plane and H-plane far-field radiation patterns are

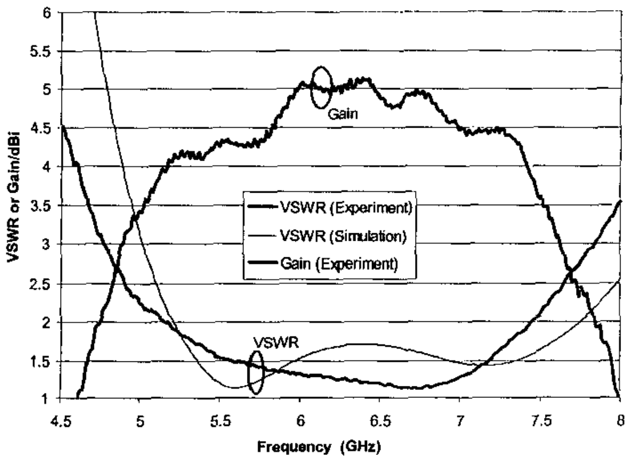

Figure 6. The simulated and measured VSWR and measured gain for the L-probe-fed patch antenna with $\varepsilon_r = 2.32$.

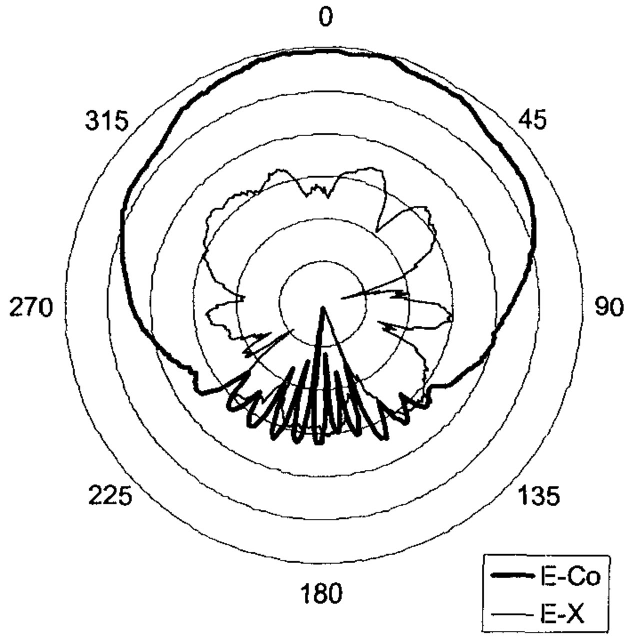

Figure 7a. The E-plane radiation patterns of the L-probe-fed patch antenna with $\varepsilon_r = 2.32$ at 6.285 GHz (one division = 10 dB).

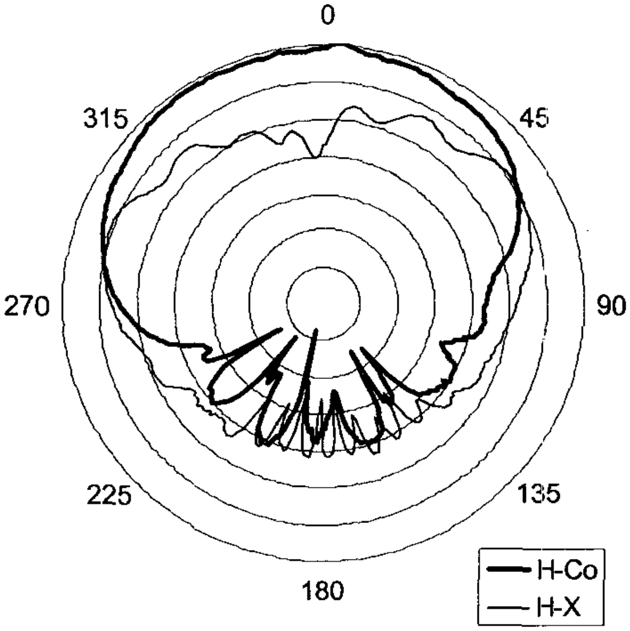

Figure 7b. The H-plane radiation patterns of the L-probe-fed patch antenna with $\varepsilon_r = 2.32$ at 6.285 GHz (one division = 10 dB).

shown in Figure 7. In the E plane, the cross-polarization was 20 dB below the co-polarization in all directions. In the H plane, the cross-polarization was greater than 20 dB below the co-polarization in the broadside direction. However, as the angle off of broadside was increased, the cross-polarization level increased until it was larger than the co-polarization, at approximately 50°. The radiation patterns were stable across the pass band of the antenna.

3.2 U-Slot Patch Antenna with a Shorting Wall on a Microwave Substrate

A U-slot patch antenna with a shorting wall was fabricated on a microwave substrate with a dielectric constant of $\varepsilon_r = 4.4$. The center frequency of the antenna was $f_0 = 2.5915\,\text{GHz}$. Figure 8 shows the measured and simulated VSWR plots for the U-slot patch antenna on a microwave substrate. While in qualitative agreement with the simulation results, the measured VSWR curve was greater than two over the frequency range from 2.58 GHz to 2.9 GHz. The measured input impedance is shown in Figure 9. The reactive portion of the input impedance was large, causing a mismatch between the frequencies of 2.58 GHz and 2.9 GHz. If this mismatch can be tolerated, the measured bandwidth was 28.5%. The design parameters for this antenna were as follows (refer to Figure 3): $W = 14\,\text{mm}$, $L = 14\,\text{mm}$, $W_s = 9\,\text{mm}$, $L_s = 12\,\text{mm}$, $b = d = 1\,\text{mm}$, $c = 2\,\text{mm}$, $F = 2\,\text{mm}$, $d_{probe} = 1\,\text{mm}$, and the thickness was $h = 12.1\,\text{mm}$. The antenna is a square patch with sides

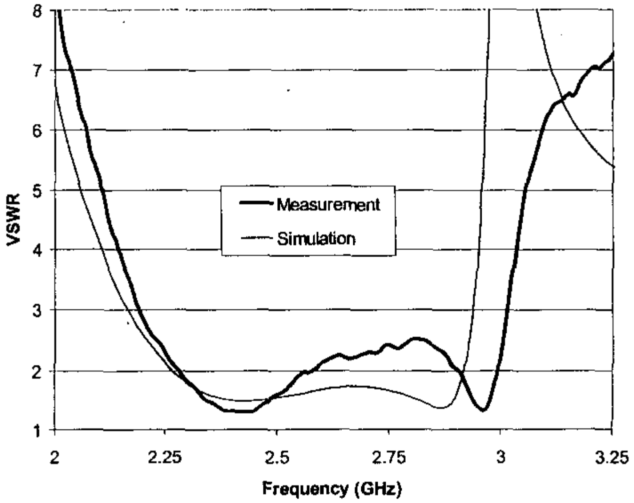

Figure 8. The simulated and measured VSWR for the U-slot patch antenna with a shorting wall and $\varepsilon_r = 4.4$.

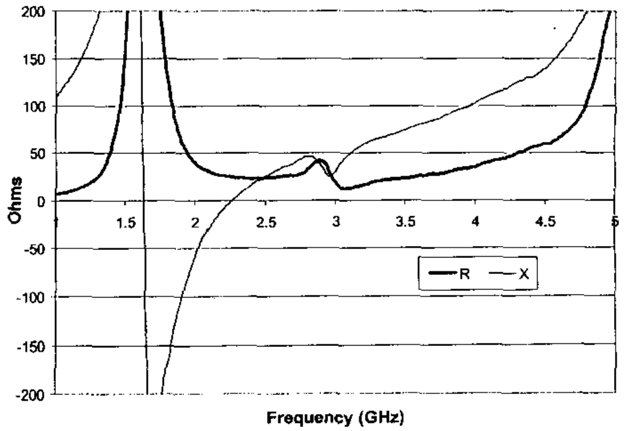

Figure 9. The measured input impedance for the U-slot patch antenna with a shorting wall and $\varepsilon_r = 4.4$.

measuring $0.121\lambda_0$ and a thickness of $0.105\lambda_0$. The area occupied by the patch is $0.0146\lambda_0^2$, a 94% area reduction when compared to a square half-wave patch.

3.3 U-Slot Patch Antenna with a Shorting Pin

To measure the characteristics of the U-slot patch antenna with a shorting pin, one such antenna was fabricated on a foam substrate ($\varepsilon_r = 1.06$). This antenna was designed for a center frequency of approximately 4 GHz. The patch was an 18 mm by 15 mm rectangle, supported by a 7 mm-thick foam substrate. Figure 10 shows the measured VSWR curve and the curve obtained from simulation, as well as the measured gain when the thickness was $h = 7\,\mathrm{mm}$. The bandwidth ($\mathrm{VSWR} \le 2.0$) obtained from simulation was 30%. For $h = 7\,\mathrm{mm}$, the measured VSWR curve exceeded two slightly in a small range of frequencies (3.75 - 4.05 GHz). Figure 11 shows the measured VSWR curve for $h = 9\,\mathrm{mm}$. The bandwidth ($\mathrm{VSWR} \le 2.0$) was 28%. The average gain was 2 dBi, and was measured at 52° from the broadside direction. Figure 12 shows the measured co-polar and cross-polar E- and H-plane patterns. The patterns were observed to be stable across the $\mathrm{VSWR} \le 2.0$ band. It is seen that the co-polar radiation was strongest at $\theta \approx 52°$ from the broadside. Such a pattern is desirable for indoor wireless networking applications: the patch antenna is mounted on the ceiling, and its radiation is beamed at $\theta \approx 52°$ from the vertical. The design parameters were as follows (refer to Figure 5): $W = 18\,\mathrm{mm}$, $L = 15\,\mathrm{mm}$, $W_s = 16\,\mathrm{mm}$, $L_s = 10\,\mathrm{mm}$, $b = 4\,\mathrm{mm}$, $c = 4.5\,\mathrm{mm}$, $F_s = 1.0\,\mathrm{mm}$, $F_p = 14.5\,\mathrm{mm}$,

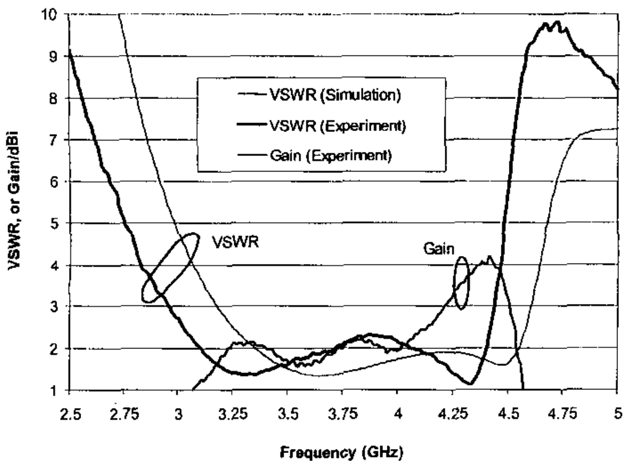

Figure 10. The simulated and measured VSWR and measured gain for the U-slot patch antenna with a shorting pin.

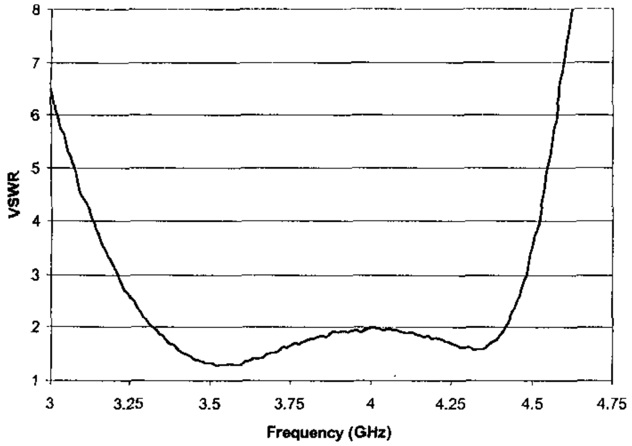

Figure 11. The measured VSWR for the U-slot patch antenna with $h = 9\,\mathrm{mm}$.

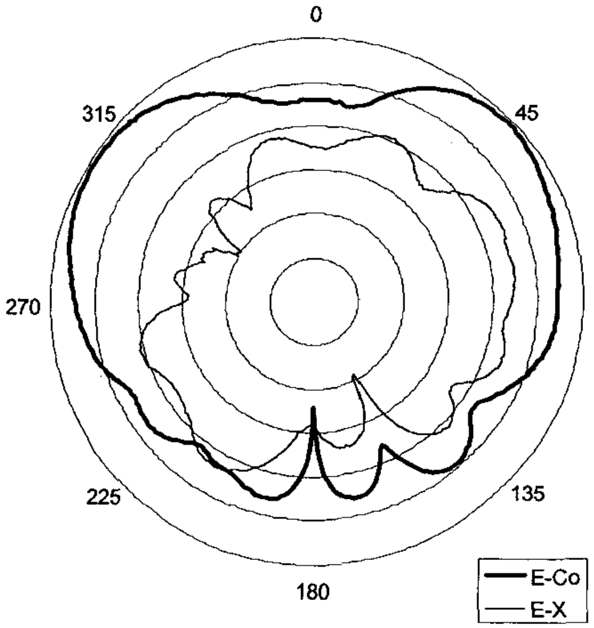

Figure 12a. The E-plane radiation patterns of the U-slot patch antenna at 3.755 GHz (one division = 10 dB).

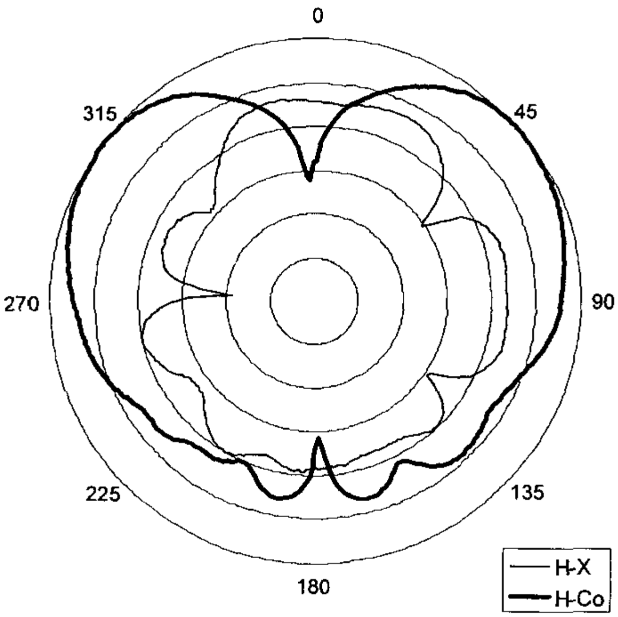

Figure 12b. The H-plane radiation patterns of the U-slot patch antenna at 3.755 GHz (one division = 10 dB).

$d_{probe} = 1$ mm, $d_{short} = 2$ mm, and the thickness was $h = 7$ mm. In terms of wavelength, the patch is a $0.200\lambda_0$ by $0.240\lambda_0$ rectangle supported by a foam substrate $0.093\lambda_0$ thick. The area occupied by the patch is $0.048\lambda_0^2$, 80.8% smaller than the area of a square half-wave patch antenna.

4. Concluding Remarks

In this paper, a number of designs for small-size wide-bandwidth patch antennas have been presented. These designs combine the wideband U-slot and L-probe-fed patches with several size-reduction techniques: utilizing a microwave substrate material, the addition of a shorting wall, and the addition of a shorting pin. Simulations were presented, and three of the simulated designs were verified by experiment. It was found that the resonant length of the patch can be reduced to as small as $0.1\lambda_0$ while maintaining greater than 20% bandwidth. The pattern characteristics of the measured antennas were found to be stable across their respective pass bands.

5. Acknowledgment

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Introducing the Feature Article Authors

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He was the Technical Program Chair of the Progress in Electromagnetics Research Symposium (PIERS 1997), held in Hong Kong in January, 1997, and the General Vice Chair of the 1997 Asia-Pacific Microwave Conference, held in Hong Kong in December, 1997. Professor Luk received an international best paper award, the Japan Microwave Prize, at the 1994 Asia Pacific Microwave Conference held in Chiba, Japan, in December, 1994. He was awarded the Croucher Foundation Senior Research Fellow in Hong Kong in 2000. He received the Applied Research Excellence Award from the City University of Hong Kong in 2001. Professor Luk is a Fellow of the Chinese Institute of Electronics, PRC, a Fellow of the Institution of Electrical Engineers, UK, and a Member of the Electromagnetics Academy, USA.

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