

A NOVEL BROADBAND DESIGN OF A PRINTED RECTANGULAR SLOT ANTENNA FOR WIRELESS APPLICATIONS

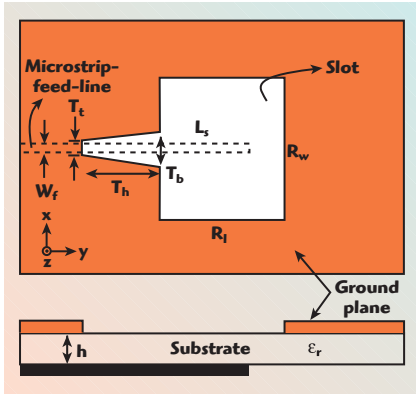
A novel compact rectangular slot antenna printed on a dielectric substrate and fed by a 50 Ω microstrip is presented. Both impedance and radiation characteristics of this antenna are studied. Experimental results indicate that a 2:1 VSWR bandwidth of 3.95 GHz is achieved at operating frequencies from approximately 1.83 to 5.78 GHz, which is approximately five times that of a conventional printed wide-slot antenna. The good radiation characteristics of the constructed prototype antenna are also shown in this article. The broadband bandwidth and good radiation properties of the proposed design are suitable for most wireless applications.

The conventional printed wide-slot antenna has an operating bandwidth on the order of 10 to 20 percent.^{1,2} Because modern wireless applications often require broadband operation, some printed wide-slot antennas for broadband operation have been reported.³⁻⁶ A square slot antenna,³ with a fork-shaped microstrip feed structure, was investigated for broadband operation. The fork-shaped microstrip feed structure was applied to a printed round corner rectangular wide-slot antenna⁴ and a broadband design was achieved. A semicircular slot antenna⁵ with a protruded small rectangular slot was excited by a 50 Ω microstrip. Recently, an isosceles triangular slot antenna⁶ with a small rectangular slot for broadband operation was

proposed, and has shown an impedance bandwidth of 77 percent for a 2:1 VSWR. However, the impedance bandwidth of this antenna design is still not enough to cover most wireless applications. It is important to enhance the impedance bandwidth of microstrip-fed wide-slot antennas.

In this article, a novel design of a microstrip-fed, printed rectangular slot antenna, with a small trapezoidal slot tuning for wireless applications, is proposed. The radiation characteristics of such a design are also

WEN-SHAN CHEN
Southern Taiwan University of Technology
Tainan Hsien, Taiwan, ROC



▲ Fig. 1 The geometry of the proposed antenna.

investigated. The proposed antenna can be easily excited by a 50Ω microstrip printed on an FR-4 dielectric substrate, and good impedance matching can be obtained for operation at frequencies within the wireless communications system bands. A comparison of the proposed design with a corresponding isosceles triangular slot antenna⁶ is also given.

ANTENNA DESIGN

Figure 1 shows the geometry of the novel broadband rectangular slot antenna printed on a dielectric substrate. In this study, the dielectric substrate material is FR-4 with a thickness $h = 1.6$ mm and relative permittivity $\epsilon_r = 4.4$. For design convenience, the proposed antenna is fed by a 50Ω microstrip, printed on the dielectric substrate. The microstrip, with a width $W_f = 3.0$ mm, is placed on the centerline of the rectangular slot (y axis). In order to achieve

broadband operation, a small trapezoidal slot is placed on the feed side of the rectangular slot. The primary slot is the rectangular slot, which has a horizontal width of R_w and a vertical length of R_l . The small trapezoidal slot has a top width T_t , a bottom width T_b and a vertical height T_h . The two slots are etched in the ground plane that is on the opposite side of the dielectric substrate. The design parameters of the proposed antenna can easily be determined. The perimeter of the polygonal slot at the lowest operating frequency required is given by

$$L_{\text{perimeter}} = T_t + 2\sqrt{T_h^2 + \left(\frac{T_b - T_t}{2}\right)^2} + 2R_l + 2R_w - T_b \quad (1)$$

The perimeter of the polygonal slot can be determined to be approximately two guided wavelengths in the slotline at the lowest operating frequency. Then, by fine tuning the small trapezoidal slot and adjusting the length of the 50Ω microstrip feed-line, a new resonant mode can be excited in the proximity of the fundamental resonant mode and good impedance matching over a broad frequency range can be obtained.

EXPERIMENTAL RESULTS AND DISCUSSION

The proposed antennas were simulated with the High Frequency Structure Simulator (HFSS) from Ansoft and the prototypes were fabricated and

measured with a HP-8720ES network analyzer. The first parameter under design was the size of the rectangular slot. For the designs shown in Table 1, the ratio of R_l to R_w is approximately 1:1.5. To achieve the requirements of wireless applications, the perimeter of the polygonal slot, $L_{\text{perimeter}}$, was chosen to be approximately $2\lambda_g$, which corresponds to approximately $2\lambda_g$ at 1.83 GHz (λ_g is

the guided wavelength at the lowest frequency of operation). Table 2 shows $L_{\text{perimeter}}$ and bandwidth of all the antennas studied. Figure 2 shows the measured and simulated return loss results of the proposed antenna 1 with an impedance bandwidth of 104 percent for $\text{VSWR} = 2$. The impedance bandwidth obtained with the present design is approximately five times that of a conventional printed wide-slot antenna. From Tables 1 and 2, for antenna 1 with the widest bandwidth, the ratio of T_b to R_w is about 1:4 and the ratio of T_t to T_b is about 1:8. The optimal microstrip feed-line length L_s was chosen to achieve a good impedance match for the constructed prototype. By observing the influence of various parameters on the antenna performance, it was found that the dominant factor in the proposed antenna designs for wireless communications applications is the perimeter of the polygonal slot in terms of λ_g . From that numerical experiment, λ_g can be calculated as

$$\lambda_g = \frac{\lambda_0}{\sqrt{\epsilon_{r,\text{eff}}}} \quad (2)$$

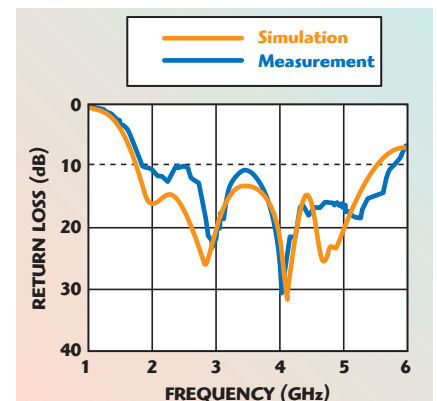
where the $\epsilon_{r,\text{eff}}$ is determined by

$$\epsilon_{r,\text{eff}} = \frac{\epsilon_r + 1}{2} \quad (3)$$

Then, the lowest frequency (f_L) relative to a half of the $L_{\text{perimeter}}$ is formulated by

$$f_L \approx \frac{C_0}{L_{\text{perimeter}}} \left(\frac{1}{\epsilon_{r,\text{eff}}} \right)^{\frac{1}{2}} \quad (4)$$

where C_0 is the speed of light in free space.



▲ Fig. 2 Measured and simulated loss of antenna 1.

TABLE I

DIMENSIONS OF THE PROPOSED ANTENNAS

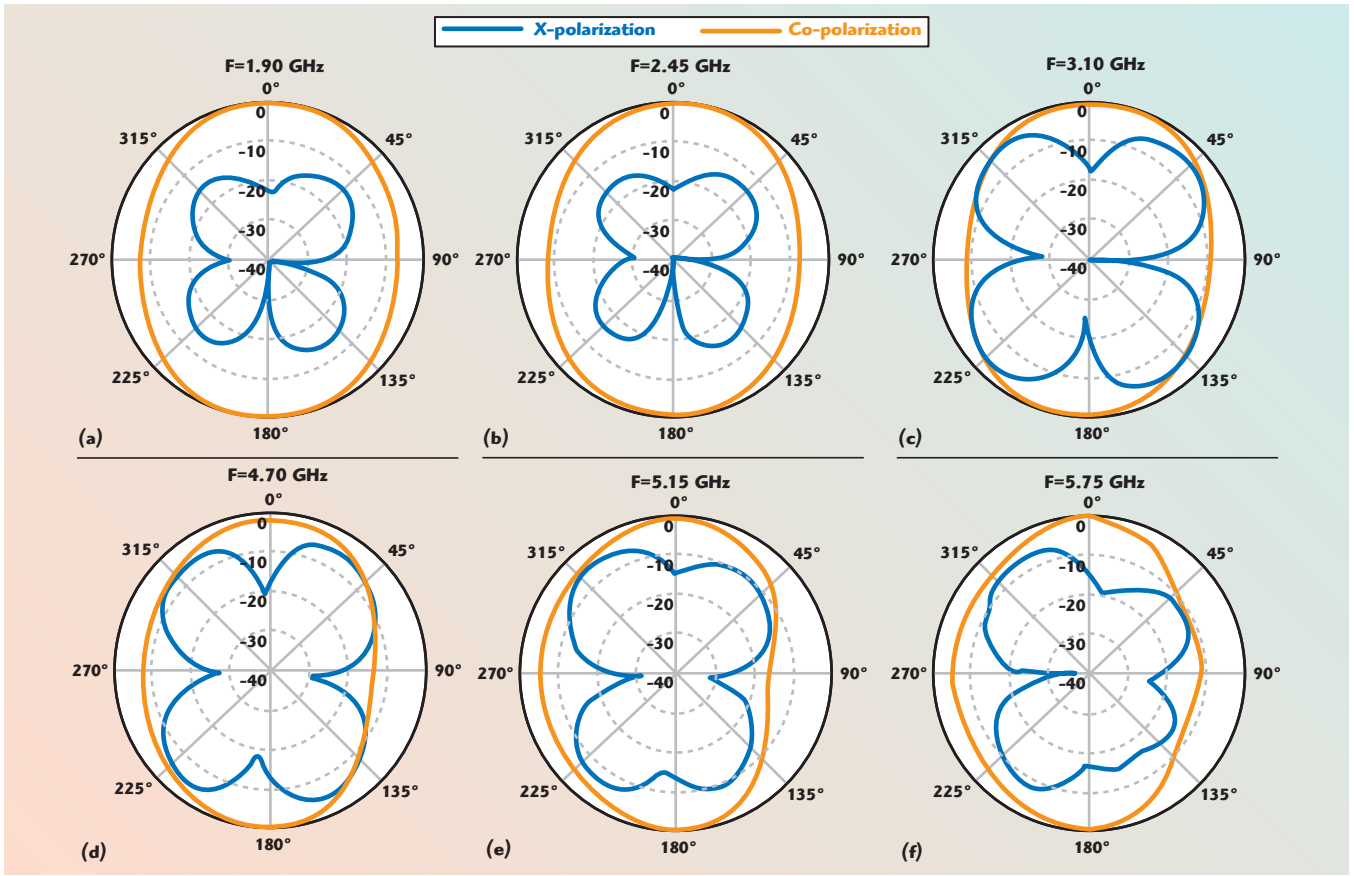
	T_t	T_b	T_h	R_l	R_w	L_s
Antenna 1	1.40	11.0	19.5	30	45	46
Antenna 2	4.60	7.0	19.5	30	45	46
Antenna 3	4.60	11.0	23.7	30	45	46

(dimensions in mm)

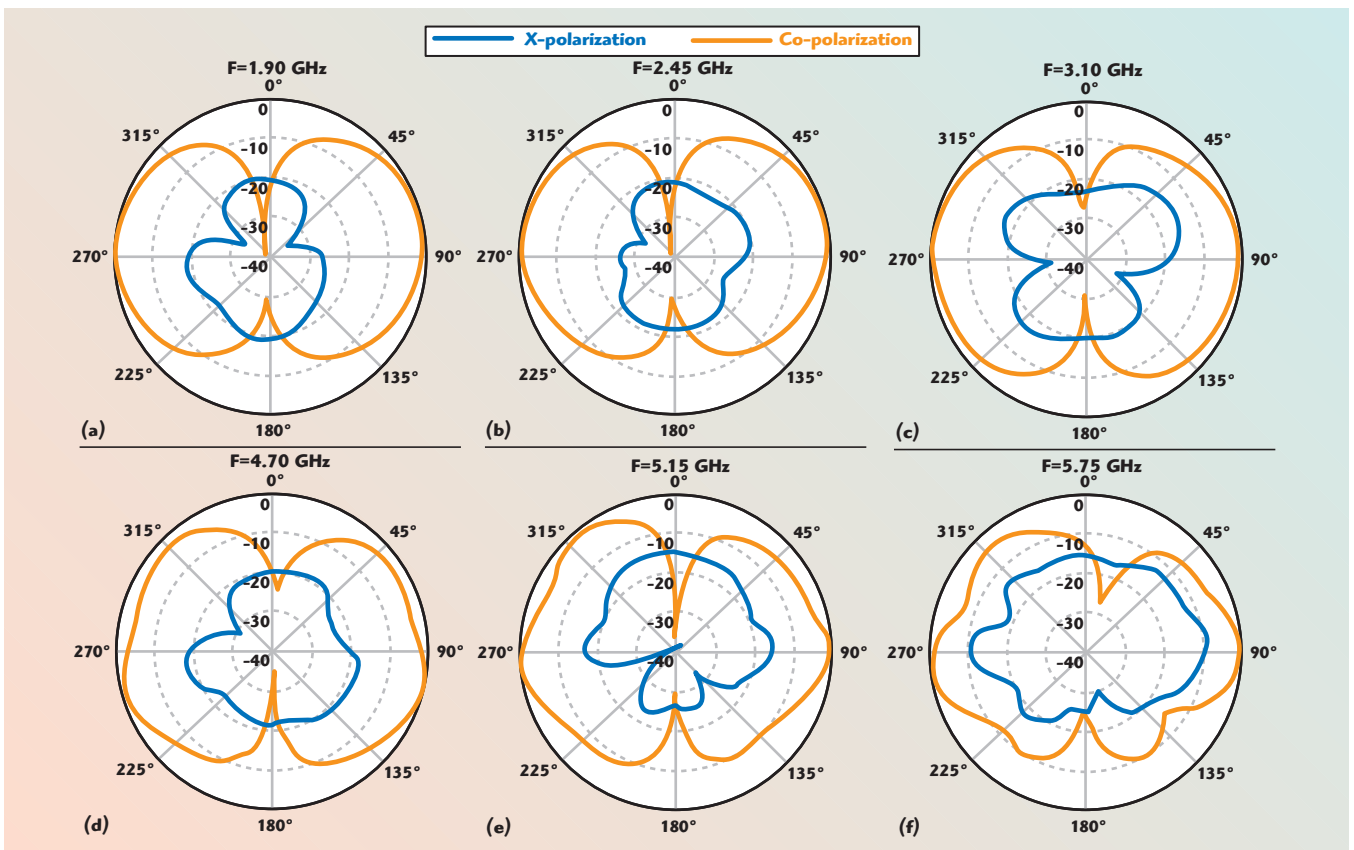
TABLE II

CHARACTERISTICS OF THE PROPOSED ANTENNAS

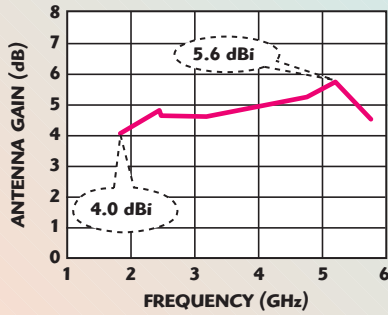
	$L_{\text{perimeter}}$ (mm)	f_L (calculated) (GHz)	f_L (GHz)	f_H (GHz)	BW (%)
Antenna 1	180.4	2.02	1.83	5.78	104
Antenna 2	186.6	1.96	1.95	4.08	71
Antenna 3	191.2	1.91	2.13	6.00	95



▲ Fig. 3 Measured far-field radiation patterns for antenna 1 in the x - z plane.



▲ Fig. 4 Measured far-field radiation patterns for antenna 1 in the y - z plane.



▲ Fig. 5 Measured peak gain of antenna 1.

For the reasons mentioned above, antenna 1 is the optimum design. Its radiation characteristics have been measured in the STUT Anechoic Chamber. **Figures 3** and **4** show the measured radiation patterns in the x-z plane and y-z planes, respectively, at $F = 1.90, 2.45, 3.10, 4.70, 5.15$ and 5.75 GHz. Antenna 1 is suitable for GSM (1900 to 1990 MHz), PCS (1900 to 1990 MHz), IMT-2000 (1920 to 2170 MHz), Bluetooth (2400 to 2484 MHz), IEEE 802.16a/e, IEEE 802.11b/g (2400 to 2484 MHz), IEEE 802.15.3a (UWB), PHS (1905 to 1915 MHz), PACS (1930 to 1990 MHz), UMTS (Regular 1, 2, 3), IEEE 802.11a (5150 MHz) and HIPERLAN /1 /2 (5150 MHz). It is also noted that, for antenna 1, the radiation patterns in the x-z plane and y-z plane are good, which makes the proposed antenna suitable for practical applications. The measured peak antenna gain for antenna 1 is also presented in **Figure 5**. It shows a peak gain of approximately 5.6 dBi; the gain variation is observed to be less than 1.6 dB.

A comparison of the proposed design with a corresponding isosceles triangular slot antenna⁶ is given in **Table 3**. It shows a small gain variation for the proposed antenna design compared to that of the isosceles triangular slot antenna. In addition, the

104 percent impedance bandwidth of the proposed antenna is larger than that of the isosceles triangular slot antenna.

CONCLUSION

A microstrip-fed, printed rectangular slot antenna with a small trapezoidal slot for broadband operation has been implemented. Experimental results show that the impedance bandwidth of a printed rectangular slot antenna can be significantly improved by selecting the proper dimensions of the small trapezoidal slot and the perimeter of the polygonal slot. The results, obtained in this study, show that the impedance bandwidth for the proposed antenna is approximately 104 percent (1.83 to 5.78 GHz) for a 2:1 VSWR. In addition, the proposed antenna also shows a compact structure and a simple feeding structure, compared to a corresponding printed wide-slot antenna. The design of this proposed antenna, with broadband operation, is suitable for most wireless applications. ■

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TABLE III

CHARACTERISTICS OF THE PROPOSED ANTENNA AND THE ISOSCELES TRIANGULAR ANTENNA

	Maximum Antenna Gain (dB)	Gain Variation (dB)	f_L (GHz)	f_H (GHz)	BW (%)
The isosceles triangular slot antenna ⁶	5.9	1.8	2.33	5.23	77
The proposed antenna (Antenna 1)	5.6	1.6	1.83	5.78	104

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Wen-Shan Chen received his BS degree in electronic engineering technology from the National Taiwan Institute of Technology (now the National Taiwan University of Technology) and his PhD degree from National Sun Yat-Sen University, Kaohsiung, Taiwan, ROC, in 2001. From 2001 to 2002, he was an assistant professor at the Chien-Kuo Institute of Technology, Changhua, Taiwan, ROC. He is currently an assistant professor of electronics engineering at the Southern Taiwan University of Technology, Tainan, Taiwan, ROC. His research interests include antenna design, RF and microwave circuits.