Tapered Slot Antenna with Squared Cosine Profile for WLAN Applications

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***Abstract*-This paper presents a tapered slot antenna with squared profile for wireless local area network (WLAN) applications. The proposed antenna is composed of a feed line, a microstrip-slotline transition and a radiating slot by using squared profile. The measured results for the optimized design show the bandwidths for the $S_{11} \leq -10$ dB are about 830 MHz (from 1.97 to 2.80 GHz) and 2850 MHz (from 3.97 to 6.82 GHz), which can cover the 2.4/5.2/5.8 GHz WLAN operating bands and 2.5/5.5 GHz for worldwide interoperability for microwave access (WiMAX) bands. The performances of the proposed antenna are demonstrated along with the measured and simulated results.**

I. INTRODUCTION

As wireless communications systems, especially, the wireless local area network (WLAN) and worldwide interoperability for microwave access (WiMAX) communications have developed and expanded rapidly, the many types of antennas to be with wideband or multiband performances to satisfy WiMAX (2.5-2.69 GHz, 3.4-3.69 GHz and 5.25-5.85 GHz) and WLAN (2.4-2.484 GHz, 5.15-5.35 GHz and 5.725-5.825 GHz) have been proposed. It was found that the planar antennas still play a key role in wireless communications systems. The tapered slot antennas (TSAs) are typical examples of planar antennas. The designs of several different TSA have been reported such as linearly tapered slot antenna (LTSA), exponentially tapered slot antenna (ETSA or Vivaldi antenna), constant width slot antenna (CWSA) and broken linearly tapered slot antenna (BLTSA) [1]. TSAs offer a wide operating bandwidth depending on its tapered radiator profile. Compared to other wideband or multiband antennas, tapered slot antennas have nearly symmetrical radiation patterns and moderate gain. They also have the advantage of easy fabrication and geometric simplicity. Because of their potential modern wideband or multiband applications, TSAs have been increasingly studied in recent years [2]-[3]. The performance of the antennas can be improved by change the radius of exponential taper curvature in the case of Vivaldi antenna [4] or design of new tapered profile [5].

In this paper, the new tapered profile of TSA, which can operates in WLAN applications, is proposed. By using squared cosine profile, the antenna can provides appropriate characteristics and can candidates with exponential profile of TSA. The performance of the antenna is verified by experimental data which is obtained from fabrication and measurement. The CST microwave studio software is employed to perform the design and optimization processes. Parametric studies and radiation characteristics are proposed. The measured results of the fabricated prototype are compared with the simulated ones, which show that the antenna can cover 2.4/5.2/5.8 WLAN bands.

II. ANTENNA CONFIGURATION

Fig.1. shows the geometry of the proposed TSA, which is printed on the inexpensive FR4 substrate with the thickness of h = 1.6 mm and the relative permittivity $\varepsilon_r = 4.4$. The basic antenna structure consists of a feed line, a microstrip-slotline transition and a radiating slot. The total size of the antenna is about $90 \times 63 \times 1.6\,\mathrm{mm}^3$ ($L_a \times W_a \times h$). As shown in Fig.1, the microstrip-slotline transition is connected to the feed line and the radiating slot, respectively. The microstrip-slotline transition can offer a frequency independent transition characteristic of electromagnetic fields from microstrip feed line to slotline, and vice versa [6]. The squared cosine profile of the radiating slot is defined by equation,

$$x = -C_1 \cos^2\left(\frac{\pi y}{W}\right) + C_2 \qquad (1)$$

where C_1 is a scale factor and C_2 is offset factor of tapered profile, which can be calculated by given the start point (x_1, y_1) and end point (x_2, y_2) of tapered profile. The taper length, L is $x_2 - x_1$ and the aperture width W is $2(y_2 - y_1) + W_s$, where W_s is the slotline width.

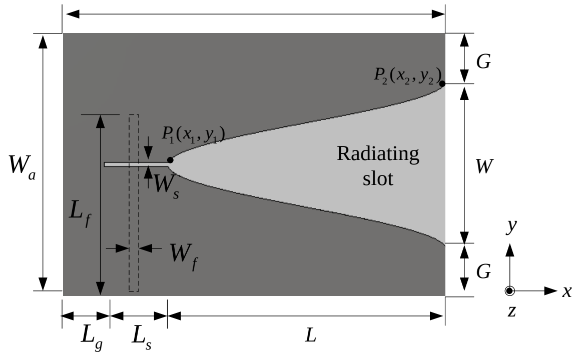


Figure 1. Geometry of the proposed antenna.

The squared cosine profile can be expressed by varying $W_s/2 \le y \le W/2$. The width of the antenna W_a is set to close the half free space wavelength at 2.4 GHz, which is lowest frequency for antenna design. To investigate the performance of the proposed antenna, the commercially simulation software CST was used for numerical analysis and to obtain the optimal antenna geometric parameters as summarized in Table I.

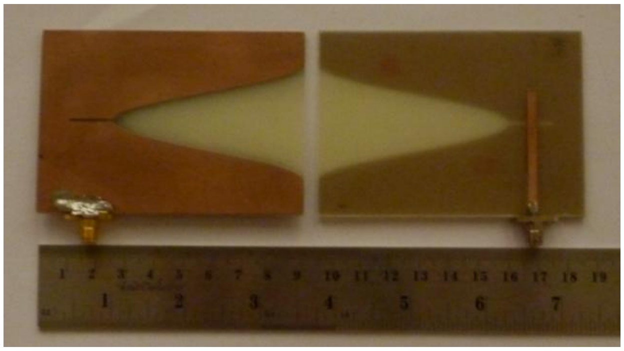


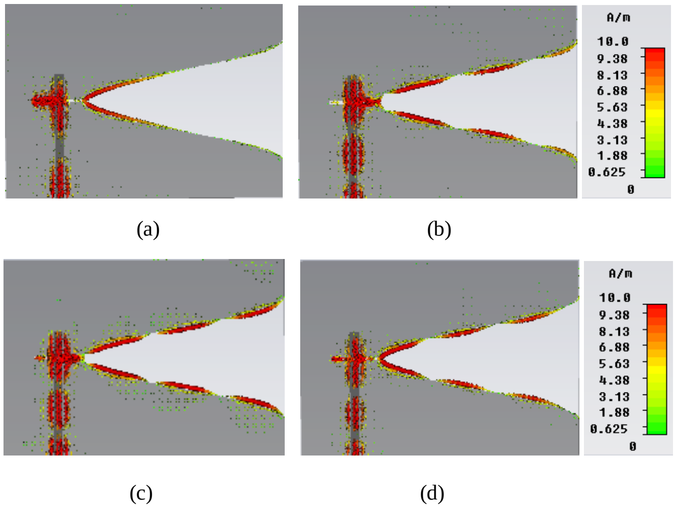
Figure 2. Photograph of fabricated antenna.

TABLE I. OPTIMAL PARAMETERS OF THE TSA.

Parameters	Values (mm)	Parameters	Values (mm)
W_s	1	L_g	10
W_a	63	L_s	15
L_a	90	W_f	3
W	40	L_f	40
L	65	G	11.5

III. RESULTS AND DISCUSSION

Based on the design dimensions as shown in Table I, an experimental prototype of the proposed antenna was fabricated as illustrated in Fig. 2. By using CST software, the surface current distributions on the TSA with squared cosine profile at 2.4 GHz, 5.2 GHz, 5.5 GHz and 5.8 GHz are shown in Fig.3. As shown in Fig. 3(a), the surface current at 2.4 GHz is significantly distributed along the end of slotline and narrow part of squared cosine profile. The current distribution as shown in Fig. 3(b)-(c), it is observed that the current distribution is relatively constant at 5.2 GHz, 5.5 GHz and 5.8 GHz. It may be concluded that the pattern at these three frequencies will be similar to each other. Fig. 4 shows measured and simulated return loss of proposed antenna. The measured impedance bandwidths at $S_{11} \le -10$ dB are about 830 MHz (1.97-2.80 GHz) and 2850 MHz (3.97-6.82 GHz), which can cover the WLAN bands in the 2.4 GHz (2.4-2.484 GHz), 5.2 GHz (5.15-5.35 GHz) and 5.8 GHz (5.725-5.825 GHz). Moreover, the bandwidths of the proposed antenna can also cover the WiMAX bands in the 2.5 GHz (2.5-2.69 GHz) and 5.5 GHz (5.25-5.85 GHz). As shown in this figure, the agreement between the simulated and measured results is achieved. The disagreement is mainly caused by the fabrication error.



(a) (b)

(c) (d)

Figure 3. Simulated current distributions of the proposed antenna at (a) 2.4 GHz, (b) 5.2 GHz, (c) 5.5 GHz, (d) 5.8 GHz.

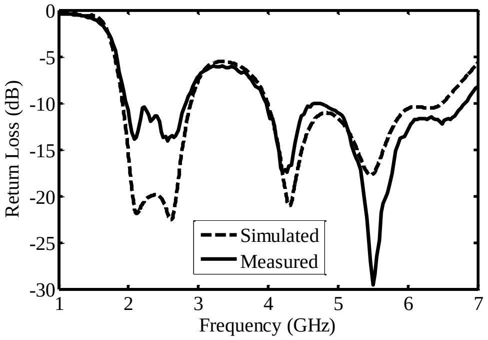


Figure 4. Measured and simulated return loss of proposed antenna.

Further, parametric studies are performed to understand the effects of various parameters and to optimize the final design. Fig. 5 shows the simulated return loss with different aperture widths, W = 36, 40, and 44 mm. As the aperture width is increased, it is seen that the impedance matching characteristics at lower resonant frequency is improved while the upper resonant frequency shows a worse matching with corresponding resonant frequency remaining unchanged. Next, the effect of the taper lengths L on the return loss is investigated by varying the taper lengths L = 55, 60, and 65 mm as illustrated in Fig. 6. As taper length L is increased, both lower and upper resonant frequencies are moved towards the lower frequency. This parameter controls the operating frequency bands. An important feature of the proposed antenna is the influence of the impedance matching caused from the coupling effect between microstrip-slotline transition and microstrip feed line. For this reason, the effects of feed line length L_f = 36, 38, 40, and 42 mm on the return loss of the proposed antenna are also studied and illustrated in Fig. 7. Large change due to the variation in L_f is observed. The impedance bandwidth changes significantly with varying the parameter L_f. This is due to the sensitive of the impedance matching to the parameter L_f.

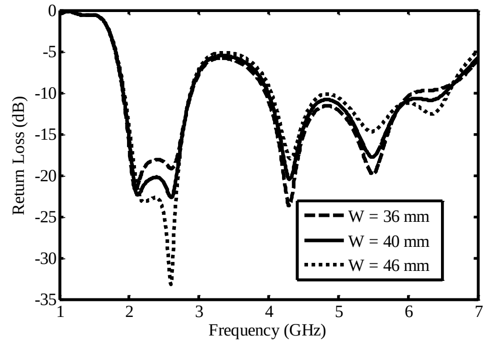


Figure 5. Simulated return loss for various aperture widths *W* of proposed antenna.

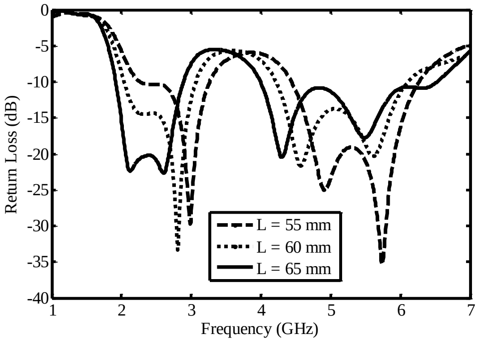


Figure 6. Simulated return loss for various taper lengths *L* of proposed antenna.

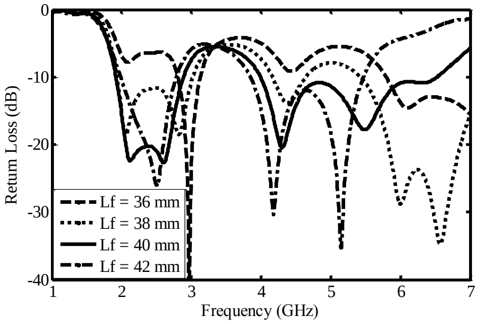
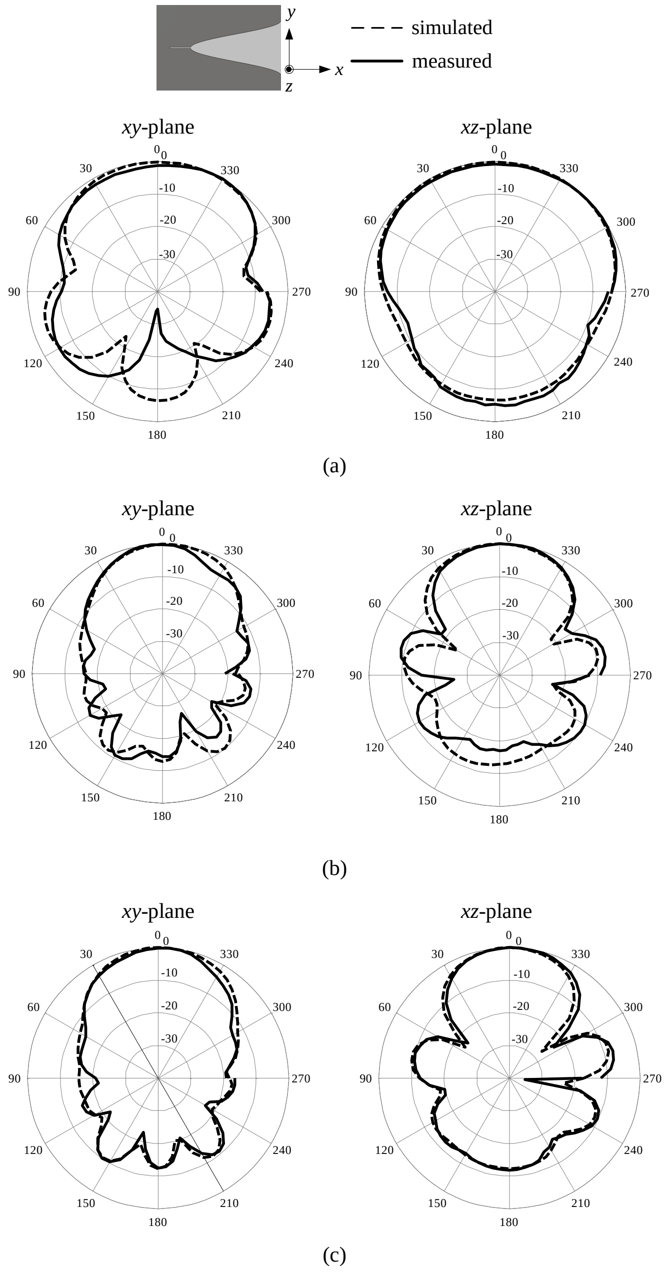


Figure7. Simulated return loss for various feed line lengths L_f of proposed antenna.

The measured and simulated radiation patterns of the proposed antenna in *xy*-plane and *xz*-plane at frequencies 2.4, 5.2, and 5.8 GHz are plotted in Fig. 8. As shown in the figure, the proposed antenna has endfire characteristic with the main lobe in the axial direction of the tapered slot (*x*-direction). It is observed that the radiation patterns of the proposed antenna are in symmetry. The peaks of measured antenna gains are about 3 dBi at 2.4 GHz and about 10 dBi at 5.2/5.8 GHz for WLAN applications.



(a)

(b)

(c)

Figure 8. Measured radiation patterns for the proposed antenna at (a) 2.4 GHz (b) 5.2 GHz and (c) 5.8 GHz.

IV. CONCLUSION

In this paper, the tapered slot antenna with squared cosine profile has been presented. The simulated and measured results in terms of return loss, radiation pattern and gain have been compared and analyzed, which show this antenna can support the 2.4/5.2/5.8 GHz WLAN bands and 2.5/5.5 GHz WiMAX bands. Moreover, the proposed antenna with squared profile has moderately high directivity and symmetrical radiation pattern. Therefore, it might be suitable for the WLAN applications.

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