Proceedings of Asia-Pacific Microwave Conference 2007

Designed Wide-Band Microstrip Line-Fed T-shaped Antenna on the Al_2O_3 Substrate

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Abstract*- Recently, there have been rapid and great developments in wireless communication, the operation frequency increase and the size of the microwave devices reduces gradually. Substrates play an important role in the design and fabrication of the small-size microwave devices, especially the dielectric constant and quality factor. In this study, we are tried to design the wide-band microstrip line antenna on ceramic substrate in order to reduce the size of fabricated antenna. High quality factor Al_2O_3 ceramic is adopted as the substrate and the influences of the structure (the metal of covering and the length of ground) are also investigated in this thesis. Due to the larger dielectric constant of Al_2O_3 ceramic (ε_r=9.8), the size of this antenna is small (25 mm × 20 mm). For the designed antenna, the resonance frequency is near 4.2 GHz, the optimum bandwidth is 760 MHz (18.1%), and the return loss (S_{11}) is –36.77 dB. The gain of fabricated antenna is acceptable for the application in the communication.

I. INTRODUCTION

In the past years, the communication had been rapid developments in the applications of wireless communication (WLAN) system [1, 2]. The antenna should be in planar form for the application in WLAN system [3]. The requirements of wide-band antenna are necessary for many applications, so printed monopole antennas with wide-band operation are in great demand. Recently, printed monopole antennas play an important role in wireless technology. The main reasons are low cost, small size, light weight, easy realization, and reasonably good performance, respectively [4, 5]. Printed microstrip patch and slot antennas have the potential to meet the above requirements due to their inherently planar structures. There are many designs that may be applied to wireless local area networks (WLAN), such antennas become good candidates when applied to wireless handheld terminals. The currently popular designs reported in [6] require a shorting pin for the ground connection inside the printed monopole antenna element. This increases the design complexity as well as the fabrication cost.

In this paper, a simpler type of printed monopole wide-band high-efficiency microstrip antenna is presented to support the IEEE802.11n wireless local area network bands (0.7–4.2 GHz). The antenna is constructed by a nonconductor-backed T-shaped strip with a microstrip feed line. Generally speaking, the single-band performance can be quite easily achieved for this type of antenna by tuning the length of individual segments of the T-shaped strip [7–9]. Using Al_2O_3 (the thickness is 0.635 mm) as the substrate of antenna and the screen-printing method as the fabrication technology, the size of antenna can be reduced due to the dielectric constant of Al_2O_3 ceramic is larger (ε_r=9.8). Because of high quality factor value of Al_2O_3 ceramic (Q×f=300,000), the return loss of the designed antenna will be reduced. Thus, in this research we will reveal that by careful adjusting the parameters, the proposed antenna will have the advantages of wide bandwidth, high return loss, and low profile. By printing method, the proposed antenna has been successfully designed and fabricated, and the fabricated antenna is suitable for the applications of Global Positioning System (GPS) (~4.2 GHz).

II. ANTENNA DESIGN AND FABRICATION

The design and fabrication procedures of proposed microstrip antenna were shown as Fig 1. The width and length of the microstrip line was according to the matching of 50Ω, using HFSS to design the parameters of this ceramic wide-band microstrip-line-fed T-shaped antenna. The mask is done according to the simulated patterns, and then using this mask to print the antenna pattern on the Al_2O_3 substrate by a screen printer. The printed pattern was fired in an oven under the condition (800°C/30 min). Finally, the SMA connectors were soldered to the antenna, and the characteristics of fabricated antenna were measured by an impedance analyzer (HP-8720).

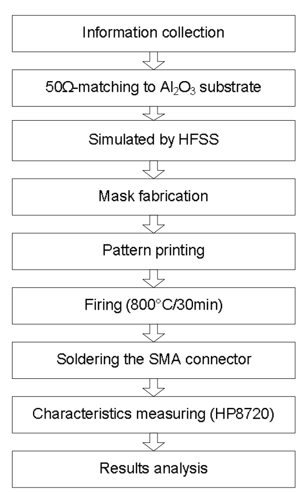

Figure 1. The fabrication flowchart.

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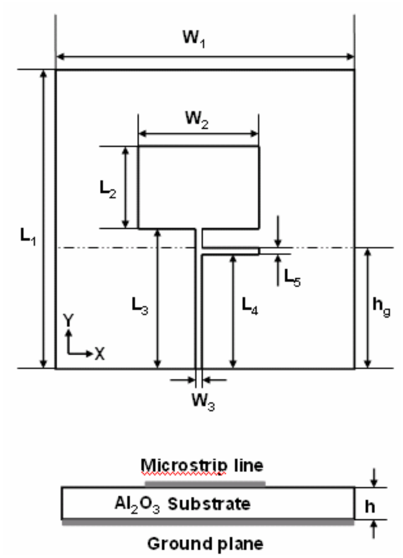


Figure 2. The geometry of the designed antenna.

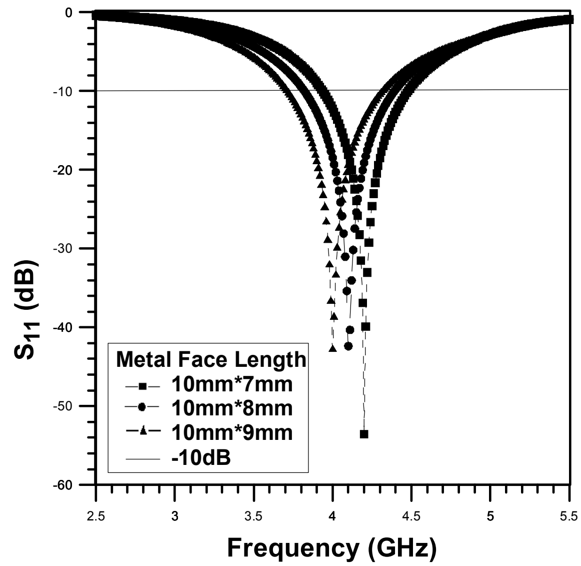


Figure 3. The simulated S_{11} of the designed antenna, as a function of L_2.

The geometry of the designed antenna was shown in Fig 2, and the structure was very simple. A rectangular antenna pattern was printed on an Al_2O_3 substrate (25 mm × 25 mm). The microstrip line length (0.6 mm × 12 mm) was printed on an Al_2O_3 substrate. The ground plane (W_1 x h_g, 25 mm × 10.45~11.05 mm) was printed on the other side of the substrate. The antenna pattern was fed by a 50Ω–matching microstrip feed line and its width was 0.6mm (w_3). The basic structure parameters of the antenna pattern were W_2=10 mm, L_2=7~9 mm, L_4=10.45 mm and L_5=0.6 mm.

III. Results and Discussion

Table I shows the simulated results of designed antenna, the length of ground (h_g) is fixed on 10.45 mm and the length of patch (L_2) is changed from 7 mm to 9 mm by a step 1 mm (with the size of W_2 x L_2 is fixed on 10 mm × 7 mm). The modulation of h_g will induce to the variation of antenna characteristics, including frequency, comparison bandwidth, and return loss. As the length of L_2 increases, the resonant frequency is shifted to lower value, the maximum return loss (S_{11}) decreases, and the bandwidth (BW, measured from the -10 dB) increases. It is found that the length of the metal covering (L_2) play an important role on the resonant frequency, return loss, and bandwidth of the designed antennas. Fig. 3 shows the operation frequencies of the designed antennas as a function of h_g. As Fig.3 shows, the longer length of L_2, the current path will increase, for that the resonant frequency will be shifted to lower value. However, the length of L_2 has no apparent influence on the S_{11} and BW values.

TABLE I
THE SIMULATION RESULTS OF ANTENNA,
THE LENGTH OF THE GROUND IS FIXED ON 10.45 MM

metal covering (W_2 mm×L_2 mm)	Frequency (GHz)	Return loss (dB)	BW (%)
10×7	4.2	-53.5	12.86
10×8	4.1	-42.38	13.90
10×9	4.0	-42.66	14.75

As the size of the metal covering is fixed on 10 mm × 7 mm, the length of ground (h_g) is changed from 10.45 mm to 11.05 mm by a step 0.2 mm. Table III shows the simulated results due to the length variation of h_g. As the length of h_g increases, the transmission characteristics of designed antenna has been changed apparently. The resonant frequency is shifted to higher value, the S_{11} value critically decreases from -53.56 dB to -17.67 dB, and the BW value slightly decreases form 12.86% to 11.01%. It is found that the size of ground plane has the more important influence on the resonant frequency, S_{11} value, and BW value of designed antenna.

Fig. 4(a) is the photograph of the fabricated antenna on the Al_2O_3 ceramic substrate with the size of 25 mm × 25 mm. The parameters for the fabricated antenna are h_g= 10.45mm and $W_2 \times L_2$ = 10mm x 7mm. Fig. 4(b) compares the simulated and measured S_{11} values. As Fig. 4(b) shows, the measured frequency is near the simulated one. However, the measured bandwidth is wider than the simulated one, and the measured return loss is smaller than the simulated value. The gain of the fabricated antenna is shown in Fig. 5, and it is found that the gain is about 2.95 dBi when this antenna is operating at 4.2 GHz. The radiation patterns are shown in Fig. 6(a), Fig. 6(b), and Fig. 6(c), which reveal the operation frequency 3.84 GHz, 4.2 GHz, 4.65 GHz, respectively. For that the fabricated antenna is suitable for the applications of the WLAN and Global Positioning System (GPS) (~4.2 GHz).

TABLE II
THE SIMULATION RESULTS OF ANTENNA,
THE SIZE OF THE METAL COVERING IS FIXED ON 10 MM × 7 MM

Length of ground h_g (mm)	Frequency (GHz)	Return loss (dB)	BW (%)
10.45	4.2	-53.56	12.86
10.65	4.27	-23.09	11.48
10.85	4.31	-18.92	11.37
11.05	4.36	-17.67	11.01

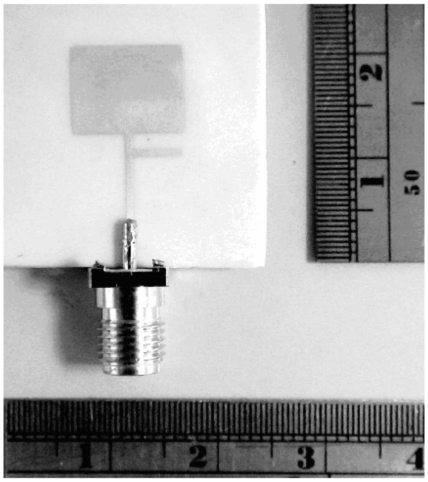
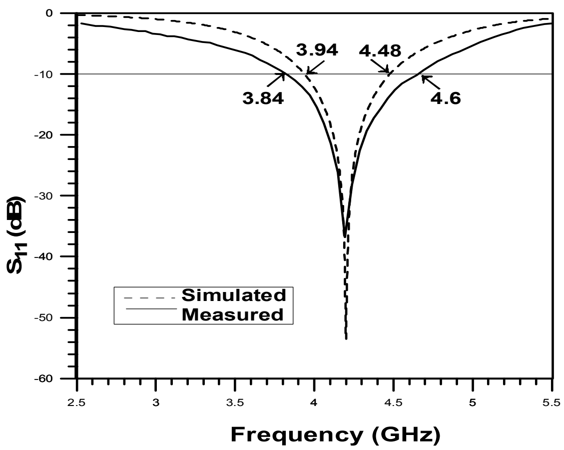
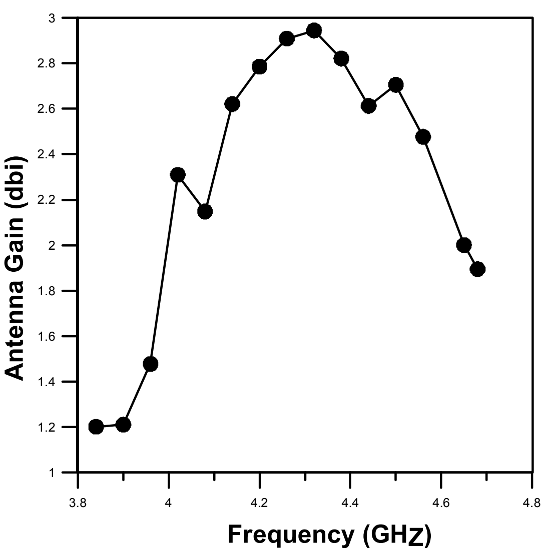


Figure 4. The photograph of the fabricated antenna.

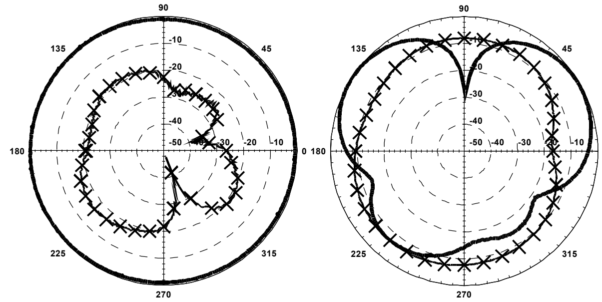


(A)



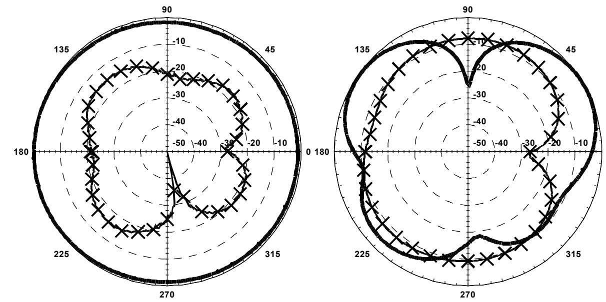
(B)

Figure 5. The characteristics of the fabricated antenna. (A) The comparison of simulated and measured S_{11} values. (B) The measured gain values as a function of frequency.



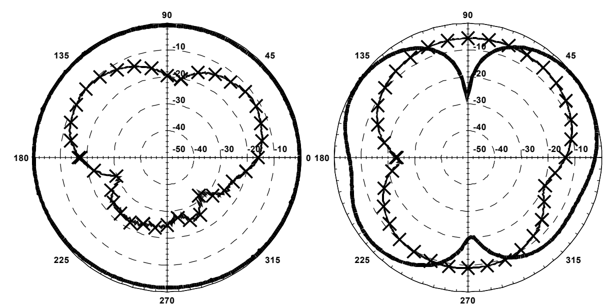
xy plane yz plane

(A)



xy plane yz plane

(B)



xy plane yz plane

(C)

Figure 6. The radiation pattern at (A) 3.84 GHz, (B) 4.2GHz, and (C) 4.65 GHz. (E_θ:×××; E_ϕ:——)

IV. Conclusions

Using the simulation toll HFSS 9.0 to simulate a wide band microstrip line T-shaped antenna, and high dielectric constant, high quality factor Al_2O_3 were used as the substrates. Screen-printing technology was used to fabricate this wide band antenna, the advantages of this antenna are:

1. The fabricated antenna has a small size of about 25 mm × 20 mm × 0.635 mm).
2. Wide bandwidth (760 MHz/18.1 % at 4.2 GHz).
3. Low return loss (–36.77 dB).
4. Large gain (2.8 dBi at 4.2 GHz).

This antenna is suitable for the applications of WLAN and GPS system.

ACKNOWLEDGMENT

The authors will acknowledge to the financial support of the National Science Council of the Republic of China (contracts NSC 95-2221-E-218-064 and NSC 95-2221-E-390-009).

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