슬릿쌍을 이용한 이중 대역 T-형 마이크로스트립 모노폴 안테나

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T-shaped Microstrip Monopole Antenna with a Pair of Slits for Dual-Band Operation

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요 약

본 논문에서는 2.4/5.2/5.8-GHz 무선 랜 대역에서 동작하는 슬릿쌍을 이용한 이중대역 T-형 마이크로스트립 모노폴 안테나를 제안하였다. 이중 대역 동작 특성을 얻고 안테나 크기를 줄이기 위해 마이크로스트립으로 급전된 T-형 모노폴 안테나에 T-형 슬릿쌍을 추가하였다. 실험 결과를 통해 제안된 안테나가 주어진 모든 무선 랜 대역에서 동작함이 증명되었다. VSWR이 2 이하인 측정된 임피던스 대역폭은 낮은 주파수 대역에서 5.7% (2.37-2.51GHz)이고 높은 주파수 대역에서 28.8% (4.76-6.35GHz)이다. 2.4GHz 대역에서 측정된 최대 이득은 1.33 dBi ~ 1.66 dBi, 5.25GHz 대역에서 3.50 dBi ~ 3.95 dBi, 5.8GHz 대역에서 2.06 dBi ~ 2.34 dBi이다.

Key Words : Monopole Antenna, T-Shaped, Slits, WLAN, Dual-Band

ABSTRACT

In this paper, a dual-band T-shaped microstrip monopole antenna with a pair of slits for 2.4/5.2/5.8-GHz wireless local area networks (WLANs) is proposed. A pair of T-shaped slits is loaded on a T-shaped monopole antenna fed by microstrip line in order to obtain dual-band operation as well as to reduce the antenna size. It is demonstrated from experimental results that the proposed antenna can cover all the required bands for WLAN. The measured impedance bandwidth for VSWR<2 is about 5.7% (2.37-2.51GHz) in the lower frequency band and about 28.8% (4.76-6.35GHz) in the higher frequency band. The measured peak gains are about 1.33 dBi to 1.66 dBi in the 2.4GHz band, 3.50 dBi to 3.95 dBi in the 5.25GHz band, and 2.06 dBi to 2.34 dBi in the 5.8GHz band.

Ⅰ. Introduction

Recently, due to the rapid development in wireless communication systems such as IEEE 802.11/a/b/g/n wireless local area network (WLAN) standards for 5.2GHz (5.15-5.35GHz), 2.4GHz (2.4-2.484GHz), and 5.8GHz (5.725-5.825GHz) band operations, multi-band operations of a single antenna with compact size are very desirable. Thus, to date, lots of dual-band printed monopole antenna (MPA) structures for WLAN operation, such as MPAs with two (or more) branches[1,2], folded (or meandered) MPAs[3,4], and MPAs with embedded slots[5-7], have been proposed. One of the common

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techniques for the design of compact antennas with dual- or multi-band operations is to introduce various slots in a planar MPA fed by a coplanar waveguide (CPW)[5,6] or a microstrip line[7].

In this paper, a novel design of a printed dual-band MPA for WLAN operation in the 2.4GHz, 5.2GHz, and 5.8GHz bands is studied. The proposed antenna is a microstrip-fed T-shaped MPA embedded with a pair of T-shaped slits. By properly selecting and embedding the slits into the T-shaped MPA, a compact antenna size and good radiation-pattern characteristics in addition to sufficient impedance bandwidth suitable for 2.4/5GHz WLAN operations were achieved. Details of the antenna design and experimental results are presented and discussed below.

Ⅱ. Antenna Design

Fig. 1 shows the geometry of the proposed microstrip-fed dual-band MPA. To achieve dual-band operations two T-shaped slits are symmetrically loaded in the T-shaped MPA. The T-shaped MPA with no embedded slits has single frequency band operation with a smaller size than a conventional MPA or whip antenna. Due to the loaded slits the T-shaped MPA is separated into 3 elements composed of a central T-shaped part and two identical side arms symmetrically placed with respect to the central element.

The effect of the geometrical parameters of the antenna, printed on an FR4 substrate with dielectric constant of $\epsilon_r = 4.4$, loss tangent $\tan\delta = 0.02$, and substrate thickness of t = 0.8 mm, on the input impedance characteristics were studied with the aid of the commercial EM simulation tool, CST Microwave Studio (MWS). The optimized dimensions of the proposed MPA suitable for the operations of dual-band over the WLAN are as follows: L_t = 12.7, W_t = 2.5, L_p = 12, W_p = 8, g = 0.7, W_f = 1.5, W_g = 28, L_g = 17, L_d = 20, s = 1.2, S_g = 1.5, L_1 = 8, L_2 = 2.5, and W_L =0.5 [unit:mm].

Fig. 2 shows the variations of input reflection coefficient for different geometrical parameters. The effects of the varied parameters can be found by comparing the curves for reflection coefficient in each case with that for the MPA optimized for the WLAN operations.

As shown in Fig. 2a, due to the loaded slits, the resonant frequency f_1 in the lower operating band is

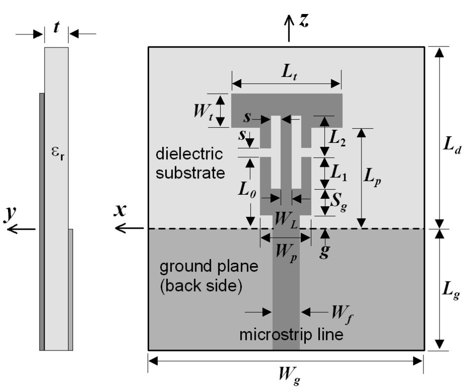


Fig. 1. Geometry of the proposed monopole antenna

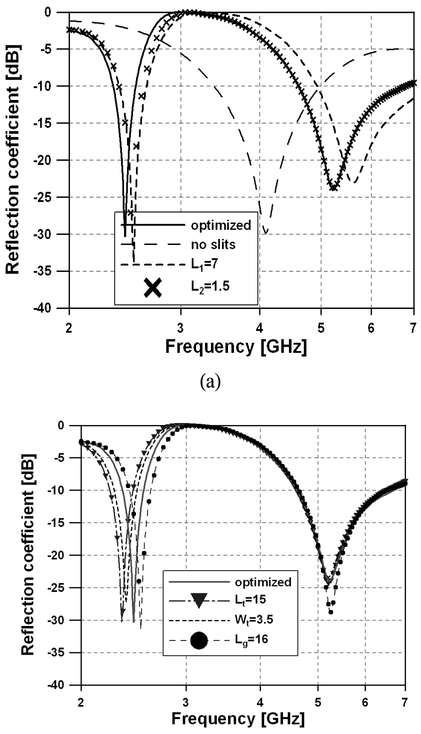


Fig. 2. Simulated input reflection coefficient against various dimensions

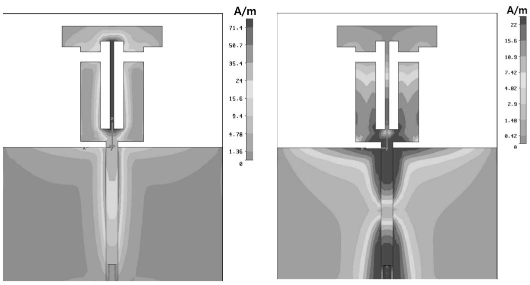
decreased to less than the resonant frequency f_0 of the MPA with no slit, which allows the proposed antenna to be a compact MPA as well as a dual-band MPA. In the higher operating band, the bandwidth can be made broad enough to accommodate both 5.2-GHz and 5.8-GHz bands for WLAN operation.

It is found that when the axial slit length L_1 is decreased, both the lower and the higher resonance frequencies are increased.

By decreasing L_2, the lower resonant frequency f_1 is increased while the higher resonant frequency f_2 is less increased. As shown in Fig. 2b, some parameters such as W_t, L_t, and L_g mainly affect the lower frequency f_1 with little effect on the higher frequency f_2.

The length L_0 of two side arms affects mainly the higher frequency f_2 rather than the lower f_1. On the other hand, both the width W_L and total length L_1+L_2 of the narrow strip in the central T-shaped part mainly affect the lower frequency f_1 rather than the higher one f_2. By use of the above observations, we can easily design a dual-band antenna for WLAN operation by adjusting the parameters which mainly affect each frequency f_1 and f_2, in turn.

Fig. 3 shows surface current densities over the optimized antenna. It is observed that the electric currents flow mainly along the central T-shaped part at the lower resonant frequency f_1, while the flows are confined near the two side arms at the higher frequency f_2.



(a) 2.45GHz (b) 5.25GHz

Fig. 3. Simulated surface current distributions

Ⅲ. Experimental Results and Discussion

The proposed antenna was successfully designed and a prototype antenna was constructed and tested. Fig. 4 shows the fabricated prototype antenna.

The simulated and measured reflection coefficients of the constructed prototype are shown in Fig. 5 in which good agreement between the measurement and the simulation is obtained. For the T-shaped MPA without the loaded slits, the measured impedance bandwidth for VSWR<2 is 34.4% and ranges from 3.54 to 5.01GHz with the center frequency of 4.27GHz which is near to the resonant frequency f_0 = 4.39GHz, as shown in Fig. 5.

In Fig. 5, the measured reflection coefficient for the proposed MPA with embedded slits shows a narrow impedance bandwidth of 140MHz (2.37-2.51GHz) or about 5.7% with respect to the center frequency 2.44GHz in the lower frequency band. Note that, in this case, the total length of the MP along the z-direction is $L_p + W_t$ = 14.5 mm

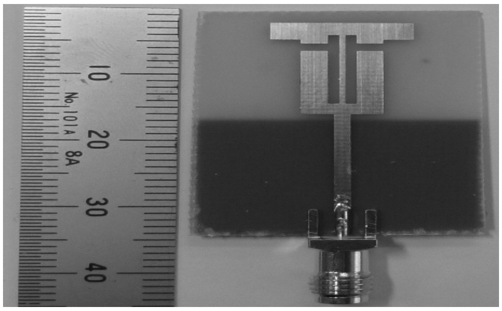


Fig. 4. Photograph of a fabricated antenna

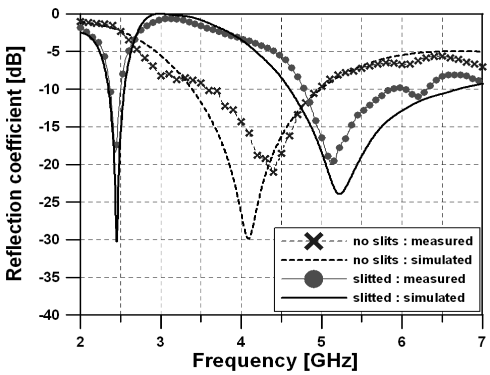
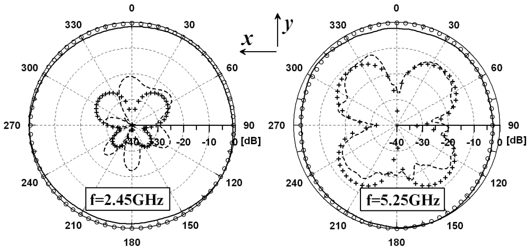
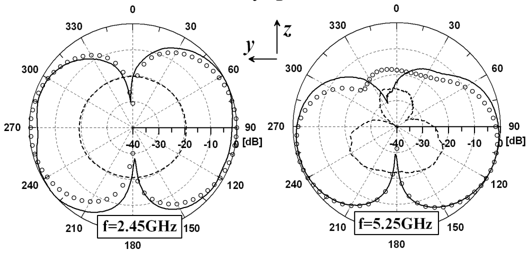


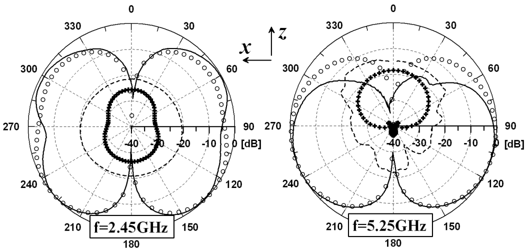
Fig. 5. Measured and simulated input reflection coefficients



(a) x-y plane



(b) y-z plane



(c) z-x plane

Fig. 6. Simulated and measured radiation patterns:
(solid line ; measured co-pol., dashed line ; measured cross-pol., ○ ; simulated co-pol., + ; simulated cross-pol.)

which is about $0.12\lambda_0$ at the center frequency 2.44GHz.

However, in the upper frequency band, it shows a broad impedance bandwidth of 1.59GHz (4.76-6.35GHz) or about 28.8% with respect to the center frequency 5.52GHz. Therefore, the obtained bandwidths for the proposed MPA can sufficiently cover all of the required bandwidths of the 2.4, 5.2, and 5.8GHz bands for WLAN operations. The measured far-field radiation patterns at 2.45 and 5.25 GHz for the proposed antenna are shown in Fig. 6. Since the patterns at 5.8GHz are similar to those at 5.25GHz, they are not given here.

The results show that the radiation patterns of the horizontal polarization component in the y-z and z-x planes are bidirectional beam patterns which have a lower level near the monopole axis.

The radiation patterns of the vertical polarization component in the x-y plane are near omni-directional with small ripple levels of about 2 dB at 2.45 GHz and 3 dB at 5.25 GHz, respectively.

The -3dB beam widths in the y-z plane are 108.5 degrees at 2.45 GHz and 71.5 degrees at 5.25 GHz.

As shown in Fig. 6, the measured radiation patterns for the co-polarization component of the fabricated antenna agree well with the simulated patterns and some discrepancies in the patterns for cross-polarization components are thought to be mainly due to the coaxial feeding cable connected to the antenna under test.

The radiation patterns of the fabricated antenna are very similar to those of typical printed monopole antenna, which reveals that the proposed antenna has suitable radiation patterns as an antenna for WLAN applications.

Fig. 7 shows the simulated and measured peak gains in each band. The measured peak gains are about 1.33 dBi to 1.66 dBi in the 2.4GHz band, 3.50 dBi to 3.95 dBi in the 5.25GHz band, and 2.06 dBi to 2.34 dBi in the 5.8GHz band. The simulated antenna efficiencies are 78.3% at 2.45 GHz, 91.1% at 5.25 GHz, and 87.5% at 5.775 GHz.

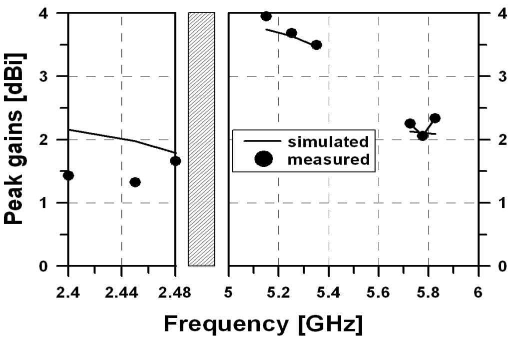


Fig. 7. Simulated and measured peak gains

Ⅳ. Conclusion

A T-shaped dual-band printed monopole antenna with a pair of loaded slits has been proposed and investigated for triple band (2.4GHz, 5.25GHz, and 5.8GHz) WLAN applications. By properly adjusting the positions and lengths of the loaded slits, dual-band operation has been achieved.

The measured impedance bandwidth is about 5.7% (2.37-2.51GHz) in the lower frequency band and about 28.8% (4.76-6.35GHz) in the higher frequency band, which can cover all the required bands for WLAN.

From the results for the measured impedance bandwidth, radiation patterns, and gains, the proposed dual-band antenna may be suitable for wireless communication systems.

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