A Multiband Antenna with Double Y-Shape Monopole and Modified Ground Plane

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1. Introduction

At present, the wireless communication systems are developed that many applications collect several operating frequencies. For this reason, the multiband operation is important property of produced antenna for wireless communication systems. Usually, the multiband operation of antenna is achieved by two main methods. First method is multi-resonator method that each resonator radiates electromagnetic wave at different operating frequencies. In [1], the stack of two T-shape monopoles produced a dual band at operating frequencies of 2.4 GHz and 5.2GHz. The monopole antenna in [2] used the trident shape strip to create three resonant paths at 2.4 GHz, 3.5GHz, and 5.2GHz, respectively, resulting in a multiband operation. Combining between the strip line and U-shape resonator of the monopole antenna in [3] can generate multiple resonance frequencies. Another method, a multiband antenna can be produced by creating band-notched frequencies on a conventional wideband antenna. In [4], the multiple U-shaped slots caused two band-notched frequencies in a wideband monopole antenna. The CPW-fed conventional wideband antenna in [5] was modified by adding slits and slot into the radiating patch and ground plane to produce notched frequencies, resulting in a multiband antenna. The property results occurred by the putting various shape of parasitic resonator on the wideband antenna to produce the multiband operation proposed in [6].

The modified ground plane techniques were employed for improving antenna performance. By inserting two semicircles into ground plane, the antenna performances such as input impedance bandwidth and high frequency radiation of planar ultrawideband antenna were improved in [7]. In [8], the current on ground plane was rearranged by the modifying with T-shape ground plane, resulting in propagation improvement of omni-directional pattern.

In this paper, we propose a multiband antenna with double Y-shape monopole and modified ground plane. However, the proposed antenna can be operated in according to bands of Global System for Mobile Communication (GSM850/900), Digital Communication System (DCS1800), Personal Communication System (PCS1900), Universal Mobile Telecommunication System (UMTS), WCDMA 2100, Wireless Local Area Network (WLAN IEEE 802.11b/g), and Worldwide Interoperability for Microwave Access (WiMAX). Several parameters of the proposed antenna will be investigated by simulation using the full wave method of moment (MOM) software package from IE3D. The antenna prototype with optimum values of the antenna parameters is fabricated and experimented. The details of design, simulation and experiment will be discussed in the following sections.

2. Antenna Design

The proposed antenna is designed and fabricated on a low-cost FR4 substrate with relative permittivity \( \varepsilon_r \) of 4.2 and thickness \( h \) of 1.6 mm. The proposed antenna configuration is illustrated in Fig. 1(a). The proposed antenna is composed of the double Y-shape radiating patch and T-shape ground plane. Firstly, the upper Y-shape resonator with rectangular ground plane can operate at the first resonant frequency of 900 MHz. Then, the arm of Y-shape below the upper Y-shape resonator is added to generate at the operating frequency band of 1.62-2.52 GHz and resonant
frequency of 3.5 GHz, occurring due to the harmonic behavior of antenna geometry. However, the simulated bandwidth result of the designed antenna at the third operating frequency band does not matched impedance and covered in WiMAX systems due to coupling effect of the electromagnetic wave between double Y-shape resonator and rectangular ground plane. Therefore, the rectangular ground is developed with T-shape geometry to improve antenna bandwidth and matching impedance at higher frequency band, as shown in Fig. 2(a). In order to clearly understand the behavior of the proposed multiband antenna, many effective parameters of \( L_2 \), \( L_5 \), and \( L_{gt} \) will be observed. The alternating resonance frequency in the next section and the optimal parameters of the proposed antenna are following: \( W_1 = 4 \text{ mm}, W_2 = 5 \text{ mm}, W_3 = 7 \text{ mm}, W_6 = 22 \text{ mm}, W_8 = 62 \text{ mm}, W_g = 64 \text{ mm}, W_{gt} = 30 \text{ mm}, W_f = 3 \text{ mm}, L_1 = 10 \text{ mm}, L_3 = 26 \text{ mm}, L_4 = 12 \text{ mm}, L_g = 50 \text{ mm}, L_{gt} = 22 \text{ mm}, g = 0.5 \text{ mm}, S = 9 \text{ mm}, \) and \( h = 1.6 \text{ mm}. \)

3. Simulation and experiment

This section discusses the investigation on the effective parameters \( L_2 \), \( L_5 \), and \( L_{gt} \) respectively, as shown in Figs. 2. When increasing parameter value of \( L_2 \) illustrated in Fig 2(c), it has been found that the impedance bandwidth is improved at the second operating frequency band of 1.61 - 2.51 GHz, resulting in the coupling between the arms and center body of Y-shape, as the third resonant frequency shifting to the left due to increasing the electrical length on the arms of Y-shape. Then, the parameter \( L_5 \) will be varied to observe effects at the first resonant frequency. As illustrated in Fig. 2(d), the first and third resonant frequencies shift to the left due to the extending electrical length on upper Y-shape. Also, the upper bandwidth at the second resonant frequency expands due to the extending electrical length and coupling effect between upper Y-shape and the center body. Finally, the parameter \( L_{gt} \) is changed and investigated the affecting impedance bandwidth at all of operating frequencies as depicted in Fig. 2(e). It has been obviously found that the second and third operating frequency band are improved to cover the application of GSM850/900, DCS1800, PCS1900, UMTS, WCDMA 2100, WLAN IEEE 802.11b/g, and WiMAX with the appropriated parameter \( L_{gt} \) value of 22 mm. As a result, the optimal values of parameters \( L_2 = 21 \text{ mm}, L_3 = 25 \text{ mm}, \) and \( L_{gt} = 22 \text{ mm} \) are agreed for covering the operating frequency bands of 810-992 MHz, 1.62 – 2.52 GHz GHz, and 3.13 – 3.87 GHz GHz for using in applications of GSM850/900 (824-894 MHz/880-960 MHz), DCS 1800 (1710 – 1880 MHz), WCDMA 2100 (1710 – 2155 MHz), WLAN IEEE802.11 b/g (2.4-2.483 GHz), and WiMAX (3.3 – 3.8 GHz). Especially, the proposed multiband antenna with optimal values is fabricated by chemical etching process. The photograph of prototype antenna is shown in Fig. 1(b). The simulated and measured return loss bandwidths of the antenna are illustrated in Fig. 2(b). It is obviously seen that the slighty difference between simulated and measured return losses of the antenna occurred because of the chemical etching process and the effect of an SMA connector to feed the antenna. From the results, it has been found that the proposed antenna can respond to the applications of GSM850/900, DCS1800, PCS1900, UMTS, WCDMA 2100, WLAN IEEE 802.11b/g, and WiMAX. Additionally, the measured X-Z plane and Y-Z plane radiation patterns are exhibited in Fig. 3. It is clearly noticed that the X-Z at all operating frequencies are almost the omni-directional radiation patterns, and also the radiation patterns in Y-Z plane are bi-directional radiation pattern. Nevertheless, the cross polarization in X-Z plane patterns are expanding as increasing frequency due to the higher order mode of the operating frequency. Moreover, the average gains of simulated and measured results are above 2 dBi at operating frequency bands, as shown in Fig. 4.

4. Conclusion

This paper presented a multiband antenna with double Y-shape monopole and T-shape ground plane. A multiband operation of the proposed antenna is obtained by using the multi–resonators method. The different dimensions of both Y-shape resonators can generate multi-resonant frequencies. Moreover, the modified ground plane with T-shape geometry can improve impedance matching and performances of the proposed antenna. The comparison results of the proposed antenna between simulation and measurement are agree well covering the applications of
wireless communication systems following GSM850/900, DCS1800, PCS1900, UMTS, WCDMA 2100, WLAN IEEE 802.11b/g, and WiMAX.

References


Figure 1: The proposed antenna (a) overall configuration and (b) prototype.
Figure 2: Measured and simulated return loss results from antenna design and investigation.

Figure 3: Measured radiation patterns of the proposed antenna at the resonant frequencies 900MHz, 1.8GHz, 2.1GHz, 2.4GHz, and 3.5GHz (a) X-Z plane (b) Y-Z plane.

Figure 4: Simulated and measured gains of the proposed antenna.