Mutual Coupling Reduction for Dual-Band MIMO Antenna with Simple Structure

Swamy Polgoni

Assistant Professor, Sri Indu Institute of Engineering and Technology

Sudarshan Bandi

Assistant Professor, Nova College of Engineering and Technology

S.Nagi Reddy

Associate Professor, Teegala Krishna Reddy Engineering College

Abstract.

In this paper, a novel dual-band MIMO (multiple input, multiple output) antenna for WLAN (wireless local area network) applications is presented. The MIMO antenna contains two dual-band antenna elements, each of which comprises a T-shaped monopole and a special ├- shaped stub resonator. Two operating bands with center frequencies of 5.5 GHz and 2.5 GHz are crested by the monopole of T shape and the stub resonator of ├ shape, accordingly. The ├-shaped stub also works as an isolation structure at the higher band, which can simplify the dualband isolation design into a single-band problem. Moreover, the isolation is enhanced at the lower band by inserting a metal strip which can cancel out original coupling. The inserted metal strip is the only additional decoupling structure in this design and has a simple texture with a compact size. The measured and simulated results reveal that the designed MIMO antenna can cover all the 2.4/5.2/5.8 GHz WLAN operating bands and within the recommended bands the isolations exceed by 20 dB.

Keywords Dual-band, high isolation, multiple-input multipleoutput (MIMO) antenna, wireless local area network (WLAN)

INTRODUCTION

Multiple-input and multiple output (MIMO) technology has attracted more research attention due to the demands for higher transmission rate and more reliable link in wireless communications. MIMO is a complex technology by utilizing multiple antennas to increase the channel capacity and overcome multipath fading propagation problem [1], [2]. However, due to the space limit at the sizeshrinking terminal devices, the most critical problem in a MIMO antenna design is how mutual coupling can be reduced between the closely packed antenna elements. Various studies had been performed to boost the isolation of the antenna ports [3–13]. A tree-like parasitic structure [3], or mushroom like EBG structure [4–6] can minimize the mutual coupling among radiating components though restraining the surface wave propagation.

The defected ground structure [7] or a simple ground plane modification [8] performing as a band-stop filter was designed to increase the isolation. Use of slot has been useful to include a notch in the isolation between antennas [9–11]. In [12], a method for isolation enhancement, based on metamaterial was given for the MIMO antenna.

However, these methods have the common deficiency of complex structures, which will occupy a large space on the antenna. In [13], a neutralization line is physically linked to the antenna components for improving isolation. In this structure, the exiting mutual currents on the sufferer antenna are counterbalance by implanting 180° out-of-phase currents from an excitation antenna.

The neutralization-line technique is extensively used as it occupies small space. However, this method markedly deteriorates the reflection coefficient and therefore, the trial and error process are required to obtain the suitable dimensions which need lots of time. Moreover, most decoupling methods as mentioned above are only suited for offering narrow band isolation among two antennas.

In previous studies on dual-band MIMO antennas [14–17], mutual coupling reduction is usually achieved by two isolation structures. One is used for lower band, while the other one is for higher band. However, combination of the two isolation structures may increase complexity of system, especially when the isolation structures are complex. In this design, a novel structure of the antenna element is applied, which can avoid this problem. The dualband antenna element comprises a monopole of T shape and a stub resonator of special ├ shape. At the lower frequencies, the ├-shaped stub can be considered as an antenna because it is coupled-fed by the T-shaped monopole.

At the higher frequencies, it can reduce mutual coupling though suppressing surface wave propagation, which works as a reflective component. Thus, the space of the antenna is maximum utilized and the design of dual-band MIMO antenna is simplified to a single-band problem, which only needs to consider enhancing isolation at the lower band. Moreover, instead of adding a neutralization line that is physically joined to the antenna elements [13], we put a metal strip between the antenna elements in order to artificially generate a supplementary coupling route for enhancing the isolation. The metal strip, which is the only additional decoupling structure, has small effect on initial antenna impedance as it is not physically connected to the antenna. Due to the dual function of ├-shaped stub and the small occupied space of the metal strip, this antenna has a small size and simple structure.

ANTENNA STRUCTURE

The geometry of the proposed dual-band MIMO antenna can be seen in Fig. 1. The antenna is printed on 50 mm2×a 26 FR4 substrate. This substrate has thickness of 0.8 mm with relative dielectric constant of 4.4 and loss tangent of 0.02. The MIMO antenna contains of two T-shaped monopoles, two ├-shaped grounded branches and a metal strip. A T-shaped monopole and a ├-shaped stub compose a dual-band antenna component and the two antenna components are printed symmetrically. The desirable high isolation is obtained by the metal strip and the unique structure of the antenna element. In the following, more details are studied.

Recently, lots of theoretical research has been developed to study the isolation improvement technique between antenna elements in small portable handsets. To improve isolation performance, protruded ground branch [2], half-wavelength slot etched ground [3], parasitic element [4], connecting neutralization line [5], and lumped component [6] were utilized. Metamaterial (MTM)-inspired resonators can also function as insulators and be placed periodically into a compact MIMO portable antenna system [7]. Compact diversity arrays with two/three/ four elements have been reported in [8]–[10]. However, MIMO mobile system of more elements within a limited interelement space is difficult to produce due to the strong coupling between different elements. Still more difficult is designing the dual band MIMO systems to meet the emerging requirements of multifunctional MIMO wireless devices, where it might experience the difficulty of decoupling both the operation bands.

In this letter, a new high-isolation MIMO antenna system integrated with eight elements is presented for dual-band hand- held terminals. The MIMO system comprises eight elements including two types of planar inverse-F antennas (PIFAs). One type of PIFA introduces a U-slit to achieve dual-band property, and another type of PIFA introduces an L-slit for the dual resonances. The designed antenna can operate both at the LTE band around 2.7 GHz and WiMAX band centered at 3.5 GHz. The two types of PIFAs are placed orthogonally to provide polarization diversity for coupling reduction. To achieve better isolation performance between different element ports in a small mobile handset, many decoupling methods have been proposed. First, a disconnected dispose for the ground of the various U-slit etched PIFAs (USEPIFAs) is presented to break the electric current flowing [11]. Second, a pair of metallic strips has also been utilized on the main substrate of the MIMO system to provide a resonance for the operation. In addition, a series of deformation on the L-slit etched PIFAs (LSEPIFAs) has been proposed to further improve the mutual coupling.

The total dimension of the MIMO system with eight elements is only 140 70 9.55 mm , and good return loss (above 10 dB) is achieved across the operating bands of 2.6–2.8

and 3.4–3.6 GHz. The correlations between any two elements of the MIMO antenna are less than 0.5, and total efficiencies are larger than 70%.

VALIDATION RESULTS

In order to verify the results obtained from simulations, a prototype antenna was fabricated and tested, which can be seen in Fig. 1

Fig. 1. Photograph of the fabricated antenna.

Figure 2 shows the measured and simulated Sparameters. The measured –10 dB impedance bandwidth for the 2.4 GHz is 300 MHz (from 2.35 GHz to 2.65 GHz) band and for the 5.2/5.8 GHz bands is 1.3 GHz (from 4.9 to 6.2 GHz). For the higher and lower frequency bands, the measured mutual couplings are lower than –26 dB and –20 dB, respectively. It can be confirmed by the nearness of the measured and simulated frequency responses of the fabricated antenna that the operating band satisfies the design demands. For evaluating the proposed MIMO antenna functioning, the (ECC) envelope correlation coefficient, a measure to describe how much the communication channels are isolated with each other, is taken as an analytical parameter. It can be calculated from the S-parameters using the following formula [19]:

$$ECC = \frac{\left|S_{11}^{*}S_{12} + S_{21}^{*}S_{22}\right|^{2}}{\left|\left(1-\left|S_{11}\right|^{2}-\left|S_{21}\right|^{2}\right)\left(1-\left|S_{22}\right|^{2}-\left|S_{12}\right|^{2}\right)\right|}. \qquad (1)$$

The measured and simulated ECCs across the desired frequency bands are shown in Fig. 13. It can be seen that both the ECCs of the proposed MIMO antenna are below 0.06 over the complete WLAN frequency band, which is much lower than criterion of low ECC (ECC < 0.5)[19]. In addition, equation (1) illustrates that small |S11| and |S12| can cause low ECC. It can be inferred that desired ECC demands good performances in impedance matching and isolation. With the low return loss and high isolation, the ECC of the proposed MIMO antenna is almost 0 at the operating bands (2.35 GHz to 2.65 GHz, and 4.9 GHz to 6.2 GHz). The difference in simulated and measured ECCs

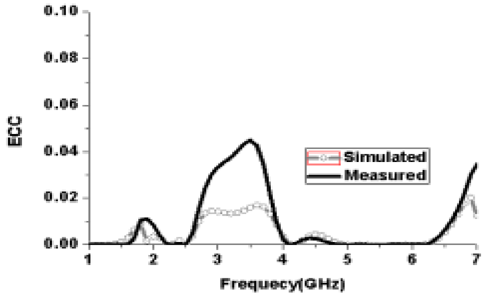

Fig. 3. Simulated and measured ECC.

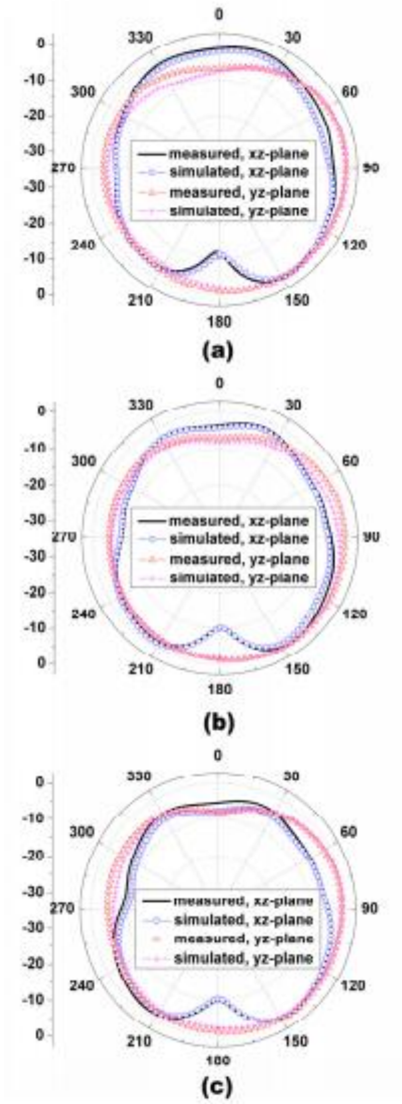

Fig. 4. Radiation patterns of the proposed MIMO antenna at (a) 2.4 GHz, (b) 5.2 GHz, and (c) 5.8 GHz. in the notched bands is relatively large.

That is because in the case of mismatch, the isolation plays a major role and has a large proportion in ECC. In Fig. 4, the measured normalized radiation patterns of the three frequencies 2.4, 5.2, and 5.8 GHz for the proposed (MIMO) antenna are plotted. For measurements, during the excitation of port1, port 2 is cut off with a matched load of 50 Ω. The radiation patterns were measured for the total electric-field. It can be seen that, in y-z plane the antenna is omnidirectional and near-omnidirectional in x-z plane, which can receive the signals from all the directions. In addition, at the frequencies of 2.4, 5.2, and 5.8 GHz, the peak gains reach 1.56, 4.43, and 4.7 dBi, respectively, with the corresponding efficiencies of 70.1 %, 82.3 %, and 81.2 %.

CONCLUSIONS

The basic idea of this design is the development of a decoupling method for dual-band with a simple and compact geometry. In this article, a dual-band (MIMO) antenna for WLAN applications is exposed. A novel monopole element is used to provide high isolation for higher band, where radiating element and the isolation structure share the same structure. Moreover, the metal strip, which is the only additional decoupling structure, has occupied a small space and produces a significant enhancement of isolation at lower band. Acknowledgments This work was supported by the National Natural Science Foundation of China (No. 61172115 and No. 60872029), the High-Tech Research and Development Program of China (No. 2008AA01Z206), the Aeronautics Foundation of China (No. 20100180003), the Fundamental Research Funds for the Central Universities (No. ZYGX2009J037), Project 9140A07030513DZ02098 and the Fundamental Research Funds for the Central Universities (Grant No. ZYGX2012YB019).

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