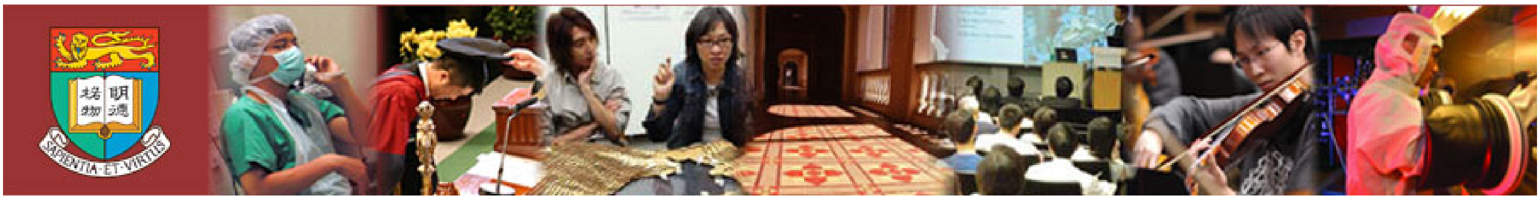

Dual-band MIMO antenna using double-*T* structure for WLAN applications

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***Abstract*—A dual-band multiple-input-multiple-output (MIMO) antenna is proposed for the wireless-local-area-network (WLAN) applications in the 2.4-GHz and 5.2-GHz bands. The antenna consists of two double-*T* monopole elements with microstrip-fed and symmetrically placed on a substrate. To enhance isolation between the two monopole elements, three slots are cut on the ground plane on the other side of the substrate. The longer slot is used for better isolation in the 2.4-GHz band, while the two shorter slots are used for the 5.2-GHz band. Simulation and measurement are used to study the antenna performance in terms of S parameters, radiation patterns, realized gain, efficiency, and envelope correlation coefficient. Results show that the MIMO antenna has the two operation bands (2.20-2.75 GHz and 5.09-5.50 GHz) with mutual coupling of less than -15 dB and envelope correlation coefficient of less than 0.1, making it a good candidate for WLAN applications.**

Keywords—dual band, Multiple-input-Multiple-output (MIMO), double-T monopole

I. INTRODUCTION

Nowadays, the wireless-local-area network (WLANs) using the IEEE 802.11 standard are widely used in many different countries. To fulfil the IEEE 802.11 standard in the 2.4 GHz (2.4-2.484 GHz) and 5.2 GHz (5.15-5.35 GHz) bands, the antennas for the portable devices are required to support dual-band operations. There have been many monopole designs proposed for WLAN applications [1]-[4]. The planar design proposed in [1]–[3] were not capable of dual-band operation. The inverted-*F* monopole antenna structure in [4] could be used for dual-band operation, but it had a shorting pin on the ground for connection, which made the fabrication quite complex. A printed dipole antenna for dual-band operation was studied in [5]. However, the size was not compact enough for portable devices.

Future wireless communication system requires large capacity and high data rate. Thus MIMIO technology has been proposed for different communication systems such as the WLAN systems, and the 3G and 4G cellular mobile systems. In a MIMO antenna system, more than one antenna element is required to be installed on the portable devices, the access point or base station. Due to the limited space in portable devices, it is quite challenging to keep high isolation between the antenna elements. In [6], a suspended microstrip line linking the shorting strips was proposed to reduce mutual coupling between the antenna elements. While in [7], single-negative magnetic (MNG) metamaterial was studied to reduce coupling.

In this paper, a dual-band MIMO antenna is proposed for applications in the 2.4-GHz and 5.2-GHz WLAN bands. Two double-*T* monopoles are used as the MIMO antenna elements, and three slots are cut on the ground plane to reduce mutual coupling between the two antenna elements in the operation bands. The double-*T* monopole was proposed in [8] and is adopted for the design of our multiple-input-multiple output (MIMO) antenna because of compact size and ease fabrication.

The antenna is designed and studied using the EM simulation tool, CST. For verification of simulation results, the MIMO antenna is fabricated and measured using the antenna equipment, Satimo Starlab system. Both simulated and measured results show that the MIMO antenna is a good candidate for portable WLAN applications.

II. ANTENNA DESIGN

The geometry of the proposed dual-band MIMO antenna is shown in Fig. 1, which was designed on a substrate with a dielectric constant of 3.5, a loss tangent of 0.004, and a thickness of 0.8 mm. The antenna consisted of two monopole elements with a double-*T* shape symmetrically printed on one side of the substrate, and a partial ground-plane on the other side of the substrate. Each monopole element was composed of one vertical strip and two horizontal strips to generate two operation bands. The upper horizontal strip having a longer total length was used to generate the lower operation band at about 2.4 GHz, while the lower horizontal strip having a shorter total length was used to generate the upper operation band at about 5.3 GHz. The lower horizontal strips had two unequal arms on both sides of the vertical strip to achieve a wider impedance bandwidth. To reduce mutual coupling between the two monopole elements, three slots, serving as resonators, were etched on the ground plane. The longer slot in the middle was used to reduce mutual coupling in the low frequency band at around 2.4 GHz, while two shorter ones placed symmetrically on two sides were used to reduce mutual coupling in the high frequency band at around 5.25 GHz. The dimensions of the MIMO antenna were optimized in terms of minimizing mutual coupling between the two input ports using the EM simulation tool CST. The optimized dimensions are

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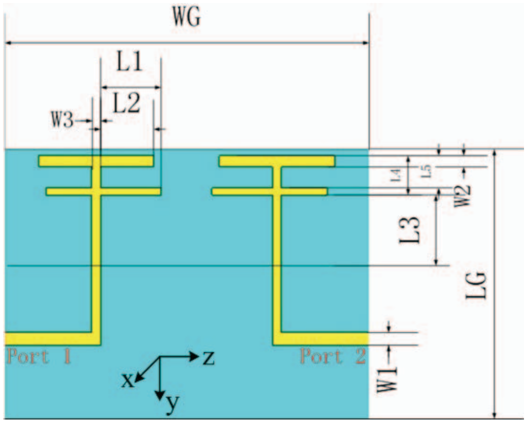
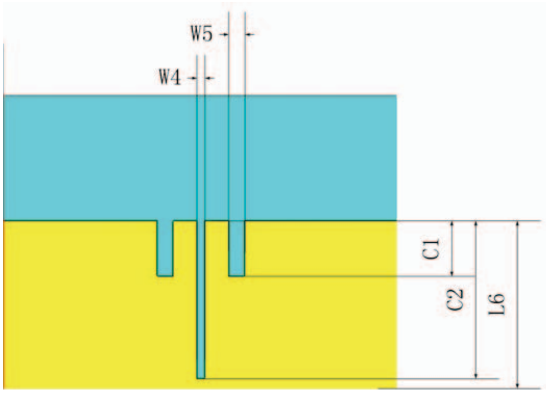
listed in Table I and were used to fabricate the prototype as shown in Fig. 2 for measurement.



(a)

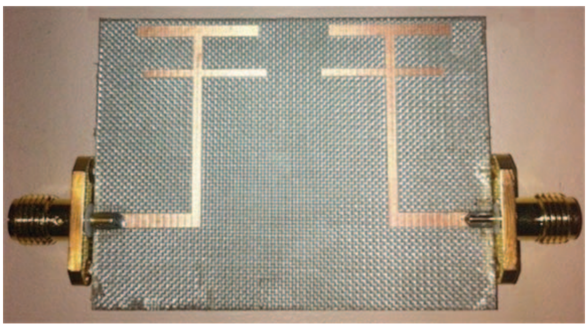


(b)

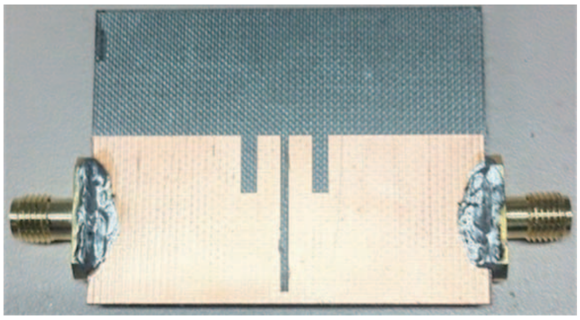
Fig. 1. Geometry of proposed antenna (a) top view, and (b) bottom view.

TABLE I. DIMENSIONS OF PROPOSED ANTENNA (MM)

L1=8.3	L2=7.3	L3=7.9	L4=6.8	L5=1.5
L6=21.5	LG=37	W1=1.8	W2=1.5	W3=1.2
W4=1	W5=2	WG=50	C1=7.5	C2=20



(a)



(b)

Fig. 2. Prototyped antenna (a) top view and (b) bottom view.

III. RESULTS AND DISCUSSIONS

A. S-parameters

The simulated S-parameters of the proposed MIMO antenna are shown in Fig. 3, which indicates that the antenna had two operation bands at a lower frequency of 2.45 GHz and a higher frequency of 5.25 GHz. The simulated frequency bands for S_{11}<-10 dB were 2.20-2.75 GHz for the lower band and 5.09-5.50 GHz for the higher band. In both frequency bands, the mutual coupling S_{21} were below -15 dB. Thus the proposed MIMO antenna had good dual-band operation in the 2.4-GHz and 5.2-GHz WLAN bands with high isolation between the two ports. The S-parameters of the prototyped MIMO antenna shown in Fig. 2 were also measured using the vector network analyzer (VNA) Rohde & Schwarz ZVA 24, with results shown in Fig. 3 for comparison. It can be seen that the measured resonances of the two frequency bands shifted to the slightly higher frequencies. This was due to the feeding cable used in measurement, which can be explained as follows. In simulation, no feeding cable was needed. However, when the antenna was measured using the VNA, a coaxial feeding cable was always needed to connect the antenna to the system. For measuring monopole antennas with small ground planes, the cable would alter the current distributions on the antennas and hence the S-parameters [9].

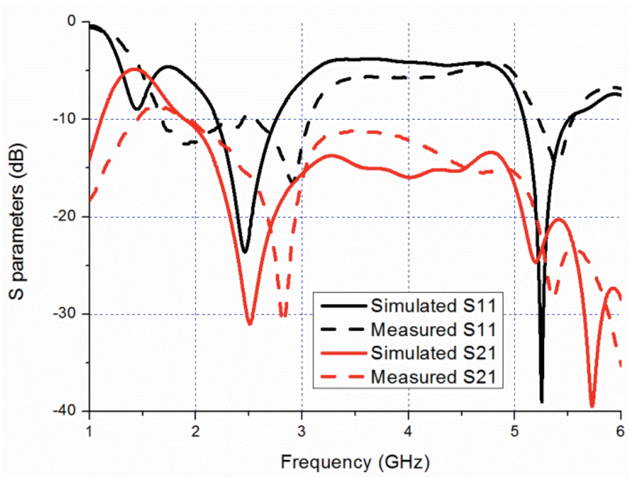
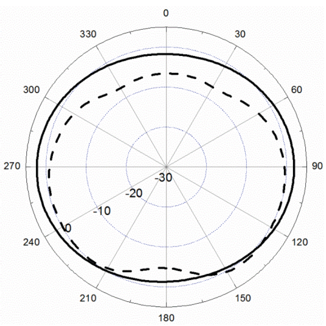


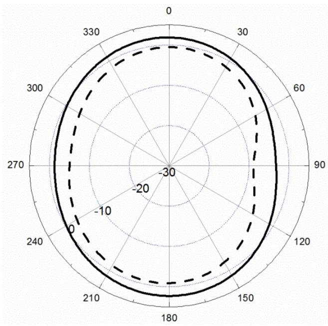
Fig. 3. Simulated and measured S parameters.

B. Radiation patterns

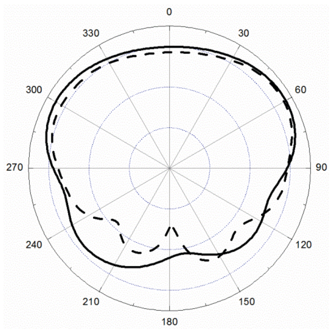
The radiation patterns for total electric-field E_{total} of the prototyped MIMO antenna were measured using the antenna measurement system Satimo Starlab. Because of symmetry, the antenna was only measured when port 1 was fed and port 2 was terminated with a 50-Ω load. The simulated and measured radiation patterns at 2.45 and 5.25 GHz are shown in Fig. 4. (The results when port 2 was fed and port 2 terminated with a 50-Ω load would be the mirror images of these results.) The radiation patterns in the x-y plane, as shown in Figs. 4(b) and (d), were not symmetrical as a typical monopole but directional at 270°, because port 1 was feeding on the left of the antenna, so most of the power was radiated toward the left side. At 5.25 GHz, Figs. 4(c) and (d) show that the simulated and measured patterns agreed well. However, at 2.45 GHz, Figs. 4(a) and (b) show that the measured radiation patterns were smaller than the simulated results. This can be explained as follows. In measuring small monopoles, at low frequencies where the electrical size of the antenna ground plane becomes relatively small compared to the wavelength, currents will flow back from the antenna to the feeding cable, giving rise to radiation and causing inaccuracy in radiated pattern measurement. To reduce the effects on the measured radiation pattern, the feeding cable provided by Satimo for use with the Starlab system is covered with EM suppressant tubing to absorb the currents flowing back to the cable and radiation from the cable. However, this method reduces the measured gain and efficiency of the antenna because part of energy is absorbed and not detected by the measurement system, so Fig. 4 shows that the measured patterns were smaller at the lower frequency of 2.45 GHz.



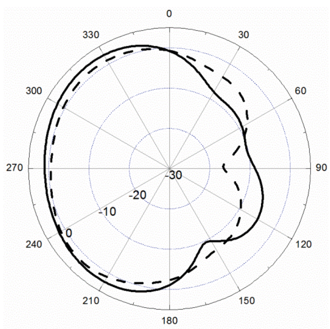
(a) x-z plane



(b) x-y plane



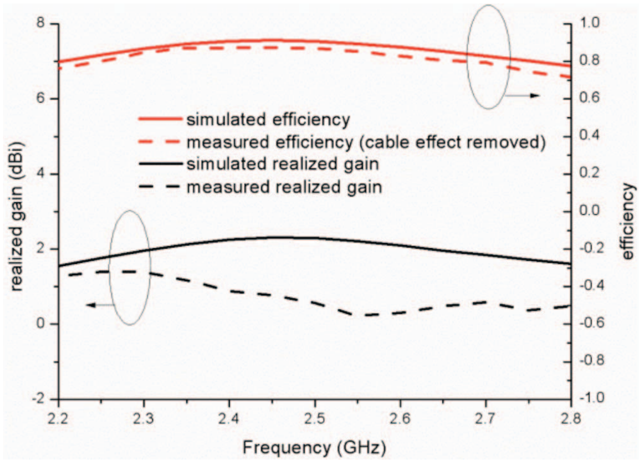
(c) x-z plane



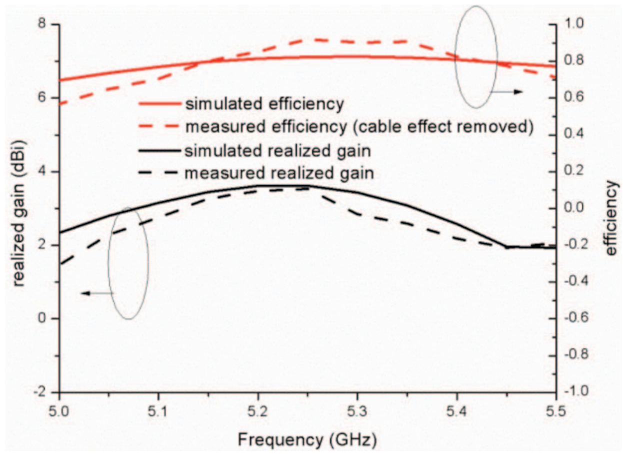
(d) x-y plane

Fig. 4. Simulated and measured radiation patters when port 1 was fed and port 2 was terminated with a 50-Ω load: (a) & (b) 2.45 GHz; (c) & (d) 5.25 GHz. (—— simulated, — — —measured)

The simulated and measured efficiencies of the antenna are shown in Fig. 5. In efficiency measurement, as described previously, the feeding cable will absorb the current flowing back to the cable, so the measured efficiency is always lower than the simulated efficiency. Thus the computer model for the feeding cable developed by us in [9] was used in simulation and the difference between the simulated efficiencies with and without using the cable model was caused by the cable effect. This cable effect was used to remove the cable effects on the measured efficiency. The measured efficiencies with cable effect removed are shown in Fig. 5 for comparison. It can be seen that, the simulated efficiency and the measured efficiency (after removing the cable effect) agreed well. The measured efficiencies in the two bands with cable effect removed were about 80%.



(a)



(b)

Fig. 5. Simulated and measured realized gain and efficiency in (a) 2.4-GHz and (b) 5.2-GHz bands.

C. Envelope correlation coefficient

Envelope correlation coefficient was also calculated using the 3D radiation patterns [10]. By assuming uniform 3D angular power spectra, the calculated correlation coefficients using simulated and measured patterns were both below 0.1 in the WLAN bands, indicating a very good diversity performance of the proposed MIMO antenna.

IV. CONCLUSIONS

A dual-band MIMO antenna operating in the 2.4 and 5.2 GHz has been designed for WLAN applications. It consists of two double-*T* monopole antennas with microstrip-fed and symmetrically placed on a substrate. Three slots are cut on the ground plane to reduce mutual coupling in the dual band between the two antenna elements. Simulated and measured results have shown that the antenna can operate through 2.20-2.75 GHz and 5.09-5.50 GHz with mutual coupling of less than -15 dB, covering the 2.4-GHz and 5.2-GHz WLAN bands. The envelope correlation coefficient is less than 0.1 in both frequency bands. All results indicate that the MIMO antenna is suitable for WLAN applications.

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