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Citation	The 2013 International Workshop on Antenna Technology (iWAT 2013), Karlsruhe, Germany, 4-6 March 2013. In Conference Proceedings, 2013, p. 87-90
Issued Date	2013
URL	http://hdl.handle.net/10722/189906
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A MIMO antenna for mobile applications

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Abstract — A multiband Multiple-Input Multiple-Output (MIMO) antenna for mobile phones applications in the next generation is proposed. The proposed MIMO antenna consists of two identical elements, each having three branches to generate two frequency bands, a wide higher and narrow lower frequency bands. Simulation results show that these two frequency bands can cover the lower band for Long-Term Evolution (LTE), the DCS1800, PCS1900 and UMTS-2100 bands, the Wibro Band, the 2.4-GHz band for the WLAN system and also the upper band for the WiMAX. By cutting a slit on the printed circuit board (PCB) serving the ground plane, a great enhancement of isolation between the two antenna elements can be achieved for the two frequency bands.

Index Terms —MIMO antennas, multiband antenna, isolation, Long-Term Evolution (LTE), mobile terminals, slit, WiMax, WLAN

I. INTRODUCTION

Multiple-Input Multiple Output (MIMO) technology has been considered as one of the attractive methods to fulfill the ever-increasing demand for wireless channel capacity, especially for the next generation communication systems. MIMO antenna technology can provide higher receiver gain, increased data rates, larger network throughput, and improved reliability through antenna diversity. However, one of the biggest challenges in the designs of antennas for MIMO systems for mobile devices applications is the mutual coupling among the closely packed antenna elements. Without good isolation between the antenna elements placed in a small area, severe performance degradation in MIMO systems will result. In [1]-[3], different techniques were proposed to reduce mutual coupling between antenna elements in MIMO antennas. These studies were not for the multiband applications on mobile phones. Moreover, the lower band of Long-Term Evolution 700 (LTE700) operation which requires a larger antenna size to obtain and is for the next generation of wireless communication system was not considered.

In this paper, the design of a compact MIMO antenna for small mobile terminals is proposed. The MIMO antenna supports dual-band operation, including the lower band of Long-Term Evolution 700 (LTE700). The lower band of LTE700 is operating at a lower frequency band of 700 MHz and so the antenna requires a relatively larger size. This imposes tremendous difficulties to design the MIMO antennas for mobile terminals. Our proposed MIMO antenna consists of two symmetrical elements, each having three radiating branches. Computer simulation is used to study and design the antenna. Simulation results show that the proposed MIMO antenna can generate two frequency bands, a lower band to cover the LTE (lower band) operation and a higher band to cover the DCS1800, PCS1900, UMTS-2100 and Wibro Band (2.3-2.4 GHz) systems, the 2.4-GHz band for the WLAN system, and upper band for the WiMax system. To reduce mutual coupling and hence increase isolation between the two antenna elements, a straight slit is cut on the printed-circuit board (PCB) serving as ground. Simulation results show that the slit can increase the isolation for both the wide higher and lower bands of the antenna. The structures of the two antennas and the length of the slit are studied and optimized by using computer simulation.

II. MIMO ANTENNA DESIGN

The geometry of the proposed MIMO antenna for mobile phone applications is shown in Fig. 1. The antenna consisted of two elements placing at the upper and lower corners of a PCB with a volume of $50 \times 110 \times 0.8$ mm³. An area 10×45 mm² was cut at the corners of the PCB to make rooms for placing the two antenna elements. The two elements were mirror images of each other on the PCB, hence complementing the radiation patterns. The two elements were placed on the top side of the PCB to achieve good diversity performance and lower correlation coefficient for the MIMO antenna [4].

The 2D layout for the antenna elements is shown in Fig. 2. Folding along the two dotted lines would make a 3D antenna as shown in Fig. 1. In Fig. 2, branch 1 was printed on the PCB for the ground plane. The other parts were in a 3D space. The parasitic element was placed near to the antenna element to widen the bandwidth of the upper band at about 2.5 GHz. In order to achieve good matching for the monopole antenna, two identical lumped impedance networks were used at Ports 1 and 2, with each network having an inductance of 5.6 nH to connect in parallel. The long branch of the radiating element in Fig. 2 was used to generate the lower bands (Bands 13 & 14) for LTE. Branches 1 & 2 were used to set the resonant frequency to about 2 GHz, which could generate a remarkably wide higher band. The parasitic element was used for the 2.4-GHz WLAN and WiMAX systems.

For MIMO antennas installed on the space-limited mobile terminals, the mutual coupling between the antenna elements will be very a serious concern, due to the sharing of the ground plane where surface currents flow. This is more serious for low frequency bands as the electrical size (space compared to the wavelength) of the ground plane becomes smaller. In our proposed MIMO antenna, we cut a slit on the PCB serving as ground to improve the isolation and hence reduce the coupling between the two antenna elements. By cutting the slit, the surface currents on the ground plane would be forced to flow along the slit, which would increase the current path on the ground plane. As a result, the currents on the PCB would become much weaker, hence reducing the effects of the mutual coupling between the MIMO elements and improving the isolation [5]. However, in this design, the length of the slit must be optimized. Computer simulation was used for optimization of the slit in our MIMO antenna and results showed the optimized dimension for the slit is $37.5 \times 1 \text{ mm}^2$.

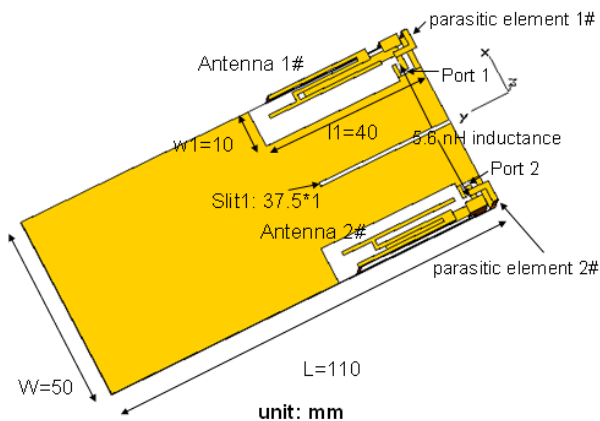


Fig. 1 Geometry of proposed MMO antenna

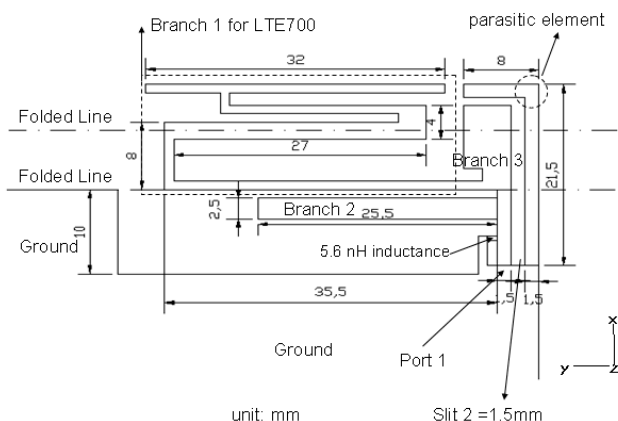


Fig. 2 Structure of radiating element

III. SIMULATION RESULTS

The MIMO antenna was simulated using the EM simulation tool CST, and the simulated S parameters with and without having the slit are shown in the Fig. 3. It can be seen from the simulated results that the antenna had two operation bands, a lower band in the 770-MHz region and a higher band in about the 2-GHz region. In the lower band, a 6-dB return loss could be achieved for the LTE700 Bands 13 & 14 (746-798 MHz). For the higher band, the MIMO antenna had sufficient bandwidth to cover the DCS1800, PCS1900, UMTS2100, WiBro (2.3-2.4 GHz), 2.4-GHz WLAN, and M-WiMAX (2.5-2.7 GHz) systems. Figure 3 shows that, without having the slit on the PCB ground, the isolation of the MIMO antenna was just about -7 dB in the LTE band and about -10 dB in the upper band (1.71-2.1GHz). With the use of the slit, the isolation was increased from -7 to -10 dB in the LTE band, and from -10 to -15 dB in the higher band (1.71-2.1 GHz). There were small degradations from 2.1 to 2.7 GHz with the slit. The simulated gains and the efficiencies of the two antenna elements are shown in Table I. The proposed MIMO antenna operated quite well in the working bands.

The simulated 3D radiation patterns of the MIMO antenna at 0.77 GHz, 2 GHz and 2.45 GHz shown in Figs. 4 and 5. It can be seen that by placing the elements with mirror images of each other, the 3D radiation patterns of each elements could complement each other.

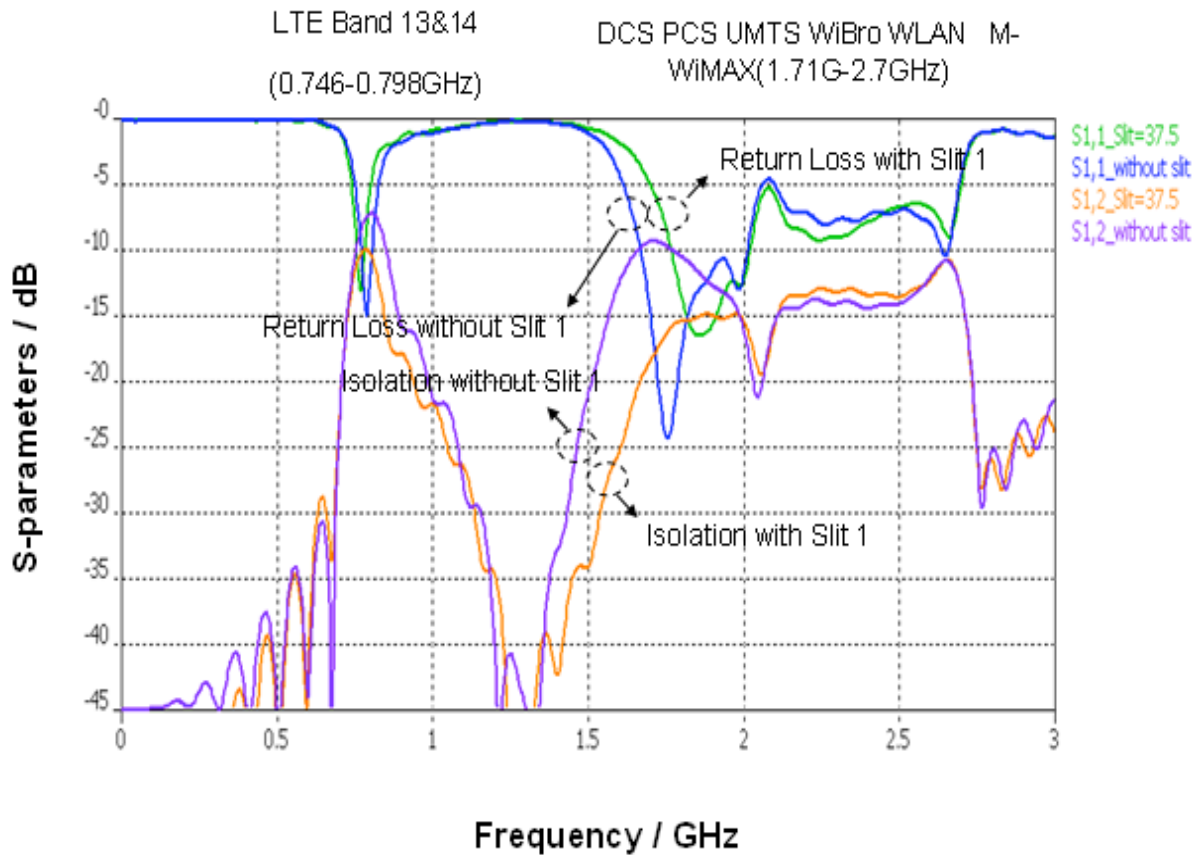


Fig. 3 Simulated S parameters

TABLE 1 SIMULATED GAINS AND EFFICIENCIES

Frequency	0.77 GHz	1.71 GHz	2GHz	2.45GHz
Ant 1#	0.87 dBi	2.56 dBi	3.27 dBi	3.75 dBi
Ant 2#	0.87 dBi	2.56	3.26 dBi	3.76 dBi
Ant 1#	67.66%	56.42%	66.83%	66.69%
Ant 2#	67.69%	56.54%	66.62%	67.75%

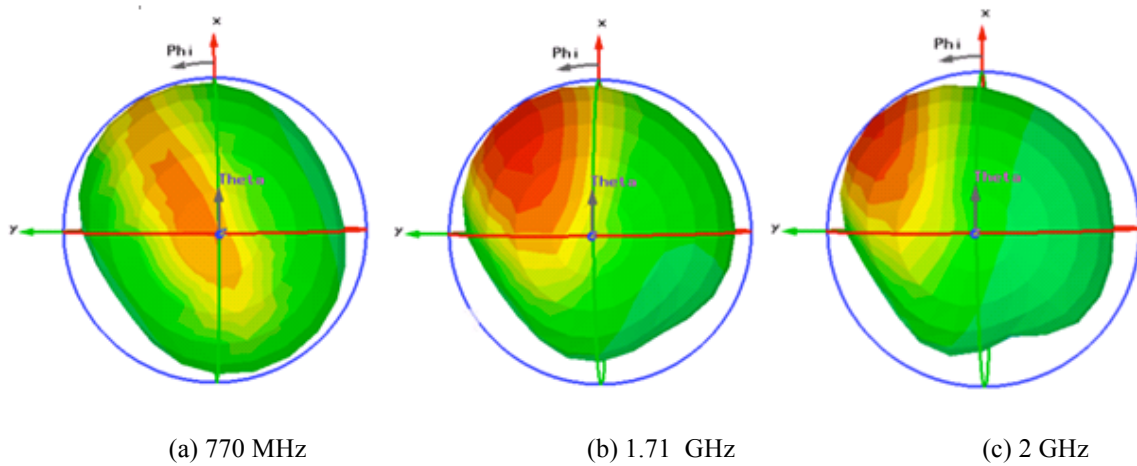


Fig. 4 Port 1 simulated 3D radiation pattern

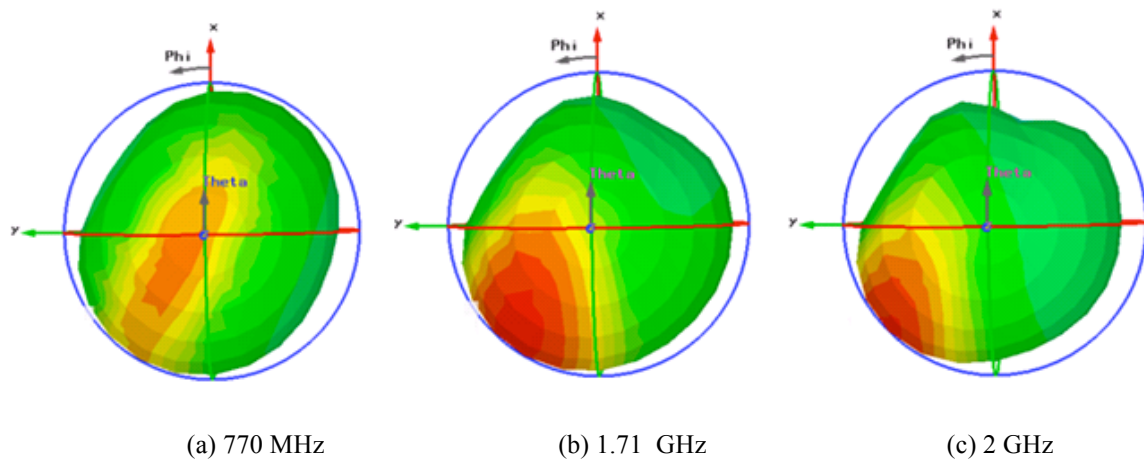


Fig. 5 simulated Port 2 3D radiation pattern

IV. CONCLUSIONS

A multiband MIMO antenna for mobile phones applications has been proposed. The antenna consists of two antenna elements and can be used for systems such as the LTE (bands 13 & 14), DCS1800, PCS1900, UMTS-2100, Wibro Band (2.3-2.4 GHz), 2.4 GHz WLAN, and WiMax (2.5-2.7 GHz) systems. A slit cut on the ground plane has been proposed to reduce the coupling and increase the isolation of the two elements. Results have shown that the isolation of the proposed MIMO with slit on the PCB ground is about -10 dB at the LTE band, and -15 dB at the upper band (1.71-2.1GHz).

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