Printed Multi-antenna Isolation Improvement Using Decoupling Network for USB Dongle Application

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Abstract **– A printed multi-antenna isolation improvement with the use of decoupling network for USB dongle application is proposed. Two coupled-fed PIFAs are placed on the opposite corners of PCB and separated by a protruded ground portion, which has the width of 14 mm as a layout area. It has been experimented and verified that a decoupling network located on the space in-between the top edge of PCB and the protruded ground plane can effectively improve the antenna port-to-port isolation over 2.4 GHz and 5 GHz bands. The proposed design is a promising candidate to integrate with the module card in the form factor of a USB dongle. Detailed antenna prototype and design consideration are discussed in the article.**

Index Terms **— Printed multi-antenna, coupled-fed PIFAs, wireless USB-dongle antennas, MIMO antennas.**

I. Introduction

Recently, multi-antenna design is more and more popular and embedded in the device for many kinds of wireless applications. The available space for antennas, however, is very limited and the port-to-port isolation of antennas will get worse while the distance in-between antennas will get closer. In consideration of the demands of isolation improvement, some methods have been reported, including an embedded slit inserted in the ground plan between two antennas [1], a parasitic strip as a wavetrap for isolation improvement [2], the use of neutralization line for 2.4 GHz single band [3, 4], and so on.

The proposed antenna consists of two coupled-fed PIFAs which are located on the opposite corners of FR4 substrate as a system circuit board and separated by a small protruded ground portion. In this article, it has been found that a decoupling network inserted in the space in-between the top edge of PCB and the protruded ground portion can obviously improve port-to-port isolation over 2.4 GHz and 5 GHz bands, compared with the conventional PIFAs. Details of the constructed antenna are analyzed, tested and discussed in the following sections.

II. Antenna Design

Fig. 1 shows the detailed dimension of the structure of the proposed two coupled-fed PIFAs with a decoupling network fabricated on a FR4 substrate with the size of 65×30 mm^2 for multi-antenna system or MIMO antenna system applications. The FR4 substrate with the electrical characteristics of ε_r = 4.2 and tanδ = 0.0245 can be considered the form factor of PCB for a USB dongle device. Each coupled-fed PIFA is printed on the clearance area (no-ground plane) of 14.5×8 mm^2, which occupied on the opposite corners of PCB. A decoupling network is located on the area of 24×3.2 mm^2 surrounded by two antennas and a protruded ground portion (14×11.3 mm^2), which is reserved for antenna feeding network, U.FL connector as an optional choice for stand-alone antenna, RF switch for the manufacturing test, etc.

The preferred dimensions of the proposed design are also given in Fig. 1 and obtained by a rigorous analysis with an aid of EM simulator ANSYS HFSS. In this paper, two coupled-fed PIFAs having identical prototype are selected for the reason of easily achieving wide operating bandwidth to cover 2.4 GHz (2400~2485 MHz) and 5 GHz (5150~5850 MHz) bands. Then, two antennas are grouped together and linked with a decoupling network. This decoupling network further comprises a longer strip $\overline{AB}$ and a shorter strip $\overline{CD}$, both strips with 0.5 mm width, for the isolation improvement over 2.4 GHz and 5 GHz bands, respectively. Notice that two terminals of the strips are linked to the short-circuiting strip of two PIFAs. The locations are chosen by rigorous analysis of input impedance and current distributions (not shown in the article for brevity).

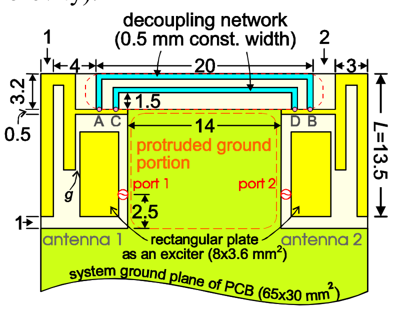

Fig. 1. Geometry of proposed antenna design.

III. Results and Explanation

The measured reflection coefficient (S_{11} is for antenna 1 and S_{22} is for antenna 2) and the isolation (S_{21}) between two antennas are shown in Fig. 2. It can be easily observed that the impedance bandwidth with the definition of -10 dB is wide enough to cover 2.4 GHz and 5 GHz bands and the isolation corresponding to aforementioned bands is below -15 dB and -20 dB, respectively. In Fig. 3, the reflection coefficient for the antenna 1 of the three prototypes including the conventional direct-fed PIFAs, coupled-fed PIFAs, and the proposed design was demonstrated and all can cover 2.4 GHz and 5 GHz bands easily. Notice that the results of the reflection coefficient of the antenna 2 were not presented in the article because both antennas have identical structures.

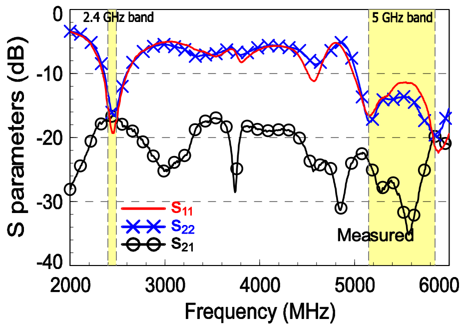

Fig. 2. Measured S-Parameter for the proposed design.

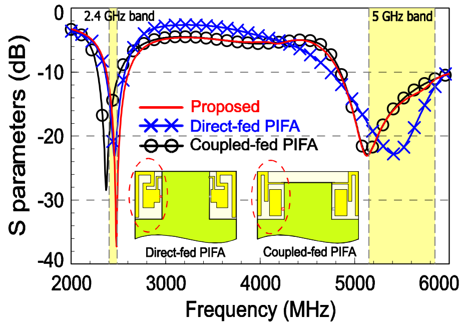

Fig. 3. Reflection coefficient of the antenna 1 for conventional direct-fed PIFA, coupled-fed PIFA and proposed design.

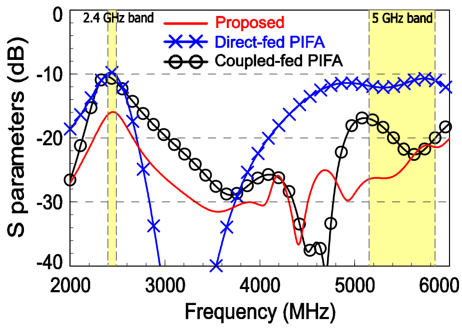

Fig. 4. Isolation between the two antennas for conventional direct-fed PIFA, coupled-fed PIFA and proposed design.

The isolation shown in Fig. 4, however, can be clearly observed that the conventional direct-fed PIFAs can only achieve -10~-12 dB in both lower and higher bands. The isolation can be less than -15 dB in 5 GHz band while the coupled-fed structures were utilized. Still, there is no obvious isolation improvement in 2.4 GHz band. Based on the prototype of coupled-fed PIFAs, the proposed design incorporates a decoupling network including a longer strip and a shorter strip, which the former one is for 2.4 GHz and the latter one is for 5 GHz band, for easily adjusting the coupling effects in-between two antennas to achieve better isolation. Fig. 5 explains 2D radiation patterns of the antenna 1 at center frequency 2450 MHz and 5550 MHz. The quasi-omnidirectional radiation patterns in x-y plane can be seen. TABLE I shows the measured antenna efficiency and peak gain for the proposed antenna 1 and antenna 2. The radiation efficiency for both antennas is in the range of 64~75% and 58~73%. Also, the peak gain for both antennas is in the range of 1.6~3.5 dBi and 1.3~3.3 dBi.

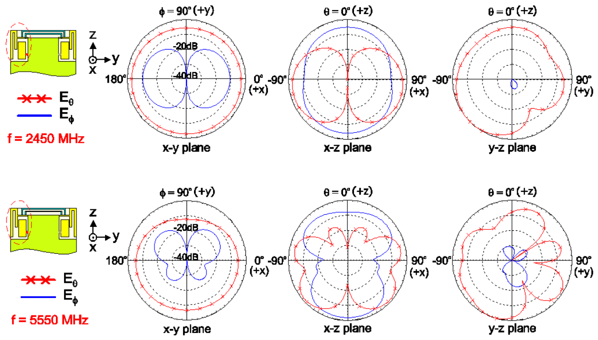

Fig. 5. 2-D radiation patterns at 2450 MHz and 5500 MHz for antenna 1 studied in Fig. 2.

TABLE I
ANTENNA EFFICIENCY AND PEAK GAIN

Frequency (MHz)	Antenna 1		Antenna 2	
	Efficiency (%)	Peak Gain (dBi)	Efficiency (%)	Peak Gain (dBi)
2400	64	1.6	58	1.3
2450	71	2.1	67	1.9
2485	73	2.3	70	2.1
5150	71	3.2	71	3.1
5550	75	3.5	73	3.3
5850	69	2.9	68	2.8

IV. CONCLUSION

The printed multi-antenna with a decoupling network, which is inserted in a small clearance in-between two coupled-fed antennas has been proposed to achieve the port-to-port isolation improvement, and the constructed prototype also have been tested. The results show the antenna isolation is lower than -15 dB and -20 dB in 2.4 GHz and 5 GHz bands respectively and is better than that of the conventional direct-fed PIFAs (-10~-12 dB). Also, both antennas yield maximum radiation efficiency 73% with peak gain of 3.3 dBi.

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