A Reconfigurable Antenna with Omnidirectional and Directional Patterns for MIMO Systems

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***Abstract*—In this paper, we propose a novel pattern reconfigurable planar antenna for employment in a 2x2 multiple input, multiple output (MIMO) system. By switching between the microstrip elements, the antenna can generate a single omnidirectional mode or four directional modes. The design has been tuned for a frequency of 3.8 GHz and has a bandwidth of at least 400 MHz, depending on the configuration. The flexibility in directional and omnidirectional operation, in concert with the wide operating bandwidth, makes this antenna an ideal candidate for future MIMO systems. This paper presents the antenna array architecture as well as simulated return loss and mutual coupling.**

I. Introduction

In modern wireless systems, the use of reconfigurable antennas has been proposed to improve system capacity and spectral efficiency [1]. Due to their ability to conveniently change radiation patterns in response to fluctuations in the environment, these designs are used as adaptive antennas. In some applications, it may be desirable to broadcast the signal omni-directionally to satisfy the connectivity of many users; while in other situations, the selection of a focused beam might be more appropriate in order to enhance communication along particular directions while suppressing interference. Recently, a planar design has been developed as reconfigurable planar antenna that combines omni-directional and directional radiation patterns [2]. Unfortunately, the reactive components around the central element increase the quality factor, resulting in a narrow bandwidth.

In this work, we present the design and coupling analysis of a broadband planar antenna that is able to generate omni-directional and directional radiation patterns over a wide bandwidth, resembling an Alford Loop design [3]. Through the electromagnetic software simulator HFSS, the design was tuned to resonate at 3.8 GHz and the layout has been etched on an FR-4 substrate. The antenna fits within a 40mm x 40mm square and the gain in omni-directional and directional modes are, respectively, 1.8 dBi and 4 dBi. The mutual coupling as a function of different inter-element spacings has also been investigated by considering the use of two antennas in a 2x2 MIMO wireless system.

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II. Antenna Design

The contribution of the antenna described in this paper is to combine the benefits of directional and omni-directional beams through a planar and low cost design while maintaining a large bandwidth. The antenna was fabricated on both sides of an FR-4 dielectric substrate having ϵ_r = 4.4. It resembles the Alford Loop layout but the branches were designed at 90° to generate directional modes and enhance the front-to-back ratio as shown in Figure 1. Eight gaps, four on the top layer and four

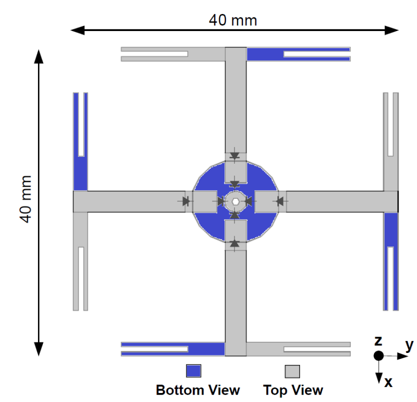

Fig. 1. Layout of the proposed antenna

on the bottom layer, were designed to include the SPST PIN diodes (model Skyworks SMP 1345-079LF) required for mode selection. A standard SMA female connector fed the antenna as probe feed configuration, with the ground connected to the bottom circle and the inner conductor soldered on the smaller top circle. The radius of the circles used as feed line act as a tuning element to improve impedance matching over the wide band of operation with the ratio between the diameters of top and bottom layer circles determines the impedance matching of the antenna. In addition, the bandwidth of the antenna can be adjusted by varying the length and width of the slot in the wing of each element.

The omni-directional mode of operation can be achieved to obtain a uniform field distribution around the azimuth plane. When the four pairs of branches are connected to the center feed (all PIN diodes in ON state), the current distribution will be uniform along the structure as shown in Figure 2(a). In this way, the overall design resembles the Alford Loop layout, but with squared branches. The return loss comparison between simulation and measurement results is depicted in Figure 2(c). In omni-directional mode the antenna has a -10 dB Return Loss (RL) bandwidth of 400MHz and -6 dB bandwidth of 600 MHz around the center frequency of 3.8 GHz. The simulated total antenna gain of this mode is about 1.8 dBi, as shown in Figure 2(b).

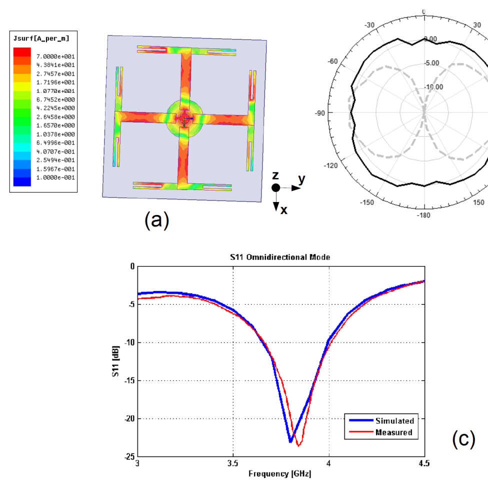

Fig. 2. Omni-directional mode of operation: uniform current distribution and radiation pattern

When a more focused beam is required, this antenna can generate four directional radiation patterns with a spatial resolution of 90°. If a single pair of branches are connected to the center feed (two PIN diodes in ON state), a reflection occurs toward the other three disabled pairs, as shown in Figure 3(a). Hence, a single directional beam is generated in the direction of the excited pair. The 90° squared branches maximize the effect of the reflectors, enhancing the front-to-back ratio.

In terms of return loss, the -10 dB RL bandwidth of a single directional mode is about 400 MHz, while the -6 dB bandwidth is 900 MHz, as shown in Figure 3(c). The gain is estimated to be about 4 dBi for every single directional mode, as shown in Figure 3(b).

III. Coupling Simulation for a 2x2 MIMO System

When multiple antennas are being used as part of a wireless MIMO system, it is important to be aware of the mutual coupling that may occur between them. To consider this MIMO situation, the coupling S_{12} has been simulated by considering two different configurations: in a 2x2 MIMO system, the two antenna elements can be broadside coupled by placing one on top of the other (Figure 4(a)) or they can be horizontally coupled along the same plane, Figure 4(b). In both configurations, the antennas' radiation pattern is not significantly affected. In Figure 4(a), the 45° azimuth rotation of one element with respect to the other was done to further

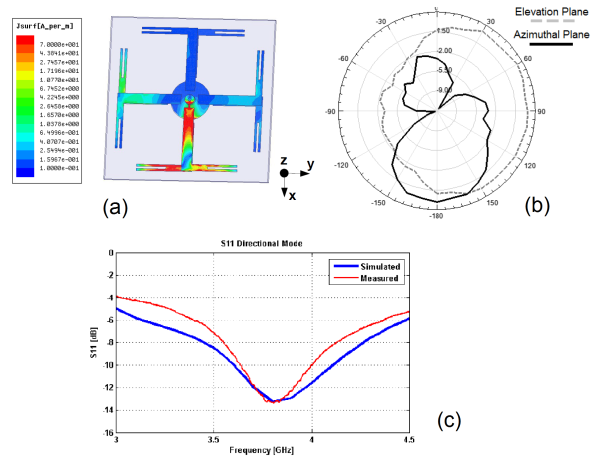

Fig. 3. Directional mode: single excited pair and radiation pattern

reduce the beams' modification. In Table I, we summarize the different mutual coupling values for the two possible array configurations and inter-element spacing.

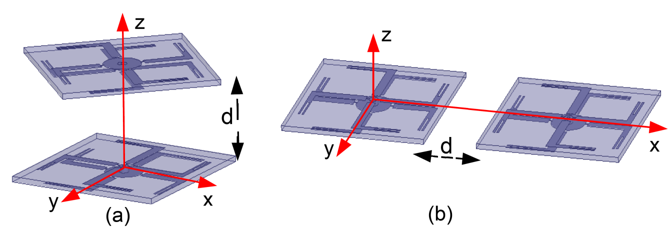

Fig. 4. Two possible 2x2 MIMO antenna configurations

TABLE I
Mutual Coupling

Distance d	Coupling S_{12} (a)	Coupling S_{12} (b)
0.5λ=40 mm	-14.5 dB	-25.3 dB
λ=80 mm	-23 dB	-30.2 dB
1.5λ=120 mm	-30.4 dB	-31.8 dB

IV. Conclusions

This work presented a wideband planar antenna centered at 3.8 GHz that is capable of generating omni-directional and directional radiation patterns as well as operating in MIMO configurations. The compact layout, pattern realizations, and low mutual coupling make this antenna a viable candidate for future MIMO systems.

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