Radiation Pattern Reconfigurable Antenna for MIMO Systems with Antenna Tuning Switches

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***Abstract*—A radiation pattern reconfigurable antenna for MIMO applications in mobile communication systems is proposed. The proposed design is a monopole antenna with two reflective strips and two antenna tuning switches. By controlling the antenna tuning switches between the strips and the ground plane, two switchable radiation patterns with correlation coefficient as low as 0.15 are achieved.**

Keywords—MIMO; pattern reconfiguration antenna; aperture tuner

I. Introduction

In recent years, there has been a rapid and successive growth in wireless communication technology. The demand for higher data rates is increasing with the advent of various services such as cellular, satellite communications and wireless local area networks. MIMO wireless systems have demonstrated the potential to increase the transmission data rate within limited bandwidth. However, the MIMO system performance is highly affected by antenna correlations when the antennas are closely placed, for example in smart mobile devices [1]. As a result, the proposed study in this paper is to obtain a solution to ensure low correlation between MIMO antennas in mobile applications under different situations.

The concept applied in this study is to provide the property of tunable radiation patterns for the MIMO antennas. I.e., under certain MIMO channel conditions the MIMO antennas are able to smartly change their radiation patterns to keep a low correlation between each other. For example, if the antennas of a two-element MIMO array have high correlation in a certain environment, one of the antennas could switch its pattern into a second mode which is not correlated to the original mode and then the MIMO channels turn into low correlation.

There are two major considerations in the design of the antenna elements. The tunable radiation patterns should be correlated to each other as little as possible and good input matching should be achieved for all the tuning states with the same input matching network. Radiation pattern reconfiguration has been widely deployed for various purposes [2][3]. However, most of these methods are difficult to implement into mobile devices due to reasons such as size, linearity and power handling capability. In this paper, antenna tuning switches (named also as antenna aperture tuners) for mobile applications used for frequency reconfiguration are implemented in a planar monopole antenna for radiation pattern reconfiguration.

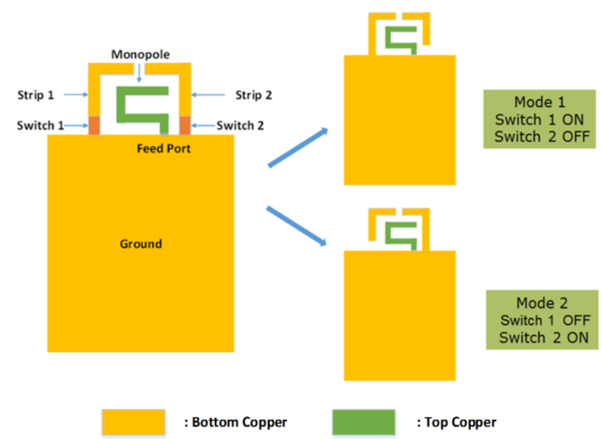

Figure 1. The design of the reconfigurable monopole antenna

II. Antenna Design and Implementation

The proposed design is a pattern reconfigurable monopole antenna complemented by two reflective L-shaped strips. The strips are symmetrically placed around the radiator to act as reflectors. One is on the left and the other is on the right. The strips can be connected or disconnected with the ground plane by the switches at their bottom. In this way, the radiation patterns are reconfigured by these two grounding elements. The operation principle of this design is shown in Fig. 1.

The monopole antenna was designed to operate at 1.7 GHz. It was printed on an FR4 dielectric substrate (dielectric constant is 4.3, loss tangent is 0.02 and substrate thickness is 1mm). In this design the antenna tuning switch BGSA13GN10 with low ON-mode resistance and low OFF-mode capacitance provided by Infineon technologies was applied to control the connection between the conductive strip and the ground plane [4]. It is a Single Pole Triple Throw (SP3T) RF antenna aperture switch supporting applications up to 5.0 GHz. The two operation modes are obtained by switching the switches on and off as shown in Fig. 1. Additionally, a lumped tuning element such as a capacitor could be implemented in the on path in

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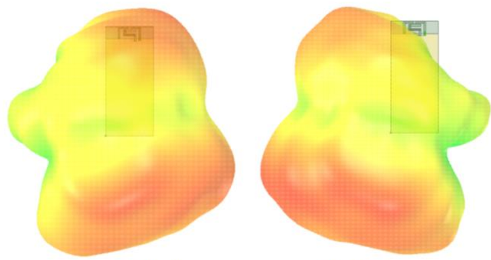

Fig. 2. Radiation patterns of monopole antenna with two modes

Fig. 3. Photograph of the monopole antenna prototype

series to optimize the antenna radiation pattern. The 3D radiation patterns for the two operation modes simulated in HFSS are presented in Fig. 2 [5]. It can be observed that two different directional radiation patterns are obtained. This proves the feasibility of the antenna design with tunable radiation patterns.

In order to check the two patterns' correlation coefficient, the equation

$$\rho_{ij} = \frac{\int \vec{F}_i(\theta,\emptyset)\cdot\vec{F}_j^*(\theta,\emptyset)\,d\Omega}{\sqrt{\int |\vec{F}_i(\theta,\emptyset)|^2 d\Omega \int |\vec{F}_j(\theta,\emptyset)|^2 d\Omega}} \quad (1)$$

is implemented [6], where $\vec{F}(\theta,\emptyset)$ is the complex normalized antenna radiation pattern. For the first design, the ON-status switch is directly shorted to the ground plane and the correlation coefficient is about 0.47, which is still not satisfactory for MIMO applications. Then, two tuning capacitors are implemented in series between the ON-status switch and the ground plane at both switches. By optimizing the capacitance, the pattern correlation between the two modes is reduced to 0.15.

The simulated and measured return loss of the pattern reconfigurable monopole antenna is shown in Fig. 4. The impedance matching for this antenna is challenging because the antenna should be matched for two different modes with

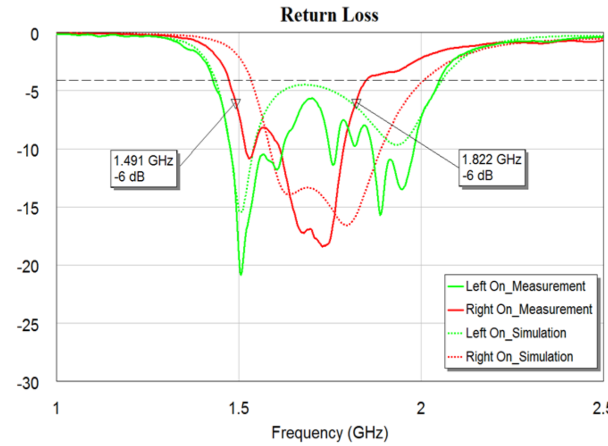

Fig. 4. Measured and simulated return loss of pattern reconfigurable monopole antenna

the same matching circuit. The measurement result shows a good agreement with the simulation result. The return loss is below -6 dB between 1491 MHz and 1822 MHz.

III. Conclusions

In this study, a radiation pattern reconfigurable monopole antenna with two L-shaped strips and antenna tuning switches was fabricated and measured in good agreement with simulation in return loss. The designed antennas have advantages over conventional pattern reconfigurable antennas in aspect of low radiation pattern correlation between the modes and compact size, where the mobile MIMO system could benefit a lot. It also owns the potential to combine pattern and frequency reconfigurability with the aperture tuners.

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