A Small Low Profile Dual-Polarization Antenna for Indoor MIMO Systems

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Abstract

A pair of small and low profile dual-polarization antennas has been developed for miniature indoor base station under the MIMO (Multiple-Input Multiple-Output) technology to restrain spatial correlation in LOS (Line-Of-Sight) channel environment. Both of the component antennas operate at 2GHz, it is expected to apply on IMT-2000 or LTE communication systems. The space volume is about W150×H120×D12mm (ground included).

Keywords: Small Low profile Dual-polarization antenna MIMO Indoor base station LOS

1. Introduction

These years, MIMO systems are becoming a noticeable technology due to its outstanding advantages and increasing demand for it. Besides, small indoor base station is spreading widely for people staying in home can obtain more steady communication and higher transmission speed. Take account of the LOS channel in some indoor environment, a pair of dual-polarization antennas is necessary for it can reduce the level of spatial correlation in limited space. Various dual-polarization antennas have been proposed. A proposed dual-polarization antenna has a thickness of about 0.24λ [1]. Numerous typical vertical polarization and horizontal polarization antennas, mostly notched ones, have been calculated and discussed [2] [3] [4]. As the prototype of the present one, a kind of polarization diversity composite antenna has been proposed and designed at lower frequency band on auto application [5]. In the initial stage of this subject, some earlier researches were done [6].

In this paper, a pair of dual-polarization antenna composed by a vertical polarization element and a horizontal polarization element is proposed. Both of the principal polarization radiation patterns are similar with which of a monopole antenna set on semi-infinite ground. It is verified that gain of both the elements are close to 5dBi. The vertical polarization element and horizontal polarization element will be introduced in Part 2 and Part 3 respectively. In Part 4, combination of the two elements and measurement result in experiment will be shown. The antennas are simulated on FEKO, which based on the Method of Moments (MoM).

2. Vertical Polarization Antenna

We use Disk Loaded Monopole antenna for the vertical polarization element. The antenna consists with a metal triangular plate, a feed pin and three short pins. As shown in Fig. 1, feed pin is located at the center of triangle plate, and three short pins are put around it central symmetrically. The radiation characteristic mainly depends on the current flow on feed pin and short pins. Comparing with wavelength, when the distance between feed pin and short pins is small enough, radiation pattern in vertical plane will be similar with that of a monopole antenna. Disk plate is non-radiating for the current distribute on it is parallel with ground. However, it`s electrical size will influence on the frequency characteristic of antenna. Short pins are necessary, because they can lower the operation frequency effectively. In addition, to obtain omni-direction in horizontal plane, we need 3 short pins at least. Considering that frequency increases proportionate to the quantity increase of short pins, we chose 3 short pins to maintain the size of antenna. The usage of triangular plate is because that lower resonant frequency can be got, comparing with circular plate in a same area. Additionally, triangular plate is easier to manufacture. The two operation modes of disk loaded monopole antenna should also be mentioned. One is called coaxial mode and the other is called patch mode. Coaxial mode occurs when the short pins are close enough to the feed pin. Feed pin plays the role of inner conductor, and the three short pins play the role of outer conductor. Patch mode occurs when short pins are far from feed pin. Resonant frequency of coaxial mode is lower than which of patch mode. However, both of the two modes are TM_{01} mode. Thanks to its operation on coaxial mode, the new design is 60% smaller than the conventional one. The radiation pattern of vertical polarization element is shown in Fig. 2. Cross polarization and radiation under the ground plane are due to the usage of finite ground.

3. Horizontal Polarization Antenna

We use Notch Array antenna for the horizontal polarization element. As shown in Fig. 3, there are 3 notches cut out from the bottom conductor plate, and 3 microstrip lines feed them respectively on the top side. A power divider which combined with antenna was proposed and located at the center. Dielectric coefficient ε=2.6, thickness of substrate is 0.8mm. When current distribute around the notch, time-varying magnetic field is caused in the space of notch. In view of the magnetic field distribution, we can suppose that there is equivalent magnetic current existing in the space of notch, and directing to the open end (Fig. 3). As notch can be imagined as the complementation of a monopole antenna which is set on semi-infinite ground plane, the length of notch should be $\lambda/4$. In view of actual electric current path, the perimeter of notch is expected to be at least $\lambda/2$ for matching and the maximization of gain. The detailed size showed in Fig. 3 is available only when the height of antenna is 12mm. For the height of antenna influences input characteristic intensely. The radiation pattern of horizontal polarization element is shown in Fig. 4. Although the principal polarization is horizontal polarization, it is verified that the radiation pattern of notch array is able to be formed similarly with a monopole antenna.

4. Composite Antenna and Experiment

As a simple way for the combination of these two component antennas, we proposed to put them side by side. After some adjustment on details, experimental model (Fig. 5) was fabricated and measured. Screws are used as short pins on disk loaded monopole antenna, for it is easy to fix and adjust. Despite the merits of it, unwanted part beneath the ground caused the decrease of resonant frequency. To solve this problem, the three angles of patch were cut off. The reflection and mutual characteristics are shown in Fig. 6. It seems that measurement result is agreed with simulation. The isolation between the two component antennas is about 23dB. This level is acceptable for MIMO systems. The radiation patterns of the two elements under the calculation and measurement are arrayed in Fig. 7 and Fig. 8 respectively. Differences are limited except the performance of vertical polarization element on horizontal plane. Serious degradation on principal polarization can be explained as the influence of coaxial line feeding to notch array antenna. This line does not exist in simulation. Besides, we found that radiation patterns of the two component antennas are not as symmetrical as which of the results calculated independently. The mutual influence is considered to be the reason of this variation. Moreover, it is found that there is a little radiation under the ground plane. If we hope to restrain the bottom radiation, a larger ground is needed. Take into account the size control, we have to tolerate the bottom radiation less than an acceptable level.

5. Conclusion

A kind of dual-polarization antenna for indoor MIMO systems has been proposed and developed, finally verified by experiment. The most outstanding feature is the small size and low profile. The antenna size is about $0.8\lambda \times 0.4\lambda$ (ground not included), and the overall thickness is 0.08λ. The two component antennas operate at 2GHz band. Both of the principal polarization radiation patterns are similar with which of a monopole antenna set on semi-infinite ground.

References

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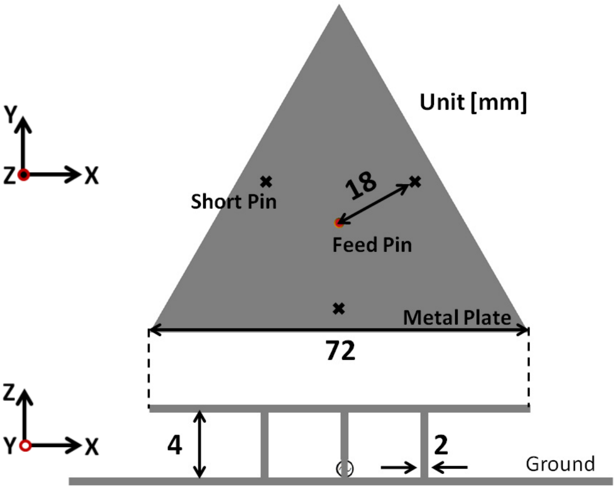
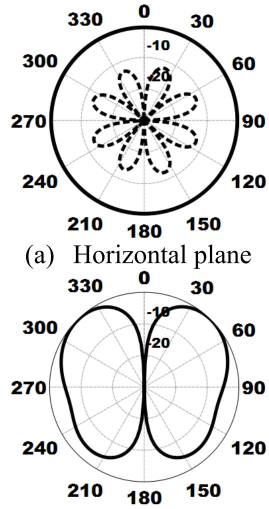


Fig. 1: Structure of disk loaded monopole antenna



(a) Horizontal plane

(b) Vertical plane

Fig. 2: Radiation pattern of disk loaded monopole antenna (solid line is E_θ, dotted line is E_φ)

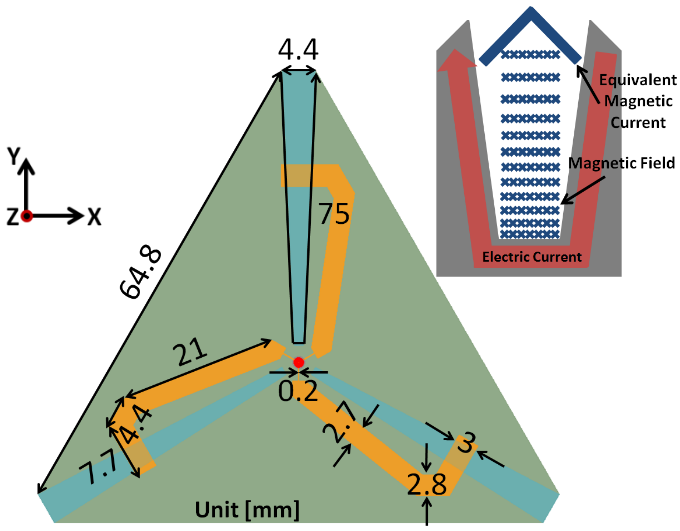
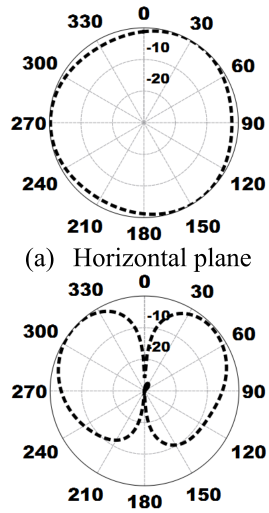


Fig. 3: Structure of notch array antenna and the form of equivalent magnetic current



(a) Horizontal plane

(b) Vertical plane

Fig. 4: Radiation pattern of notch array antenna (solid line is E_θ, dotted line is E_φ)

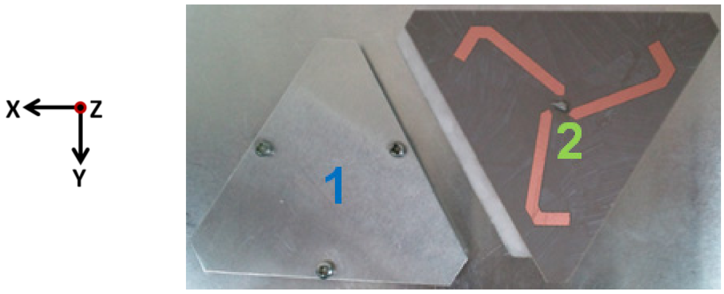


Fig. 5: Combination of the two antennas in experiment

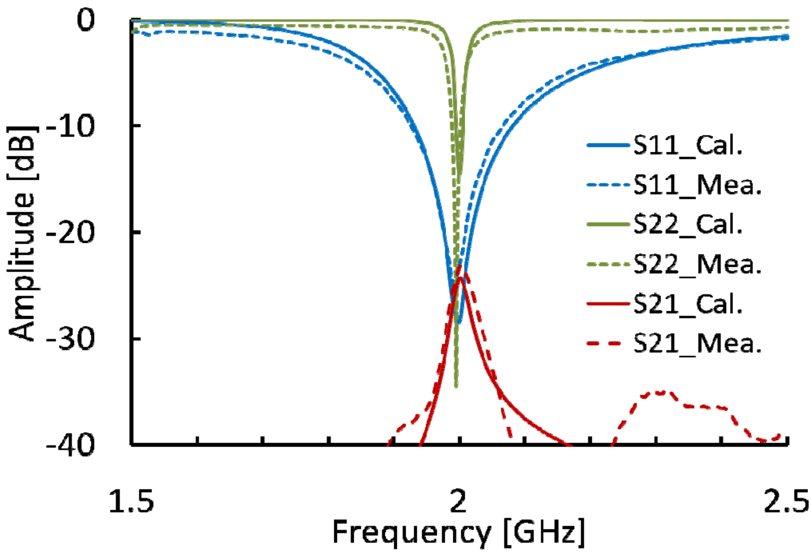


Fig. 6: Input characteristics of the two component antennas
(Port1 for disk loaded monopole antenna, Port2 for notch array antenna)

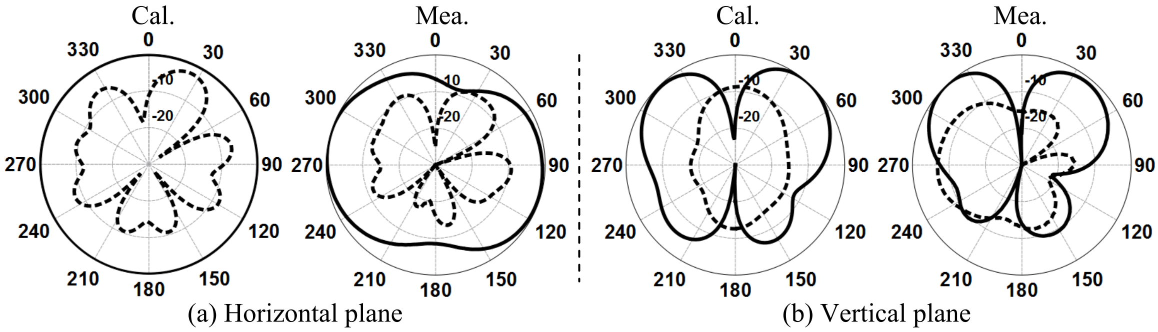


Fig. 7: Comparison of radiation pattern of the vertical polarization element in simulation and experiment (solid line is $\boldsymbol{E}_\theta$, dotted line is $\boldsymbol{E}_\varphi$)

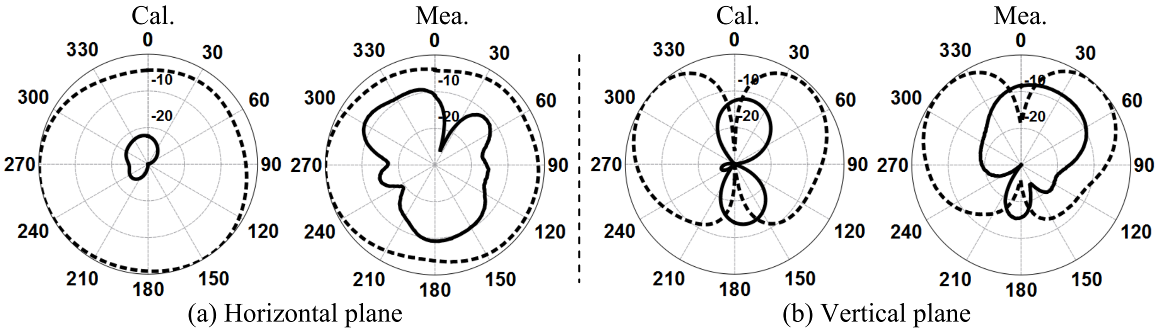


Fig. 8: Comparison of radiation pattern of the horizontal polarization element in simulation and experiment (solid line is $\boldsymbol{E}_\theta$, dotted line is $\boldsymbol{E}_\varphi$)