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A FOUR ELEMENT DIVERSITY ANTENNA ARRAY FOR A MIMO PDA TERMINAL

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1. Introduction

In the conventional wireless communication systems, there is usually one antenna at the transmitter and one at the receiver which is called SISO (Single Input Single Output) antenna system. This system has a bottleneck in terms of capacity due to the Shannon-Nyquist Limit. However, the future wireless communication system requires much higher bit-rate transmission to enable the service of Internet access, video, music, games and etc. The promising way to fulfil this demand is to employ a MIMO (Multi Input Multi Output) antenna system [1]. The MIMO system uses a number of parallel radio channels in order to multiply the throughput of a radio system. The radio channels are on the same frequency but the system relies upon there being rich multipath to ensure that multiple decorrelated transmit/receive antennas and associated signal processing resolves a number of signals arriving via different multipath routes [2].

Conventional MIMO terminals with multiple antennas often use co-polarised linear arrays based on the space diversity. This set-up is natural for a base station scenario, but is too bulky for a compact mobile terminal. There are wide research and development efforts into compact antenna arrays for MIMO wireless communication terminals. The essential requirements for this system are that the antennas must be diverse, i.e. they must be capable of receiving different signals even though they are closely spaced. At the moment, the use of multiple antennas on a compact mobile terminal (e.g. PDA and handset) for the MIMO communication systems still remains as a challenging task. We have investigated a number of different types of microstrip patch antenna arrays, such as PIFAs (Planar Inverted F Antenna) and PILAs (Planar Inverted L Antenna), which are widely used in mobile handsets. However, the isolation between the elements is poor and their cross polarisation is high. Eventually, a folded loop antenna is identified to provide both good isolation and polarisation diversity [3]-[5].

The operating frequency chosen for this study is 5.2 GHz with a bandwidth of 120 MHz, which corresponds to one band of IEEE802.11a. It is also believed that the frequency bands for the future wireless communication system will most likely lie above 5GHz and the high speed wireless access network type a (HiSWANa) is expected at a carrier frequency of 5.2GHz [6].

2. Antenna design

The diversity antenna element chosen in this study is a modification of the folded loop antenna [3]. The folded loop antenna is essentially a two-wire transmission line, folded at about a quarter-wavelength to form an equivalent half-wave folded dipole. At the same time it appears as a one-wavelength loop antenna, from which the antenna is referred to as folded loop. This antenna is originally deigned for mobile handsets and is shown that it has little current spreading on the ground plane and low cross polarisation.

The modification to the original folded loop is the insertion of a dielectric slab, as shown in Fig. 1 (a), which acts as a mechanical support while the size of the antenna is further reduced due to dielectric loading. In the fabrication, a coaxial cable is used to feed the dielectric loaded folded antenna, forming an unbalanced feeding system. It has been shown that there is only a slight difference of the current distribution on the ground plane of folded loop antenna in both unbalanced and balanced feeding system [5].

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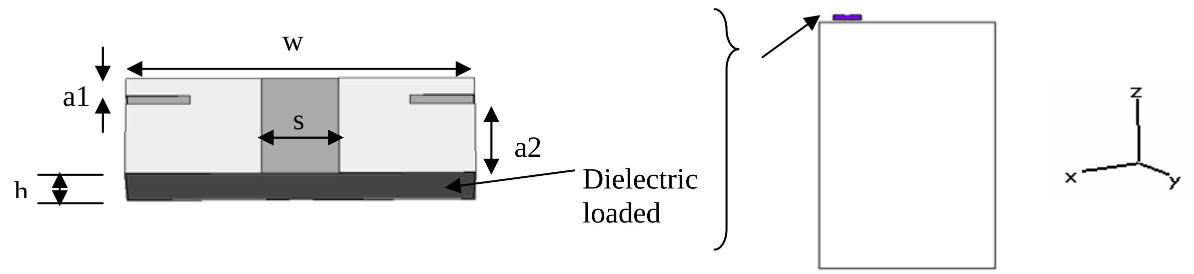
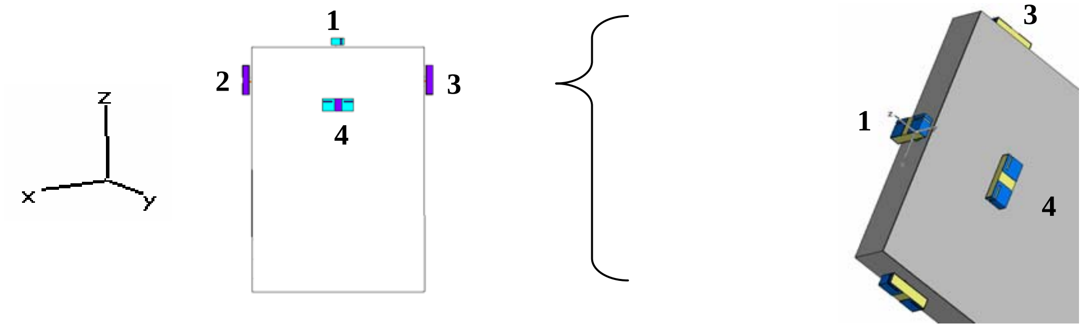


(a) (b)

Fig. 1. Schematic shows dimensions of the (a) single dielectric loaded folded antenna element. (a1=1mm, a2=4mm, w=12mm,h=2mm,s=2mm), and (b) a single antenna on PDA (110mm x 75mm x 10mm).

A single antenna element on the PDA is designed first. The CST Microwave Studio™ package, which is based on a Finite Integral technique being equivalent to FDTD in the time domain [7], is used as our design tool. The final dimension of the single antenna is shown in Figure 1. The permittivity of dielectric slab is 6. The PDA is represented by a metal case and has a dimension of 110mm x 75mm x 10mm.

After the verification of the single element in the experiment, we proceed to design a 4-element diversity antenna array on the PDA. Four antennas are mounted on the top part of the PDA as shown in Figure 2. With this arrangement, the antennas are orthogonally polarised to each other to avoid coupling, except antenna 2 and 3 are parallel to each others. Since the antennas are linearly polarized, this arrangement can achieve both pattern and polarisation diversity simultaneously.

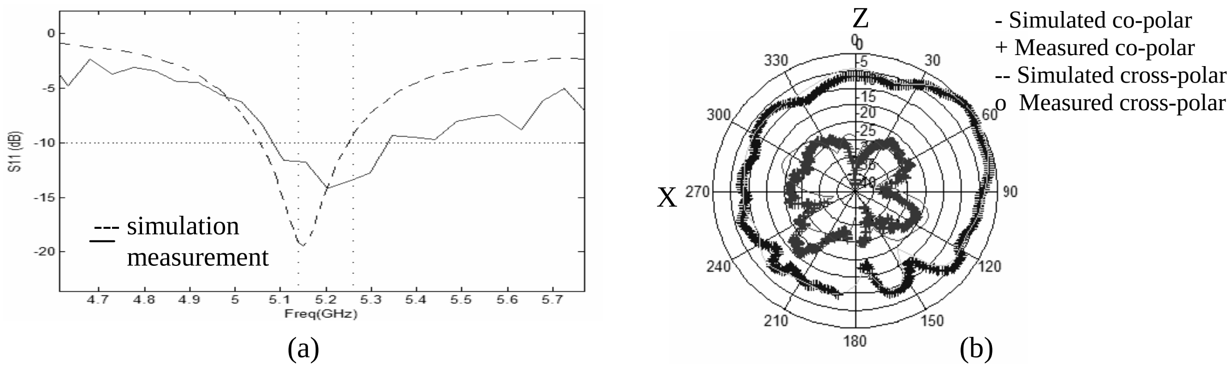


(a) (b)

Fig. 2. Schematic diagram of 4 branches diversity antennas on PDA.
(a) Location of antennas 1 – 4 in XZ plane and (b) 3D view of the model.

3. The results

The prototype of the single dielectric loaded folded antenna on the PDA, as shows in Fig. 1(b), is built in the antenna laboratory at Queen Mary, University of London (QMUL). It return loss is measured by using a HP 8720ES network analyser and the radiation patterns are measured inside the anechoic chamber. Simulated and measured results for the prototype are shown in Fig. 3.

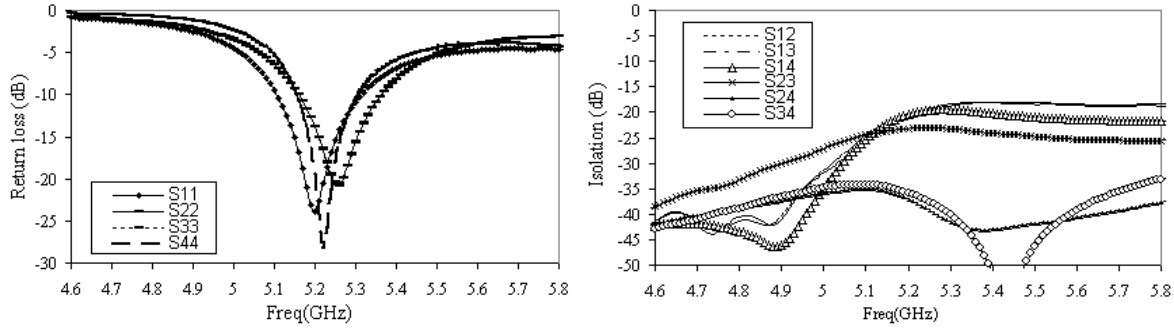


(a) (b)

Fig. 3. Simulated and measured results of the single antenna on PDA design in Fig. 1 (b). (a) return loss, and (b) E-co and E-cross radiation pattern.

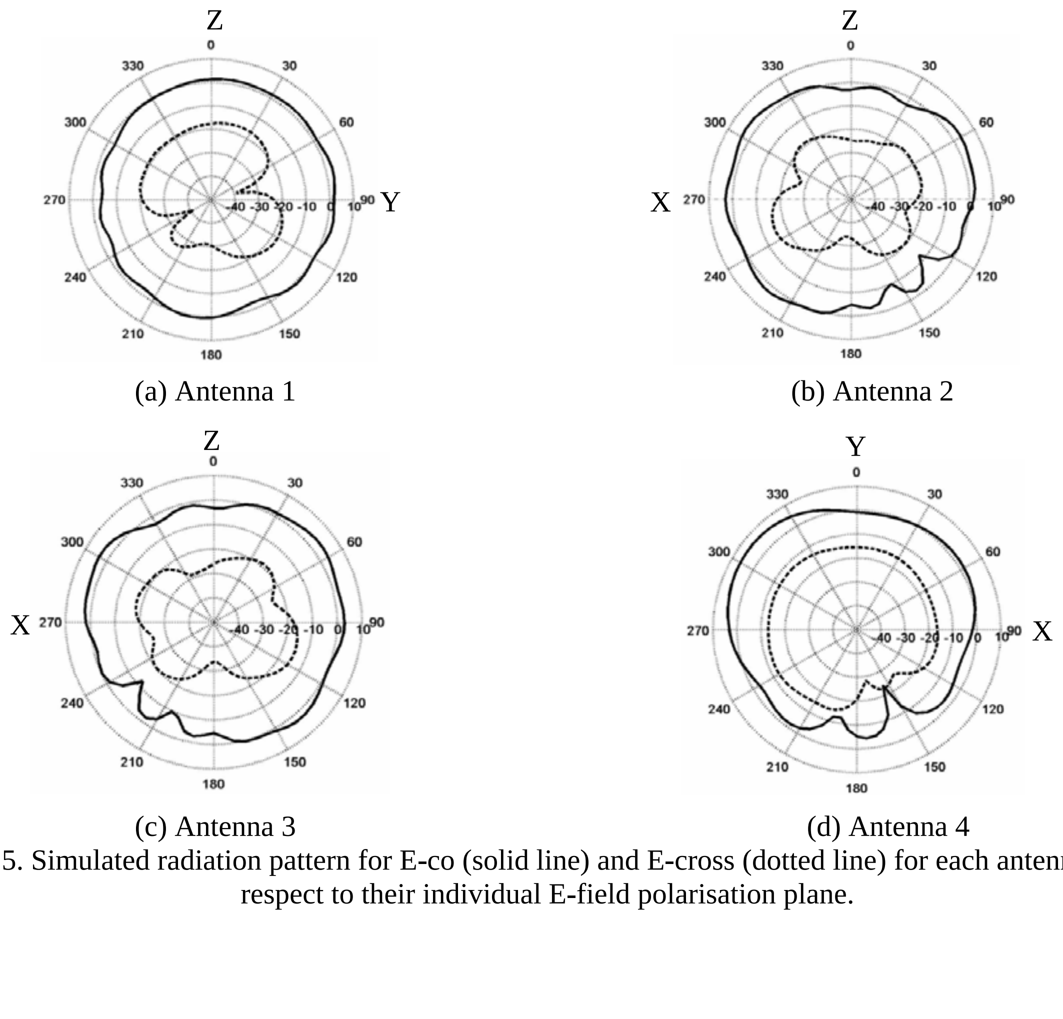
The simulated radiation patterns are in a good agreement with the measured ones. It is shown that the cross-polarisation is very low (<15dB in the most angles) in this design. Though, it is realized that the antenna element is very small hence imperfection during the fabrication process may cause a slight shifting of the resonance frequency. This has given us enough confidence in CST Microwave Studio^{TM} package as our design tool

The simulated results of the 4 element diversity array design (Fig. 2) are shown in Figs. 4 and 5. The resonant frequencies of the 4 antennas are slightly different, as shown in Fig. 4 (a). This is due to the difference of the size of the ground plane for difference antennas. The isolation between each pair of elements is better than 15 dB, as shown in Fig. 4(b). Since the orientations of the antennas are different to each other (Fig. 2), the radiation patterns of each antenna are plotted with respect to their own E-field polarisation plane. For antenna 1 the E-field is polarised at YZ plane, antenna 2 and 3 E-fields polarised at XZ plane and antenna 4 E-field is polarised at XY. It can be seen that the cross polarisation is low in most cases. The prototype of the 4-element array on a PDA is in the process of fabrication and the measurement will be carried out in due course.



(a) (b)

Fig. 4. Simulated results of the 4-element diversity array
(a) return loss of the 4 antennas, and (b) isolations between each antennas.



(a) Antenna 1
(b) Antenna 2
(c) Antenna 3
(d) Antenna 4

Fig. 5. Simulated radiation pattern for E-co (solid line) and E-cross (dotted line) for each antenna with respect to their individual E-field polarisation plane.

4. Conclusions

The modified folded loop antennas are used as the diversity array on a PDA due to its compactness in size and good isolation. The prototype of a single antenna on a PDA has been measured and the accuracy of the CAD package used in this studied is verified. The proposed 4 element diversity array operating at 5.2GHz is shown to have isolation better than 15dB between each elements and low cross-polarisation. This suggests that the proposed design of the 4-element diversity array provides a good solution for a compact MIMO terminal.

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