Experimental Study on Improving MIMO Channel by Dual-antenna System (DAS)

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1. Introduction

Recently, Li *et al*. designed a broadband reflectarray antenna as a passive repeater to overcome a problem of blind areas [1]. However, the aperture efficiency of the reflectarray degraded greatly when a very large scattering angle was desired because of a physical limitation of the reflectarray. In [2], although a dual-antenna system (DAS), composed of patch array and open-ended waveguide, was proposed to realize a large scattering angle, there were still some disadvantages in the design such as bulky size, high cost, small equivalent bi-static radar cross section (BRCS), etc. A quasi-planar DAS was proposed for solving these problems in [3], but only numerical analyses were performed. It is important to demonstrate the effectiveness of the proposed DAS in wireless communication applications. In this research, a quasi-planar DAS, which consists of a 4-element folded-patch antenna (FPA) array, a planar Yagi-Uda antenna, and a power combiner, was fabricated. Experiments were carried out in a multipath environment to demonstrate the improvement of multiple-input-multiple-output (MIMO) channel by using the DAS.

2. Configuration of the Quasi-planar DAS

Fig. 1 shows the configuration of one-unit DAS comprising a 4-element FPA array, a planar Yagi-Uda antenna, and a power combiner. The element in the FPA array building on the top side of substrate is chosen as the same as Set 1 in [4] due to its compact size. There is a trade-off between antenna's size and gain. If high gain is of primary concern in applications, other planar antenna types with slightly larger sizes can also be chosen to meet the requirement, such as the broadband patch antennas proposed in [5]. The Yagi-Uda antenna employed here has one driven element, two directors, and a large corrugated ground plane as a reflector. The ground plane is corrugated periodically to suppress the side lobes in H plane, and the antenna gain can be enhanced effectively [6]. The power combiner is mounted on the bottom side and connected to the input port of the planar Yagi-Uda antenna. Feeding probes A, B, C, and D of four patch elements are connected to four input ports of the power combiner through four via-holes on the ground plane. When an incident wave impinges on the FPA array, the received electromagnetic (EM) wave will be delivered to the Yagi-Uda antenna through the power combiner for reradiation. Further details about the DAS can be found in [3]. To verify the design, the authors fabricated a 4-unit DAS prototype shown in Fig. 2. A substrate with a thickness of 0.8 mm and relative permittivity of 3.3 was utilized for supporting the power combiner and the planar Yagi-Uda antenna.

3. Measurement Setup

A 2 x 2 MIMO system was used to demonstrate the effectiveness of the 4-unit DAS for improving the propagation channel in MIMO communications. The experiment was carried out on the second floor of a concrete building as shown in Fig. 3. It is seen that NLOS environment, similar to blind areas in urban area as shown in [1] and [3], was utilized. Two λ/2 dipole antenna arrays with 1.2λ array spacing were used as the transmitting antennas, and the transmitting signal was a continuous wave (CW) operating at 2 GHz. Because the DAS was designed to receive normal incidence wave, the incident wave was always from +y direction. Agilent 89600S vector signal analyzer, with two RF input channels, was used to receive the signals from two λ/2 dipole antenna arrays with λ/2 array spacing. The transmitting antennas were fixed, while the receiving antenna was moved gradually by a step of 2.5 cm in a 50 cm x 50 cm area. Therefore, measurement was repeated 21 x 21 times. Distance between the centre of the 4-unit DAS and that of receiving area was 12.25 m. Distance between the centre of the 4-unit DAS and transmitting antenna was 3.4 m. Ceiling height from floor was 2.42 m. The receiving antennas, the centre of transmitting antennas and the 4-unit DAS were placed above the floor at the same height of 1.21 m. The transmitting antennas were fixed to horizontal polarization, while the polarization direction of the receiving antennas was vertical.

4. Experimental Results

A total of 441 experimental results were obtained and the results were expressed in the form of cumulative distribution function (CDF).

Fig. 4 shows the CDF of the received power with/without the 4-unit DAS. The results of Rx1 are denoted by a solid line and those of Rx2 by a short-dashed line. It can be seen that when 4-unit DAS was used, the medians of the received power of Rx1 and Rx2 were improved by about 15 dB as compared to those without the 4-unit DAS.

The channel capacity also was calculated for evaluating MIMO performance. Fig. 5 shows the CDF of the 2 x 2 MIMO channel capacity with/without the 4-unit DAS. It can be found that when the received noise level was supposed to be -120 dBm/Hz, the median of the MIMO channel capacity with the 4-unit DAS was increased by 7.8 bps/Hz as compared to that without the 4-unit DAS. The foregoing experimental results demonstrate the effectiveness of the 4-unit DAS in improving the propagation channel in MIMO communications.

5. Conclusions

A 4-unit DAS was fabricated to investigate experimentally the MIMO performance in multipath environment. Based on the experimental results as obtained above, it is found that, by using the 4-unit DAS, the received power and the MIMO channel capacity could clearly be improved, thereby establishing the validity of 4-unit DAS for practical applications of MIMO system. Because of this application, at CDF = 0.5, about 15 dB improvement was obtained in the receiving power. Further, when the received noise level was supposed to be -120 dBm/Hz, the median gain of the MIMO channel capacity was increased by 7.8 bps/Hz as well.

References

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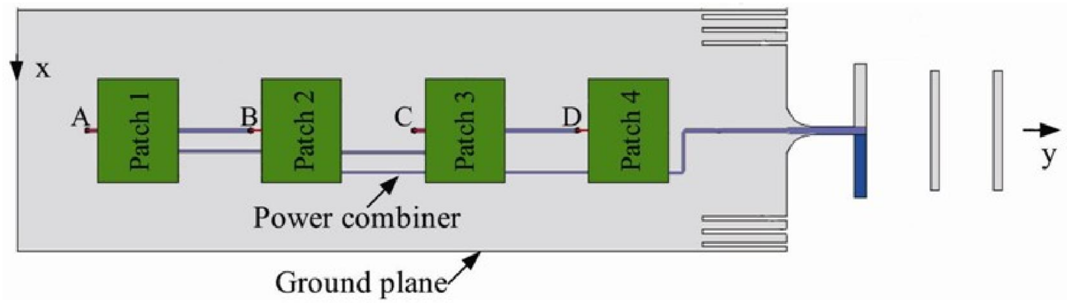
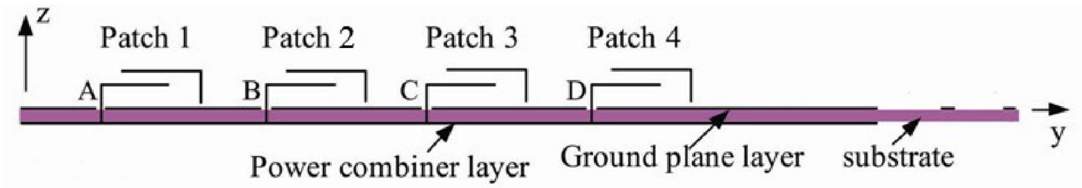
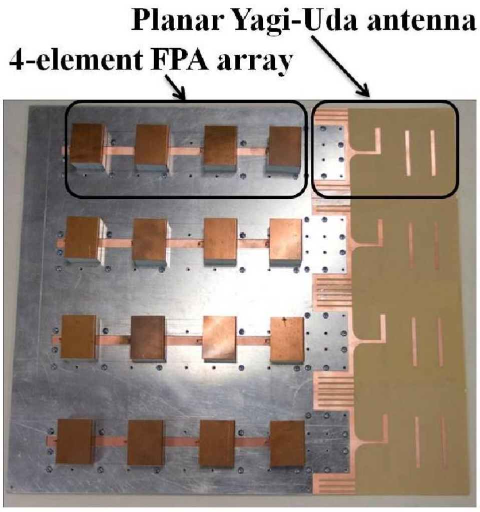


(a) Top View

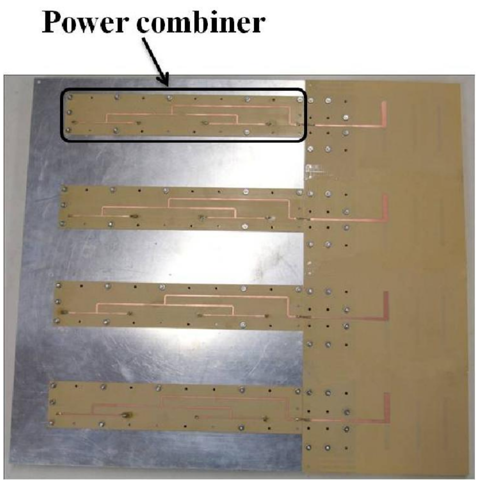


(b) Side View

Figure 1: Configuration of the One-unit Quasi-planar DAS.



(a) Top Layer



(b) Bottom Layer

Figure 2: Photographs of the Fabricated 4-unit Quasi-planar DAS.

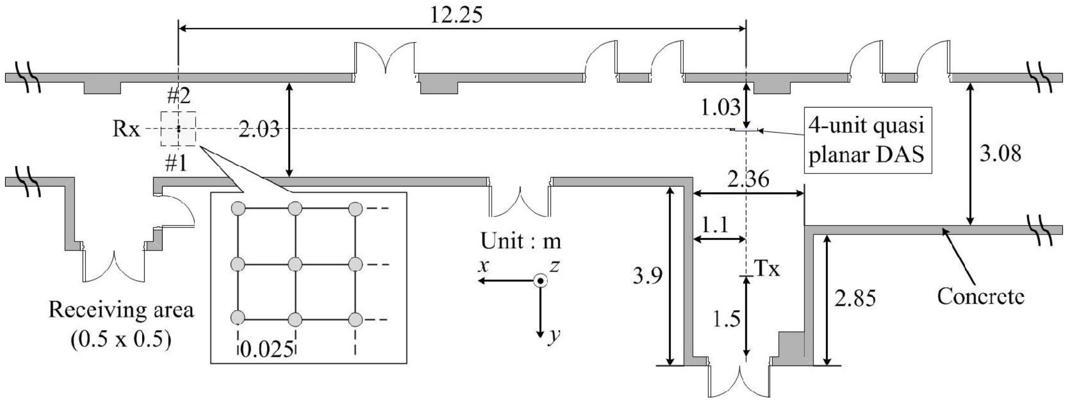


Figure 3: 2 x 2 MIMO Measurement Environment.

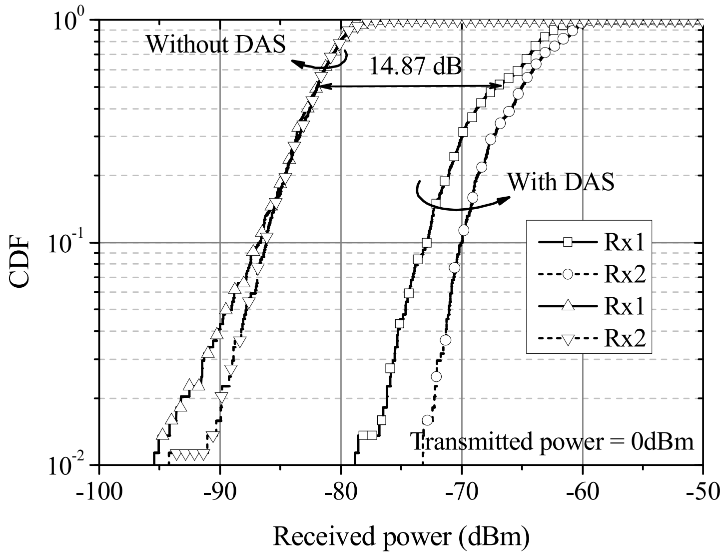


Figure 4: The CDF of the Received Power with/without 4-unit Quasi-planar DAS.

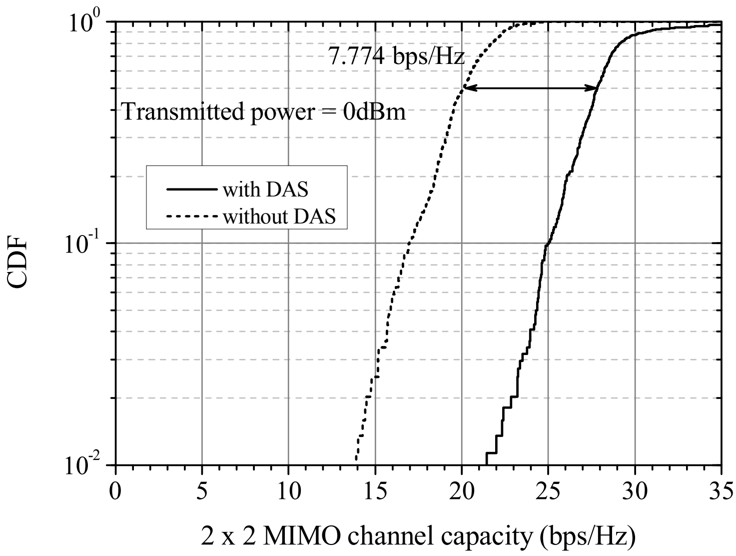


Figure 5: The CDF of the 2 x 2 MIMO Channel Capacity with/without 4-unit Quasi-planar DAS.