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Modulated scattering array antenna for MIMO applications

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Abstract: Modulated scattering array antenna (MSAA) for MIMO applications is experimentally studied. The MSAA has a multi-antenna structure, but it is composed of only one normal antenna element together with several modulated scattering elements (MSE). The Error Vector Magnitude (EVM) which indicates the MIMO performance is measured in an indoor environment when a 2-element MSAA is used as the MIMO antenna in a 2×2 MIMO system. It is demonstrated that 2-stream data link can be established. However, the EVMs of the 2 streams are quite different and an averaged 7 dB difference is observed due to the gain degradation of the MSE, indicating the MSAA can be used in the MIMO applications where simplifying the configuration of MIMO antenna system is taken high priority.

Keywords: antenna, array antenna, modulation, wireless communications, mobile handset, MIMO

Classification: Microwave and millimeter wave devices, circuits, and systems

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1 Introduction

The multiple input multiple output (MIMO) has become a promising technology for the wireless communications of next generation, because it could achieve much higher spectral efficiency and transfer reliability than the conventional wireless communication techniques with the same transmitted power and frequency bandwidth [1]. However, it is a challenging work to develop efficient array antennas suitable for mobile handsets because it is difficult to mount array antennas with sufficient space on the handsets which have low mutual coupling and correlation between the array elements [2]. Moreover, because a number of separate RF front-end circuits are required corresponding to the number of array elements, a large amount of packaging space for the RF front-end circuits is necessary. Therefore, it is important to develop array antennas and the RF front-end circuits with simple configurations for mobile handsets in MIMO applications.

We have proposed a new concept of array antennas, which is called modulated scattering array antenna (MSAA), based on the modulated scattering technique [3, 4]. The MSAA has a multi-antenna structure, but it is composed of only one normal antenna element together with several modulated scattering elements (MSE) without RF front-end circuits. Therefore, the configuration of the MSAA is much simple compared with that of the normal array antenna. We have carried out experiments to investigate diversity performance of the MSAA and found that, because the gain of the MSE was much smaller than that of the normal antenna element so that the diversity effect was very limited [3]. We have also tried to optimize the array spacing to increase the gain of the MSE and further improve the diversity gain when the MSAA is used as diversity antenna in Rayleigh fading environment, and found that the diversity performance may be increased by mounting the array elements with a compact spacing [4]. These previous researches indicated that the MSAA can be one of the possible solutions to mount array antenna to the mobile handset applications where mounting space and manufacturing cost are strictly limited.

In the MIMO communication system, the signal transmission performance is mainly dependent not only on the channel gain between the receiving and the transmission array antenna, but also on spatial correlation and mutual coupling between array elements. If the MSAA is used in the MIMO application, small array spacing may help to increase the channel gain, but high correlation due to the compact array spacing may degrade the MIMO performance. Therefore, it should be further investigated to see how it is effect to use the MSAA for the MIMO applications.

In this research, an experimental study is carried out to measure the MIMO performance in an indoor 2×2 MIMO system where the MSAA is used as the MIMO antenna. Because the EVM (Error Vector Magnitude) is an indicator of transferred signal performance in communication systems, it is measured and compared with that of the normal array antenna to demonstrate the performance of the MSAA in the MIMO communication systems.

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2 Experimental Configuration

A 2-element monopole MSAA for mobile handset applications operating at 2.4 GHz was fabricated for the experimental study which is shown in Figure 1, together with a normal monopole array antenna. Both of the monopole arrays are composed of two quarter-wavelength monopole elements with array spacing of 0.4 wavelengths. In the MSAA, the right element is the normal antenna element and the left one is the MSE. A schottky diode between the MSE monopole and the ground plane is used as the nonlinear impedance for modulation. The structure and mechanism of the MSAA is described in Yuan.

We have developed a measurement system for evaluating antenna performance in a 2×2 MIMO communication system operated with 802.11n protocol. Two Agilent E4438C vector signal generators with N7617A Signal Studio for creating IEEE 802.11n data packets are used to feed two log-periodic array antennas with a half-wavelength array spacing as the transmitting antennas. The Agilent 89600S-040 vector signal analyzer with two RF input channels and software option 89601x-B7Z for IEEE 802.11n MIMO modulation analysis are used to demodulate and analyze the signals received by the evaluated MSAA. The baseband signal is QPSK modulated in 36 MHz bandwidth, and the data rate is 39 Mbps according to the IEEE 802.11n regulation.

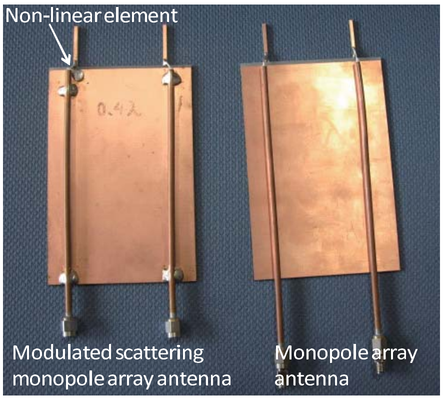

Fig. 1. 2-element modulated scattering monopole array antenna (left) and 2-element normal monopole array antenna (right).

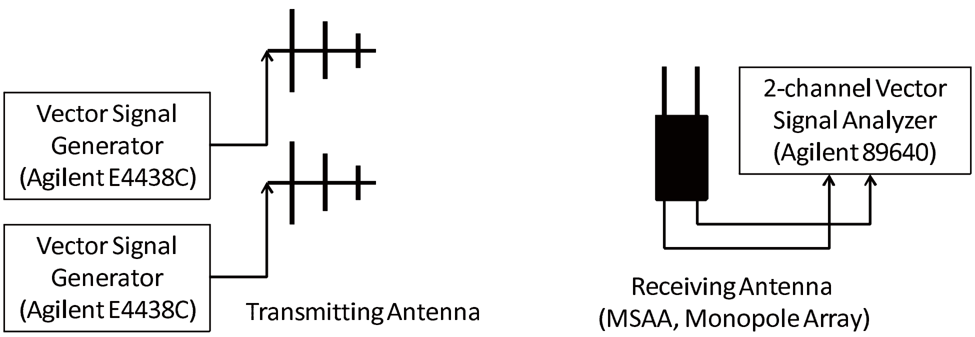

Fig. 2. 2-channel MIMO measurement system.

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The measurement was performed in a 6×7 meters office room with concrete structure. The distance between the transmitting and receiving antennas is about 5 meters and LOS (line of sight) environment was kept in the measurement. RF frequency was 2.4 GHz.

The location of transmitting antenna was fixed but the receiving antenna was moved by steps of 3 cm in a 12 cm $\times$ 12 cm area. Therefore, the measurement was repeated 5×5 times. The constellation diagrams of the demodulated IEEE 802.11n signals for 2 streams were recorded in each measurement. Further, the EVM was calculated for the constellation diagram for every location of the receiving antenna.

3 Experimental Results

Figure 3 shows the constellation diagrams of two streams demodulated from 802.11n signals received by the MSAA, which includes QPSK-modulated data symbols and BPSK-modulated pilot symbols. It is shown that symbols of stream 2 are shifted slightly from their ideal locations. The degradation of stream 2 is caused by the lower gain of the MSE element as reported in [3], where it was found that the gain of the MSE element was usually 15–20 dB lower than that of the normal antenna element. The constellation diagram can be evaluated using the values of EVM. Because the measurement is repeated 25 times while slightly changing the location of the receiving antenna array, 25 values of the EVM were obtained and they were further expressed in the form of CDF. Figure 4 shows comparison of the CDF of EVM between the 2-element monopole MSAA and 2-element monopole array antenna. If they are compared at CDF = 50%, it is shown that the EVM of the stream 1 is almost the same as that of the stream 2 for the normal monopole array antenna, because of the LOS environment and equal gain of the two array elements. However, in the case of the MSAA, although the EVM of stream 1 is almost the same with that of the normal monopole array antenna, the EVM of the stream 2 is about 7 dB lower than that of the stream 1.

The experimental results indicate that although the MSAA has only one RF receiving channel because of its particular array structure, it can be

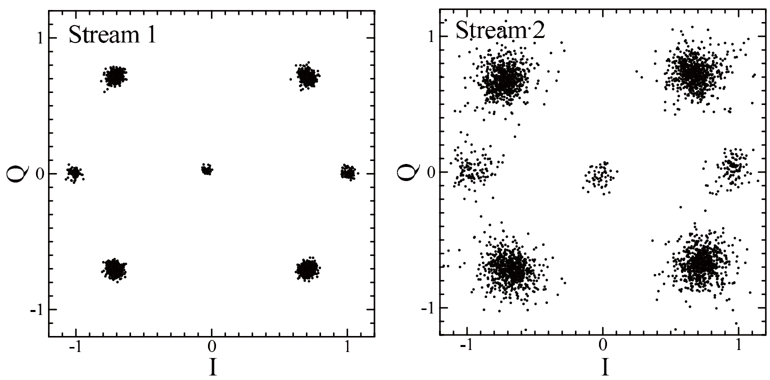

Fig. 3. Constellation diagrams of 2 streams demodulated from 802.11n signals received by MSAA.

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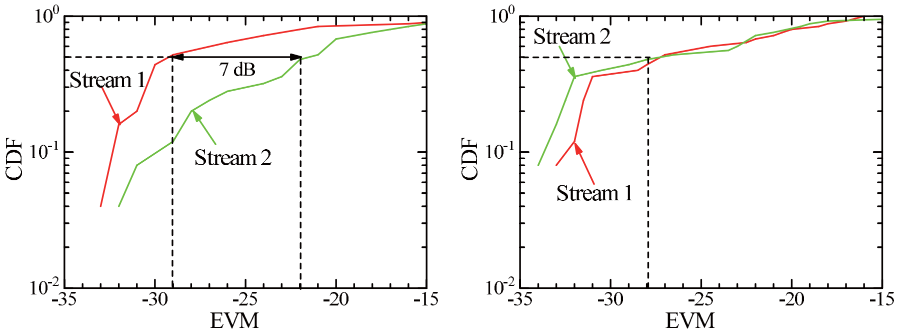

Fig. 4. CDF of EVM of MSAA and normal monopole array.

used in the application of the multi-channel communication system. The quality of the transmitted symbol streams, except for one stream, is degraded because of the low channel gain of the MSE channels, but the MSAA can be used in the application of MIMO applications where the production cost and implementing space of array antenna system are more important factors.

4 Conclusions

In this research, an experimental study has been carried out to measure the MIMO performance in an indoor 802.11n 2×2 MIMO system where the MSAA is used as the receiving antenna. The EVM was measured to demonstrate the performance of the MSAA in the MIMO communication systems. It has been found the EVM of the stream 2 is about 7 dB lower than that of stream 1 in the case of MSAA, indicating the MSAA can be used as the multi-antenna in the MIMO applications where simplifying the configuration of MIMO antenna system is taken high priority.

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