第 508 回　伝送工学研究会

Experimental Study on MIMO Performance of Modulated Scattering Array Antenna

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平成 20 年 2 月 26 日

Experimental Study on MIMO Performance of Modulated Scattering Array Antenna

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Abstract. The modulated scattering array antenna (MSAA) is composed of one normal antenna element and several modulated scattering elements (MSE). In this research, a 2-element MSAA is used as the receiving antenna in a 2 by 2 multiple input multiple output (MIMO) system. The MIMO performance of the MSAA with various array spacing is measured to investigate experimentally the relation between the array spacing and the MIMO performance of the MSAA in the LOS (Line-of-Sight) and NLOS (Non-Line-of-Sight) indoor environment. It is found that the Error Vector Magnitude (EVM) which reflects the MIMO performance can be improved by increasing the array spacing.

1. INTRODUCTION

The multiple input multiple output (MIMO) communication system has become a promising technology for the next-generation wireless communications system, 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 very difficult to develop array antennas suitable for mobile handsets, because of some problems such as the limited space on the handset to mount array antennas with sufficiently low mutual coupling and correlation between array antennas [2], [3]. 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 essential to develop array antennas with simple configurations which are suitable for mobile handsets in MIMO communication.

A new concept of array antennas, which is called modulated scattering array antenna (MSAA), based on the modulated scattering technique (MST) has proposed [4], [5]. The MSAA consists of one normal antenna element and several modulated scattering elements (MSE) without RF front-end circuit. The previous researches showed that the MSAA is suitable for mobile handsets in the MIMO communications where the space and the cost are limited because of its simple configuration [6].

It is apparent that reducing the array spacing between the normal antenna element and the MSE can increase the scattering signal, but high correlation due to the compact array spacing may degrade the MIMO performance. Therefore, we investigated further the MSAA in MIMO communications to see whether the MIMO performance of the MSAA for mobile handsets can be improved by regulating the array spacing. An experimental measurement was carried out to study the MIMO performance in the LOS and NLOS environment of an indoor 2 by 2 MIMO system where the MSAA was used as the receiving antenna. Because the Error Vector Magnitude (EVM) reflects MIMO performance, it was measured and compared along with the different array spacing to study the relation between the array spacing and the MIMO performance of the MSAA.

The experimental configuration of the MIMO communication system is presented in Section 2. Section 3 shows the experimental results. Finally, a summary and conclusions are presented.

2. EXPERIMENTAL CONFIGURATION

A model and photo of 2-element monopole MSAA are shown in Fig. 1. The MSAA is composed of two quarter-wavelength monopole elements with array spacing of 0.1, 0.2, 0.3, 0.4, and 0.5 wavelengths, respectively. 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.

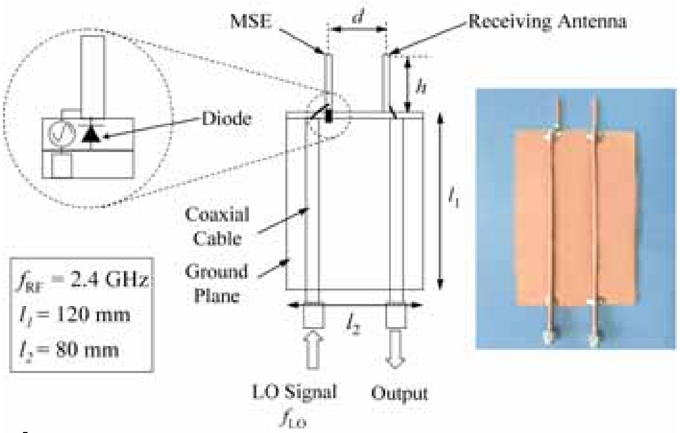

Fig. 1. Model (left) and photo (right) of 2-element monopole modulated scattering array antenna

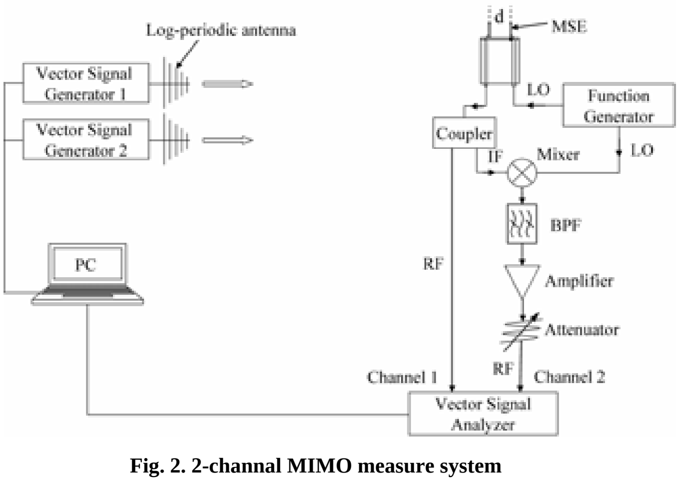

Fig. 2. 2-channal MIMO measure system

Fig. 2 shows that a measurement system has been developed to demonstrate the MIMO performance of the MSAA in a 2 by 2 MIMO communication system operated with 802.11n protocol. Two Log-periodic antennas with two wavelength array spacing are used as the transmitting antennas. The Agilent 89600S vector signal analyzer with two 2.4 GHz RF input channels and software option 89601X-B7Z for IEEE 802.11n MIMO modulation analysis are used to receive the signals from the measured MSAA.

The experiment was implemented in a 6.5 × 8.5 meters meeting room with concrete structure. The distance between the transmitting and receiving antennas is about 7 meters in a LOS (line-of-sight) and NLOS (non-line-of-sight) environment. While the location of transmitting antenna was fixed, the receiving antenna was moved by steps of 5 cm in a 50 cm×50 cm area. Therefore, 11 × 11 times were measured and the constellation diagrams of the demodulated IEEE802.11n signals for 2 streams were recorded in each point. Further, the EVM is calculated for the constellation diagram for every location of the receiving antenna.

3. EXPERIMENTAL RESULTS

Fig. 3 shows the constellation diagram of 2 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 2 streams are shifted slightly from their ideal location. The degradation of stream 2 is caused by the lower gain of the MSE as reported in [4] and [5], where it was found that the gain of the MSE element was usually 15-20 dB lower than that of the normal antenna element. Because the measurement is repeated 121 times while slightly changing the location of the receiving antenna, 121 values of the EVM were obtained and they were further expressed in the form of CDF.

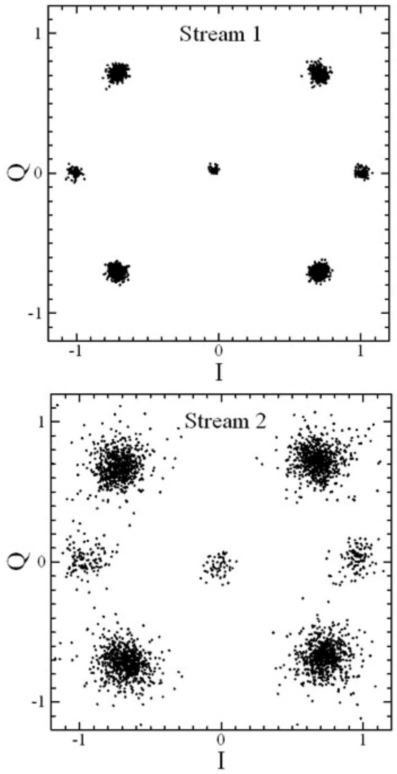

Fig. 3. Constellation diagram of 2 streams demodulated from 802.11n signals received by MSAA

Fig. 4 and 5 shows the CDF of the EVM of MSAA along with various array spacing in LOS and NLOS environment, respectively. It is shown that the CDF of the EVM of stream 1 and stream 2 will be changing along with various array spacing. Moreover, the difference between the stream 1 and stream 2 at CDF=50% is also changing along with the different array spacing. And the EVM of the stream 1 is lower than that of the stream 2 because of the low channel gain of the MSE channel.

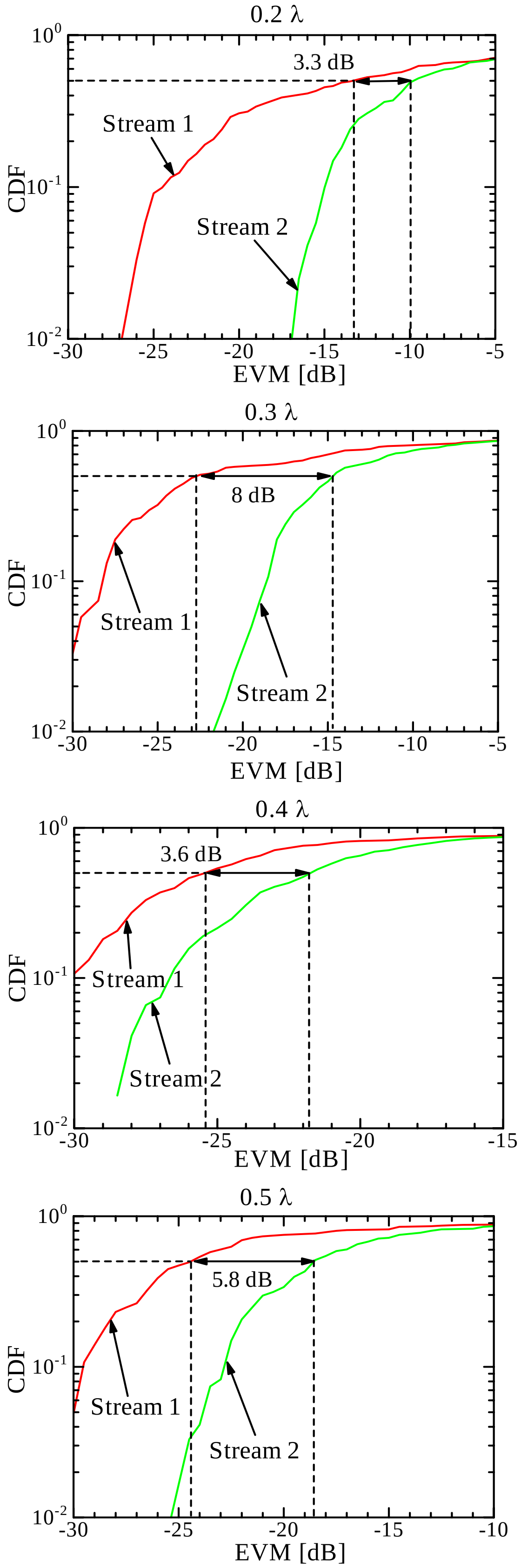

Fig. 4. CDF of EVM of MSAA with various array spacing in the LOS environment

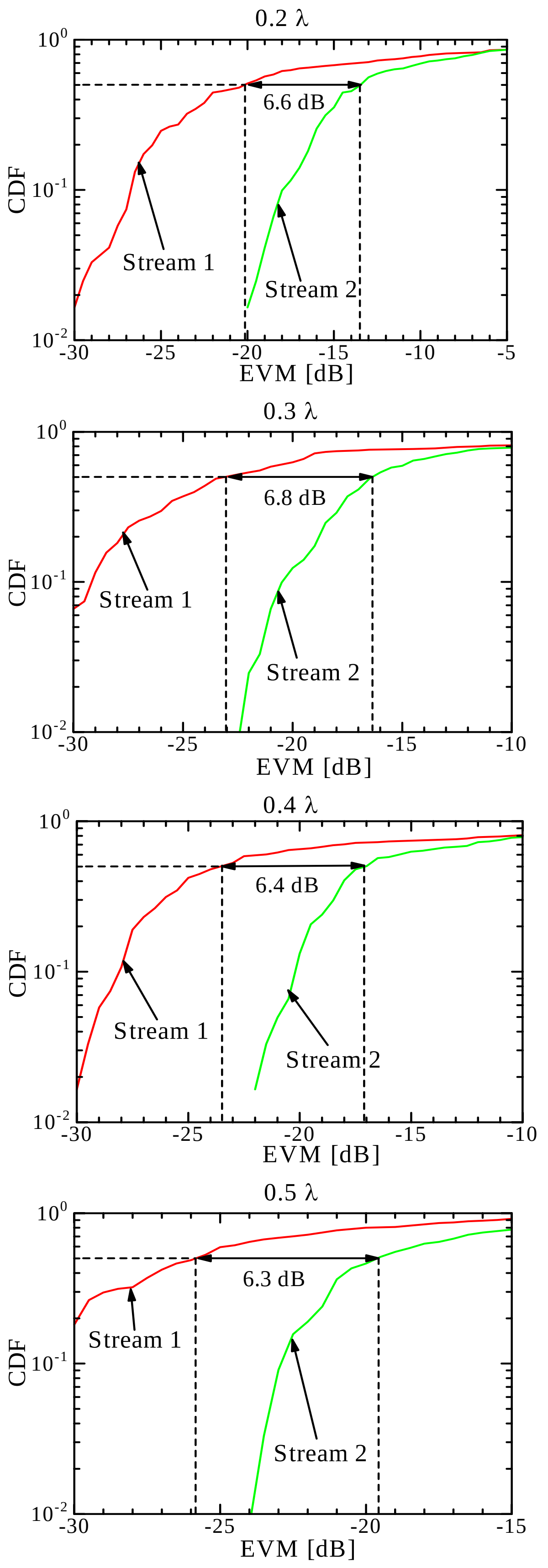

Fig. 5. CDF of EVM of MSAA with various array spacing in the NLOS environment

Fig. 6 and 7 shows the CDF of the EVM of the stream 1 and stream 2 along with various array spacing in LOS environment, respectively. Fig. 8 and 9 shows the CDF of the EVM of the stream 1 and stream 2 along with various array spacing in NLOS environment, respectively. In the case of the LOS and the NLOS, it is easy to see that when the array spacing is increasing, both the EVM of the stream 1 and the stream 2 will be improved.

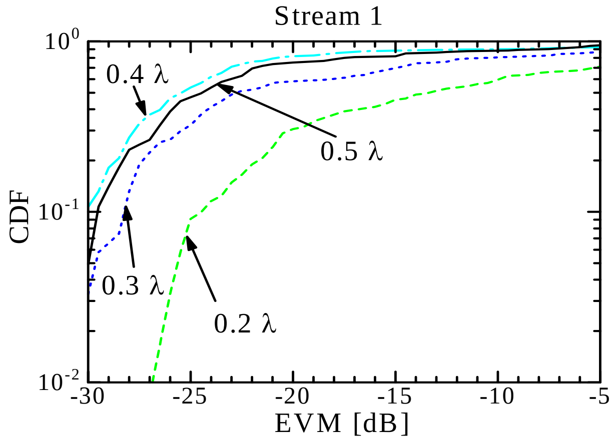

Fig. 6. CDF of EVM of the stream 1 with various array spacing in the LOS environment

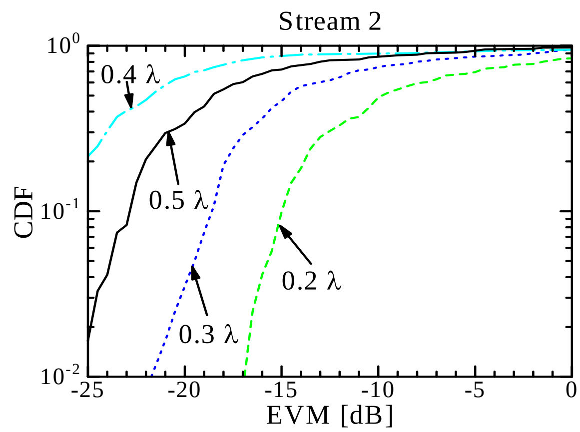

Fig. 7. CDF of EVM of the stream 2 with various array spacing in the LOS environment

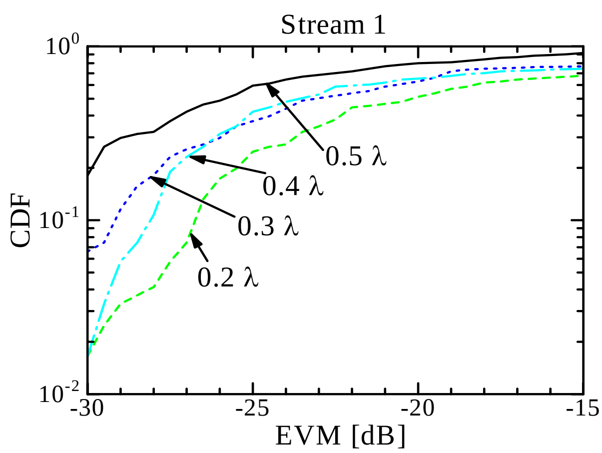

Fig. 8. CDF of EVM of the stream 1 with various array spacing in the NLOS environment

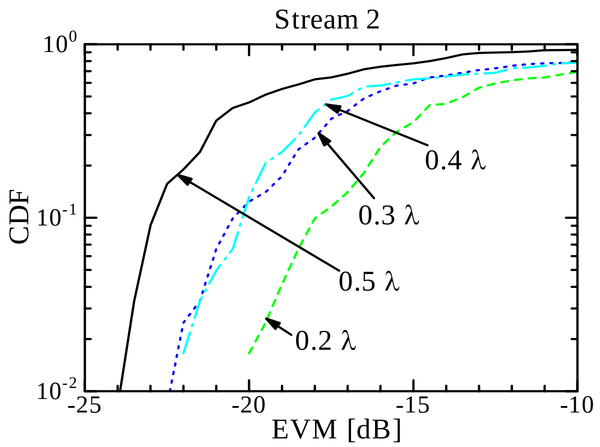

Fig. 9. CDF of EVM of the stream 2 with various array spacing in the NLOS environment

Fig. 10 and 11 shows that the EVM of 2 streams with various array spacing are compared at CDF=50% in LOS and NLOS environment, respectively. It is shown that the EVM of 2 streams can be improved by increasing the array spacing as large as about 0.4 wavelengths in the case of LOS environment. Similarly, when the array spacing is about 0.5 wavelengths, the EVM will be improved in the case of NLOS environment.

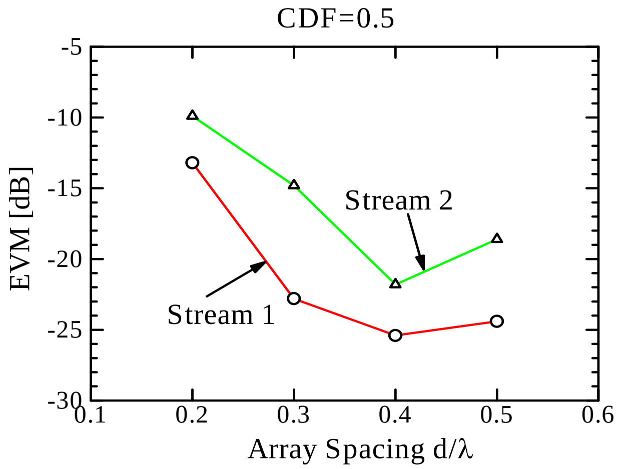

Fig. 10. EVM of 2 streams with various array spacing at CDF=50% in the LOS environment

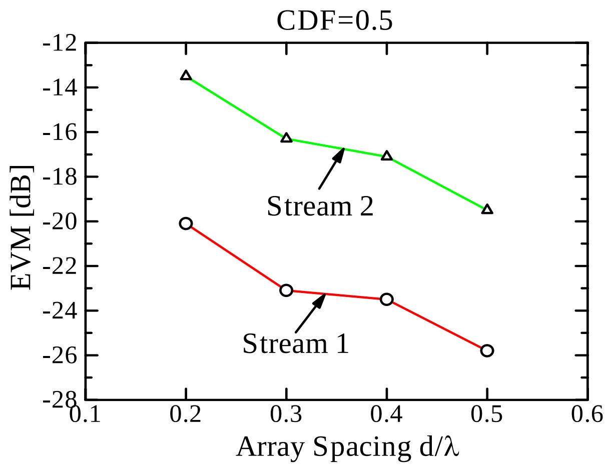

Fig. 11. EVM of 2 streams with various array spacing at CDF=50% in the NLOS environment

The experimental results indicate that the EVM which reflects the MIMO performance can be improved by increasing the array spacing at 0.2-0.5 wavelengths adjustable range in LOS and NLOS environment.

4. CONCLUSIONS

In this research, an experimental measurement has been carried out to study the MIMO performance in the LOS and NLOS environment of an indoor 2 by 2 MIMO system where the MSAA was used as the receiving antenna. EVM which reflects the MIMO performance was measured and compared along with the different array spacing to study the relation between the array spacing and the MIMO performance of the MSAA. The result has shown that EVM can be improved by increasing the array spacing at 0.2-0.5 wavelengths adjustable range in LOS and NLOS environment.

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