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EXPERIMENTAL STUDY ON MIMO PERFORMANCE OF MODULATED SCATTERING ANTENNA ARRAY IN INDOOR ENVIRONMENT

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ABSTRACT

The modulated scattering antenna array (MSAA) is composed of one normal antenna element and several modulated scattering elements (MSEs). In this report, a 2-element MSAA is used as the receiving antenna in 2 × 2 multiple input multiple output (MIMO) system. MIMO performance of MSAA with various array spacing is measured to investigate the relation between the array spacing and the MIMO performance of the MSAA experimentally in the non-line-of-sight (NLOS) indoor environment. It is found that the error vector magnitude (EVM) and the channel capacity which reflect MIMO performance can be affected by the array spacing. The measured results of the MSAA were compared with that of two-dipole antenna array at the same condition.

I. INTRODUCTION

Multiple input multiple output (MIMO) communication system has become a promising technology for the next-generation wireless communication 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 antenna arrays suitable for mobile handsets, because of some problems such as the limited space on the handset to mount antenna arrays with sufficiently low mutual coupling and correlation between 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 antenna arrays with simple configurations which are suitable for mobile handsets in MIMO communications.

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

It is apparent that the reduction of 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 MSAA in MIMO communications to see whether MIMO performance of the MSAA for mobile handsets can be improved by regulating the array spacing. Experimental measurement was carried out to study the MIMO performance in 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) and the channel capacity reflect MIMO performance, they were measured and compared for different array spacing. MIMO performance of the MSAA was also compared with that of two normal dipole antenna arrays.

The report is organized as follows. The experimental configuration of the MIMO communication system is described in Section 2. The experimental results are shown in Section 3. Finally, conclusions are given in Section 4.

II. EXPERIMENTAL CONFIGURATION

The geometry of a 2-element dipole MSAA is shown in Fig. 1. MSAA is composed of two half-wavelength dipole elements with array spacing from 0.1 to 0.7 wavelength in the experiment. In Fig. 1 of MSAA, the above element is the dipole antenna and the below one is the MSE. A Schottky diode is mounted at the centre of MSE which is used as the nonlinear impedance for modulation.

Fig. 2 shows the measurement system which was developed to demonstrate MIMO performance of MSAA in 2 × 2 MIMO communication system operated with IEEE 802.11n protocol. Two log-periodic dipole antenna arrays with two wavelength array spacing were used as the transmitting antennas. Agilent 89600S vector signal analyzer with two RF input channels and software option 89601X-B7Z for IEEE 802.11n MIMO modulation analysis were used to receive the signals from the measured MSAA.

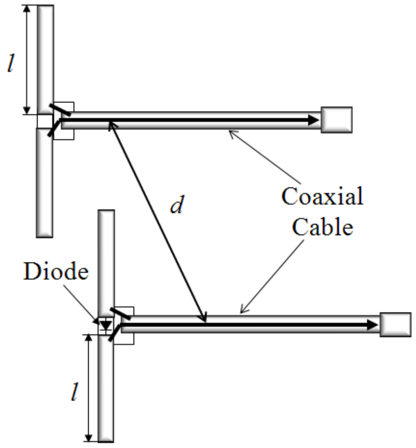


Figure 1: Geometry of modulated scattering dipole antenna array

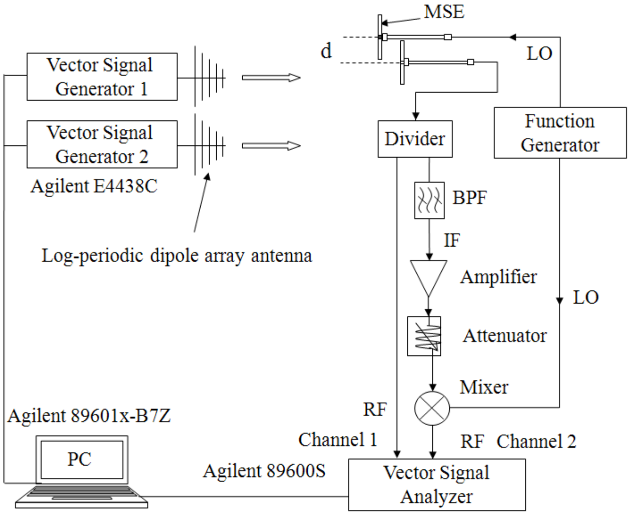


Figure 2: 2-channal MIMO measurement system

The experiment was implemented in a room of a basement with the concrete structure which is shown in Fig. 3. The distance between the transmitting and receiving antennas was about 6 meters. In the transmitting path, several tens of conducting scatterers with a size of several wavelengths are distributed randomly around the transmitting antenna to form the Rayleigh fading environment. The location of transmitting antenna was fixed, while the receiving antenna was moved by a step of 5 cm in a 50 cm×50 cm area. Therefore, measurement was repeated 11×11 times.

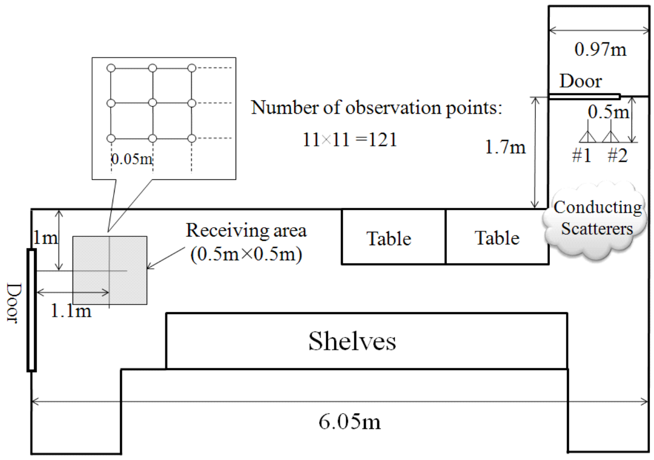


Figure 3: MIMO measurement environment

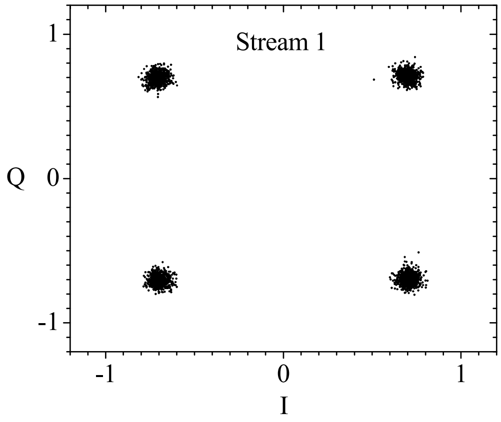
III. EXPERIMENTAL RESULTS

Fig. 4 shows the constellation diagram of 2 streams demodulated from IEEE 802.11n signals received by the MSAA, which includes QPSK-modulated data. 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], where it was found that the gain of the MSE element is usually 15-20 dB lower than that of the normal antenna element. Because the measurement was 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 cumulative distribution function (CDF).

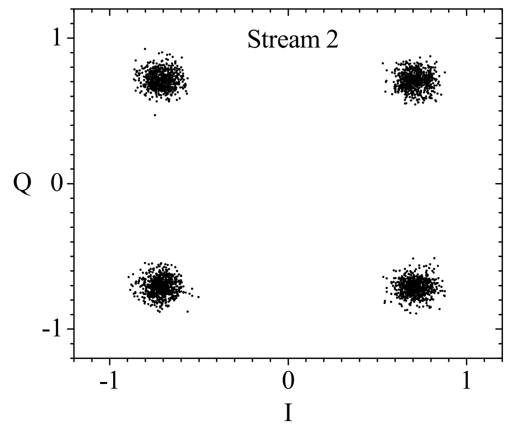
EVM is defined as:

$$EVM = \frac{|V_{error}|}{|V_{reference}|}$$

where the error vector is a vector between the ideal point and the real received point by the receiver in the constellation diagram.



A) Constellation diagram of the stream 1



B) Constellation diagram of the stream 2

Figure 4: Constellation diagram of 2 streams demodulated from IEEE 802.11n signals received by MSAA

Fig. 5 shows the CDF of the EVM of MSAA with the 0.2 and 0.5 wavelengths in the NLOS environment, respectively. It is shown that the CDF of the EVM of stream 1 and stream 2 is changed for various array spacing. Moreover, median EVM of the stream 1 and stream 2 is also shown along with the different array spacing in Fig. 6, where the dipole MSAA and dipole antenna array were used as the receiving antennas. In both the cases, the difference between EVM of the stream 1 and stream 2 was small. However, EVM of the dipole antenna array increases as the array spacing decreases, while EVM of dipole MSAA can be improved by decreasing array spacing since normal antenna element is able to receive much more scattering signals from MSE for compact array spacing. And it is beneficial to improve EVM.

The channel capacity is also calculated for evaluating MIMO performance. The channel capacity can be expressed as:

$$C=\log_2\left|I_{M_0}+\frac{P_{Total}}{M\sigma_n^2}\mathbf{HH}^\dagger\right|$$

$$=\sum_{i=1}^{M_0}\log_2\left(1+\frac{P_{Total}}{M\sigma_n^2}\lambda_i\right)\quad M_0=\min(M,N)$$

where superscript † for conjugate transpose, I_{M_0} for the $M_0\times M_0$ identity matrix, P_{Total} is the total transmission power, σ_n^2 is the received noise power, H is the MIMO channel matrix, λ_i is the ith eigenvalue of HH†, M is the number of the transmitting antennas and N is the number of the receiving antennas.

Condition number K-factor is defined as:

$$\kappa=\sqrt{\frac{\lambda_1}{\lambda_2}}$$

where there are only two eigenvalues due to the 2 by 2 MIMO system in this experiment.

Fig. 7 shows the result of median condition number K-factor of MSAA for various array spacing in the NLOS environment where the dipole MSAA and dipole antenna array were used as the receiving antennas. And K-factor is decreased by decreasing array spacing in the case of the dipole MSAA, but it is increased for the case of two-dipole antenna array due to high correlation. Although performance of MSAA will be also affected by high correlation due to the compact array spacing, the difference between received power level of RF signal and IF signal will decrease by decreasing array spacing. It is the main reason that condition number K-factor of MSAA will increase while array spacing is decreasing.

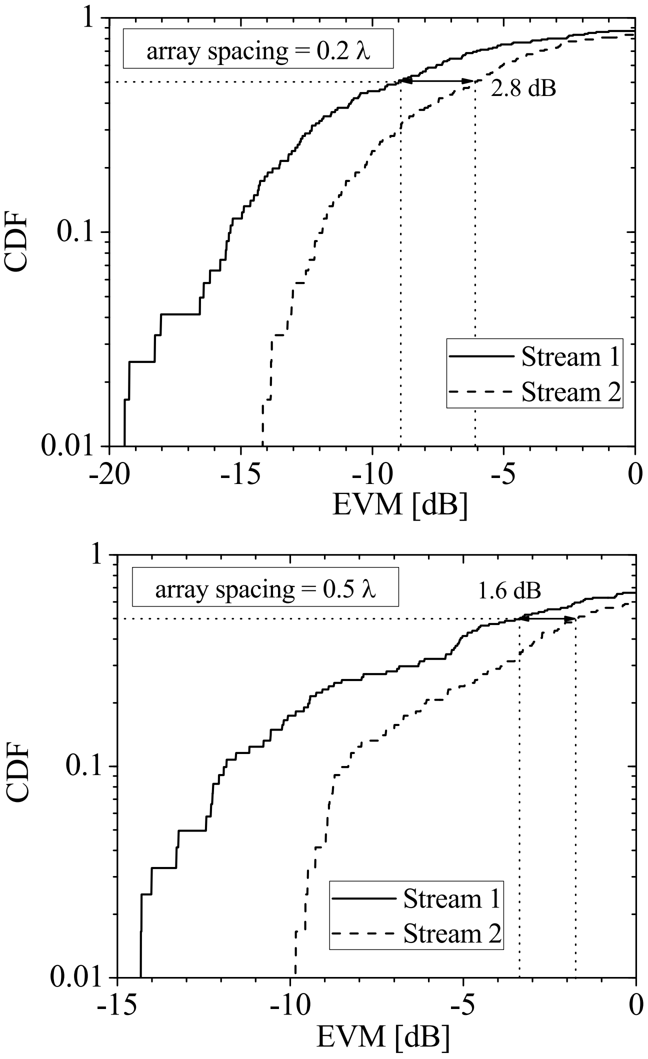


Figure 5: CDF of EVM of MSAA with the 0.2 and 0.5 wavelengths array spacing in the NLOS environment

Fig. 8 shows the results of median MIMO channel capacity for various array spacing in the NLOS environment where the dipole MSAA and two-dipole antenna array were used as the receiving antennas. It is noted that the MIMO channel capacity is improved by compact array spacing in the case of dipole MSAA. On the other hand, the MIMO channel capacity decreases by decreasing array spacing of two-dipole antenna array. The MIMO channel capacity of the dipole MSAA is almost the same to that of dipole antenna array when array spacing is 0.1 wavelength.

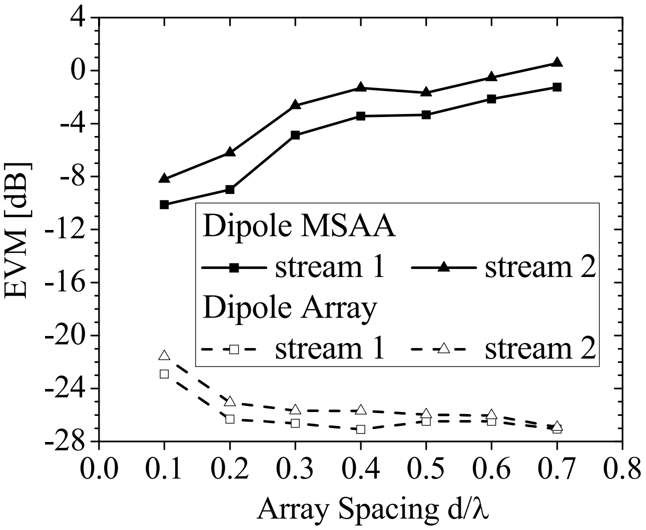


Figure 6: Median EVM of dipole MSAA and two dipoles antenna array versus various array spacing in the NLOS environment

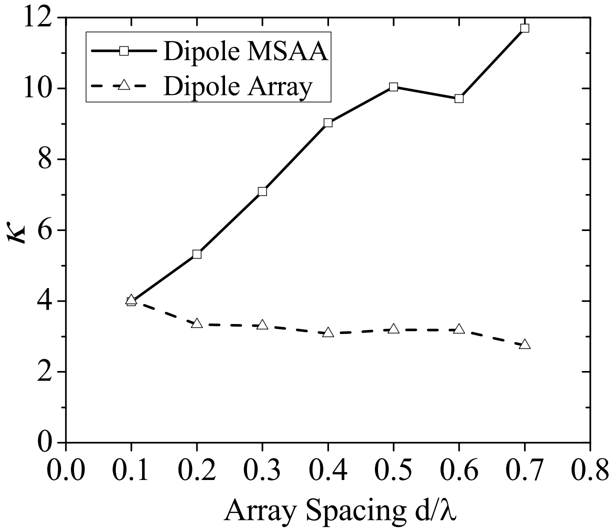


Figure 7: Median condition number *K*-factor of MSAA and two dipoles antenna array versus various array spacing in the NLOS environment

IV. CONCLUSIONS

In this report, an experimental measurement has been carried out to study the MIMO performance in the NLOS environment of an indoor 2 by 2 MIMO system where the dipole MSAA was used as the receiving antenna. The EVM and the channel capacity which reflect the MIMO performance were measured with various array spacing to study the relation between the array spacing and MIMO performance of MSAA. The results have shown that EVM and the MIMO channel capacity can be improved by decreasing the array spacing in the range of 0.1 to 0.7 wavelength.

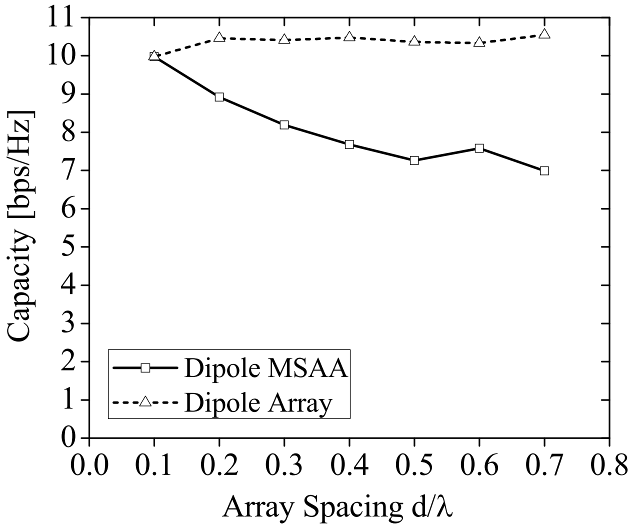


Figure 8: Median MIMO channel capacity of dipole MSAA and two dipoles antenna array versus various array spacing in the NLOS environment

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