Numerical Analysis of Correlation Coefficient for MIMO Antennas in a Mode-Stirred Chamber

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***Abstract* –The spectral contents inside a mode stirred chamber have been computed by using the FDTD method. They can describe the directional dependence in the reverberation chamber. Correlation coefficients between spectral fields generated by two transmit antennas have been found to evaluate the performance of MIMO systems.**

***Index Terms* — correlation coefficient, diversity gain, multiple-input-multiple-output(MIMO), reverberation chamber (RC).**

I. INTRODUCTION

Reverberation chambers have been widely used for characterization of multiple-input multiple-output (MIMO) systems in multipath environments. One of the most important parameters in MIMO over-the-air measurement of wireless devices is correlation. It is a parameter to describe the independence of signal receiving capability in MIMO channels. The lower level is desirable for improving independence between the signal paths.

The correlation coefficient is originally found from the complex radiation patterns in a spherical coordinate system. Such a measurement of a MIMO system in an anechoic chamber measurement system is a time-consuming process. In [1]-[3], it has been shown that to ease this measurement process, the correlation coefficient can be determined by using S-parameters. However, this method is only accurate for highly efficient antennas; hence this approach is not practical for characterizing MIMO antennas in mobile phones with low radiation efficiencies, normally less than 40% [4].

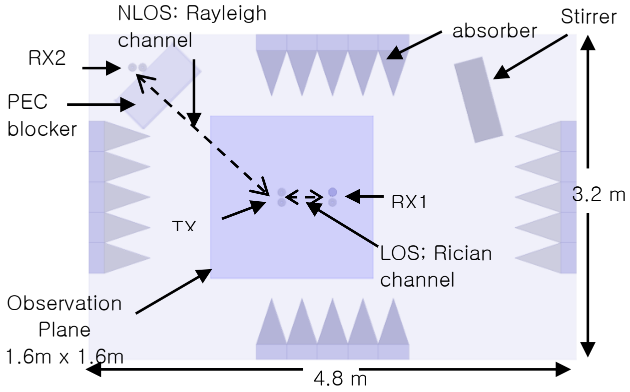

Fig. 1. The cross-sectional view of the reverberation chamber with biconical antennas, a mode stirrer, absorbers, and an observation plane.

In this paper, the spectral contents of spatial field distribution from each antenna of MIMO systems inside an RC have been found on an observation plane and then used to estimate the correlation between two receiving signal paths. It is possible to estimate the channel capacity and diversity gain of MIMO systems by finding all the correlation coefficients between the spectral electric fields by MIMO antennas for all angles of a rotating stirrer. The diversity gains of Rayleigh and Rician links are determined in an RC to investigate the use of these correlation coefficients for the frequency band of interest.

II. SIMULATION SETUP

The dimension of the RC considered is 4.8 (W) x 3.2(L) x 2.8 (H) m^3 and a vertically oriented and z-folded mechanical stirrer is contained within this chamber. The fundamental resonant frequency of the RC is approximately 120 MHz, and the lowest usable frequency (LUF) is about 500 MHz. The cross-sectional view of the exciting antennas, mode stirrer, and the working volume are shown in Fig.1, in which the sizes and positions of all elements are designated. The RC is excited by using vertically-oriented biconical antennas with a cone angle of 50°, and a length of 120 mm. The mode stirrer has the dimensions of 17 (W) x 48 (L) x 102 (H) cm^3, and it rotates around its center point. The TX antennas and the mode stirrer are located at the mid-points along the vertical direction of the RC. RF absorbers are mounted on four side walls of this chamber to control the number of multipath components and power spread delays in wireless communication environments. The observed electric fields are the performance of MIMO antennas. The dimension of the plane is 1.6 (W) x 1.6 (L) m^2 at the height of 1.68 m from the bottom of the chamber. The RC was simulated for the frequency band ranging from 500 MHz to 2.5 GHz. The vertical six-paddle stirrer was incrementally rotated by using an angular step of 15° between 0° and 345°. The orthogonal electric field (E_z) components on the observation plane are stored at 41 frequency points, with a frequency step of 50 MHz within the band of interest. The plane is divided into 150x150 cells, along the x and y directions.

III. SIMULATION RESULTS

The spectral distributions of E_z field at all frequency points, and for all stirrer angles, can be obtained by converting the observation data derived from the FDTD calculation via Fourier transformation. We can observe the directional dependence of the wave propagation at each angle and the number of modes supported at all frequencies of interest by the spectral field components.

There are two MIMO systems in Fig.1. The first one is the Rician channel created between two TX and two RX1 antennas, while the second is a Rayleigh 2x2 channel between TX and RX2. Two RX1 antennas are 0.3 m away from TX antennas, while the RX2 antennas are placed behind the PEC blocker in order to avoid the line of sight (LOS). While Rician channels of 2x2 MIMO array have four direct links, Rayleigh channels don't have line-of-sight. The two TX antennas are shared by RX1 and RX2 antennas.

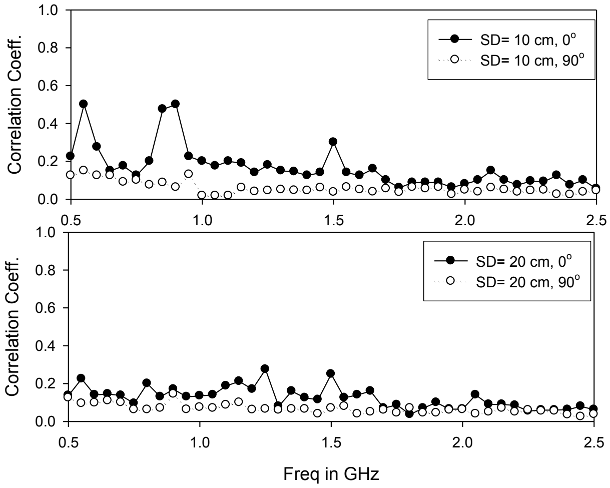

Fig. 2. Correlation coefficients between the spectral fields generated from each transmit antenna of a 2x2 MIMO system.

Fig. 2 shows the correlation coefficients between two spectral fields generated by two TX antennas with separation distances (SD) of 10 and 20 cm. Correlation is lower at higher frequencies due to high stirring effect at that frequency region. At small distance of 10 cm, correlations are higher due to increase of mutual coupling. Both parallel and perpendicular configurations of the two TX biconical antennas are evaluated. The perpendicular direction has lower correlation than the parallel one, owing to the generation of orthogonal fields, as expected. The correlation coefficient for different MIMO configurations of position, distance, polarization and environmental conditions can be investigated by finding the spectral fields. Correlation is tightly related to MIMO system parameters, such as channel capacity, diversity gain, power delay profile, RMS delay spread, and so on.

Fig. 3 shows the diversity gains (DG) for the separation distance of 10 cm and parallel antennas arrangement, the worst case in Fig. 2. Its cumulative distribution functions (CDF) of 2x2 MIMO systems are evaluated for both Rician and Rayleigh channels. The DGs can be determined at 1% probability level of the CDFs for the calculated S21 of 2x2 MIMO links. DGs of Rayleigh channel are about 7.0 dB, except for the frequency band of 0.7-1.0 GHz. Note that relatively high correlations are observed at that frequency band, as shown in Fig. 2.

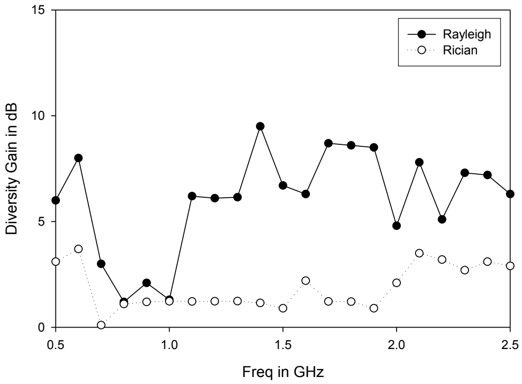

Fig. 3. Diversity gains of Rician and Rayleigh 2x2 MIMO systems.

The trends are found to be similar between correlation coefficients and diversity gains for Rayleigh channel. However, small DGs of about 1-2 dB are obtained for the Rician channel because of the presence of strong direct components in this channel. Consequently, correlation factors found from spectral field components inside the RC can account for various wireless parameters.

IV. CONCLUSION

The spectral fields by the received signals from two antennas describe all the modes supported inside an RC. We have shown that correlations of MIMO systems can be evaluated by the use of spectral components on an observation plane inside an RC. We can observe the close relationship between correlation and system performances of MIMO antennas by investigating diversity gains of Rayleigh and Rician channels inside an RC. This approach requires neither 3-D measurement facilities, nor network parameters of lossy antennas.

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