Performance Analysis of 2x2 MIMO Antennas by Finding Correlation Coefficient in a Mode-Stirred Chamber

Jongsung Kim*, Raj Mittra[o]

*Information and Communications Eng., Kyungsung University, South Korea

[o] Electrical Eng., University of Central Florida, FL, USA

Email: jskim@ks.ac.kr

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Contents

Abstract

The spectral contents inside a mode stirred chamber have been computed by using the FDTD method. They describe the directional dependence of all guided modes supported in the reverberation chamber. Correlation coefficients between spectral fields generated by two transmit antennas have been found for two separation distances and orientations of 2x2 MIMO system. By finding diversity gains of two MIMO channels, Rayleigh and Rician links, the correlation coefficient can be a good parameter to predict the performance of MIMO system.

Keywords — correlation coefficient, diversity gain, multiple-input-multiple-output(MIMO), reverberation chamber (RC)

Biography

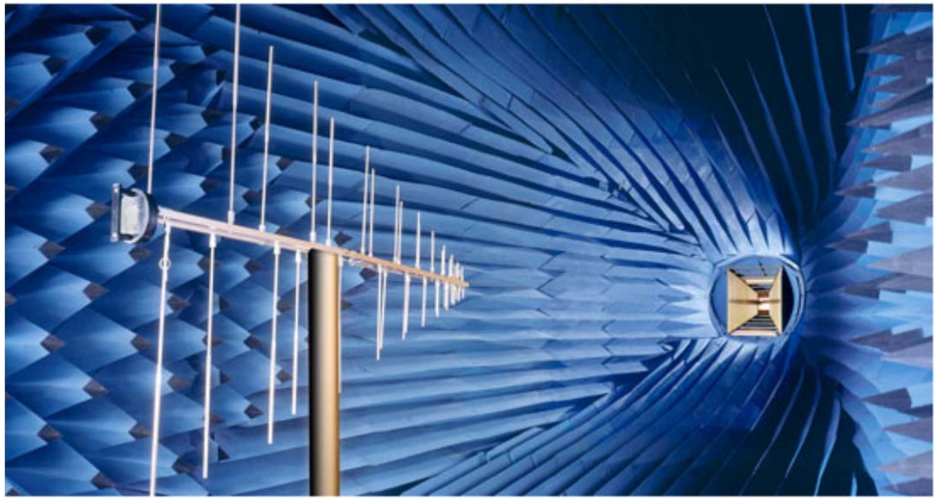
Jongsung Kim is an associate professor at Kyungsung University, Pusan, South Korea. He received the B.S. degree from Kyungpook National University, Daegu, South Korea, in 1988, the M.S. degree from the Korea Advanced Institute of Science and Technology, Daejeon, South Korea, in 1990, and the Ph.D. degree from POSTECH, Pohang, South Korea, in 2001, all in electrical engineering.

From 1990 to 2002, he was a member of technical staff with telecommunication network research center of Korea Telecom, where he was involved in development of Fiber Loop Carrier and Metro Ethernet systems.

Since 2004, he has been with Kyungsung University, Pusan, as an associate professor. He spent as a visiting scholar for two years at Pennsylvania State University, University Park, PA, where he studied numerical analyses of MIMO systems in a mode-stirred reverberation chamber, and design of scan-capable Fabry Perot cavity antenna using artificial magnetic conductors in 2010, and SAR reduction of multi-band antenna by using partially reflective surface in 2014.

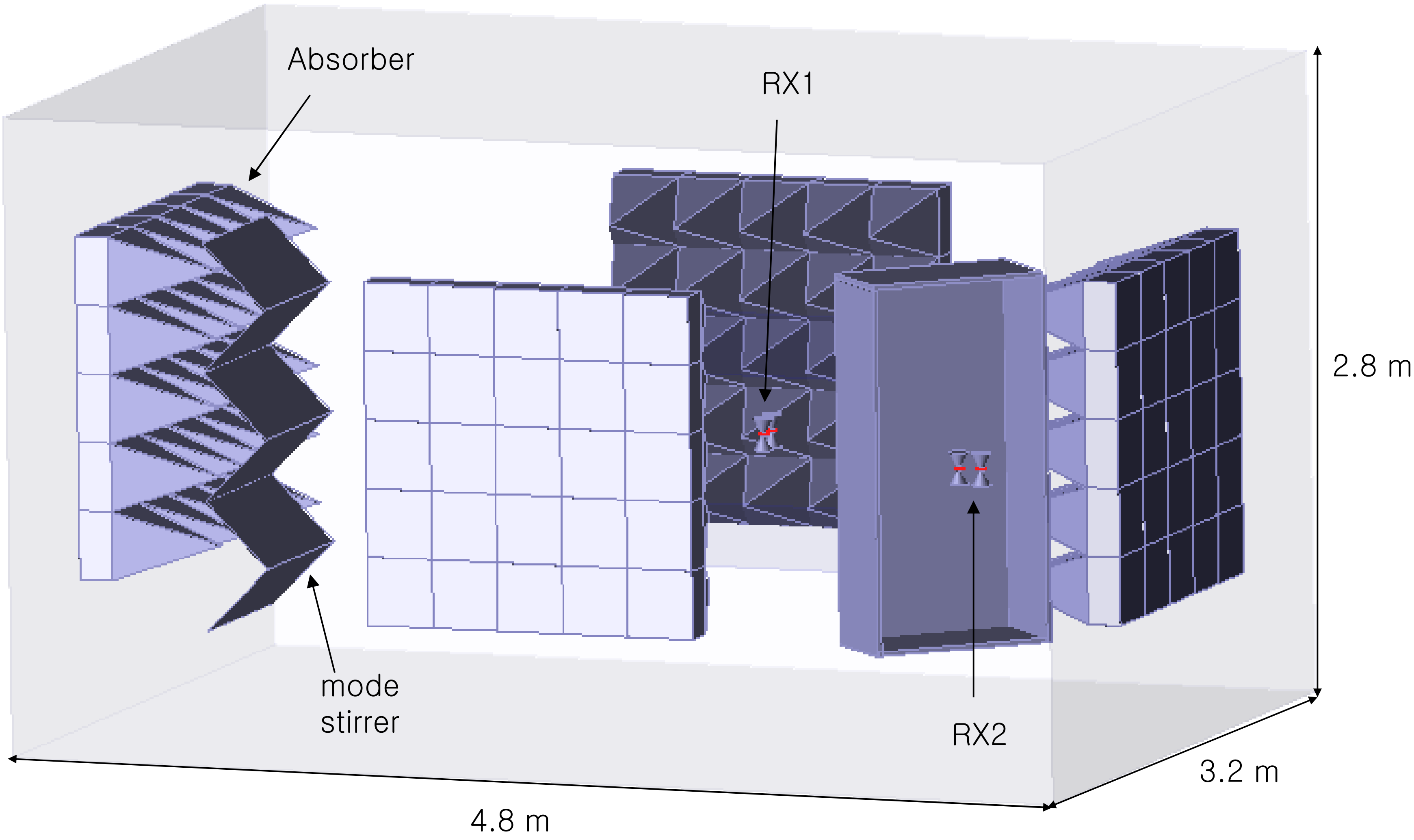
His current research interests include mobile handset antenna, and analytical and numerical techniques in the area of electromagnetics.

Motivation: Measurement of Correlation Coefficients for MIMO Systems

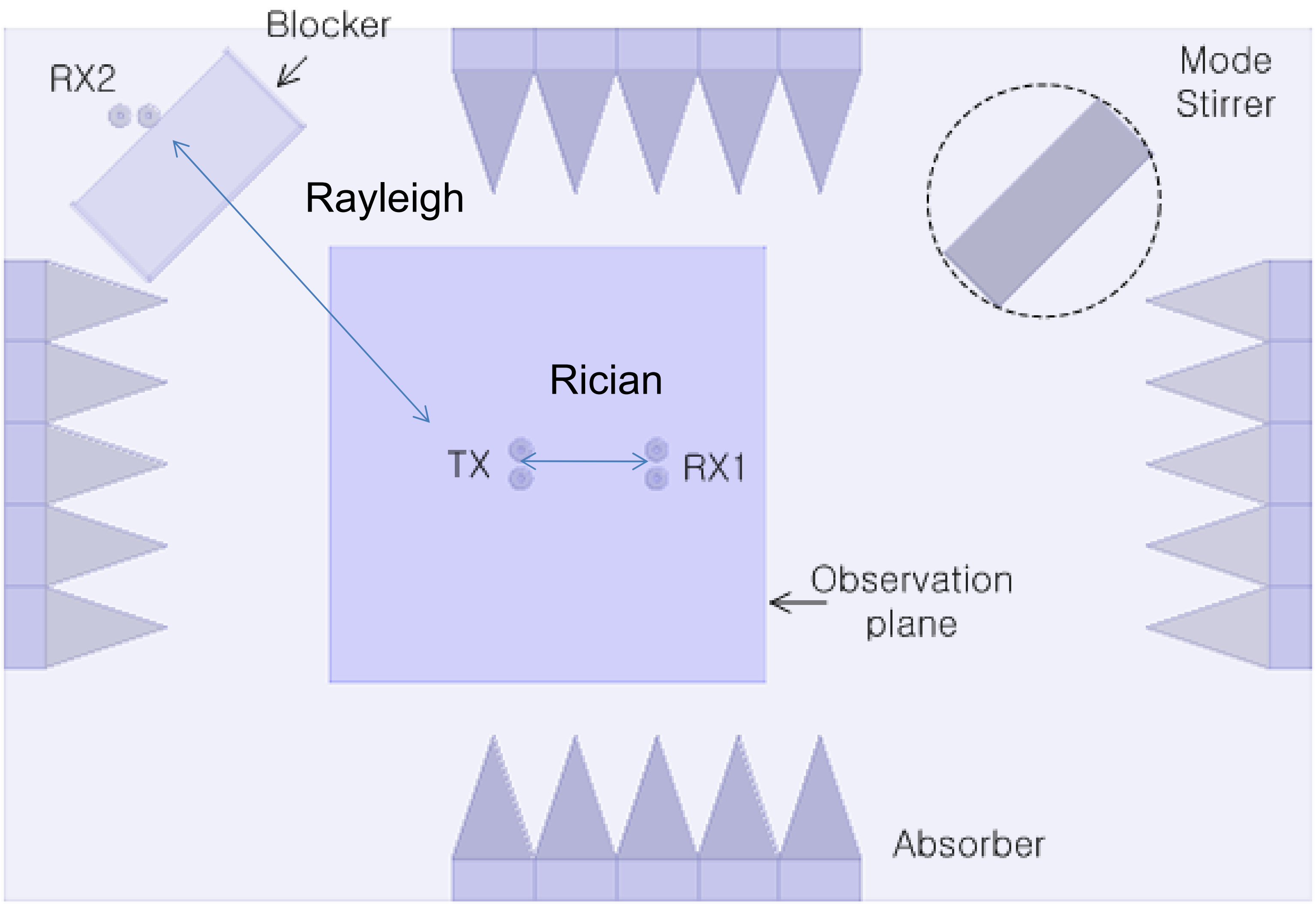


3-D Measurement

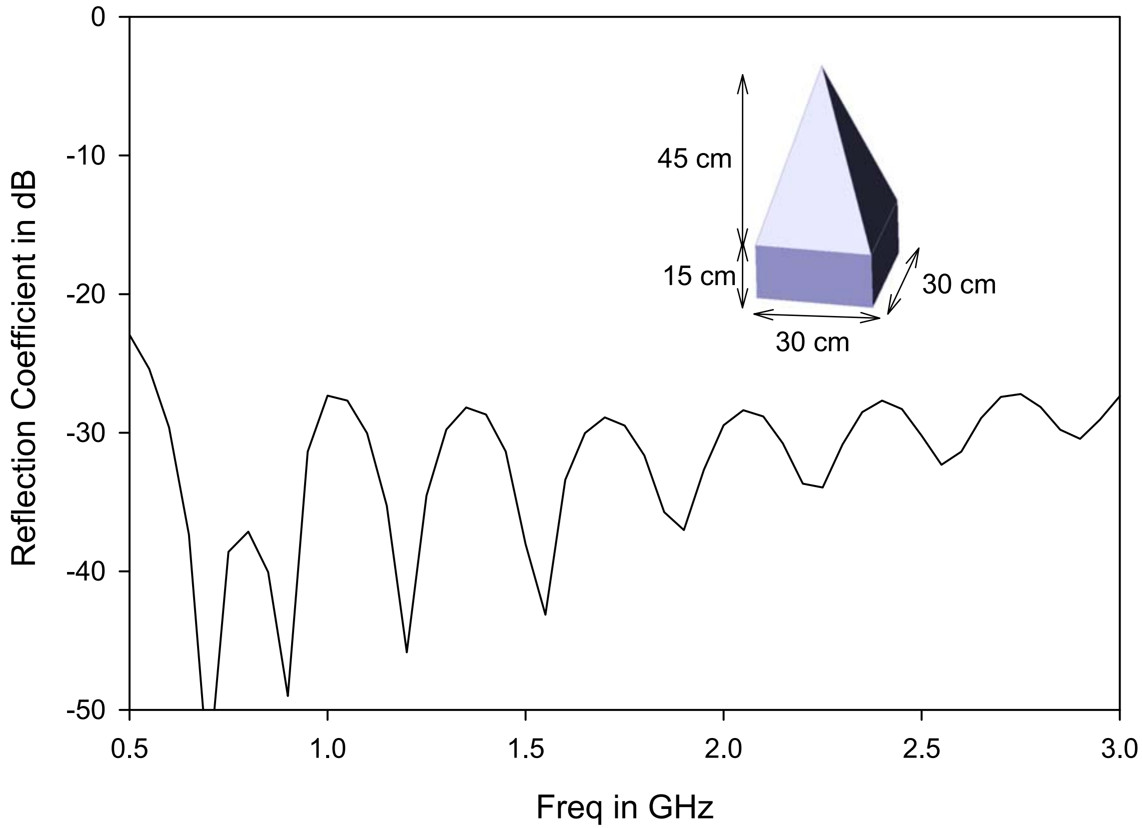
S-parameters


Absorber
RX1
2.8 m
mode
stirrer
RX2
3.2 m
4.8 m

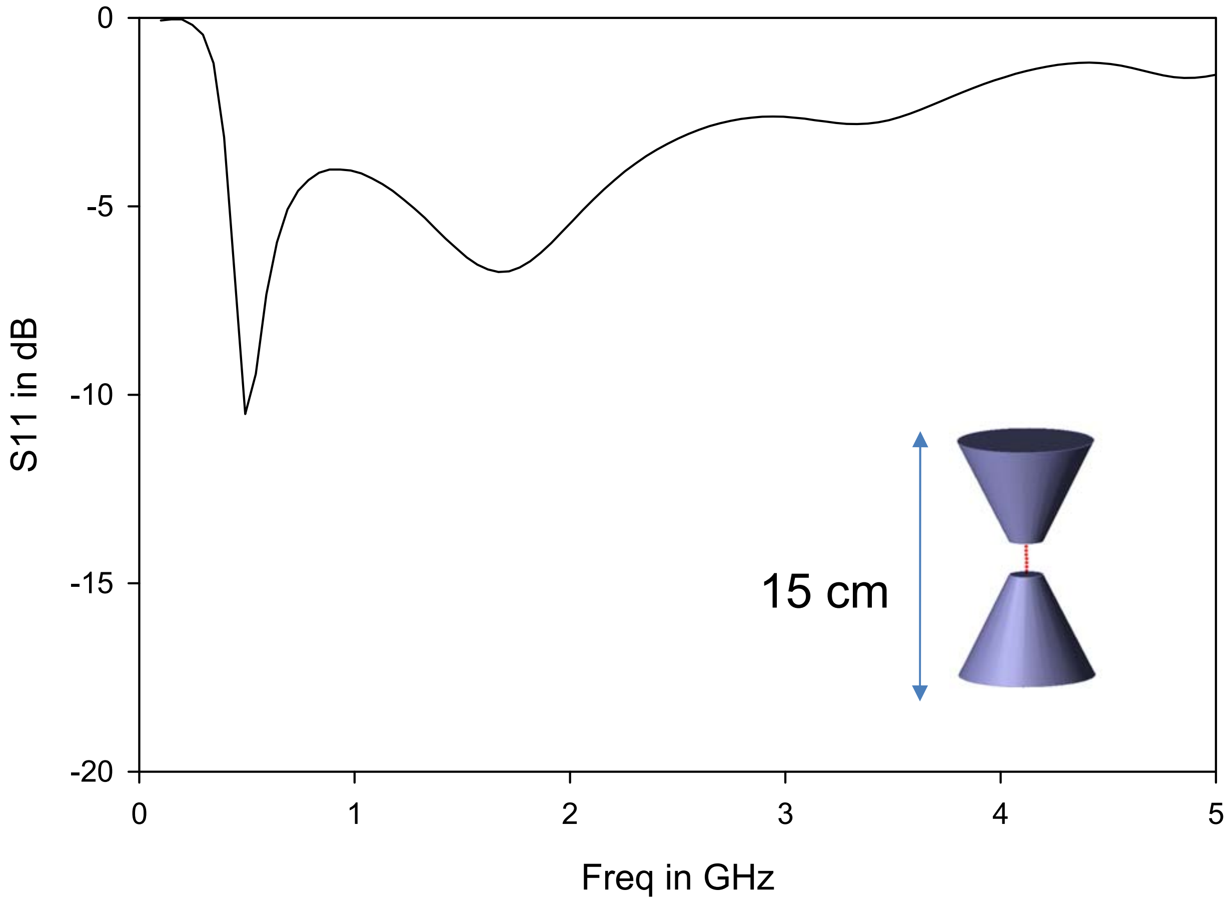
Configuration of MIMO Systems



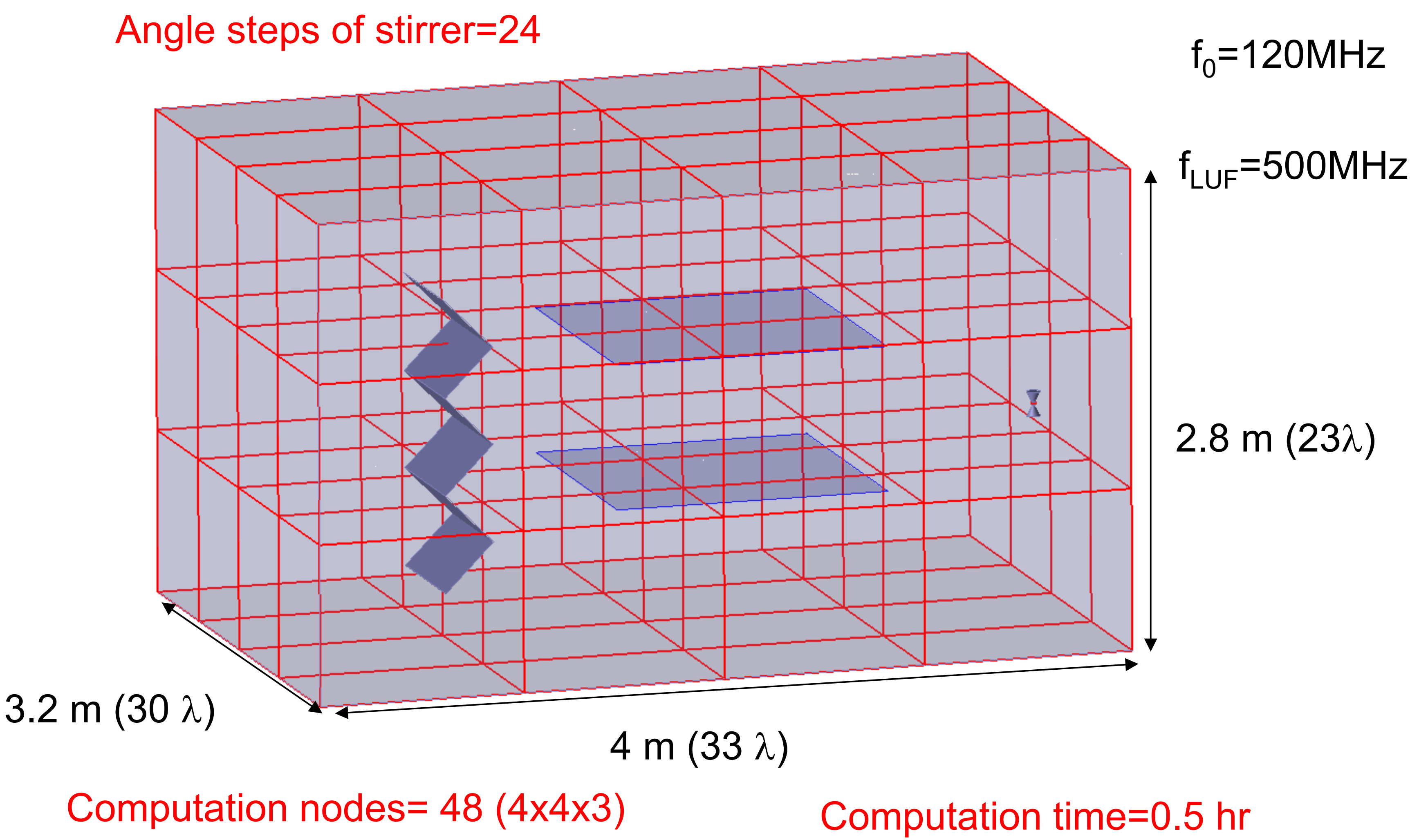
Reflection Coefficient



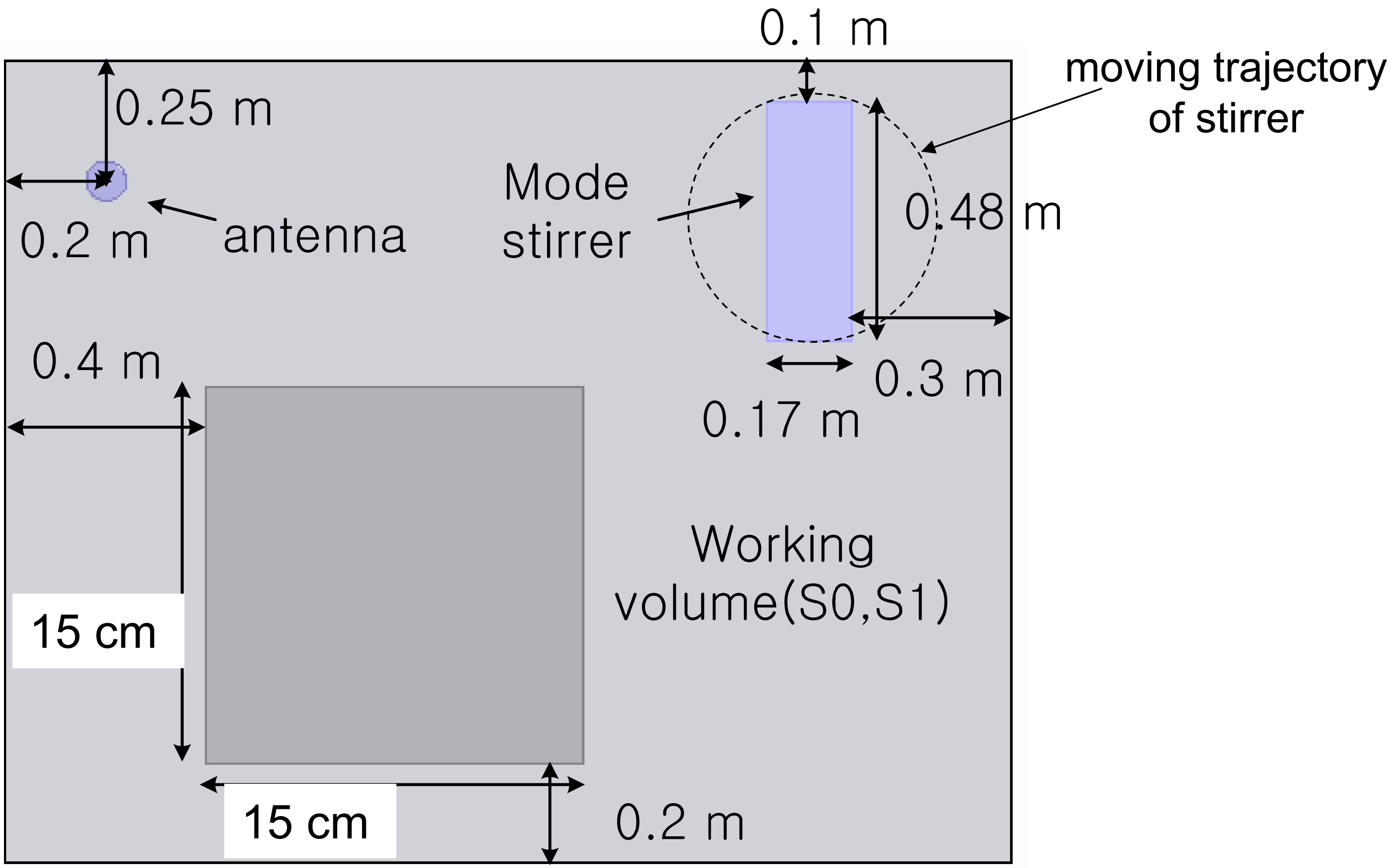
Biconical Antenna



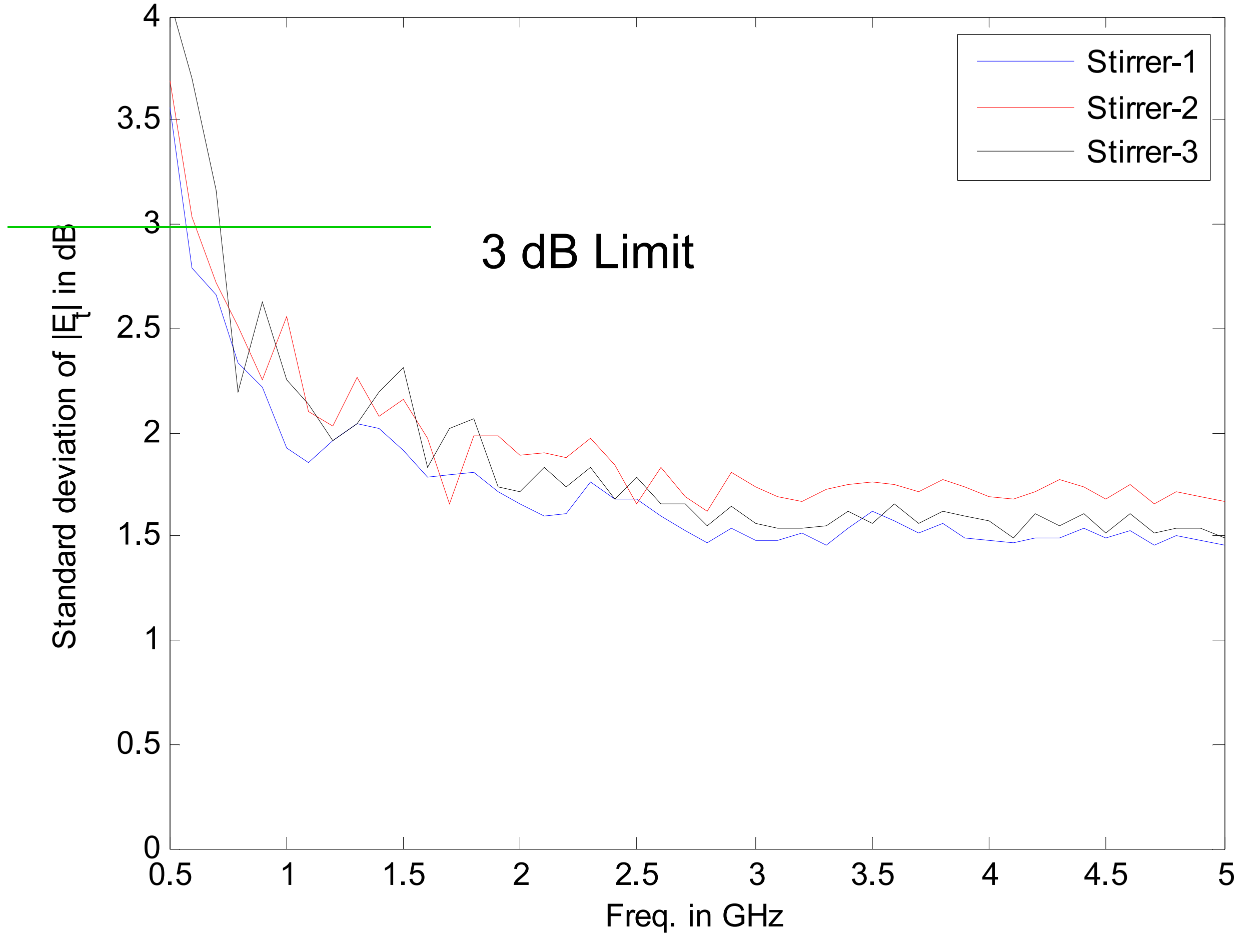
FDTD analysis by parallel division



Cross Section of the RC

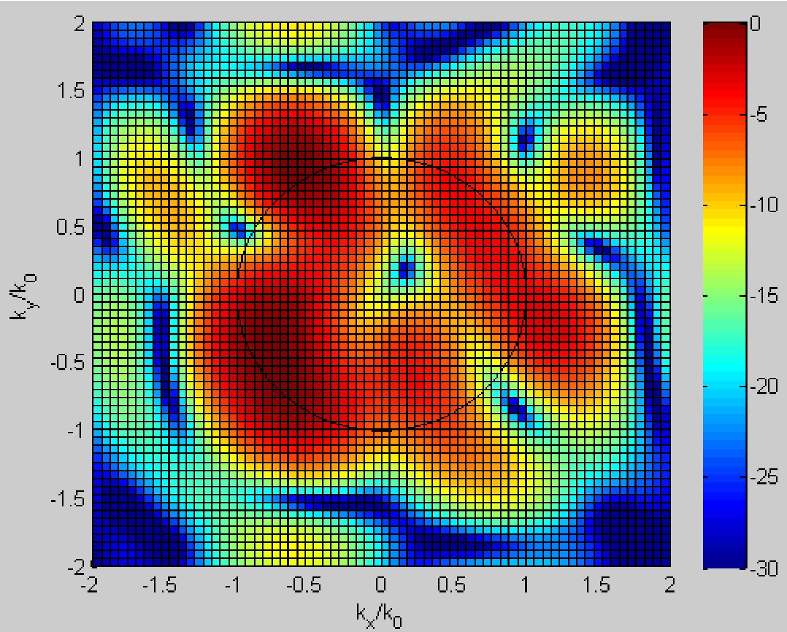


Investigation of field uniformity by statistical analysis

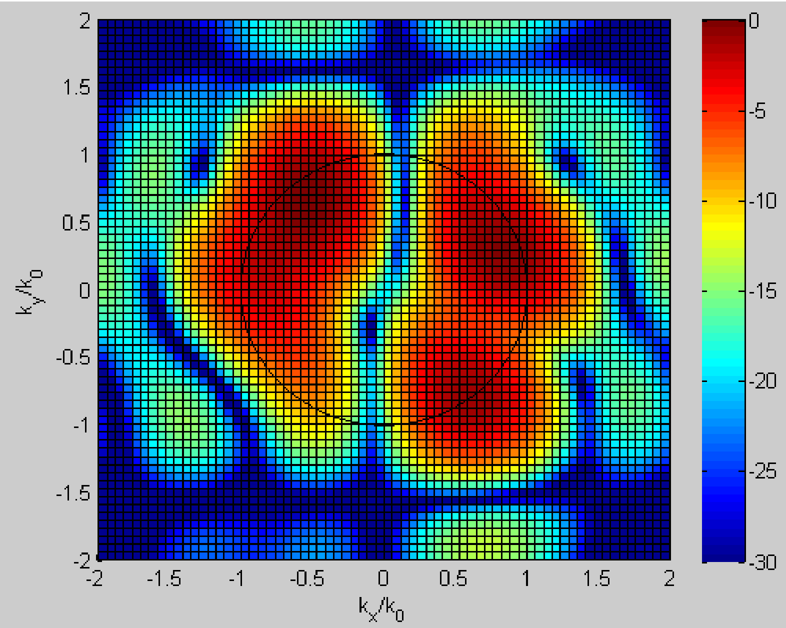


Std_dB=20*log(1+std(E)/mean(E))

E_z in Spectral Domain on Observation Plane ($150x150cm^2$) at 0.5 GHz



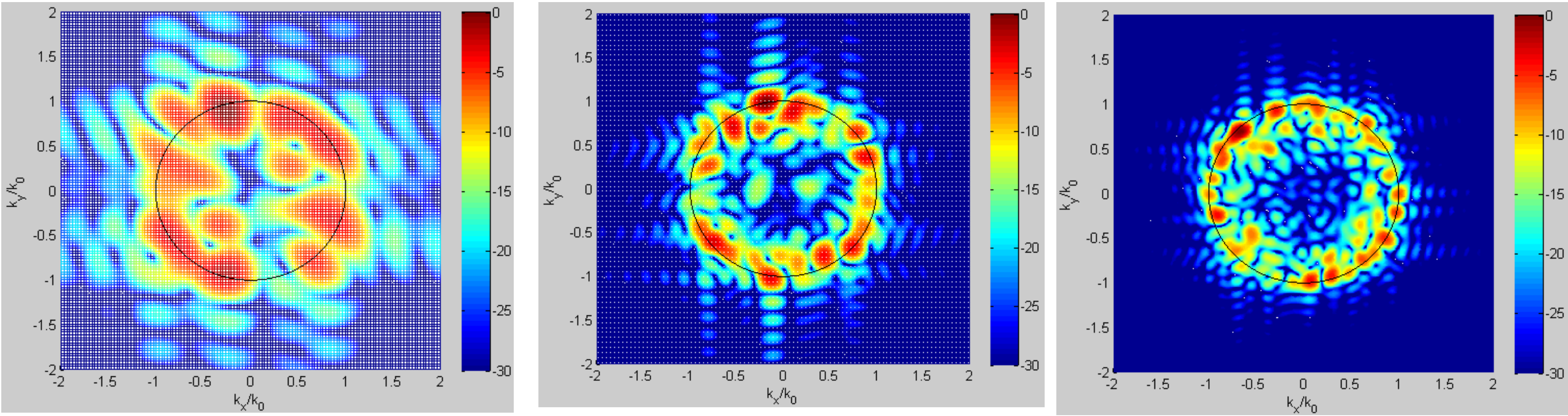
(a) Stirrer angle = 0°



(b) Stirrer angle = 15°

The propagation behaviors of Ez change over a rotating mode stirrer.
The mode behaviors in RC can be found by the spectral contents

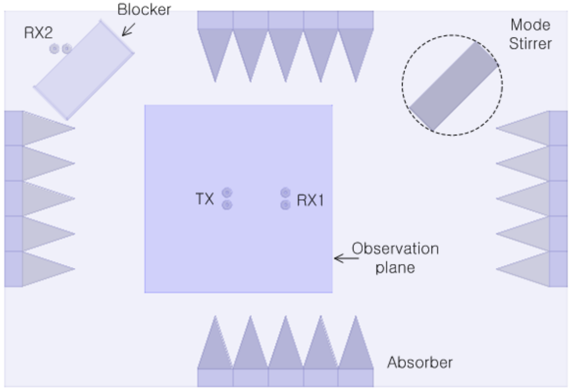
Electric Fields in Spectral Domain on Observation Plane



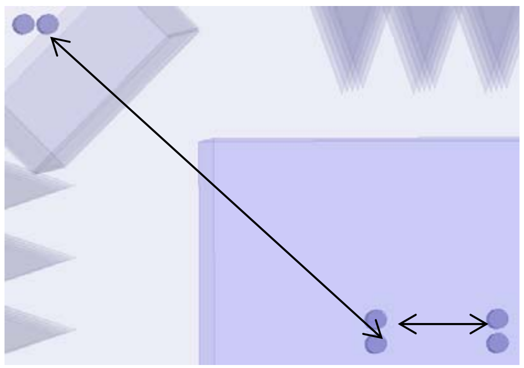
(a) 1 GHz (b) 2 GHz (c) 3 GHz

The spectral behaviors of Ez are shown for 1.0, 2.0 and 3.0 GHz.

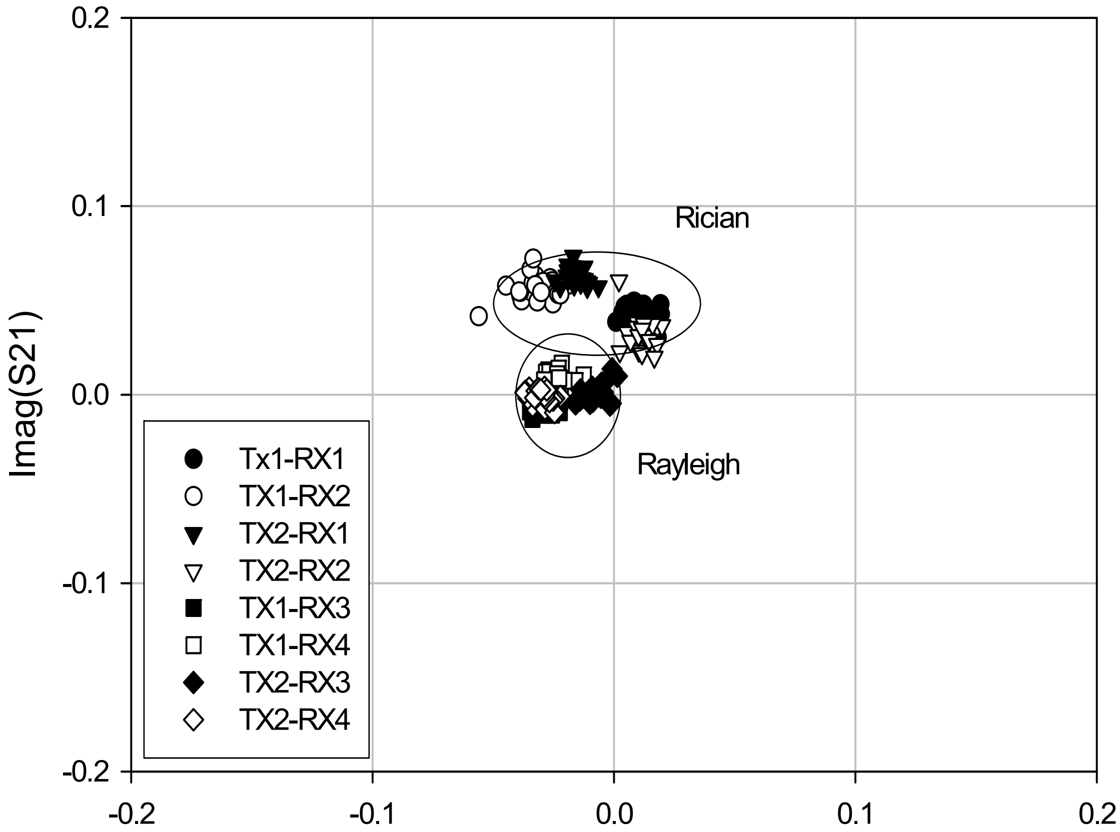
Complex S21 (absorbers of 4 walls)



Rayleigh



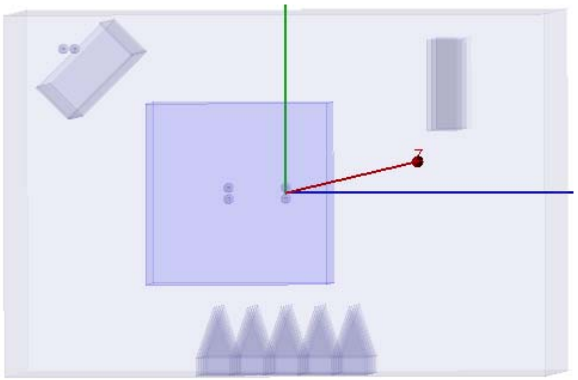
Rician



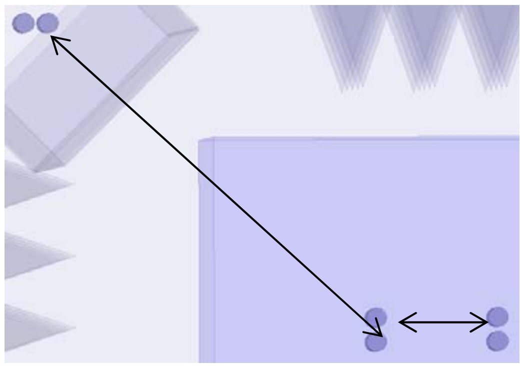
$$K = \frac{\text{direct component}}{\text{scattered components}} = \frac{A^2}{2\sigma^2}$$

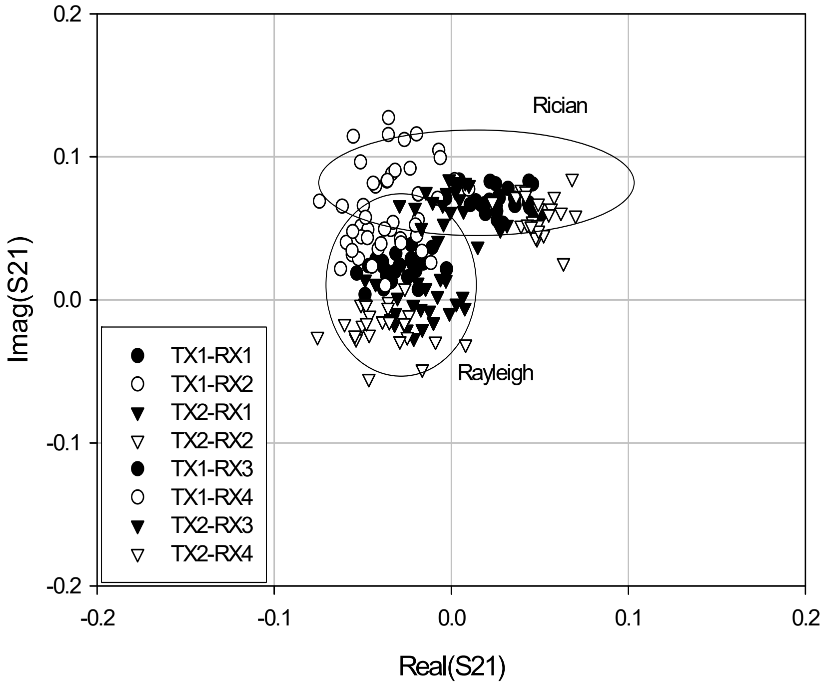
$$= \frac{(|< S_{21} >|)^2}{<| S_{21} - < S_{21} >|^2>}$$

Complex S21 (absorbers of 1 walls)



Rayleigh

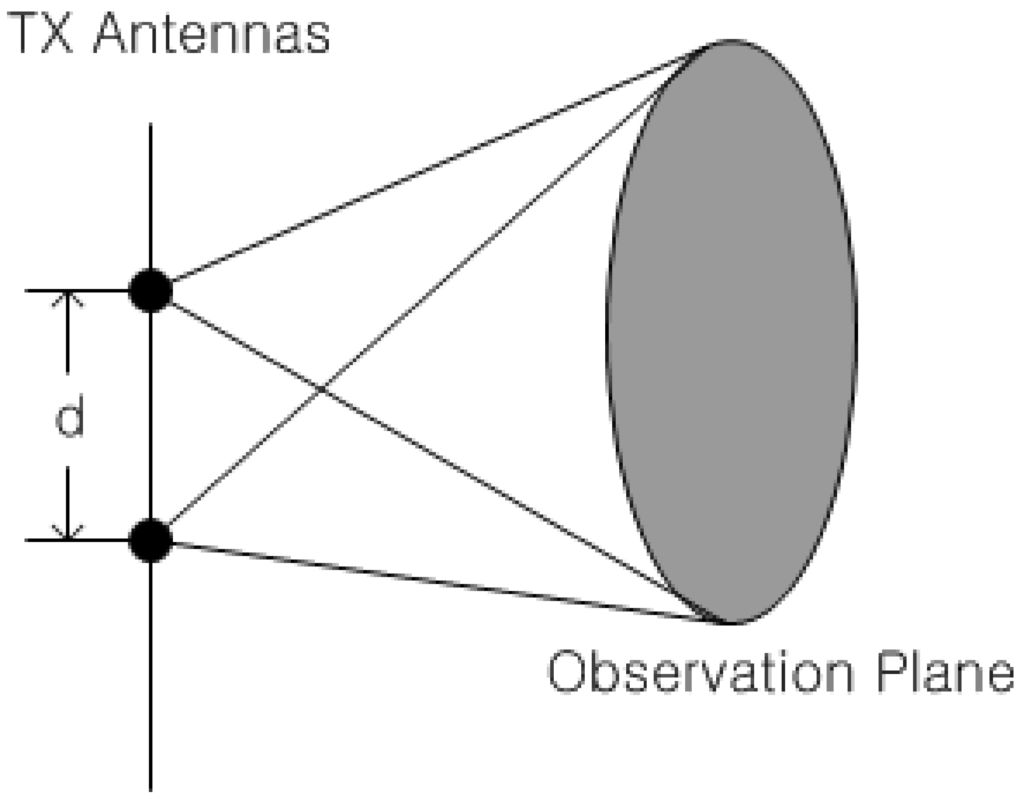




$$K = \frac{\text{direct component}}{\text{scattered components}} = \frac{A^2}{2\sigma^2}$$

$$= \frac{(|< S_{21} >|)^2}{<| S_{21} - < S_{21} >|^2 >}$$

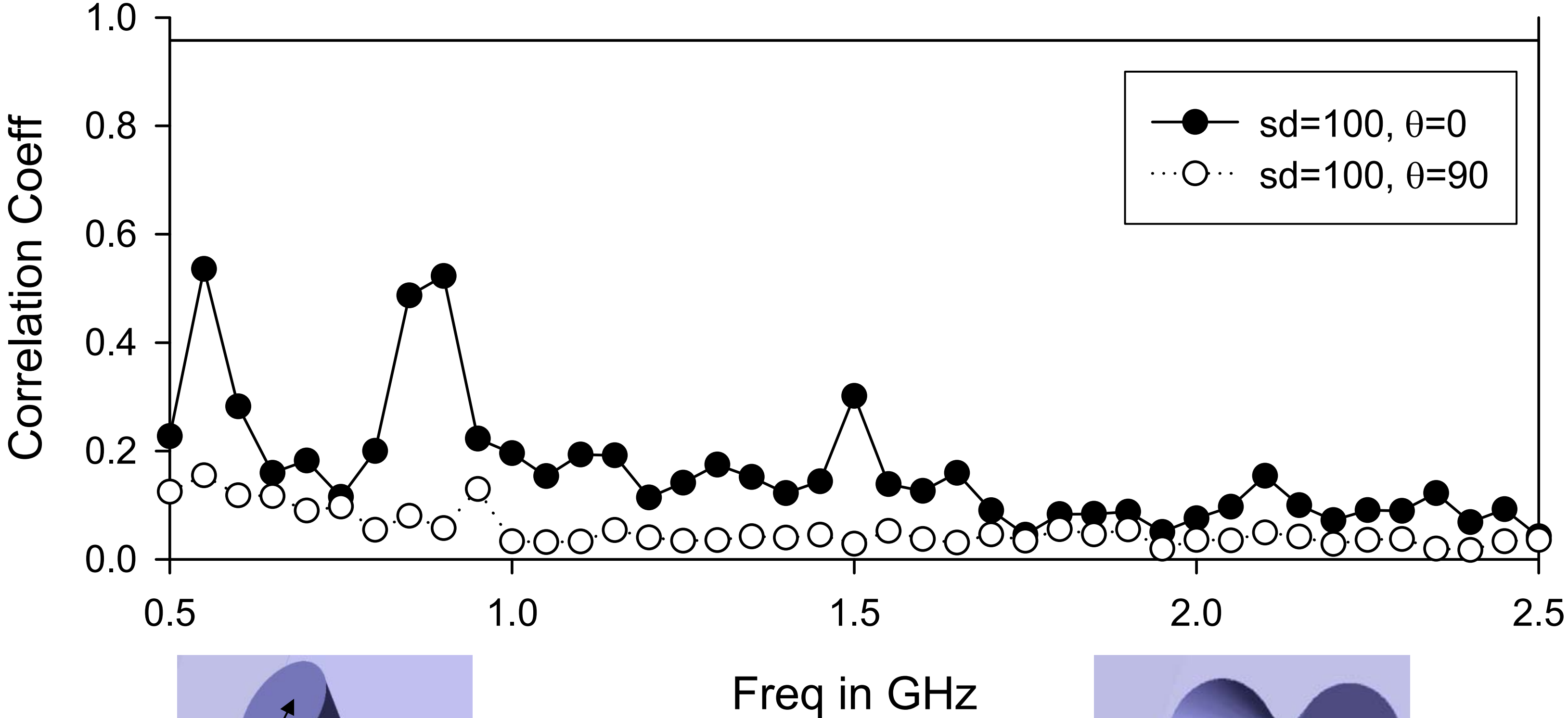
MISO(Multiple-Input-Single-Output)



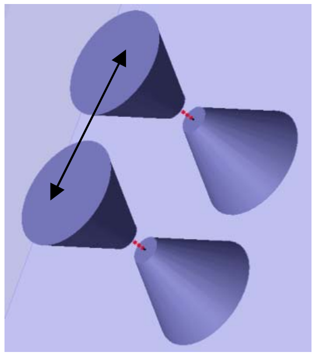
$Ez(x,y) \rightarrow Ez(k_x,k_y)$

Corr(Ez1,Ez2)

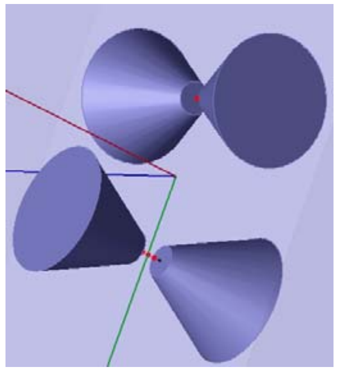
Correlation Coeff. (d=100 mm)



sd

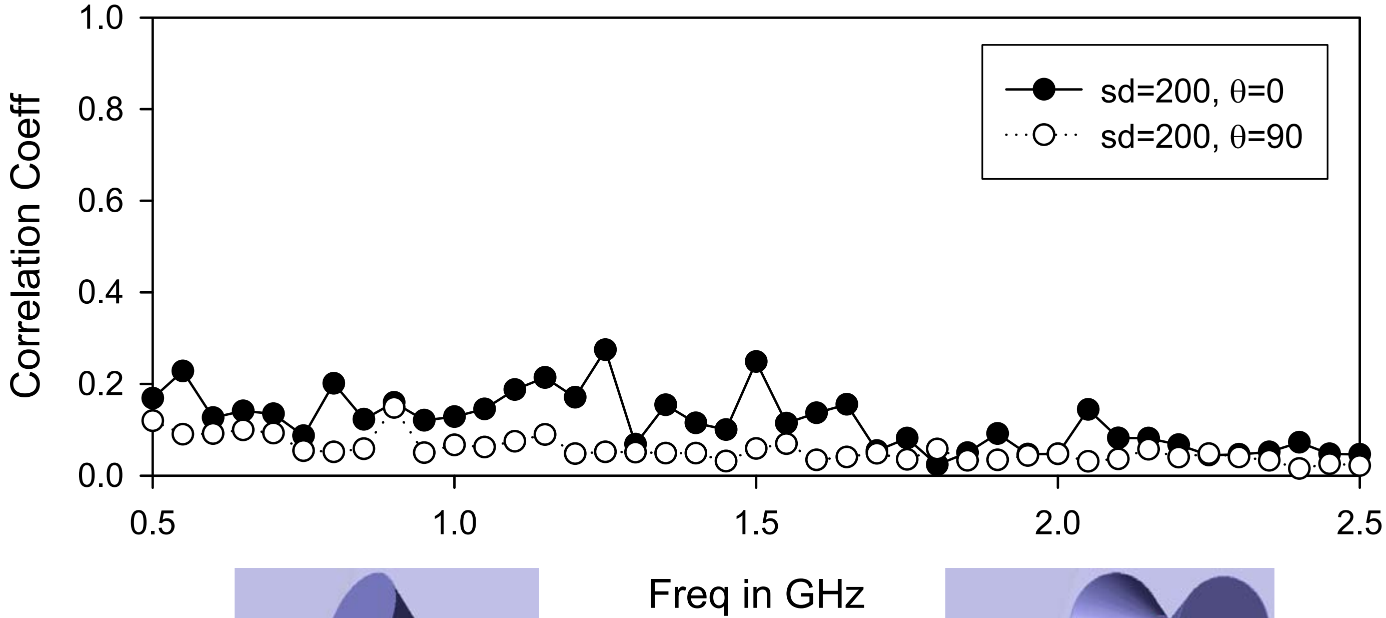


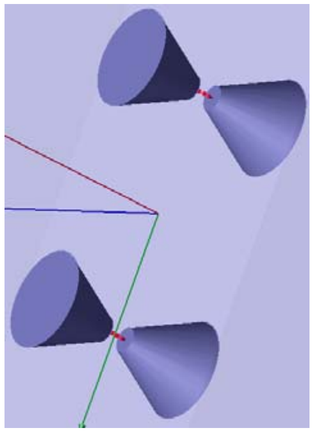
sd=100 mm, θ=0°



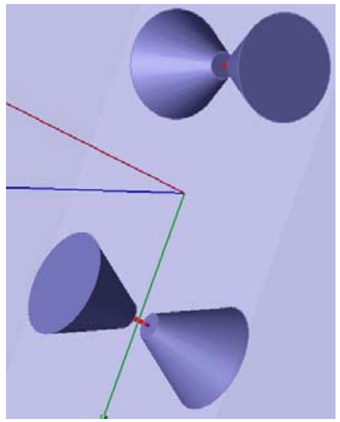
sd=100 mm, θ=90°

Correlation Coeff. (d=200 mm)



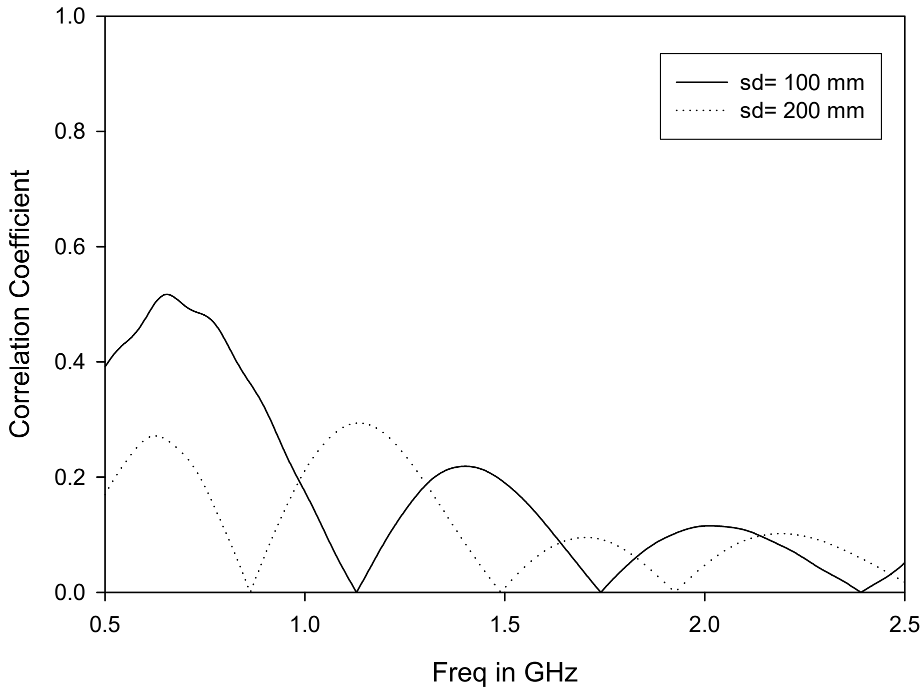


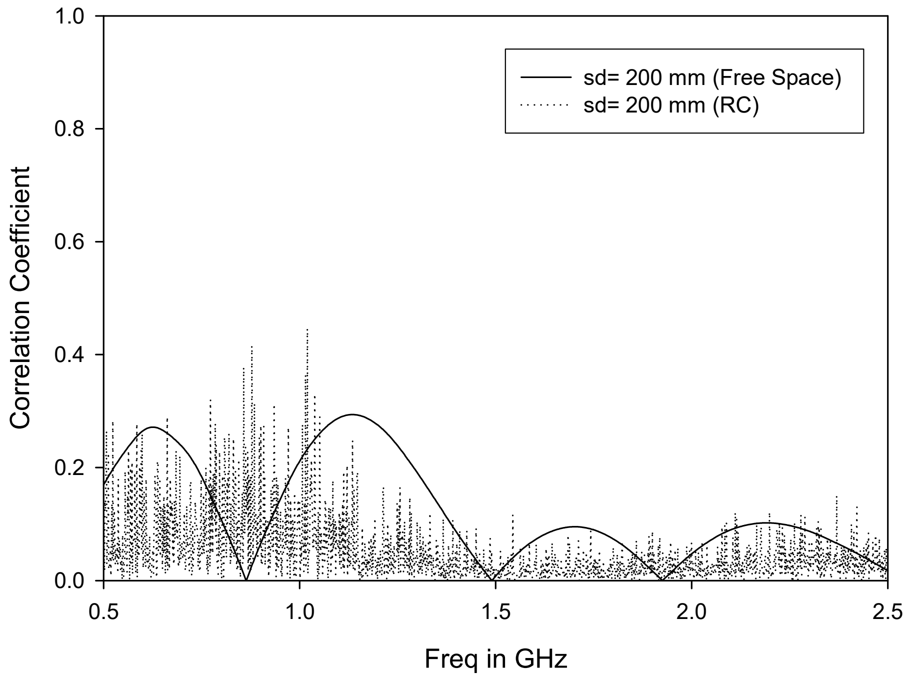
sd=200 mm, θ=0°



sd=200 mm, θ=90°

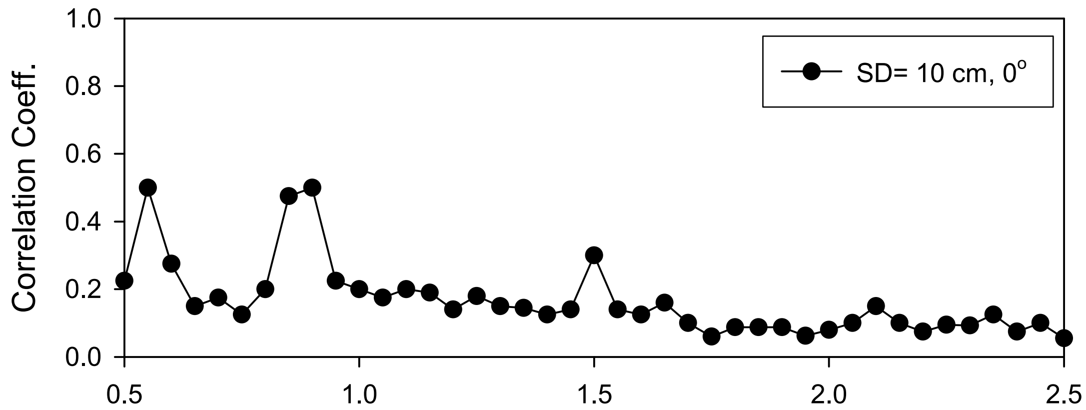
Correlation Coefficients by S-parameters



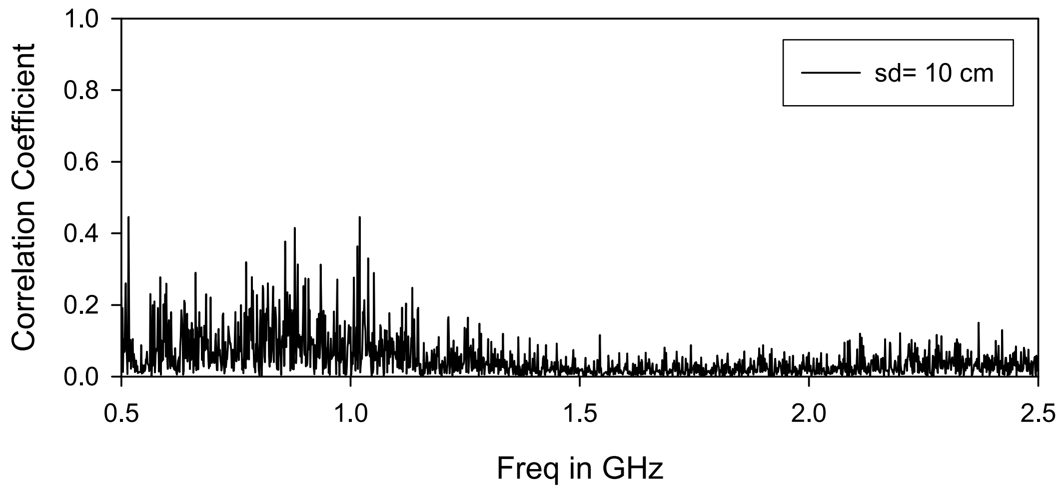


Comparison of two correlation coefficients

2-D field data in RC

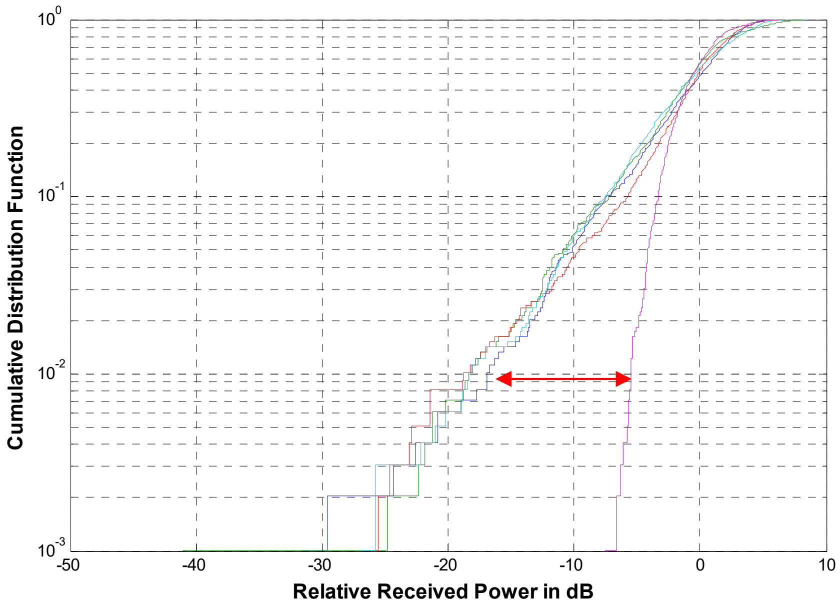


S-parameters



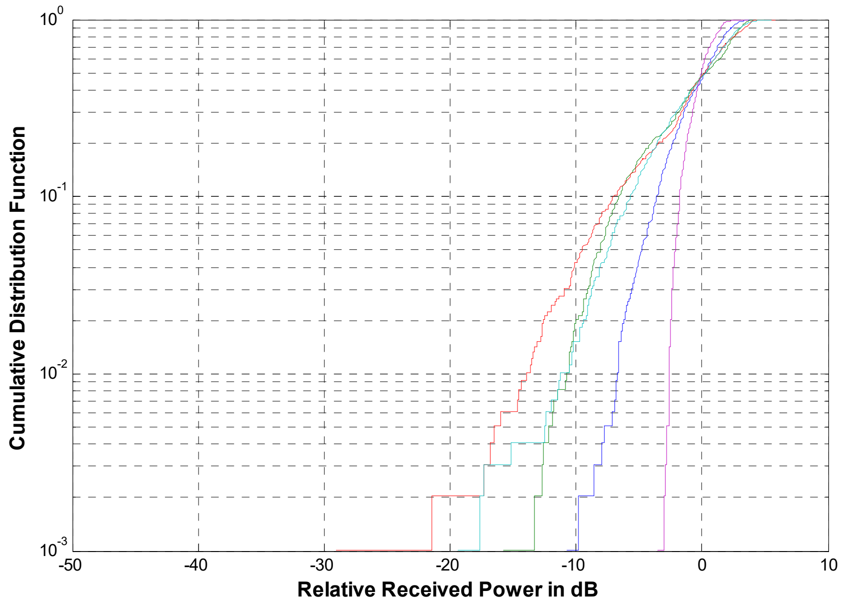
Cumulative Density Functions @1.5GHz

Rayleigh channel



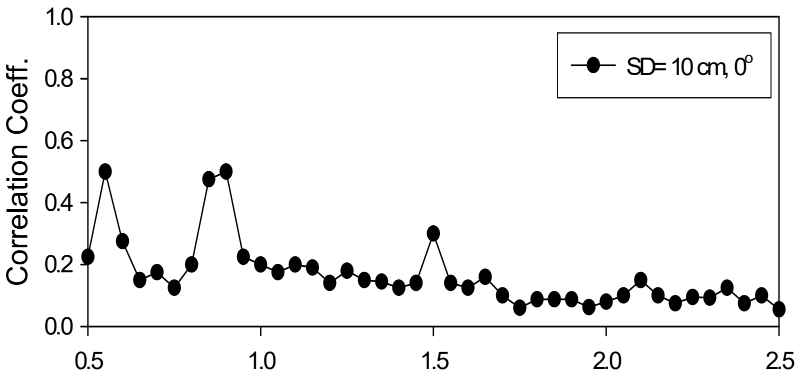
Diversity Gain of 10 dB @ 1%

Rician channel

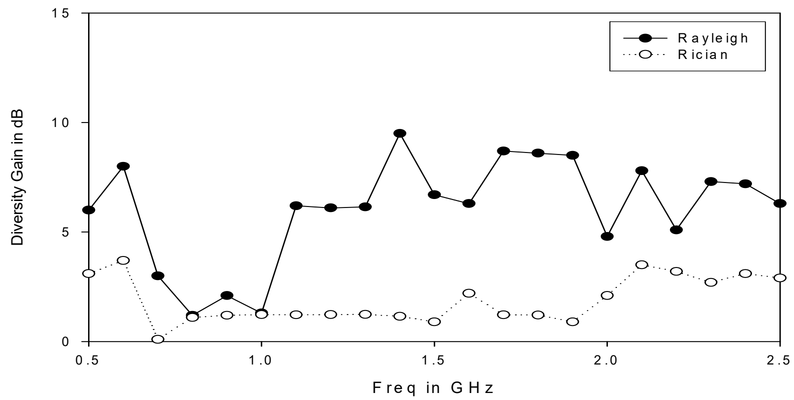


Diversity Gain of 4 dB @ 1%

Comparison of two data

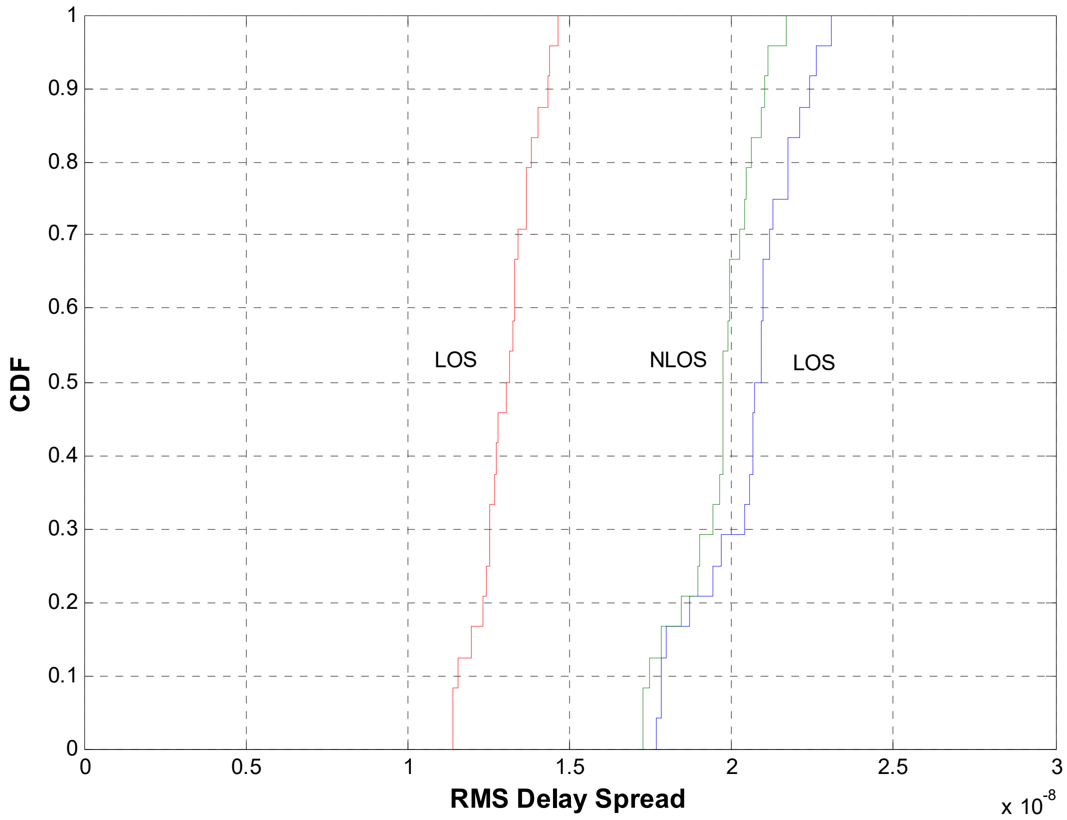


Correlation Coefficient



Diversity Gain

RMS delay spread



$$\sigma_S = \sqrt{\overline{\tau^2} - (\overline{\tau})^2} = \sqrt{\frac{\sum_k P(\tau_k)\tau_k^2}{\sum_k P(\tau_k)} - \left(\frac{\sum_k P(\tau_k)\tau_k}{\sum_k P(\tau_k)}\right)^2}$$

Conclusions

- The spectral correlation for a multipath environment based on a 2x2 MIMO system have been computed on the observation planes in the Rayleigh/Rician fading channels inside a mode stirred chamber.
- The correlation coefficients have been obtained and compared for different distances and orthogonal polarization between two transmit antennas.
- The proposed method is useful for evaluating the potential diversity gain in antenna diversity systems.

References

[1] Jongsung Kim, and Raj Mittra, “Numerical Analysis of 2x2 MIMO System in a Mode-Stirred Reverberation Chamber,” 2017 2017 IEEE AP-S Symposium on Antennas and Propagation and USNC-URSI Radio Science Meeting, July 9–14, 2017, San Diego, California, USA
[2] D. Piao, L. Yang, Q. Guo, Y. Mao, and Z. Li, “Measurement-based performance comparison of coloca ted tripolarized loop and dipole antennas,” IEEE Trans. on Antennas and Propagation, V.63, No 8, pp. 3 371 – 3379, 2015
[3] J. F. Valenzuela-Valdes, A. M. Martinez-Gonzalez, and D. Sanchez-Hernandez, “Effect of user prese nce on receive diversity and MIMO capacity for Rayleigh-fading channels,” IEEE Antennas and Wireless Propagation Letters, V. 6, pp.596 – 599, 2007
[4] S. Blanch, J. Romeu, and I. Corbella, “Exact representation of antenna system diversity performance from input parameter description,” IEE Electron. Lett., Vol. 39, No. 9, pp. 705-707, May 2003.
[5] N. Janssen, K. A. Remley, C. L. Holloway, and W. F. Young, “Correlation coefficient and loading effect s for MIMO antennas in a reverberation chamber,” Int. Sym. On Electromagnetic Compatibility, pp. 514-5 19, 2013.
[6] K. Rosengren and P.-S. Kildal, "Radiation efficiency, correlation, diversity gain and capacity of a six-monopole antenna array for a MIMO system: theory, simulation and measurement in reverberation cha mber," IEE Proceedings: Microwave, Antennas, and Propag., vol. 152, no. 1, pp. 7-16, 2005
[7] S. A. Saputro, and Jae-Young Chung, “An improved method for estimating antenna correlation coeffi cient of lossy MIMO arrays,” Asis-Pacific Radio Science Conference, pp. 21-25, 2016