Optimal Test Set-up for Generating Rayleigh Fading Channel in Reverberation Chamber

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Abstract — **This paper reports a measurement study of generating Rayleigh fading channels in a reverberation chamber. The latter has a dimension of 1.8 m x 2.4 m x 1.6 m and its operation frequency range is 650 MHz to 6 GHz, suitable for testing mobile handset devices. The fading channel inside the chamber is observed by altering stirring conditions and its difference to the ideal Rayleigh is examined by the mean square error between two. With this, optimal measurement set-up for emulating Rayleigh fading channel can be carried out.**

Index Terms — **Reverberation chamber, Rayleigh fading channel, mechanical stirring, polarization stirring.**

1. Introduction

A reverberation chamber (RC) is an effective, reliable, and economic measurement facility widely used for evaluating wireless communication devices. From a statistical viewpoint, the real and imaginary parts of the fields inside an RC are Gaussian distributed due to various mode-stirring techniques [1]. With a well-stirred RC, a rich multipath environment close to the ideal Rayleigh fading channel can be generated [2].

This work reports the measurement set-ups and the corresponding results of the Rayleigh fading channel in a RC. The measurement results obtained by varying platform-, mechanical-, polarization-, and frequency-stirring conditions are compared and analyzed by Mean Square Error (MSE) to find the proper measurement set-ups to emulate the Rayleigh channel.

2. Measurement Set-ups in Reverberation Chamber

Figure 1 depicts the RC measurement set-ups for emulating Rayleigh fading channels. The RC has the size of 1.8 m x 2.4 m x 1.6 m with one horizontal and two vertical stirrers. A wideband discone is used as a receiving (Rx) antenna while the transmitting (Tx) antenna is a four-port multiple input multiple output (MIMO) antenna [3]. These antennas were connected to a network analyzer to collect the spatial transmission coefficients (S_{21}).

The S_{21} were collected in the frequency range of 650 MHz to 3 GHz with an interval of 2 MHz. In the meantime, the stirrers and a turntable supporting the Rx antenna continuously rotate until the number of S_{21} samples reaches around 900. These collected samples were post-processed in a computer code to evaluate the cumulative distribution function (CDF) with different stirring conditions. The latter indicates mechanical stirring (stirrers), platform stirring (turntable), and polarization stirring (MIMO antenna).

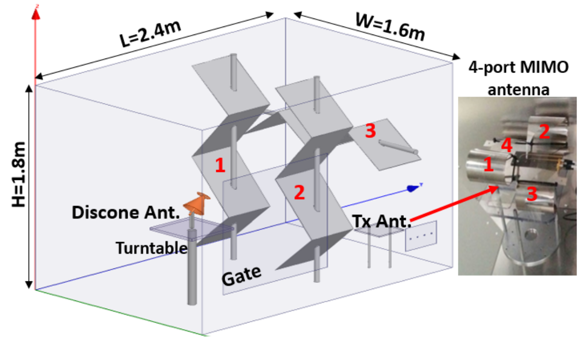

Fig. 1. Measurement set-ups in the reverberation chamber

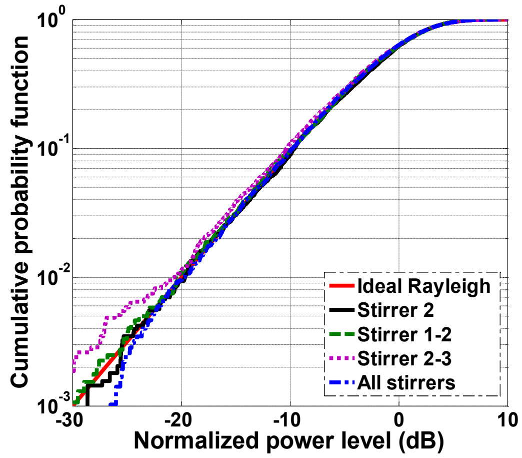

Fig. 2. Comparison of CDF with different mechanical stirring configurations.

3. Measurement Results and Discussion

Fig. 2 shows the CDF at 1900 MHz with different mechanical stirring configurations. More specifically, the S_{21} were collected with only the stirrer 2 rotating; stirrer 1-2 rotating; stirrer 2-3 rotating and all the three stirrers rotating (see Fig.1 for stirrer's numbering definition). These curves were compared to the ideal CDF of Rayleigh fading channel by means of Mean Squared Error (MSE):

$$MSE = \frac{a}{N}\sum^{N}\left[F^{measured}(S_{21}) - F^{ideal}(S_{21})\right]^2$$

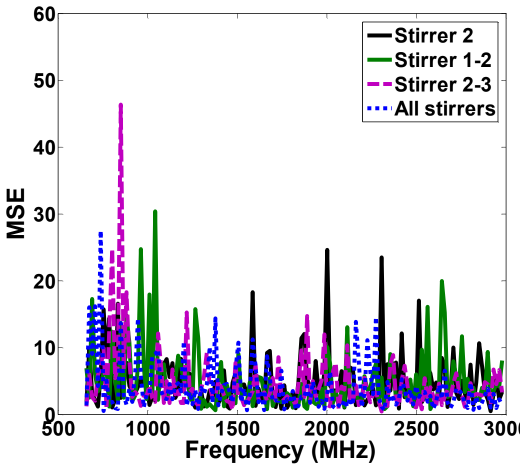

Fig. 3. MSE versus frequency with different mechanical stirring configurations.

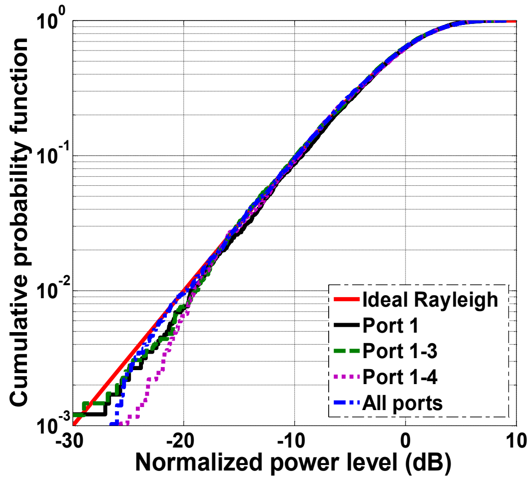

Fig. 4. Comparison of CDF with different polarization stirring configurations.

, where N is the number of samples and a is a scaling factor. Figure 3 shows MSE versus frequencies for different mechanical stirring configurations. Here we used $\alpha=10^5$. The averaged MSE over the frequency range is 4.8 when only stirrer 2 operates, 4.97 for stirrer 1-2 combination, 4.47 for stirrer 2-3 combination, and 4.0 for all stirrer operation. Based on this, we can conclude that using all the three stirrers is the most effective way to generate Rayleigh fading channel close to the ideal one.

In the next experiments, the effect of polarization stirring was investigated by manipulating the Tx-antenna port excitations while all the stirrers were under operation. Figure 4 compares the ideal Rayleigh CDF to the measured ones at 1900 MHz with different antenna port excitations (see Fig.1 for port's numbering definition). Figure 5 is the MSE values calculated from the CDFs at each frequency of observation. The averaged MSE over the frequency range are 10.92, 7.53, 6.49 and 4.0 when only port 1 is excited, port 1-3, port 1-4, and all the ports are excited, respectively. This result proves that using all the Tx-antenna ports is the most effective for generating Rayleigh fading channel.

Although not included here, the effect of platform stirrings was investigated by turning on and off the turntable rotation. Based on these tests and comparisons, the optimum measurement set-up for generating Rayleigh fading channel turns out to be as the followings: continuously rotating the turntable (platform-stirring), using all four ports of the MIMO Tx-antenna (polarization-stirring), and using all stirrers (mechanical-stirring).

4. Conclusion

This study shows a method of using the MSE to compare fading channel in a RC with the ideal Rayleigh one. The analytical results indicate using the combination of one vertical stirrer and one horizontal stirrer (a common setup) leads to the higher MSEs (i.e. less effective) than using all the stirrers. Besides, the polarization-stirring with all Tx-antenna ports reduces considerably the MSEs compared to the other combinations.

Throughout many experiments in the RC with three stirrers designed for mobile handset testing purpose, the

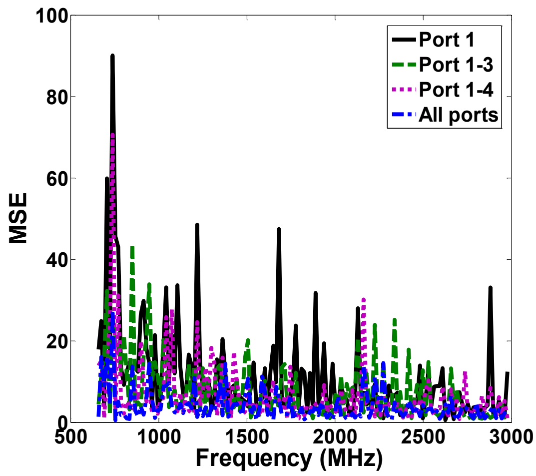

Fig. 5. MSE versus frequency with different polarization stirring configurations

optimal set-up for emulating the Rayleigh fading channel is using all stirrers, all antenna ports and a turntable for Rx-antenna.

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References

[1] P. S. Kildal, X. Chen, C. Orlenius, M. Franzén, and C. S. L. Patané, "Characterization of reverberation chambers for OTA measurements of wireless devices: Physical formulations of channel matrix and new uncertainty formula," *IEEE Trans. Antennas and Propagat.*, vol. 60, no. 8, pp. 3875-3891, 2012.

[2] C. L. Holloway, D. A. Hill, J. M. Ladbury, P. F. Wilson, G. Koepke, and J. Coder, "On the use of reverberation chambers to simulate a Rician radio environment for the testing of wireless devices", *IEEE Trans. Antennas Propag.*, vol. 54, no. 11, pp. 3167-3177.

[3] A. Al-Rawi, A. Hussain, J. Yang, M. Franzén, C. Orlenius, and A. A. Kishk, "A new compact wideband MIMO antenna—the double-sided tapered self-grounded monopole array", *IEEE Trans. Antennas Propag.*, vol 62, no. 6, pp. 3365-3369.