An Experimental Reconfigurable OTA Chamber

Rashid Mehmood, Jon W. Wallace, and Michael A. Jensen
Electrical and Computer Engineering, Brigham Young University, Provo, UT, USA
r.mehmood@ieee.org, wall@ieee.org, jensen@byu.edu

***Abstract*—This paper presents an experimental prototype of a reconfigurable chamber for over-the-air testing of wireless devices. Initial measurements obtained from this prototype demonstrate that through proper optimization of the reconfigurable elements, the chamber can be used to generate target fading statistics at the device under test.**

I. INTRODUCTION

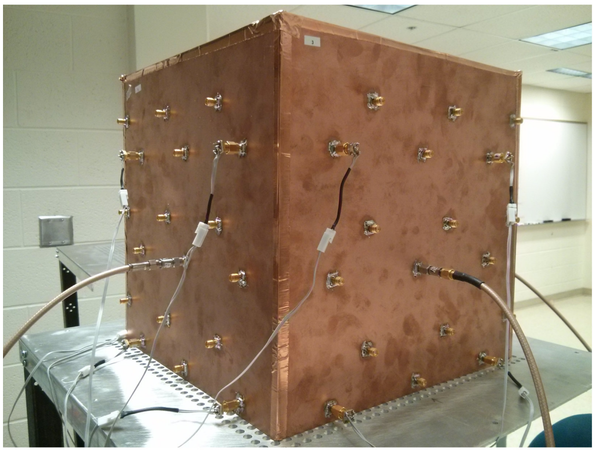
Over-the-air testing (OTA) for characterizing the complete end-to-end performance of wireless devices in a repeatable propagation environment uses either a costly multi-antenna anechoic OTA chamber that offers high emulated field control [1] or a lower-cost mode-stirred reverberation chamber (RC) with reduced emulation flexibility [2]. While adding controllable delay lines to a RC increases control over the field emulation [3], the range of field characteristics that can be realized at the device under test (DUT) still falls short of that offered by the multi-antenna technique.

We recently introduced a RC whose walls are lined with antennas, a small number of which are connected to transmitting sources and the remainder of which are connected to reconfigurable impedance elements (REs) [4]. Simulations of a two-dimensional version of this *reconfigurable OTA chamber* (ROTAC) demonstrate that controlling the statistics of the RE impedances enables control over the emulated fading distribution, spatial correlation, power angular spectrum, and channel frequency selectivity observed at the DUT [4]. This paper reports on the design of a functional prototype ROTAC and experimentally confirms that the technique has the potential to provide flexible, low-cost OTA testing.

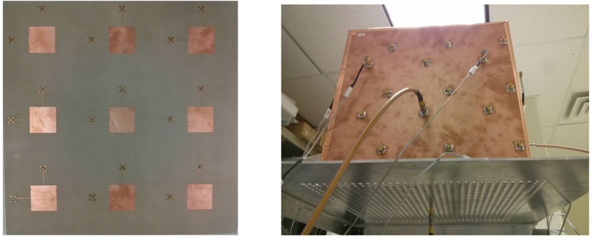
II. ROTAC PROTOTYPE

Figure 1(a) depicts our initial prototype ROTAC, which is a cube formed from five panels that are 11 inches square. Each individual panel, an example of which is shown in Figure 1(b), hosts a 3×3 grid of dual-port, dual-polarization patch elements separated by $\lambda/2$, where λ is the free space wavelength. The cube is placed on a ground plane, as shown in Figure 1(c), that is perforated with a grid of small holes that allow cable access to a DUT within the chamber.

Figure 2 shows the individual dual-polarized patch antenna used on the ROTAC panels. The patch is fabricated on 60 mil Taconic RF substrate with a relative permittivity of 3.5. Quarter-wave transformers are used on each feeding transmission line to match the antenna input impedance to 50 Ω. Figure 2 also plots the reflection coefficients (S_{11} and S_{22}) and cross coupling coefficient (S_{12}) of the fabricated antenna. The antenna is resonant near 2.53 GHz, with a 3 dB bandwidth of approximately 80 MHz. Cross-coupling between the two feed ports is less than -30 dB.



(a) Chamber side



(b) Single panel

(c) Chamber bottom

Fig. 1. Prototype ROTAC: (a) Complete chamber from side, (b) a single chamber panel hosting a 3×3 grid of dual polarized square patch antennas, (c) bottom view of the chamber with one receive dipole placed in the middle of the chamber above the ground plane.

The 18 ports on each of the five panels provide a total of 90 ports that can be connected either to RF sources (*feed ports*) or REs (*reconfigurable ports*). For these initial measurements, the vertical polarization port of the center antenna on each of the four side panels is fed while the vertical polarization ports of the antennas at the four corners of these side panels are loaded with REs. Ports connected neither to sources nor to REs are left unterminated (open circuit). The RE used, which is similar to that reported in [5], enables a phase tuning range of 200° with a maximum power loss of 3 dB. We measure the field using a monopole in the middle of the chamber above the ground plane, with the antenna connected to the receiver by a cable through the ground plane as shown in Figure 1(c).

III. INITIAL MEASUREMENTS

Measurements were performed using an 8×8 multiple-input multiple-output channel sounder, where four sounder transmit ports were connected to the four ROTAC feed antennas and a single sounder receive port was connected to the monopole. The transmit RF signal consisted of four tones separated

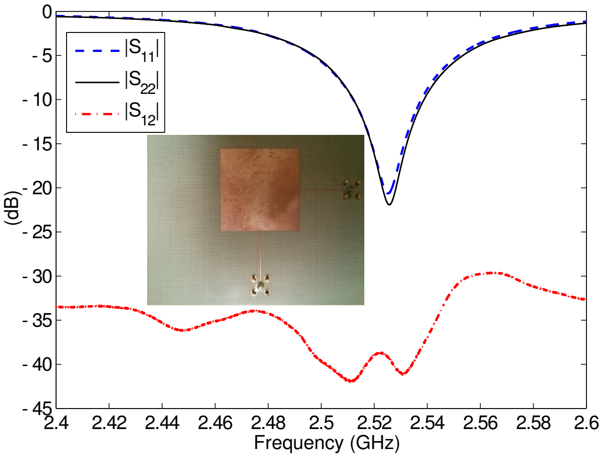


Fig. 2. S-parameters of a single fabricated patch antenna used in the prototype ROTAC.

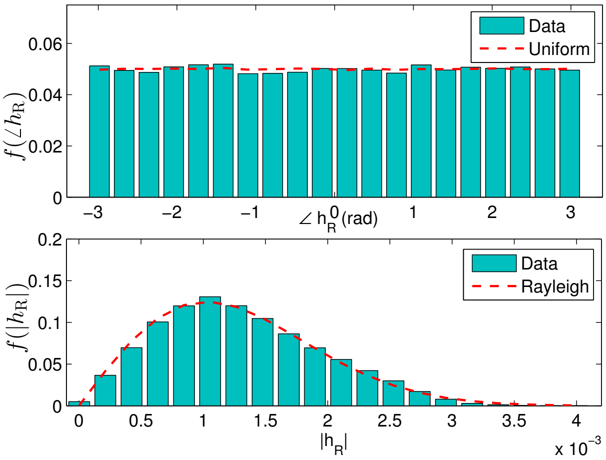


Fig. 3. Histograms of the phase and amplitude of the field sampled at the DUT antenna in the ROTAC compared to uniform phase and Rayleigh amplitude distributions.

by 5 MHz and centered at 2.53 GHz. Because the sounder activates one transmit port at a time, it measures the transfer function $h_i[n]$ from the ith feed port to the receive port, where n is the frequency bin index. Measurements of the four transfer functions, $1 \leq i \leq 4$, were captured for 10^6 different combinations of random RE states (bias voltages). If the phase of the signal transmitted from the ith feed port is ϕ_i, the realized channel response from the transmitter to the DUT at the nth frequency is computed as

$$h_{\mathrm{R}}[n] = \sum_{i=1}^{4} h_i[n] e^{j\phi_i}. \tag{1}$$

Based on the measured data and (1), we perform a brute-force optimization where we realize 10^4 random phase combinations and then determine the single phase combination that produces channel responses whose magnitude and phase distributions are approximately Rayleigh and uniform, respectively. Figure 3 shows the realized field histograms along with the target amplitude and phase distributions. To achieve Rician fading, we fix the phases at $\phi_i = 0$ and select a subset of the RE states that achieves the desired field amplitude distributions. Figure 4 shows the pdfs for these results for different target Rician distributions, where the Rician parameters are discussed in [4]. These results demonstrate that the ROTAC is capable of providing a range of different fading distributions.

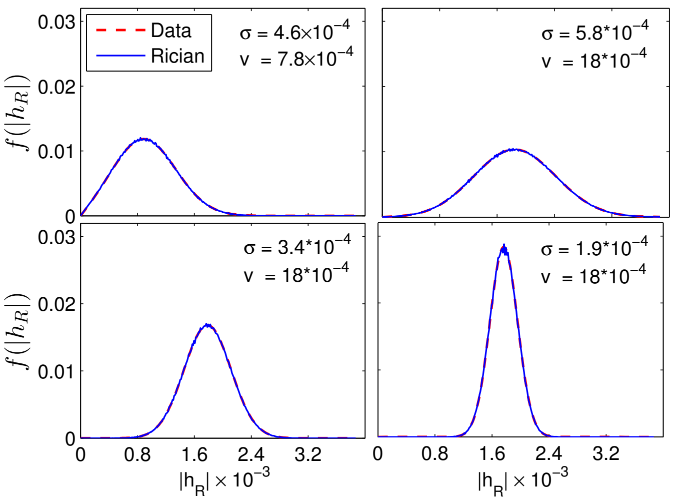


Fig. 4. Amplitude pdfs of the field sampled at the DUT antenna in the ROTAC compared to different Rician distributions, where σ and v control the Rician statistics.

IV. CONCLUSION

This paper reports on an experimental prototype ROTAC and demonstrates that it can be used to generate Rayleigh and Rician fading statistics at the DUT by controlling the impedance of the REs along with the phase shift applied to the signal from each transmit port. The results demonstrate that the ROTAC can potentially offer high emulated field control at a relatively low cost.

ACKNOWLEDGEMENT

This work was supported in part by the U. S. Army Research Office under Grant # W911NF-12-1-0469.

REFERENCES

[1] Wei Fan, Xavier Carreño Bautista de Lisbona, Fan Sun, Jesper Odum Nielsen, Mikael B. Knudsen, and Gert Frølund Pedersen, "Emulating spatial characteristics of MIMO channels for OTA testing," *IEEE Transactions on Antennas and Propagation*, vol. 61, no. 8, pp. 4306–4314, 2013.

[2] M. A. Garcia-Fernandez, J. D. Sanchez-Heredia, A. M. Martinez-Gonzalez, D. A. Sanchez-Hernandez, and J. F. Valenzuela-Valdes, "Advances in mode-stirred reverberation chambers for wireless communication performance evaluation," *IEEE Communications Magazine*, vol. 49, no. 7, pp. 140–147, 2011.

[3] Jeff Frolik, Thomas M Weller, Stephen DiStasi, and James Cooper, "A compact reverberation chamber for hyper-Rayleigh channel emulation," *IEEE Transactions on Antennas and Propagation*, vol. 57, no. 12, pp. 3962–3968, 2009.

[4] Jon W. Wallace, Rashid Mehmood, and Michael A. Jensen, "Electronically reconfigurable reverberation chambers," in *8th European Conference on Antennas and Propagation (EuCAP)*, 2014, pp. 3669–3673.

[5] Rashid Mehmood, J. Wallace, and M. Jensen, "Key establishment employing reconfigurable antennas: Impact of antenna complexity," *IEEE Transactions on Wireless Communications*, June 2014.