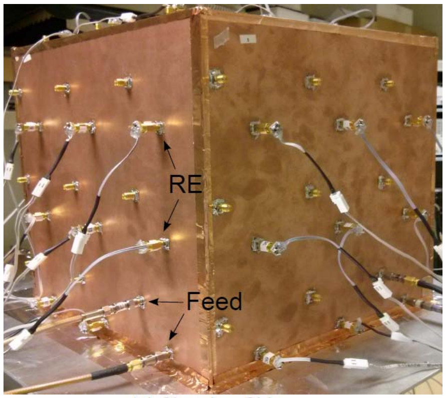
PAS Control in a Reconfigurable OTA Chamber

Rashid Mehmood, Jon W. Wallace, and Michael A. Jensen
Electrical and Computer Engineering, Brigham Young University, USA
E-mail: {r.mehmood,wall}@ieee.org, jensen@byu.edu

***Abstract*—A reconfigurable chamber for over the air testing of wireless devices has recently been introduced, with potential performance examined through simulation. This paper reports an experimental prototype of such a chamber. Measurements using a circular array explore the angular characteristics of the multipath fields that can be synthesized in the chamber.**



(a) Chamber Side

(b) Single panel (c) Chamber bottom

Fig. 1. Prototype ROTAC: (a) Side view of the complete chamber showing representative feed and RE ports; (b) A single chamber panel hosting the 3×3 grid of dual-polarized square patch antennas; (c) Bottom view of the chamber showing the RF cables that connect to an eight-element circular array of receiving monopole antennas.

I. INTRODUCTION

Over the air testing (OTA) designed to characterize the performance of wireless devices in realistic but repeatable propagation environments is typically accomplished in one of two ways: use of a multi-antenna OTA chamber that provides high level of control of the multipath environment but at high expense [1], or use of a low-cost mode-stirred reverberation chamber that offers limited control over the emulated environments [2]. More recently, we introduced the concept of a reconfigurable OTA chamber (ROTAC) whose walls are lined with antennas, a few of which may be attached to a channel emulator and the balance of which are connected to reconfigurable impedances [3]. Initial simulations with this topology have demonstrated that through control of the impedances and the port excitations, the chamber offers significant control over the achieved fading distribution, spatial correlation, and power angular spectrum (PAS) at the device under test (DUT). The objective of this paper is to report on experimental implementation of a prototype ROTAC and present measurements that indicate the degree of control over the synthesized channel spatial characteristics.

II. PROTOTYPE ROTAC

The initial prototype ROTAC is a cube 11 inches on a side consisting of five panels fabricated using 60 mil Taconic RF substrate having a relative permittivity of 3.5. The panels are formed into a box that is mounted on a ground plane as shown in Figure 1(a). Each of the five panels (Figure 1(b)) hosts a 3×3 grid of dual-polarized rear-fed square patch antenna elements that are impedance matched to $50\ \Omega$ with a quarter-wave transformer and are separated by $\lambda/2$, where λ is the free-space wavelength. The patch antennas are resonant at 2.53 GHz and offer a 3 dB bandwidth of 80 MHz.

The five panels offer a total of 90 antenna ports that can be connected to a source (feed port) or reconfigurable impedance element (RE). Each RE consists of a biased varactor diode and is identical to the design presented in [4]. The varactor diode offers an approximately reactive load with a maximum power loss of 3 dB and a reflection coefficient phase that can be tuned over a range of 200° by varying the bias voltage from 0 to 5V. To measure the fields inside the chamber, we use an array of eight monopole antennas arranged in a circle of radius $\lambda/2$ at the center of the chamber, with each monopole connected to the receiver using RF cables as shown in Figure 1(c).

III. MEASURED RESULTS

We terminate the vertical polarization port of eight antennas on each panel with an RE whose bias voltage is provided by an FPGA-controlled D/A, for a total of 40 independently-controlled terminations. One antenna on each of the four side panels is then fed by an independently-controlled source, with the feed antenna selected according to: **Case 1** – the vertical polarization port at each panel center; **Case 2** – the vertical polarization port at the panel lower right corner; **Case 3** – the horizontal polarization port at the panel lower right corner. Cases 2 and 3 are illustrated in Figure 1(a). Note that all remaining ports remain unterminated (open circuit).

The system uses the custom 8×8 MIMO channel sounder presented in [5]. The excitation signal consists of four equally-spaced frequency tones separated by 5 MHz and centered at 2.53 GHz. Let $\hat{h}_{k\ell}[n]$ represent the transfer coefficient from the ℓth transmit to the kth receive antenna at the nth discrete frequency bin for one set of RE bias voltages (state). The

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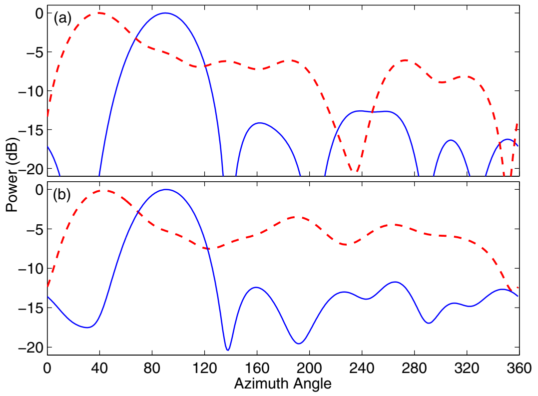

Fig. 2. Power incident on the DUT as a function of azimuth arrival angle for sources on the vertical polarization port at the center of each face (Case 1): (a) Single RE state; (b) Average over 50 RE states.

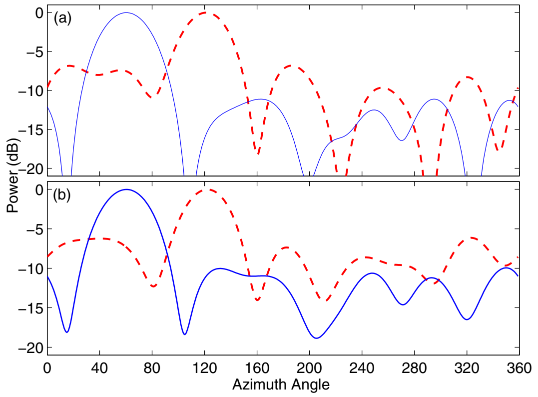

Fig. 3. Power incident on the DUT as a function of azimuth arrival angle for sources on the vertical polarization port at the lower right corner of each face (Case 2): (a) Single RE state; (b) Average over 50 RE states.

signal at the kth receive antenna for this frequency is

$$h_k[n] = \sum_{\ell=1}^{N_{\mathrm{F}}} a_\ell e^{j\theta_\ell} \hat{h}_{k\ell}[n] \tag{1}$$

where N_{F} is the number of feed ports and $a_\ell e^{j\theta_\ell}$ is the complex gain applied to the ℓth feed port signal and normalized such that $\sum_\ell a_\ell = 1$. The measurement record includes channels for 10^4 different RE states.

While we have performed a variety of different measurements, we focus here on the angular characteristics of the multipaths synthesized by the chamber. For each RE state, we apply a randomly-chosen set of 10^4 complex gains $a_\ell e^{j\theta_\ell}$ and use the Bartlett beamformer on the circular array to estimate the PAS. For each gain combination, we find the peak of the PAS and define the sidelobe level (SLL) as the peak power observed at angles beyond the array beamwidth, which is the angular range between PAS first nulls for an incident plane wave. For each gain combination, we store the SLL for each state as well as the SLL averaged over the 50 states that achieve the lowest SLL for that gain.

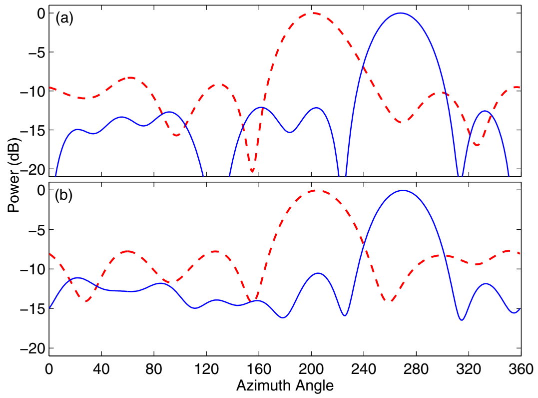

Fig. 4. Power incident on the DUT as a function of azimuth arrival angle for sources on the horizontal polarization port at the lower right corner of each face (Case 3): (a) Single RE state; (b) Average over 50 RE states.

Figures 2-4 plot the azimuth PAS for Cases 1-3. In each case, the solid and dashed lines depict the cases with the lowest and highest SLL, respectively. Furthermore, the top and bottom plots show results when we look at the SLL for each state and averaged over the best 50 states, respectively. The results demonstrate that the SLL depends on the peak angle of arrival. Furthermore, while the SLL is higher for the averaged results, the difference is generally small, meaning that a single gain combination can be effective for multiple different RE states. The results for different feed ports show that the worst case SLL is improved by moving the feed location to the corner and transmitting on the horizontal polarization. The most important observation is that the ROTAC offers considerable control over the PAS.

IV. CONCLUSIONS

This paper reports on an experimental prototype ROTAC and shows measurements of the achieved PAS over a broad range of RE states and transmit array gains. The results demonstrate that the PAS can be controlled, motivating further explorations of this topic including application of more sophisticated beamformers and optimization algorithms for transmit gain selection.

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