# Reconfigurable Antennas in Highly Multipath Environments

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***Abstract*—Highly reflective environments, such as ships, aircraft, and industrial warehouses, can be challenging for wireless communications. This effort investigates the use of transmitter-side reconfigurable antennas to mitigate the effect of multipath interference in such environments. Software-defined radios were used to transmit and receive IEEE 802.11g OFDM packets in "tuned" reverberation chambers at the Naval Surface Warfare Center in Dahlgren, VA. The reconfigurable antenna improved signal integrity by 4.9 dB over a conventional, omnidirectional antenna for SISO, and by a smaller margin for MRC. The reconfigurable antenna achieved greater capacity than the omnidirectional antenna with 16% improvement. It is concluded that reconfigurable antennas are well suited for use with access points and other stationary network infrastructure to facilitate the design and mobility of receivers in highly reflective environments.**

## I. Introduction

There is an increasing interest in deploying wireless communication networks in highly multipath environments such as below-deck spaces on naval vessels [1], industrial facilities [2], and underwater [3]. Attempts have been made to determine the impacts that such environments have on communications performance (e.g., [4]). Reconfigurable antennas have been proposed for mitigating the multipath interference in such environments [5]. However, only little work has been done on the communications performance of electrically reconfigurable antennas in such extreme multipath environments.

The current study seeks to measure the communications performance benefits of using electronically reconfigurable antennas in a highly multipath environment. The study was conducted in a reverberation chamber at the Naval Surface Warfare Center, Dahlgren, VA. The highly reflective environment was controlled so as to mimic the reflectivity and dynamic nature of practical highly multipath environments.

## II. Experimental Setup

The reverberation chamber is a sealed, metallic enclosure subdivided into a main chamber and an ante chamber. A transmitter and two receivers were positioned as shown in Fig. 1. The reflectivity of the reverberation chamber was "tuned" to match below-deck spaces typically found aboard ships [6]. A dynamic wireless environment was created inside the reverberation chamber by altering, or "stirring," the reflective surfaces in the chamber. This stirring had the effect of changing the boundary conditions of the system, varying the electromagnetic field and the nature of multipath components arriving at the receiver nodes.

A MATLAB-based 802.11g OFDM measurement platform was developed for the WARP v3 Kit, a software-defined FPGA radio [7]. This platform implements both SISO and MRC physical layer schemes. A COTS, dual-band (2.4/5.8 GHz) omnidirectional antenna and a reconfigurable, leaky wave antenna [8] were selected for comparison. The transmissions alternate between the two antenna types to improve the correlation of the wireless channel.

## III. Results

While five configurations of the reconfigurable antenna were tested, the optimally performing configuration was selected for evaluation in order to simplify analysis and represent an upper bound on the best-case scenario performance for the antenna. The optimal configuration is selected based on the minimal EVM as determined on a per-transmission basis.

Fig. 2 shows that reconfigurable SISO outperforms omnidirectional SISO by 4.9 dB in PP-SNR for Receiver 1. Since Receiver 1 has LOS to the transmitter, the degradation of omnidirectional SISO is likely the result of destructive multi-

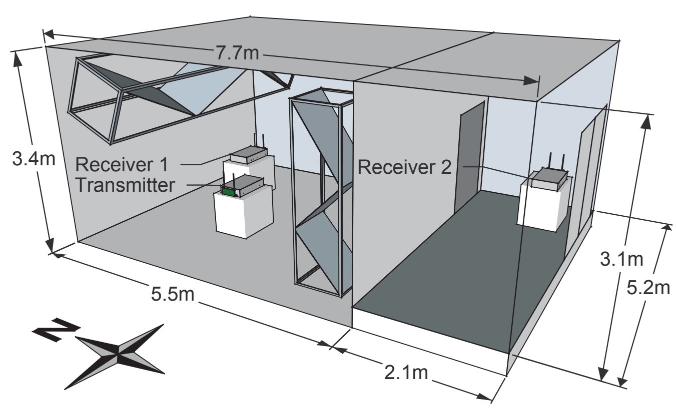


Fig. 1. Diagram of the test environment in the reverberation chamber.

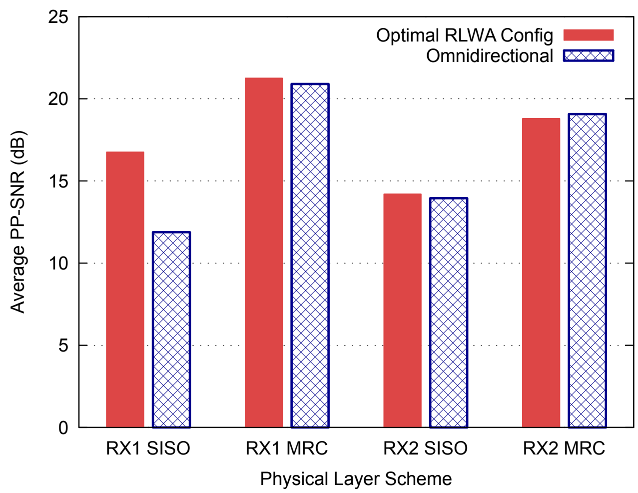


Fig. 2. The PP-SNR for Receivers 1 and 2.

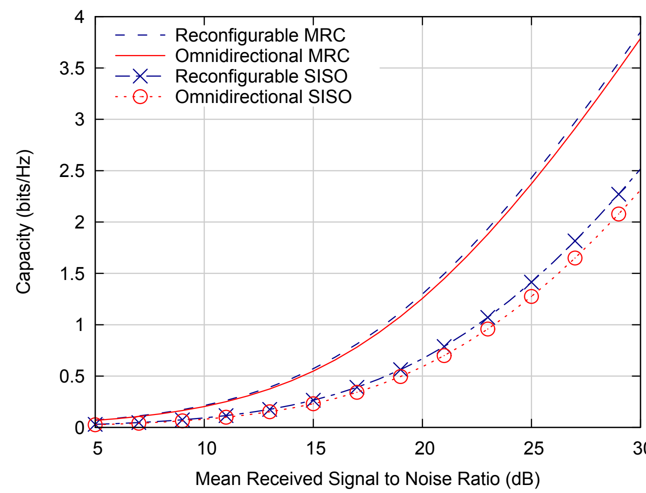


Fig. 3. Channel Capacity for Receiver 1.

path interference. Operating at the optimal configuration of the reconfigurable antenna reduces the effect of this interference.

The PP-SNR of reconfigurable SISO is only 0.3 dB greater than omnidirectional SISO for Receiver 2. Due to the highly reverberant nature of the main chamber, energy is coupled into the ante chamber at the same rate regardless of the antenna pattern or type. Since the effective aperture between chambers is held constant, it is expected that both antennas have similar performance.

For MRC, the reconfigurable antenna provides only minor advantage over the omnidirectional antenna. MRC implements receiver diversity, which provides a greater improvement than altering the transmit antenna radiation pattern. Both reconfigurable and omnidirectional MRC outperform their respective SISO schemes in PP-SNR. MRC is expected to outperform SISO since it uses the weighted combination of two SISO signals.

The channel capacities for Receivers 1 and 2 are shown in Figs. 3 and 4. Reconfigurable SISO has a 16% increase over omnidirectional SISO, further strengthening the recommendation to use a reconfigurable antenna in such scenarios. The reconfigurable antenna also has a small advantage over the omnidirectional for all other cases, with improvements ranging from 1% to 12%.

The ability of the reconfigurable antenna to dynamically alter its radiation pattern makes it particularly well suited for mitigating multipath interference. Even if a receiver does incorporate additional diversity schemes (such as MRC), the reconfigurable antenna still slightly outperforms the omnidirectional antenna. Performance never suffered as a result of using the reconfigurable antenna at the transmitter, and was much improved in some cases. Therefore, a reconfigurable antenna would be beneficial for use with access points and other stationary network infrastructure to facilitate the design and mobility of receivers.

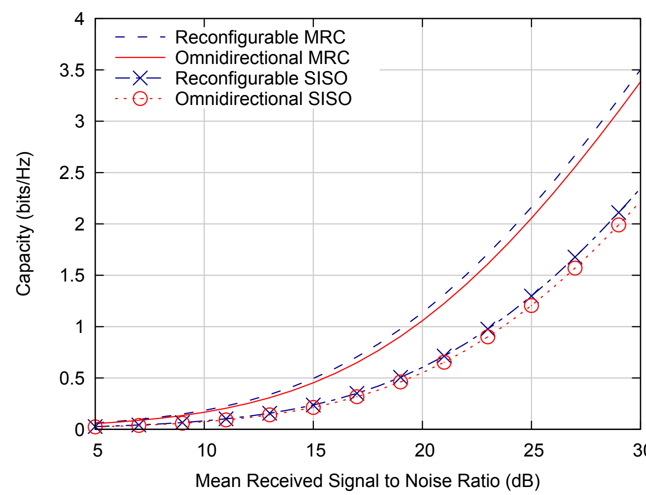


Fig. 4. Channel Capacity for Receiver 2.

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