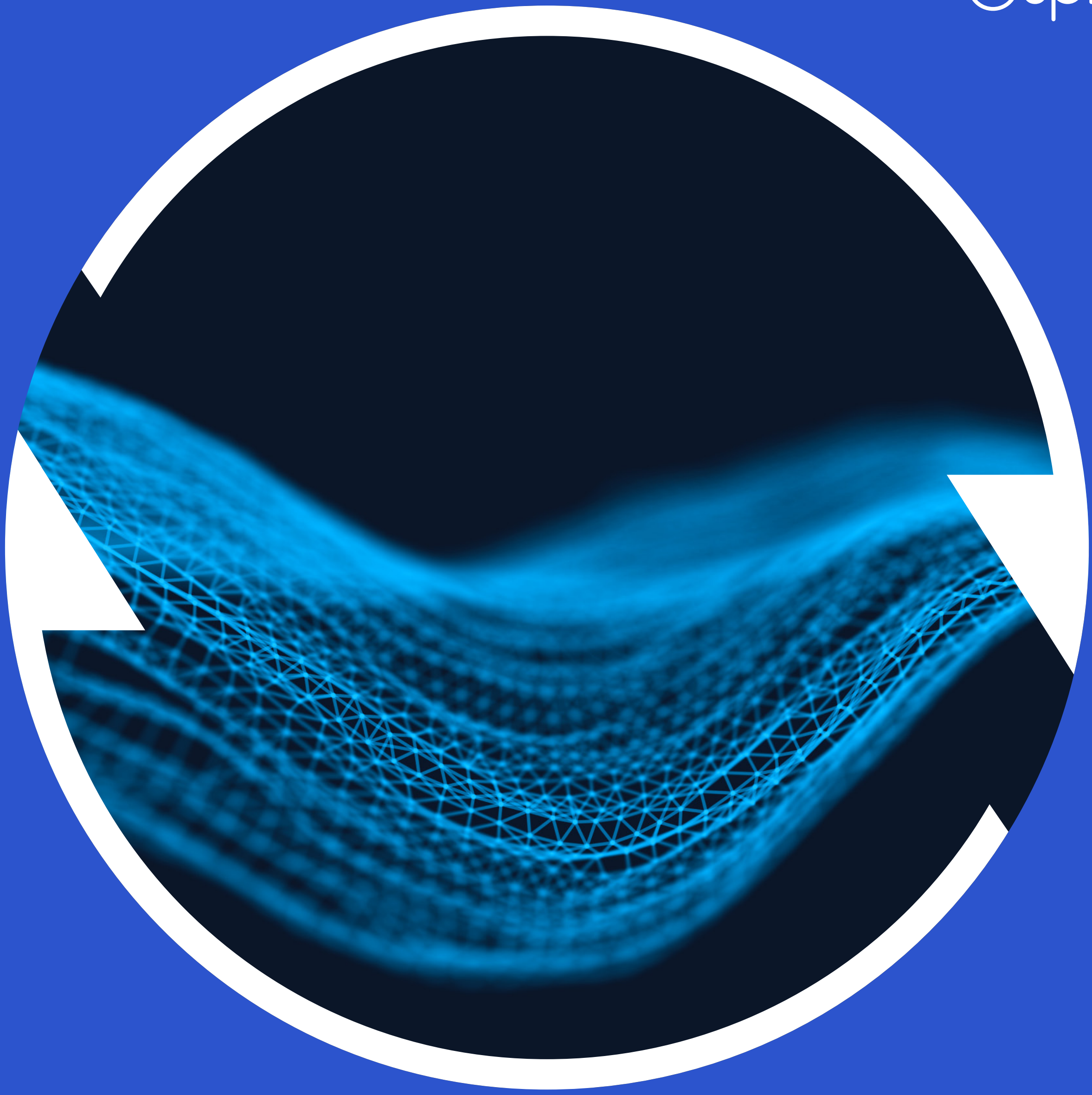

WHITE PAPER

Small Anechoic Chamber Channels

Estimating Channel Capacity from a Chamber Model

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Many recent and emerging standards serve to increase the adoption of MIMO technology, including IEEE 802.11n, 802.11ac and 802.11ax (Wi-Fi), Long Term Evolution (LTE) and LTE Advanced (standards developed by the 3rd Generation Partnership Project (3GPP)). These standards utilize multiple antennas in both the base station and the mobile device. Inherently, MIMO systems are dependent on the spatial orientation of the antennas at both ends of the links and the geometry of the antenna arrays themselves. The development and deployment of next generation devices greatly depends on the ability to test and analyze the devices under realistic conditions; it is for this purpose that MIMO-OTA testing platforms are being developed.

Recent research has demonstrated that, for a reduced set of standard MIMO-OTA channels, a small anechoic chamber with a reduced array of probe antennas can be utilized [1] [2] [3]. Small chambers are considerably more affordable and portable than traditional large anechoic chamber solutions [3], which can result in smaller development costs for electronics manufacturers. This could serve to lower the cost of next-generation wireless devices for consumers, which could in turn assist in wider adoption of these technologies.

MIMO technologies can be tested in the near-field (specifically the Fresnel region and near- Fraunhofer distances) because the near-field OTA channel can be quantified and analyzed, and this test chamber channel is repeatable. A full characterization of the wireless communications channel is critical for defining system performance limits when developing a new technology and creating test metrics for throughput testing of an existing technology. An effort to characterize a near-field MIMO communications channel must include an understanding of the propagation between the transmitter and receiver, specifically, the propagation between each transmitting antenna, and each receiving antenna.

To gain this understanding, a measurement campaign was performed using log-periodic probe antennas and a single receive (DUT) dipole antenna over the entire 5GHz WiFi band in an octoBox BOX-38. The broadband channel was measured using a vector network analyzer between a pair of probe and DUT antennas. The DUT antenna was moved along a grid on the chamber floor to sample the channel over the entire chamber. This procedure was repeated for each of the four probe antennas. This produced a set of sampled channels from each of the four probes to an arbitrary z-oriented DUT antenna location. For model simplification, only the channel samples in a test zone (a 22cm by 19cm rectangular region centered on the chamber floor center) were utilized, as this is the most likely location for an array of DUT antennas in testing. This model could be extended to larger test zones or over the entire chamber in future work.

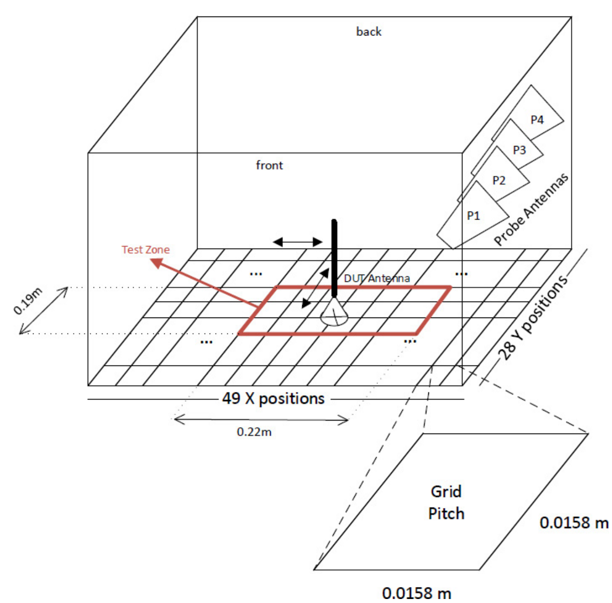

Figure 1: Measurement Diagram

Analysis of the measured channel from each probe antenna yielded a model consisting of the weighted sum of point sources, plane waves, and a statistically- modeled term that accounted for any residual between the measured channel and modeled channel. One model per probe antenna was created, with the resultant channel a function of DUT x- and y-position, and frequency. Figure 2 illustrates the magnitude and phase at 5.15GHz over the test zone from probe 4. For additional detail about the development and implementation of this channel model, refer to [2], chapters 4 and 5.

Utilizing the channel models from each probe to a set of DUT array antenna locations in the test zone, a channel matrix can be generated with each element consisting of the channel between a single probe antenna and a DUT antenna at one location. This channel matrix is generated at each frequency of operation and normalized. The normalized channel matrices are then used in the broadband Foschini MIMO capacity formula in conjunction with a specified SNR to calculate the theoretical channel capacity. Using a square 4-antenna array as the DUT array, we can "slide" this array around the test zone to calculate capacity over the test zone for that DUT configuration. Assuming 60dB SNR as is often observed in small anechoic chamber test scenarios, capacities were calculated for quarter- lambda square, half-lambda square, lambda-square, and 1.5 lambda-square DUT arrays over the test zone area. The plots in Figure 3 illustrate the channel capacity over the test zone for these four DUT sizes, with the capacity shown at the DUT array center location. The quarter Lambda square DUT capacity is between 61 and 68 bps/Hz across the test zone. As the DUT array spacing increases, the MIMO spatial diversity increases and as a result the capacity increases. The largest DUT spacing, 1.5 lambda square, has a capacity between 70 and 77 bps/Hz. Despite the observed 4x4 channel containing relatively low 3rd and 4th eigenvalues (especially in the quarter lambda DUT case), the high SNR of the system allows for all spatial streams to be utilized, and high capacities to be obtained.

New technologies such as 802.11ax (WiFi 6) utilize higher-order MIMO (such as 8x8 MIMO), MU- MIMO, and up to 1024-QAM. A higher QAM rate particularly will allow a system under test to utilize available capacity more efficiently and allow observed data rates to approach the theoretical data rates determined using the channel model. Higher-order MIMO systems will require an extension of the channel model to additional probes in the chamber. An extension of this model to MU-MIMO systems will likely require the model to cover a wider test area to allow for multiple DUTs to be located within the chamber with adequate spatial separation. In conclusion, this model can be extended through additional measurements to further quantify the channel for use in emerging wireless MIMO technologies.

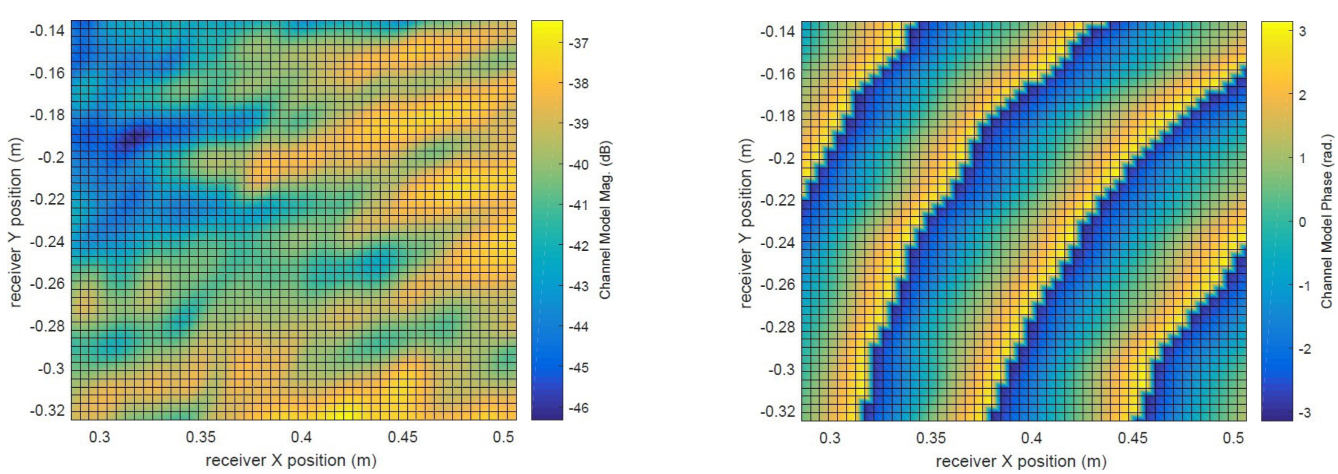

Figure 2: Mag. and Phase of Channel Model, Probe 4

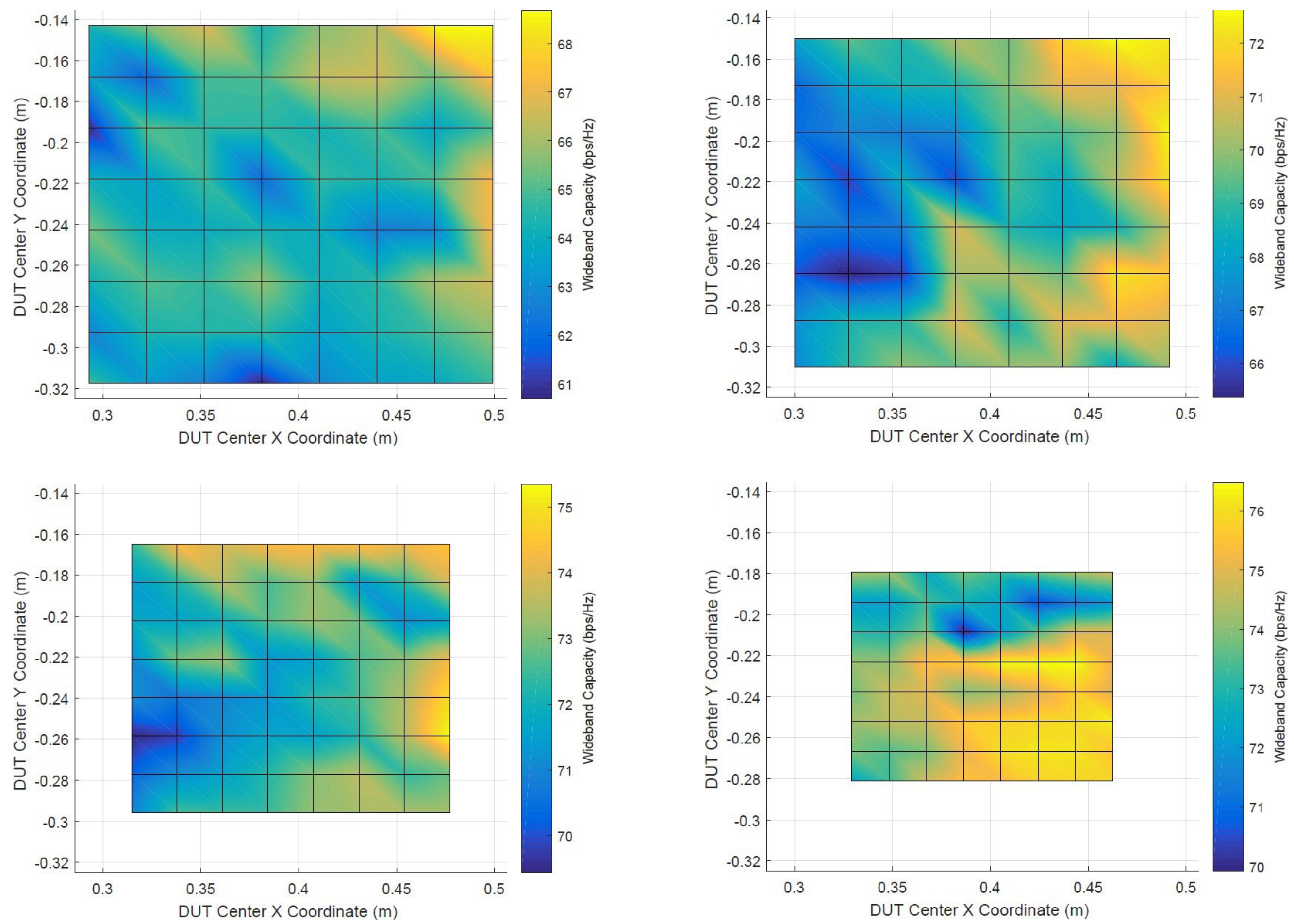

Figure 3 - Test Zone Channel Capacities

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