Azimuth®
Wireless Test & Channel Emulation Experts

Testing True Mobile Device Performance with Advanced Over-the-Air Testing

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Introduction

Multiple Input, Multiple Output (MIMO) technology, a necessary building block for 4G and evolved wireless technologies such as LTE and LTE-Advanced, is used to enhance the overall performance of radio transmitters and receivers with respect to the effects of the air interface. Multiple transmit and receive data paths are used in MIMO systems to provide significant increases in throughput and robustness by exploiting the characteristics of the radio channel. As a result, MIMO system performance is directly related to the propagation environment in which the device is operating.

To understand true performance as experienced by the user, devices need to be tested in the manner in which they are actually used -- over the air. As MMO algorithms are strongly influenced by the propagation environment and critically affected by the design of the device's antennas and antenna placement, the entire device should be tested in an active operational state, with the actual interaction of the antennas, RF front ends and baseband processing elements. Over-the-Air Testing (OTA) provides a highly effective and accurate method for measuring the performance of MIMO algorithms. Laboratory-based OTA testing solutions create an environment where signals are transmitted physically "over the air" to enable the capture of the effects of device design, including antenna design and placement, in a suite of performance measurements that allows testers to verify the performance of an entirely integrated product and accurately distinguish a good device from a poorly performing device.

There is an advanced new methodology for MIMO/SISO OTA testing that combines the use of channel emulators that use propagation models to recreate the dynamic over-the-air conditions typical in mobile wireless conditions with a mobile isotropic chamber, an environment for testing electromagnetic compatibility, that provides the most balanced and cost-effective approach to achieving repeatability while producing realistic performance results.

Obtaining Device Performance Measurements Using MIMO Over-the-Air Testing

As testing the overall device as it would normally operate is the best way to understand true performance as experienced by the user, operational environments of the device such as indoor, outdoor, rural, urban, nomadic, mobile or highly mobile become a basic set for which the device must be tested. Furthermore, the antennas within the mobile device would, ideally, be totally efficient and fully independent of each other but today's preference for reduced size and greater complexity make this increasingly difficult. Spatial diversity gain is also *extremely* difficult to benchmark without physically measuring the OTA performance of the complete device.

These items, along with many other factors such as the need to support multiple bands and multiple technologies with a limited number of antennas and power restrictions, have

substantial impact on MIMO performance. The overall result, particularly for MIMO products, is that testing the entire device, including antennas, is more important than ever.

Summary of Current MIMO OTA Methods

Several candidates for MIMO OTA methods have emerged from the work of 3GPP RAN4 and COST2100. These candidates include anechoic chambers, standalone reverberation chambers and mobile isotropic chambers with channel emulators.

The anechoic chamber solution utilizes a controlled environment to dissipate as much wave energy as possible before reflecting it away, creating a reference environment with a controlled "quiet zone" that removes all signal channel variables. The anechoic chamber systematically eliminates multipath reflections, but in order to test MIMO, the effects of multipath must be added back to the measurement system by implementing a new kind of reference environment.

The reverberation chamber method takes the opposite approach in creating an OTA test environment [1].The reverberation chamber is a highly reflective environment where multipath signals fill the chamber with standing waves, which are mechanically stirred to expose the device under test (DUT) to a distribution of this highly variable propagation environment. By getting many samples, the statistical response of the DUT to this reflective environment can be characterized. With accurate calibration of the chamber, a reference environment can be created that is repeatable and encompasses some of the conditions that are challenging to the designers of today's high performance wireless devices. The standalone reverberation chamber, however, falls short in its ability to provide and control conditions such as Doppler, delay and correlation.

The mobile isotropic chamber with the channel emulator approach provides a completely isotropic, three-dimensional multipath environment with full control over the above channel conditions as well as provides the ability to test with statistical channel models. Furthermore, the mobile isotropic chamber's true 3D isotropic environment is captured in a significantly smaller form factor, without forsaking technical accuracy, to provide the benefits of portability and low cost to OTA testing. The addition of a channel emulator enables testers to create real-world channel conditions such as delay, Doppler and correlation – which cannot be done without a channel emulator. The channel emulator also features the flexibility to add other channel effects such as shadow fading, noise, etc., and the creation of precise, repeatable channel conditions. The combination of a high-fidelity wireless channel emulator with a compact mobile isotropic chamber creates a precise, mobile solution that can be used to more accurately test mobile devices over the air.

In contrast to the anechoic chamber OTA test method, the mobile isotropic chamber is small enough to fit through most standard doorways, eliminating logistical challenges while providing more test flexibility. Additionally, the fact that the test environment created by the mobile isotropic chamber is completely isotropic greatly simplifies testing as opposed to an anechoic chamber that has to compensate for not being isotropic in its native state by testing mobile devices in different orientations. This provides the ability to run more tests, resulting in higher productivity and ultimately a much higher ROI.

A study item to define a 3GPP methodology for measuring the radiated performance of multiple antenna reception and MIMO receivers in the UE is currently in progress [2]. Part of this effort has been a Round Robin test to compare the outcomes of the various proposed test methodologies. The results obtained from the Round Robin showed that mobile isotropic chamber-based testing that combines channel emulation gives much better results than standalone reverberation chamber systems, which lacked consistency. The results for a mobile isotropic chamber with channel emulator methodology were comparable to the anechoic chamber based approach technically but offer a better value proposition in terms of ease-of-use and ROI [3].

Exploration of the Channel Emulator and Mobile Isotropic Chamber Approach to MIMO OTA Test

A channel emulator cascaded with a mobile isotropic chamber gives many degrees of freedom for creating specific channel conditions and producing FOM results useful in MIMO/SISO OTA test. The channel conditions that will be discussed with resultant behavior include multipath or power delay profile, Doppler spectrum and MIMO correlation.

Power Delay Profile

The scattering of EM waves within a mobile isotropic chamber creates a Rayleigh distributed signal amplitude at a receiver. The mobile isotropic chamber can be damped or loaded to create a PDP or multipath delay with various decay times using, for example, blocks of RF absorber material, a phantom head, or a tank filled with liquid.

This use of a mobile isotropic chamber alone creates a dense exponentially decaying PDP with an rms delay spread that is a function of the chamber loading [4]. Although this may be appropriate for a single cluster model, it is not representative of the typical multicluster or outdoor urban models. Standard channel models for LTE testing typically have many discrete multipath environments with greatly delayed multipath components. Using the channel emulator and mobile isotropic chamber solution, PDPs to support both indoor and outdoor environments can be accurately created.

Doppler Spectrum

The PDP described in previous section was referred to as “static” but was actually time-varying according to the motion within the chamber. The chamber motion is given by the paddle or stirrer movement but is relatively slow, creating a Doppler shift that is on the order of a few Hz. For a mobile device, this may not adequately represent the range of motion it will encounter in typical operation. To model higher Doppler shifts, independent Rayleigh fading is introduced on each emulator tap.

Doppler, or device velocity, can be created with the proper Doppler spectrum as given by standard channel models with the channel emulator and mobile isotropic chamber combination.

MIMO Fading Correlation

MIMO correlated fading can be provided by programming a specific correlation matrix into the channel emulator for the desired correlation at the device under test. The correlation can be defined on a tap-by-tap (multipath) basis, as is the case with standard MIMO channel

models. Investigations of the solution show a very strong dependence on the desired or set emulator correlation and virtually no dependence on the spacing of the wall antennas.

Azimuth ACE™ OTA Test Solution: True Over-the-Air Testing Made Easy

The Azimuth ACE over-the-air (OTA) test solution from Azimuth Systems creates a laboratory-based environment where signals are transmitted physically "over the air" to enable the capture of the effects of device design, including antenna design and placement, in a suite of performance measurements that allows testers to accurately distinguish a good device from a poorly performing device. Azimuth provides support for both SISO and MIMO.

Based on a significant R&D effort, Azimuth's advanced OTA test methodology combines a mobile isotropic chamber with the company's ACE MX MIMO channel emulator to create an environment where devices can be reliably tested in the same mode as they are used in real-world conditions.

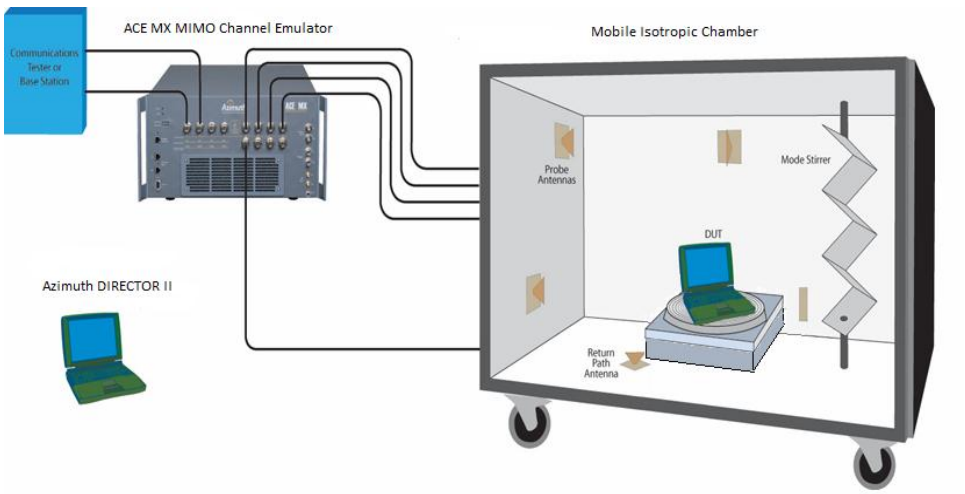

Figure 1. Azimuth ACE OTA Test Set-up Combining a Channel Emulator and Mobile Isotropic Chamber

While chambers exist that are fully isotropic, they lack some important degrees of realism, namely the ability to control the delay, Doppler and correlation. Azimuth set out to create a chamber that would create a true 3D isotropic environment in a compact form factor without forsaking technical accuracy. The result of this effort is the Azimuth mobile isotropic chamber (MIC); approximately 1.6m x 0.9m x 1m and small enough to fit through most standard doorways. This provides a portability option that until now has not been possible with over-the-air test solutions, eliminating the logistical challenges that are experienced with using the large anechoic chambers used in some SISO/MIMO OTA test methodologies while providing more test flexibility.

The addition of the ACE MX MIMO channel emulator enables testers to create real-world channel conditions such as delay, Doppler and correlation, with the flexibility to add other channel effects such as shadow fading, noise, etc., and the creation of precise, repeatable channel conditions. This combination of the high fidelity ACE MX wireless channel

emulation platform with a compact mobile isotropic chamber creates a truly advanced, cost-effective and portable OTA test solution that can be used to more accurately test mobile devices over the air.

Azimuth's ACE OTA Test Solution dramatically shortens the product delivery cycle, while improving product quality and reducing overall product costs by enabling more productive, more flexible and more accurate SISO/MIMO OTA testing prior to field testing/deployment.

The Azimuth ACE OTA Test Solution's world-class features include:

- **Automation -** As one of the only solutions available to incorporate fully automated, integrated SISO/MIMO OTA device testing, The Azimuth ACE OTA Test Solution provides more productive and repeatable testing with fewer errors. Featuring one-step, automated setup, configuration and calibration, as well as automated test execution, Azimuth's complete automation features also allow for automation of BS/BSE, UEs and other equipment such as network analyzers. The automation scripts are even reusable across companies and product lines.

- **Unparalleled Ease-of-Use -** The "ready to test" Azimuth ACE OTA Test Solution incorporates "push button" operation that simply requires a user to place a device in its chamber and then begin the test with little setup. Featuring an intuitive and user-friendly interface, the Azimuth OTA Test Solution allows both novices and experts to work with ease. Additional ease-of-use features include detailed and high-level logging, allowing multiple OEMs to run tests using the same setup as an operator, enabling the submission of results in the same format that can be archived and referred to easily.

- **Flexibility -** Azimuth is closely involved in the development of Figures of Merit (FOM) for MIMO OTA device test. The Azimuth ACE OTA Test Solution currently includes support for throughput as a FOM, providing more dimensions to compare mobile devices and benchmark performance to create a more holistic view of device performance.

- **Future Proof -** The Azimuth ACE OTA Test Solution has the ability to support additional FOMs that arise in the future (support for two new FOMs will be released subsequently) and to also add more dimensions of reality, such as using drive test data, so that users will rarely find themselves in a situation where they won't be able to do something with the Azimuth test setup.

Conclusion

The combined channel emulator and mobile isotropic chamber OTA methodology illustrates that it is possible to emulate standard channel models used for cabled testing in a relatively small and portable OTA environment as an alternative to using a large anechoic chamber.

The combined channel emulator and mobile isotropic chamber system enables flexibility in creating static or dynamic power-delay profiles, use of much higher Doppler rates and programmable downlink fading correlation. It provides a simple, true over-the-air modeling

framework with enhanced realism that provides a portable, cost-effective, powerful and practical solution for enhanced MIMO/SISO OTA testing.

Commercially-available solutions such as the Azimuth ACE OTA Test Solution create a laboratory-based environment where signals are transmitted physically "over the air" to enable the capture of the effects of device design, including antenna design and placement, in a suite of performance measurements that allows testers to accurately distinguish a good device from a poorly performing device.

References

[1] M. Anderson, A. Wolfgang, C. Orlenius and J. Carlson, "Measuring Performance of 3GPP LTE Terminals and Small Base Stations in Reverberation Chambers," *Handbook of Long Term Evolution of 3GPP Radio/Cellular Technology*, CRC Press, Boca Raton, FL, 2009.

[2] TR 37.976, "Measurement of radiated performance for MIMO and multi-antenna reception for HSPA and LTE terminals (Release 10)", version 1.1.0 (2010-05).

[3] R4-101441, Azimuth Systems, RAN WG4 Ad Hoc #2, Dublin, Ireland, 12 April 2010.

[4] Chen, X., P-S Kildal, C. Orlenius, J. Carlsson, "Channel Sounding of Loaded Reverberation Chamber for Over-the-Air Testing of Wireless Devices–Coherence Bandwidth Versus Average Mode Bandwidth and Delay Spread," *IEEE Antennas and Wireless Propagation Letters*, Vol 8, 2009.

[5] Erceg, V, *et al*, "TGn Channel Models," IEEE P802.11-03/940r4, 10 May 2004.