Testing modern MIMO Wi-Fi and LTE radios

By Fanny Mlinarsky

MODERN RADIO TECHNOLOGIES such as the IEEE 802.11 and 3GPP (3rd generation partnership project) LTE (long term evolution) rely on MIMO (multiple input multiple output) techniques to increase the radio transmission range and speed. MIMO algorithms use multiple synchronized radios (up to 4 for 802.11n and LTE; up to 8 for the emerging 802.11ac) to adapt to continuously changing conditions in the wireless channel. These techniques include TX and RX diversity to add robustness to the communications when channel conditions are challenging (e.g. low SNR or high multipath); spatial multiplexing to increase throughput by sending multiple simultaneous streams when channel conditions are favorable; beam forming to extend range or to enable multiple users to share the wireless channel; and MU-MIMO (multi-user MIMO) to enable multiple stations to transmit simultaneously in the same frequency channel by focusing the antenna pattern.

Modern MIMO radios sense the conditions in the channel on a packet-by-packet basis and make instantaneous decisions on which of the above techniques to employ. Testing of these radios requires new generation over-the-air (OTA) technology. In the past, radios could be tested in a conducted environment whereby antennas are disconnected and coaxial cabling connected instead of antennas to guide the signal to controlled test circuitry, as shown in figure 1.

Today's sophisticated MIMO techniques including TX diversity and beam forming call for OTA test methods.

The IEEE 802.11T task group developed a document specifying test metrics and methods, "IEEE P802.11.2/D1.01, draft recommended practice for the evaluation of 802.11 wireless performance". This document specifies conducted and over-the-air (OTA) test environments.

While the conducted test environment is considered controlled, OTA testing can be performed under controlled or uncontrolled conditions. Uncontrolled OTA test methods include using a typical house or outdoor setting to measure throughput and range of the devices. Controlled OTA testing is typically performed in an anechoic chamber. Uncontrolled environment results in measurements that can vary over time. Controlled environment, either conducted or OTA, when properly implemented produces repeatable measurements as shown in figure 2.

With today's sophisticated MIMO and beam forming algorithms that involve antenna arrays, conducted environment testing is quickly becoming inadequate. New generation of controlled OTA test stations, such as octoScope's octoBox are emerging on the market to bring small anechoic chambers to more development engineers.

New generation anechoic test stations

The key difference between the traditional walk-in anechoic chambers and new generation anechoic test stations, such as the octoBox (see figure 3), is that in the case of traditional anechoic chambers test equipment and engineers typically sit and work inside the chamber while in the case of small anechoic test stations only the DUT and the test setup are placed inside. The engineers can comfortably work at a nearby lab bench or at a desk. Small anechoic test stations require that all power, control and data cabling be guided into the chamber through specialized feed-through filters. Otherwise copper cabling will act as antennas bringing outside interference in to disturb the test. High speed data filters (e.g. USB or Ethernet filters) must maintain the integrity of the data signals while attenuating the RF frequencies under test so as to keep the interference away from the test environment inside the chamber. For traditional large anechoic chambers typically only power cables are filtered since the equipment and data cabling are inside.

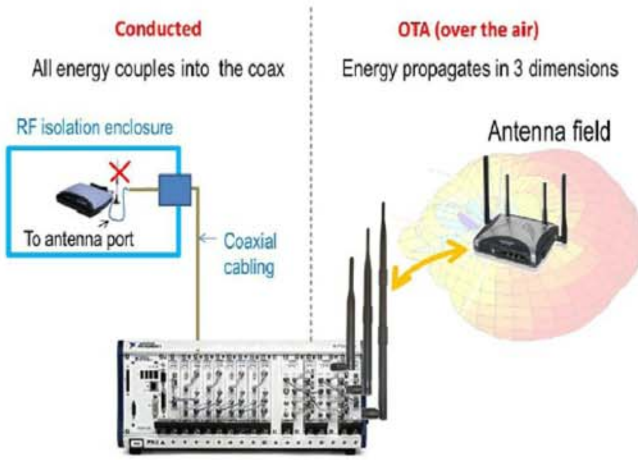

Fig. 1: Traditional conducted test setup (left) involves disconnecting the antenna from the DUT and connecting coaxial cabling to the antenna port of the DUT. OTA test setup (right) requires coupling the DUT antenna field into the test equipment via measurement antennas.

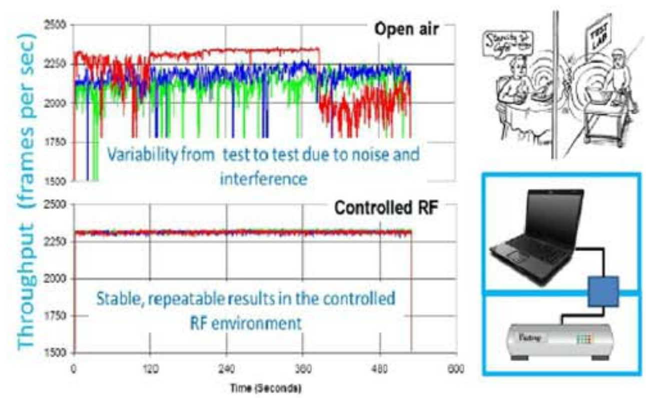

Fig. 2: Measurements obtained in the uncontrolled test environment (top) can be highly variable. Measurements obtained in a controlled environment (bottom), which can be conducted or controlled OTA, are stable and repeatable. Accuracy of the measurements is a function of proper calibration.

Fanny Mlinarsky is President of octoScope www.octoscope.com
She can be reached on fm@octoscope.com

Creating anechoic (non-echoing) environment requires that absorptive material cover the metal walls of the chamber to dampen any reflections and to eliminate uncontrolled multipath in the chamber. Multipath causes time-variable signal fading due to standing waves and impacts the accuracy and repeatability of the measurements. Another important consideration for small anechoic chambers is creating far-field conditions for the measurement.
While there is a lot of confusion in the industry about how far-field is defined, it is generally accepted that far-field antenna radiation is characterized by a path loss proportional to 1/r (see figure 4), whereas near-field radiation is characterized by path loss proportional to 1/r2 or 1/r3 or a product thereof. Far-field distance between the measurement antennas and the DUT (device under test) ensures stable and repeatable OTA measurements. The 3GPP TS 34.114 document, “user equipment (UE) / mobile station (MS) over the air (OTA) antenna performance conformance testing” defines far-field as the highest value of 3 variables shown in figure 5. A small anechoic test station must ensure RF isolation, absorption and far-field conditions in order to create a stable and repeatable test environment.

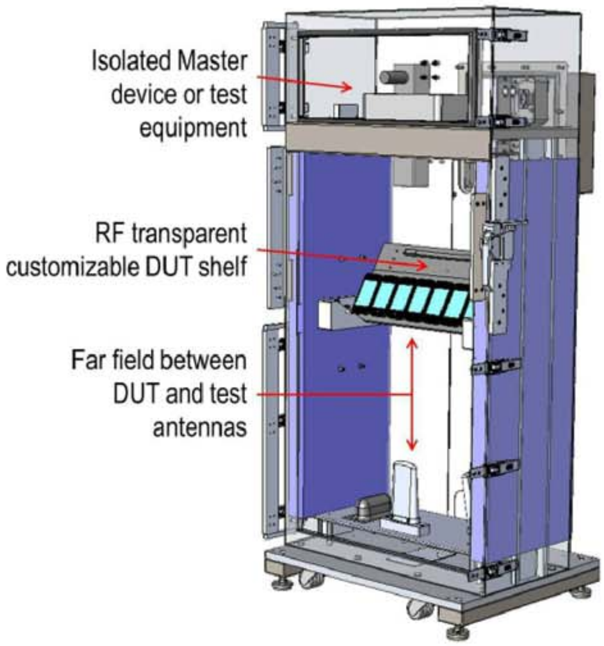

Fig. 3: The octoBox dual-chamber anechoic test station neatly houses test equipment, measurement antennas and the devices under test.

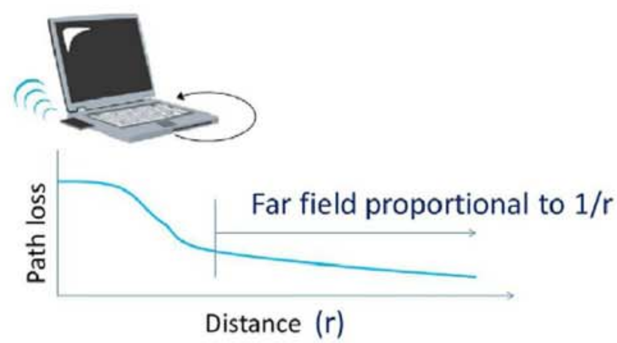

Fig. 4: Far-field can be established by plotting path loss vs. distance and should be measured at different orientation of the DUT since antenna pattern is impacted by the mechanical form factor of the DUT.

D the maximum extension of the radiating structure

$$r > \max\left(\frac{2D^2}{\lambda}, 3D, 3\lambda\right)$$

Wavelength

Fig. 5: 3GPP TS 34.114 document defines far-field as the maximum of 3 terms shown here.

Once the OTA environment is stabilized, the next challenge is to create controlled channel impairments (e.g. multipath and Doppler fading, noise and interference) for testing the MIMO algorithms. 3GPP is currently developing a MIMO/OTA test methodology standard, TR 37.976. This methodology, although being developed currently for LTE devices, will also be applicable to 802.11 radios.