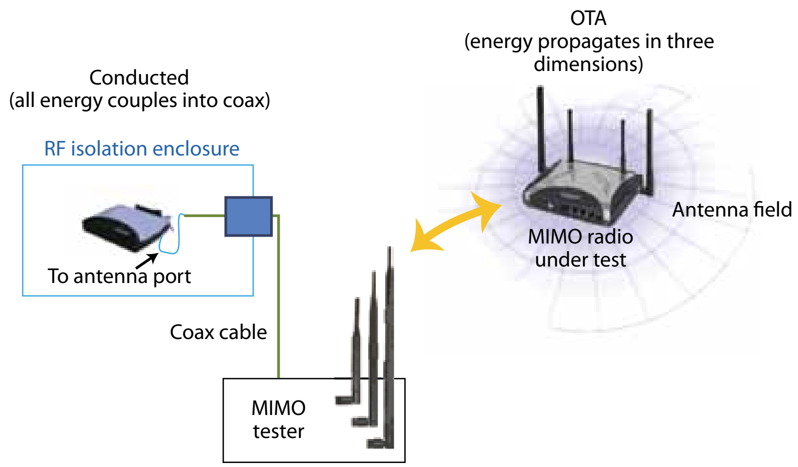

FIGURE 1. (Left) A traditional conducted test setup involves disconnecting the antenna from the DUT (device under test) and connecting coaxial cabling to the antenna port of the DUT. (Right) An OTA test setup requires coupling the DUT antenna field into the test equipment with measurement antennas

Test MIMO Wi-Fi and LTE radios over the air

OTA testing can simulate conditions such as reflections and fading in a controlled environment.

BY FANNY MLINARSKY, OCTOSCOPE

Radio technologies such as IEEE 802.11 and 3GPP (3rd generation partnership project) LTE rely on MIMO (multiple input, multiple output) techniques to increase the range and data rates of radio transmissions. Using digital-signal processing, MIMO radios sense the conditions in the channel on a packet-by-packet basis and make instantaneous decisions on whether to employ 802.11 or LTE techniques. Tests of MIMO radios require OTA (over-the-air) measurements and simulations of transmission channels that are more complex than those needed for single-radio systems.

MIMO technology uses multiple synchronized radios—up to four for 802.11n and LTE and up to eight for the emerging 802.11ac—to adapt to continuously changing conditions in the wireless channel. MIMO radios use any of four techniques to extend range and data rates:

- TX (transmit) and RX (receive) diversity, which adds robustness when channel conditions are challenging (e.g., low signal-to-noise ratio or high multipath conditions);
- Spatial multiplexing, which increases throughput by sending multiple simultaneous streams when channel conditions are favorable;
- Beamforming, which extends the range or enables multiple users to share the wireless channel; or
- MU-MIMO (multi-user MIMO), which enables multiple stations to transmit simultaneously in the same frequency channel by focusing the antenna pattern.

In the past, engineers could test radios in a conducted environment by disconnecting the antennas and replacing them with coaxial cabling that guided the signal to the controlled test circuitry (**Figure 1,** left side). Today's sophisticated MIMO techniques, including TX diversity and beamforming, require OTA test methods (Figure 1, right side). An IEEE 802.11 task group has developed a draft document that specifies test metrics and methods for conducted and OTA test environments (Ref. 1).

Controlled and uncontrolled OTA test methods

Many engineers consider conducted test environments to be controlled environments and consider OTA environments to be uncontrolled. OTA testing can, however, be performed under both controlled and uncontrolled conditions.

Uncontrolled OTA test methods include using a typical house or outdoor

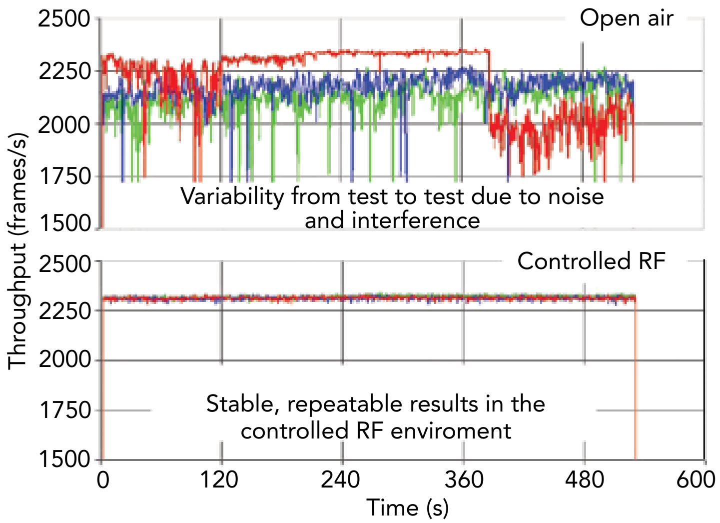

FIGURE 2. (Top) Measurements obtained in an uncontrolled test environment can be highly variable. (Bottom) Measurements obtained in a controlled environment, which can be conducted or controlled OTA, are stable and repeatable. The accuracy of the measurements depends on proper calibration.

setting to measure the throughput and range of the devices. Controlled OTA testing is typically performed in an anechoic chamber. Uncontrolled environments result in measurements that can vary over time, while controlled environments (either conducted or OTA), when properly implemented, produce repeatable measurements (**Figure 2**).

Because wireless devices now use sophisticated MIMO and beamforming algorithms that involve antenna arrays, conducted environment testing is quickly becoming inadequate. OTA test stations that use small anechoic chambers (**Figure 3**) can remove outside interference from MIMO tests and create a controlled environment.

The key difference between the traditional walk-in anechoic chambers and a new generation of anechoic test stations is that in a traditional chamber, engineers typically sit inside the chamber to work with the test equipment. New chambers are smaller: Only the DUT (device under test) and the test setup are placed inside. The engineers can comfortably work at a nearby lab bench or at a desk.

For these small anechoic test chambers, all the power, control, and data

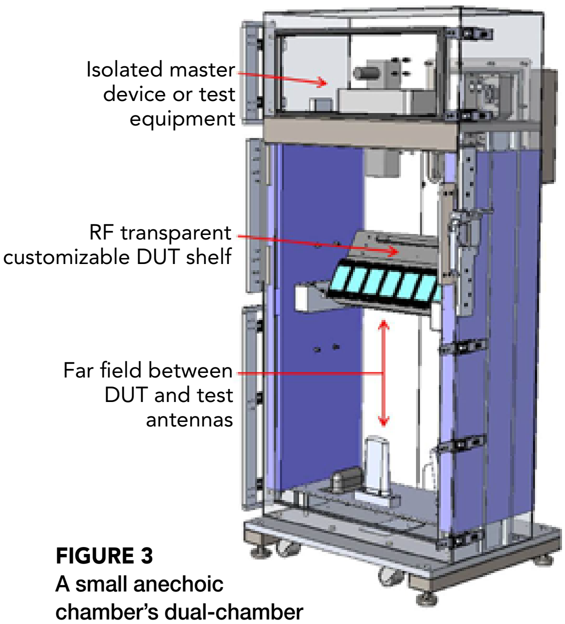

FIGURE 3
A small anechoic chamber's dual-chamber design houses test equipment, measurement antennas, and DUTs.

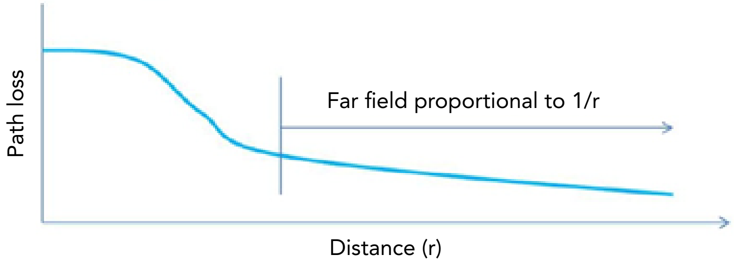

FIGURE 4. Far-field conditions ensure measurement stability. A far field can be established by plotting path loss vs. distance and should be measured at different orientations of the DUT, because the antenna pattern is affected by the mechanical form factor of the DUT.

cabling enter the chamber through specialized feed-through filters. Without the filters, copper cables will act as antennas, which will let outside interference disturb the test. High-speed USB or Ethernet data filters maintain the integrity of the data signals while attenuating RF frequencies and, thus, keeping interference away from the test environment inside the chamber. For traditional, large anechoic chambers, only power cables are typically filtered, because all equipment and data cabling are positioned inside the chamber.

In an anechoic (non-echoing) environment, absorptive material covers the metal walls of the chamber to dampen any reflections and eliminate uncontrolled multipath conditions. Multipath conditions cause time-variable signal fading due to standing waves, and this affects the accuracy and repeatability of the measurements.

Another important consideration for small anechoic chambers is finding a way to create far-field conditions for the measurement. While engineers may disagree as to the definition of "far field," they generally accept that far-field antenna radiation is characterized by path loss proportional to 1/r (**Figure 4**), whereas near-field radiation is characterized by path loss proportional to $1/r^2$ or $1/r^3$.

A far-field distance between the measurement antennas and the DUT ensures that the OTA measurements will be stable and repeatable. The 3GPP TS 34.114 document defines "far field" as the highest value of these variables: 2D2/λ, 3D, or 3λ, where D is the maximum extension of the radiating structure and λ is the signal's wavelength (Ref. 2).

To summarize, a small anechoic test station must ensure RF isolation, absorption, and far-field conditions in order to create a stable and repeatable test environment. Once the OTA environment is stable, the test needs controlled channel impairments—multipath and Doppler fading, noise, and interference—for testing the MIMO algorithms.

The 3GPP is currently developing a MIMO/OTA test methodology standard, TR 37.976 (Ref. 3). This methodology, although being developed currently for LTE devices, will also be applicable to 802.11 radios. T&MW

REFERENCES

1. IEEE P802.11.2/D1.01, "Draft Recommended Practice for the Evaluation of 802.11 Wireless Performance." www.ieee.org.

2. 3GPP TS 34.114, "User Equipment (UE) / Mobile Station (MS) Over The Air (OTA) antenna performance; Conformance testing," 3GPP Specification series. www.3gpp.org/ftp/Specs/html-info/34-series.htm.

3. 3GPP TR 37.976, "Measurements of radiated performance for MIMO and multi-antenna reception for HSPA and LTE terminals," 3GPP Specification series. www.3gpp.org/ftp/Specs/html-info/37-series.htm.

Fanny Mlinarsky is president of octoScope, a manufacturer of small anechoic test stations. The company focuses on IEEE 802.11 wireless and 3GPP 3G/4G technologies and standards. fm@octoscope.com.