

Cost-effective OTA performance testing of MIMO-enabled LTE devices

High-quality wireless devices require an omnidirectional and uniform antenna radiation pattern. This pattern can be verified by measuring the over-the-air (OTA) performance. These measurements, which are an essential part of the certification test, need to be extended to include MIMO operating modes. The Rohde&Schwarz two-channel test method makes these measurements both cost-effective and reproducible.

MIMO OTA measurements require new test methods

Currently, OTA performance tests for single input single output (SISO) are standardized for 2G, 3G and WLAN devices. These tests provide important information about the behavior of wireless devices within the network. Within an anechoic environment, the radiated 3D pattern of both output power and receiver sensitivity are measured and used to derive the total radiated power (TRP) and the total isotropic sensitivity (TIS) as specified by CTIA [1], and similarly by 3GPP [2].

Multiple input multiple output (MIMO) techniques were established to increase network performance for data applications in particular. The channel capacity of the allocated frequency spectrum is increased by the use of spatial multiplexing. However, with new transmission technologies come new test requirements.

For 2×2 MIMO mode with two downlink data streams, the user equipment (UE) has two receive antennas. The correlation of the RX antennas has to be as low as possible to achieve a good separation of the simultaneously received data streams. To understand the performance of the antennas, it is not sufficient to evaluate the pattern of each receiving antenna separately. OTA performance tests for MIMO-enabled devices need to verify the following transmission schemes:

- Transmit diversity with redundant data streams for a wider signal range
- Spatial multiplexing with multiple data streams for higher data throughput

LTE modems are mostly operated inside buildings. Full 3D evaluation is required to assess the modem's multipath reception from all angles of arrival (AoA). A spherical (3D) test approach provides realistic test conditions similar to operation in the field.

Cost-effective MIMO OTA measurements using the two-channel test method

The two-channel test method from Rohde&Schwarz [3] presents a straightforward, cost-effective approach for verifying OTA performance on MIMO devices. The UE is positioned close to two rotating, cross-polarized test antennas, each radiating different signals for the MIMO downlink. Repeating the measurement for several other constellations and polarizations provides a comprehensive overview of the UE's antenna characteristics.

SISO OTA measurements for 2G and 3G are still mandatory. Ideally, the anechoic chamber can be used for both SISO and MIMO tests without any modification. Existing SISO OTA test systems should be easy and inexpensive to upgrade for MIMO operation.

The R&S®TS8991 OTA performance test system fully supports the two-channel test method for MIMO OTA (FIG 1). An OTA test chamber contains a communications antenna for the uplink (ANT UL) and two angular positioners to set an arbitrary geometrical constellation of the two test antennas ANT DL1 and ANT DL2. The 3D evaluation is performed with a constant angular separation of the test antennas during the movement. An offset of 10° simulates rural conditions, 90° in contrast urban conditions. The UE is placed on an azimuth positioner. External instrumentation includes the R&S®CMW500 wideband radio communication tester as a base station emulator (BSE) and the R&S®OSP130 open switch and control platform as a switch matrix.

The two-channel method also verifies the performance of smart UE antennas with adaptive receiving characteristics and load impedances. True load impedance of UE antennas is assured, since the method does not require connecting any auxiliary RF cabling to the antenna ports during the test.

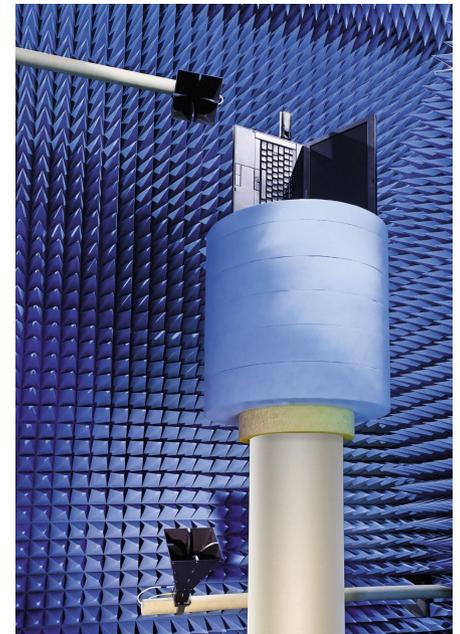
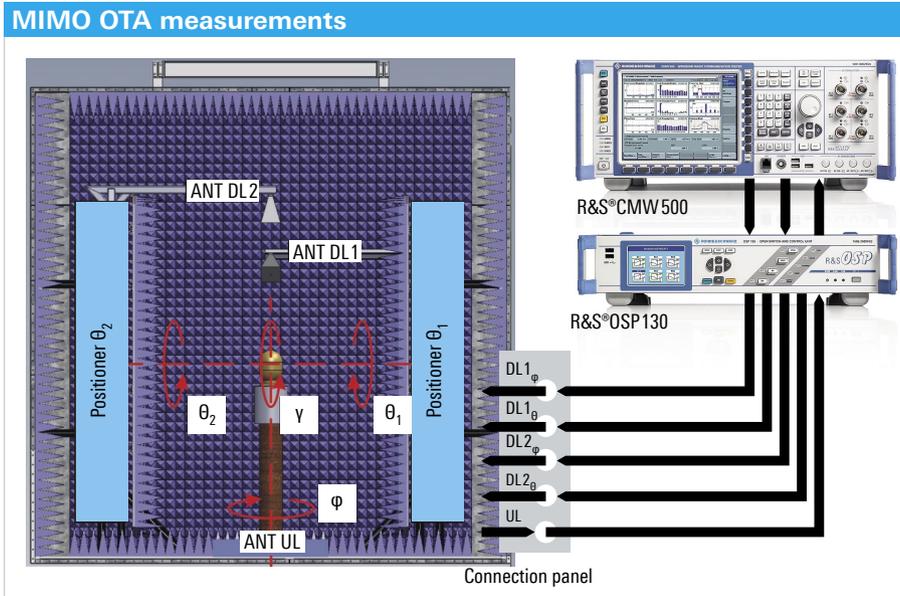


FIG 1 Main components of the R&S®TS8991 OTA performance test system for MIMO measurements.

Conclusive test results through conducted and radiated measurements

OTA tests characterize MIMO performance of the UE under simulated real-world conditions. MIMO antenna performance can be determined by additionally carrying out optional conducted measurements and comparing them against the results of the radiated measurements. Tests in conducted and radiated mode are performed with the same BSE signaling settings.

The following example shows a series of tests performed on four different LTE modems. The tests use 2x2 open-loop spatial multiplexing as a DL MIMO transmission scheme with 16QAM modulation. In conducted mode, data throughput is measured as a function of absolute DL power. Two RF cables connect the BSE ports to the corresponding UE antenna ports. The obtained results provide the reference sensitivity performance for the selected transmission scheme and BSE settings. Maximum spatial diversity is achieved, since there is no coupling between the two RF channels. Accordingly, MIMO throughput in conducted mode represents the best possible MIMO sensitivity of the UE under test. The throughput is limited only by UE receiver performance.

See FIG 2 for the results of the test example. In conducted mode, UE 2 and UE 4 provide the best receiver sensitivity. UE 1 has an up to 4 dB poorer sensitivity. UE 1, UE 2 and UE 3 were tested in band 7 (2.6 GHz); UE 4 was tested in band 20 (800 MHz).

In radiated mode, the UEs were tested in different geometrical constellations of test antennas, with four polarization combinations for each constellation. The average throughput TP_{av} (RS EPRE) is the linear average of the throughputs in all measurement cases for the given RS EPRE power level (FIG 3). UE 2 utilizes its original built-in antennas. UE 2 ExtAnt utilizes two cross-polarized dipoles separated by half a wavelength connected to the UE 2 antenna ports. This arrangement

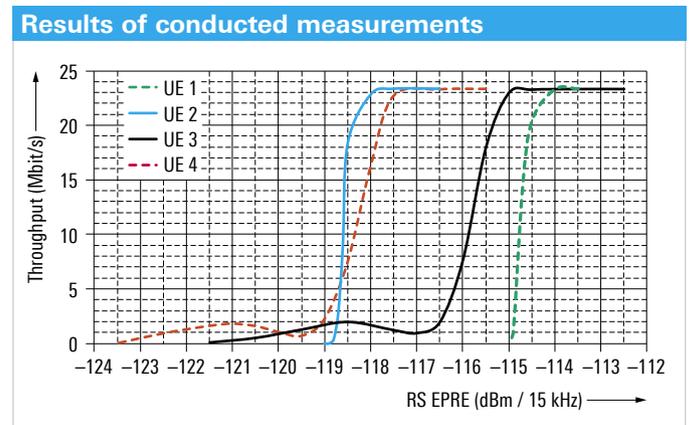


FIG 2 Data throughput as a function of downlink power (RS EPRE) at the UE antenna ports.

provides the best MIMO antenna performance because the external antennas are arranged to maximize spatial and polarization diversity.

Significant deterioration of MIMO antenna performance is noticeable for UE 4. Even though it achieved the best MIMO sensitivity in conducted mode, it has the worst average throughput TP_{av} in radiated mode. To obtain a TP_{av} of 50 %, UE 4 requires 5 dB higher DL power than UE 2. This result agrees with expectations because UE 4 operates in band 20, where wavelengths are more than three times longer. Since the geometrical dimensions are similar to UE 2, it is much more difficult to obtain an antenna design with similar spatial and polarization diversity.

An example of 3D spherical distribution of MIMO effective isotropic sensitivity (EIS), which was generated by the R&S®AMS32 system software, is presented in FIG 4. The received power correlates to a block error rate (BLER) of 50 %.

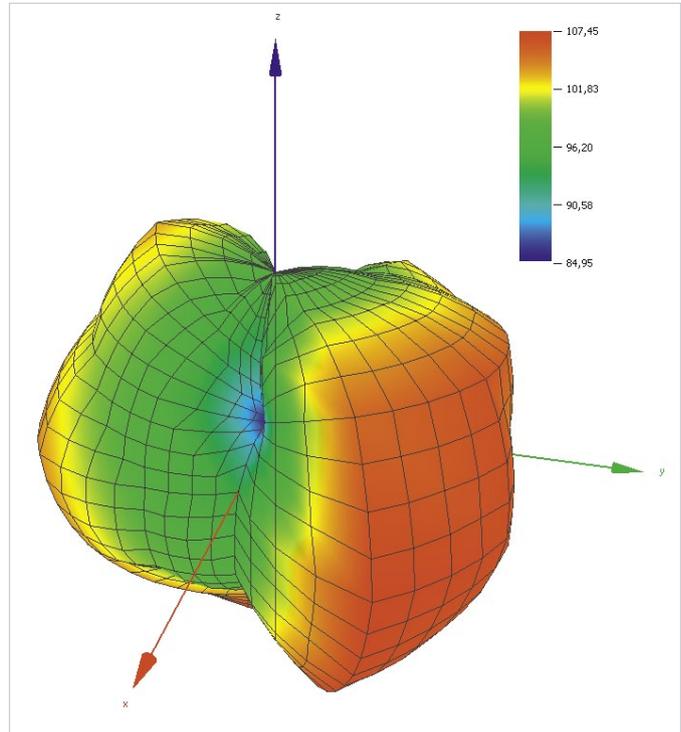


FIG 4 MIMO EIS 3D distribution of UE 4.

Standardization for MIMO OTA tests

Candidate test methods for MIMO OTA performance were proposed and discussed. The standardization bodies involved in getting an OTA standard ready are mainly CTIA in the USA and RAN4 at 3GPP. At the moment, it is not clear which body will be faster in having an agreed test proposal ready for publication.

The decision for a test method needs to be based on more than just the quality of results (in other words, how well the method can judge performance and discriminate between

good and not-so-good designs). It must also take the complexity of the solution into account, since this is closely related to the investment costs for that solution. Test times are another important consideration.

The European COST Action 2100 has worked out the fundamentals of MIMO OTA testing. The new COST Action IC1004, slated to start in summer 2011, will support standardization.

Summary

To obtain a complete picture of MIMO OTA performance, UE antennas need to be tested under varying geometrical conditions in a 3D environment. Tests performed in two dimensions are no longer sufficient; a wide range of AoAs and polarizations is necessary. Additional measurements in conducted and radiated mode help to distinguish antenna and receiver performances of a wireless device and to identify design errors.

The two-channel test method can also be used to verify the effects of multipath propagation (fading). This is accomplished by adding the R&S®AMU200A baseband signal generator and fading simulator to the R&S®TS8991 MIMO OTA test system and by including the appropriate fading profiles in the DL data streams generated by the R&S®CMW500.

The Rohde&Schwarz two-channel test method can be easily implemented in existing SISO test systems by simply adding

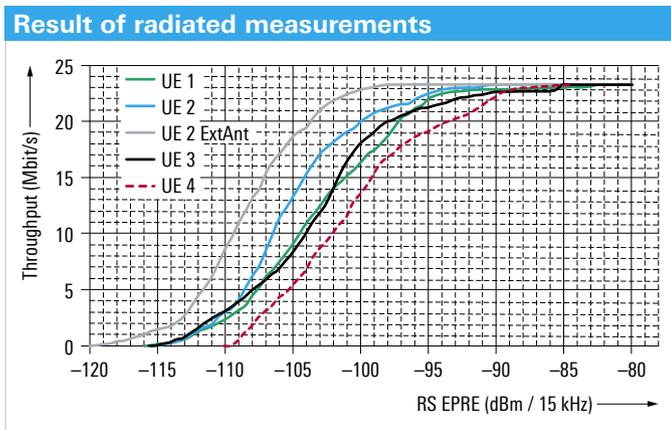


FIG 3 Average throughput TP_{av} (RS EPRE) in radiated mode; all four polarization combinations.

an angular positioner with a second test antenna to the system. The presented test approach facilitates systematic OTA verification of MIMO-enabled devices. Good designs can be distinguished from those that are not so good, and ranked on the basis of quantitative and reproducible measurements.

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References

- [1] CTIA Test Plan for Mobile Station Over the Air Performance; Rev. 3.1; 2011-01.
- [2] 3GPP TS 34.114; User Equipment (UE) / Mobile Station (MS) Over The Air (OTA) antenna performance; V8.4.0 (2010-06).
- [3] Rohde&Schwarz White Paper 1SP12; Two-Channel Method for OTA Performance Measurements of MIMO-Enabled Devices; www.rohde-schwarz.com (search term: 1SP12).

Abbreviations

3GPP	3rd Generation Partnership Project
BLER	Block error rate
COST	European Cooperation in Science and Technology
CTIA	Cellular Telecommunications Industry Association
DL	Downlink
EIS	Effective isotropic sensitivity (single geometrical point)
MCS	Modulation and coding scheme
MIMO	Multiple input multiple output
OTA	Over the air
RS EPRE	Energy per resource element (EPRE) of the reference signal (RS)
SISO	Single input single output
TIS	Total isotropic sensitivity
TP	Throughput
TRP	Total radiated power
UE	User equipment
UL	Uplink

LTE basics, compact and concise

A new book from Rohde&Schwarz introduces the LTE standard and provides an overview of the air interface measurements required for the base station and the UE. "Long Term Evolution", written by Rohde&Schwarz author Christina Geßner, is priced at EUR 58. It can be purchased in bookstores and from the Rohde&Schwarz web shop, where an extract can be read. Plus, it is available as an eBook for iPad and Amazon Kindle.

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