

Activities in the U.S.

NIST Metrology for Wireless Systems Group April 9, 2018

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NMIs, Measurements, and Advanced Communications

National Metrology Institutes (NMIs):

The shall a plant and a so

- o Link measurements to reference standards; traceability to fundamental physical units
- o "To facilitate fair trade, there must be an agreed-upon system of measurement." (Wikipedia)

Targeted research: measurement and uncertainties for communication technologies

- o NIST Communications Technology Laboratory; March 2014
- o Calibrations, traceability and uncertainty for wireless instrumentation
- o Validation of test-protocols, models, and simulation tools
- New test methods for spectrum sharing, 5G and other national priorities

mmWave channel sounder verification



Reverberation chamber for mmWave wireless device power



Traceable Sparameters in WR-15 (50-75 GHz)



National Institute of Standards and Technology U.S. Department of Commerce

tions Laboratory Note: display of specific products throughout this talk does not imply endorsement by NIST. Other products may work as well or better.



mmWave Transistors, Amplifiers, New materials Complex mmWave Modulated Signals, Nonideal DACs, ADCs, Frequency Converters

Channel Measurement and Modeling, Standards development Over-the-Air Test for Integrated Devices, Directional, Multiple Antennas and Massive MIMO

Measurement challenges for an industry in its infancy





Modulated-Signal Characterization

Hardware errors increase Error Vector Magnitude (EVM) of generated and received signals



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Millimeter-Wave Signal Characterization

- Effects of nonideal frequency converters and signal converters (DACs and ADCs)
- Source and transmitter characterization (with nonlinearities)
- Impedance, power, noise
- Uncertainty and demodulation errors
- Separate EVM of device from EVM of instrument







Millimeter-Wave Signal Characterization

The NIST Microwave Uncertainty Framework: Tracking uncertainties and their correlations

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VNA measurements and uncertainties for various calibrations within the Uncertainty Framework



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Traceability and Uncertainty in EVM

Distribution of EVM and uncertainty for a 44 GHz, 64 QAM signal (DARPA ELASTx)







Channel-Measurement Challenges

Stall and and the start and

Errors distort channel response: path loss, timing, and angle





Channel



PDPs for a single location, different angles of arrival

Indoor 83 GHz channel measurements

Channel Measurement and Modeling

- Need for mmWave data: Indoor and Outdoor
- Need for Channel Modeling and Standards
- Measurement Uncertainty on Metrics, Models
- Angle of Departure, Angle of Arrival
- Many bands: 28, 38, 60, 72, 83 GHz, ...



Non-line-of-sight, high-multipath indoor environments (NOAA server room)







Over-the-Air (OTA) Measurements for Integrated Devices

Errors in power, sensitivity, and throughput: reduce comparability of test results





All and all all and a sol

Machine-to-Machine and Internet of Things: Ubiquitous wireless





Cellular OTA test of multiple antenna system in anechoic chamber



OTA test at mmWave in reverberation chamber

OTA Test and DUT Verification

- Integrated antennas: on-wafer-to-OTA test planes
- Calibrated Free-Field modulated signals for verifying test methods
- Anechoic-Chamber Methods
- Reverberation-Chamber Methods



Over-the-Air Test for Future Cellular

Contrate Still Kill Million Station

• Traceability for Free-Field Modulated Signals

Reference modulated-signal field in space (resolve OTA test differences, test off-axis EVM, etc.)

Reverberation Chamber OTA Measurements

Large-Signal techniques for nonlinear effects and directional testbed



Known Field

Tx ref

Cal

Тχ

Rx ref

Cal

Rx

Calibrations for E-field Metrology

NIST quantum field probe





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Measurement of Beamforming and Multiple Antennas

Errors in directionality: critical for spatial channel modeling



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MIMO and Spatial Diversity



Beam Forming



New Applications in Challenging Environments (e.g., Factories)

Beam Forming and Multiple Antenna Systems

- Testing Beam-Forming Algorithms
- Large Number of Elements/Operating States
- Antenna Element Coupling
- Wideband Antenna Calibrations
- Massive MIMO Antenna Test
- Spatial interference testing (leakage due to non-ideal antennas)



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NIST Work in Multiple Antenna and Massive MIMO

Robotic Methods for Antenna Positioning and Traceability

CROMMA facility: 25 μm alignment

Digital Beamforming Hardware Testbed

Constant State Ball Ball Street Street





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• Antenna Element Coupling by use of Large-Signal Measurements





Watch this space for updates to metrology issues

- Transistors and nonlinear device characterization
- Modulated-signal field traceability and off-axis EVM
- Channel measurement and modeling
- Multiple-antenna metrology for wideband signals
- Extending metrology for fundamental parameters to communications applications:
 - Power
 - S-parameters
 - Noise





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