R&D and DvT Test Challenges for IoT and Emerging Wireless Technologies

June 24, 2014
Agenda

- **Testing IoT devices**
  - The need for RF and functional test
  - The phases of testing
  - Commonly performed tests
- **IoT test challenges common to all technologies**
  - Interference & operating environment replication
  - Testing multiple technologies in one device
  - Battery current drain challenges
- **Technology specific IoT test challenges**
  - NFC/EMV
  - WLAN 802.11ac/p/ah
  - LTE/LTE-M
The Need for RF Test
With 50 Billion “Things” connecting by 2020

– How do we ensure devices play well together?
– How do we ensure devices will work in a wide range of environments?
– How do we do this quickly and inexpensively given the volumes of products and market cost demands?
Supply Chain

Chip > board

Cellular or non-cellular radio IC

Cellular PA/components

m-PCIe

Surface mount module

Chip > Module > board > SI

Chip

PA/components

Gateway

Gateway IO card

Sensor/actuator

Smartphones

Wearable

Consumer IoT gateway

Consumer IoT thing

Platform service

Platform services

Industrial application

Consumer

Custom system integrator

Platform services

KEYSIGHT TECHNOLOGIES
Test Occurs Throughout the Product Lifecycle
Each Phase has Unique Test Needs

<table>
<thead>
<tr>
<th>Product Development</th>
<th>Conformance Testing</th>
<th>Production Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design/develop device with desired parameters such as:</td>
<td>In cellular:</td>
<td>• Final device calibration, if required</td>
</tr>
<tr>
<td>• Leading edge technology features</td>
<td>• Ensure device conforms to standards / network requirements</td>
<td>• Verification that no manufacturing defects are present</td>
</tr>
<tr>
<td>• Long battery life</td>
<td>In WLAN / unlicensed bands:</td>
<td></td>
</tr>
<tr>
<td>• Low cost</td>
<td>• Ensure device will meet applicable FCC/ETSI (or other regulatory authority) standards</td>
<td></td>
</tr>
<tr>
<td>Ensure device will work in a variety of user environments</td>
<td>Conformance Testers (also used for R&amp;D and Mfg Test)</td>
<td></td>
</tr>
</tbody>
</table>

**Signal Source/Signal Analyzer**

**Cellular Base Station Emulator**

**DC Power Analyzer**

**USB Power Sensors**

**Cellular / Bluetooth Conformance Test System**
Transmitter Test

Common Transmitter Tests
- Transmit Power
- Spectrum Mask
- Modulation Accuracy
- Adjacent Channel Power
- Spurious Emissions
Transmitter Test

Transmit Power

Channel Power

-31.49 dBm / 20 MHz

Power Spectral Density

-43.24 dBm / MHz
Transmitter Test

Spectrum Mask

Ref: -30.0 dBm

Center Freq: 2.411980000 GHz
Trig: Free Run
#Atten: 10 dB

Total Power: -31.51 dBm / 18 MHz

Spectrum Peak Ref: -47.33 dBm
Transmitter Test
Modulation Accuracy

Zigbee

802.11ah
Transmitter Test

Adjacent Channel Power
Transmitter Test

Spurious Emissions

BT LE In-Band Spur Test
Transmitter Test

More Advanced R&D Tools

802.11ac MIMO modulation analysis

802.11ac persistence and waterfall
# Receiver Test

## Common Receiver Tests

<table>
<thead>
<tr>
<th>Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
</tr>
<tr>
<td>Adjacent Channel Selectivity</td>
</tr>
<tr>
<td>Maximum Input Level</td>
</tr>
<tr>
<td>Co-channel Rejection</td>
</tr>
<tr>
<td>Intermodulation Immunity</td>
</tr>
<tr>
<td>AWGN &amp; Fading Channel Performance</td>
</tr>
</tbody>
</table>
**Receiver Test**

**Common Receiver Tests**

- **Sensitivity**
- Adjacent Channel Selectivity
- Maximum Input Level
- Co-channel Rejection
- Intermodulation Immunity
- AWGN & Fading Channel Performance
Much like adjacent channel selectivity, an LTE receiver blocking characteristics measurement uses two RF vector signal generators summed at the input of the test device.
Receiver Test

Common Receiver Tests

- Sensitivity
- Adjacent Channel Selectivity
- Maximum Input Level
- Co-channel Rejection
- Intermodulation Immunity
- AWGN & Fading Channel Performance
Receiver Test

Common Receiver Tests

- Sensitivity
- Adjacent Channel Selectivity
- Maximum Input Level
- Co-channel Rejection
- Intermodulation Immunity
- AWGN & Fading Channel Performance
Receiver Test

Common Receiver Tests
- Sensitivity
- Adjacent Channel Selectivity
- Maximum Input Level
- Co-channel Rejection
- Intermodulation Immunity
- AWGN & Fading Channel Performance
Receiver Test

Common Receiver Tests

- Sensitivity
- Adjacent Channel Selectivity
- Maximum Input Level
- Co-channel Rejection
- Intermodulation Immunity
- AWGN & Fading Channel Performance
# Receiver Test

## Common Receiver Tests

<table>
<thead>
<tr>
<th>Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
</tr>
<tr>
<td>Adjacent Channel Selectivity</td>
</tr>
<tr>
<td>Maximum Input Level</td>
</tr>
<tr>
<td>Co-channel Rejection</td>
</tr>
<tr>
<td>Intermodulation Immunity</td>
</tr>
<tr>
<td>AWGN &amp; Fading Channel Performance</td>
</tr>
</tbody>
</table>
Receiver Test
Fading – Why is it important?

Fast fading

Linear distortion (ISI) is corrected via adaptive equalization

Slow fading

Loss in SNR is corrected via error correction coding and receive diversity
A Growing Need for Battery Current Drain Testing

– In Hardware Development, optimize energy efficiency:
  • Evaluate and optimize overall device and its sub circuits for battery drain

– In Software Development, validate new code builds:
  • Run application code regression test suites, assess impact on battery drain

– In Design Integration and Validation, run suites of benchmark tests:
  • Validate battery drain for all required operational modes
  • Validate operating time with product’s battery (battery run-down test)

Benefits:
– Maximize your device’s battery life
– Multiple methods for viewing and understanding what parameters in your design affect battery life, increasing your confidence in repeatable results
Agenda

- **Testing IoT devices**
  - The need for RF and functional test
  - The phases of testing
  - Commonly performed tests
- **IoT test challenges common to all technologies**
  - Interference & operating environment replication
  - Testing multiple technologies in one device
  - Battery current drain challenges
- **Technology specific IoT test challenges**
  - NFC/EMV
  - WLAN 802.11ac/p/ah
  - LTE/LTE-M
Interference

Popular Frequency Use

- NFC/EMV
- Wireless M-Bus
- China WMRNET
- LoRa
- SIGFOX
- Telensa
- OnRamp
- Wi-SUN
- Zigbee
- Thread
- WirelessHART
- ISA100.11a
- Z-Wave
- EnOcean
- ANT+
- Bluetooth
- 802.11a/b/g/n/ac
- 802.11ah
- 802.11p
- 802.11af
- Positive Train Ctrl

MHz
54-698
13.56 169 220 315 426 433 470 779 868 915 920 2400 5800 5900

Sub-GHz IC families

"802.15.4" family
Replicating Actual Operation Environment
Testing Performance in the Presence of Interference
Battery Life and Energy Consumption Measurements

- Accurately measuring battery life and dynamic current drain is a big design and test challenge.

- Measuring battery current drain over a wide dynamic range is difficult:
  - Extremely wide dynamic range
  - Current signal rapidly changing (sleep, wake up, transmit, sleep)
  - Current varies (random in nature) depending on what tasks the device is doing.

Hardware design engineers, firmware engineers, and application developers can all impact current drain!
Analyzing & Optimizing LTE Battery Drain

Example System Configuration

Base station emulator with built in application server to simulate real network operation

Power analyzer with very high dynamic range for current measurements and very high speed current and voltage sampling

DUT with battery

LAN

RF

Voltage and current
A Single Device Supports Many Standards

NFC

GNSS

LTE

WiFi

Bluetooth
Agenda

- **Testing IoT devices**
  - The need for RF and functional test
  - The phases of testing
  - Commonly performed tests
- **IoT test challenges common to all technologies**
  - Interference & operating environment replication
  - Testing multiple technologies in one device
  - Battery current drain challenges
- **Technology specific IoT test challenges**
  - NFC/EMV
  - WLAN 802.11ac/p/ah
  - LTE/LTE-M
## Technology Specific Test Challenges

<table>
<thead>
<tr>
<th>Technology</th>
<th>Unique Test Challenge</th>
</tr>
</thead>
<tbody>
<tr>
<td>802.11n/ac</td>
<td>Wider bandwidth signals, multi-user MIMO, high data rates</td>
</tr>
<tr>
<td>802.11p</td>
<td>Strict SEM requirements</td>
</tr>
<tr>
<td>802.11ad</td>
<td>60 GHz operating frequency, 2GHz bandwidth</td>
</tr>
<tr>
<td>Bluetooth LE</td>
<td>Must be tested under NOC and EOC</td>
</tr>
<tr>
<td>NFC/EMV</td>
<td>Stringent physical positioning requirements</td>
</tr>
<tr>
<td>LTE-M</td>
<td>Unique signaling protocols</td>
</tr>
</tbody>
</table>
NFC Testing
Main Certification Programs

**NFC Forum**
- Covers proximity Technologies A, B and F.
- Planning to add vicinity technology soon (15693)
- Device supports R/W, P2P and CE (optional)
- Test require DTA
- Accredited certification labs

**EMV contactless (EMVCo)**
- Specs and certification program for payment devices
- Contact testing (ISO/IEC 7816)
- Contactless testing (ISO/IEC 14443 A and B)
- L2 according to each payment scheme

Test equipment needs to be qualified by one of these certification programs
802.11ac Test Challenges

Wider Bandwidth Signals

– Generating wider bandwidth signals
  • Mandatory channel bandwidth of 20 MHz, 40 MHz, 80 MHz
  • Optional channel bandwidth of 160 MHz, 80 + 80 MHz
  • Minimum 2x oversampling to avoid aliasing

– Analyzing wider bandwidth signals
  • Analyzer must support 40 MHz, 80 MHz, 160 MHz for in-band modulation analysis measurements
  • Digital pre-distortion may require 3-5x signal bandwidth: 800 MHz

– MIMO
  • Requires wide bandwidth, multi-channel hardware
802.11ac Wave1 & Wave2

<table>
<thead>
<tr>
<th></th>
<th>Wave 1</th>
<th>Wave 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel BW</td>
<td>80 MHz</td>
<td>160 MHz 80+80 MHz</td>
</tr>
<tr>
<td>Spatial Streams</td>
<td>Up to 4</td>
<td>Up to 8</td>
</tr>
<tr>
<td>MIMO</td>
<td>Single-User (SU)</td>
<td>Multi-User (MU)</td>
</tr>
<tr>
<td>Data Rates</td>
<td>Up to 1.3 Gbps</td>
<td>Up to 6.9 Gbps</td>
</tr>
</tbody>
</table>

Wireless Evolution and Test Challenges

802.11ac Wave1 2013/2014
802.11ac Wave2 2015/2016
802.11ah Test Challenges
Some Common Test Challenges for IoT

Transmitter Tests
– Spectrum Emission Mask
– Modulation Accuracy
– Spurious Emissions

Receiver Tests
– Receiver Sensitivity
– Adjacent channel selectivity
– Co-channel rejection
802.11ah Test Challenges

Some Common Test Challenges for IoT

Transmitter Tests
– Spectrum Emission Mask
– Modulation Accuracy
– Spurious Emissions

Receiver Tests
– Receiver Sensitivity
– Adjacent channel selectivity
– Co-channel rejection
802.11ah Test Challenges

Transmitter Tests
– Spectrum Emission Mask
– Modulation Accuracy
– Spurious Emissions

Clear Write
802.11ah Test Challenges

Transmitter Tests

- Spectrum Emission Mask
- Modulation Accuracy
- Spurious Emissions

Trigger on Waveform
802.11ah Test Challenges

Transmitter Tests

- Spectrum Emission Mask
- Modulation Accuracy
- Spurious Emissions

Max Hold
802.11ah Test Challenges

Transmitter Tests
- Spectrum Emission Mask
- Modulation Accuracy
- Spurious Emissions

RTSA Long Acquisition
802.11ah Test Challenges

Transmitter Tests
- Spectrum Emission Mask
- Modulation Accuracy
- Spurious Emissions

RTSA Short Acquisition
802.11ah Test Challenges

Some Common Test Challenges for IoT

Transmitter Tests
– Spectrum Emission Mask
– Modulation Accuracy
– Spurious Emissions

Receiver Tests
– Receiver Sensitivity
– Adjacent channel selectivity
– Co-channel rejection
802.11ah Test Challenges
Some Common Test Challenges for IoT

802.11ah vs. 802.11ac Receiver Minimum Sensitivity Test Limit

<table>
<thead>
<tr>
<th>Modulation</th>
<th>Coding Rate</th>
<th>1MHz (802.11ah)</th>
<th>2 MHz (802.11ah)</th>
<th>20 MHz (802.11ac)</th>
<th>80 MHz (802.11ac)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BPSK</td>
<td>½ with 2x repetition (MCS10)</td>
<td>-98 dBm</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>BPSK</td>
<td>1/2</td>
<td>-95 dBm</td>
<td>-92 dBm</td>
<td>-82 dBm</td>
<td>-76 dBm</td>
</tr>
</tbody>
</table>

Receiver Tests

– Receiver Sensitivity
– Adjacent channel selectivity
– Co-channel rejection
802.11ah Test Challenges

Some Common Test Challenges for IoT

Receiver Tests

- Receiver Sensitivity
- Adjacent channel selectivity
- Co-channel rejection

Sensor Networks – Up to 8,000 devices (sensors) may connect to a single AP
802.11p Test Challenges

Much Stricter SEM Requirement for CLASS C and D Device
Test Challenges for LTE and LTE-Advanced

Keeping current with the Standards

- Verifying Throughput of Data
- Software that stays current with Releases
- Higher bandwidths and use of multi-carriers

Higher Order MIMO

- Up to 8 Channel TD-LTE Beamforming
- Complex Antenna Design, Interference, Power Control and OTA Test

Battery Drain

- Maximizing UE and BS power efficiency
- Using ET and DPD in Power Amplifiers
Summary

– There are many tests that need to be done to verify the performance of IoT devices

– Some general test challenges include:
  • Interference testing/replicating actual operating environment
  • Battery current drain testing
  • Multiple standards supported by a single device

– Many technologies or standards come with their own unique set of test challenges
Common measurement methodologies across hardware and software provide consistent results.

**Keysight Benchtop, Modular and OBT Solutions**

**Design Simulation & Early R&D Hardware Testing** → **Development** → **Integration & Verification** → **Manufacturing**

**Benchtop Benefits:**
- Higher RF performance
- Front panel maximizes measurement insight

**Modular/OBT Benefits:**
- Flexibility
- Test speed
- Small footprint
Questions?

Thank you!