Techniques to Reduce Femtocell Manufacturing Test Time
Agenda

- Femtocell test challenges
- Improving Test Time and Throughput
  - What is Test time?
  - Test faster with Measurement Sequencer techniques (SAMM)
  - Increase test throughput with Pipeline and Ping Pong
- Introduction to the Keysight E6650A EXF Femtocell test solution
– Femtocell test challenges

– Improving Test Time and Throughput
  • What is Test time?
  • Test faster with Measurement Sequencer techniques (SAMM)
  • Increase test throughput with Pipeline and Ping Pong

– Introduction to the Keysight E6650A EXF Femtocell test solution
Femtocell and Small Cell units expected to grow at 46% CAGR from 2014-2018 to account for 90% of all mobile infrastructure equipment units sold in 2018.
Femtocell Manufacturing Test Requirement and Challenges

Test Items & Requirements

3GPP Specified tests have strict requirements for conformance

Calibration
• Tx – Frequency, Power, IQ
• Rx – Uplink & Monitor Gain

Verification tests
• Tx – Power, OBW, ACP, EVM, SEM, Freq error
• Rx – RSSI, BER

Multiple Cellular Radio formats

Incremental WLAN Test

Test Challenges

Test Plan development and test

Time to volume

Low Cost of Test

Faster Test equipment & Multi format Support

LONG Test Times
– Femtocell test challenges

– Improving Test Time and Throughput
  • What is Test time?
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– Introduction to the Keysight E6650A EXF Femtocell test solution
How to Reduce Femtocell Manufacturing Test Time?

One device, One test Set: Measurement and Sequencer Techniques

- Calibration time
- Mode switch and Boot time
- Tx measurement time
- Rx measurement time

Reduce measurement time

Sequencer (analyser and Source)

Multiple Devices, One test Set: Smart Scheduling Techniques

Smarter Scheduling method
**Traditional Signal Analyzer Measurement Concept**

**Single acquisition single measurement (SASM)**

<table>
<thead>
<tr>
<th>Acquisition 1</th>
<th>Acquisition 2</th>
<th>Acquisition n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burst 1</td>
<td>Burst 2</td>
<td>... Burst n</td>
</tr>
<tr>
<td>Meas 1</td>
<td>X1</td>
<td></td>
</tr>
<tr>
<td>Meas 2</td>
<td></td>
<td>X2</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td></td>
</tr>
<tr>
<td>Meas n</td>
<td></td>
<td>Xn</td>
</tr>
</tbody>
</table>

- Reports back a single measurement result every time
- Need to switch between two measurements
Parallel Measurement Concept

Two approaches to improve the measurement speed

Approach 1: “Combined” measurements under one measurement mode

<table>
<thead>
<tr>
<th>Acquisition 1</th>
<th>Acquisition 2</th>
<th>Acquisition n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burst 1</td>
<td>Burst 2</td>
<td>Burst n</td>
</tr>
<tr>
<td>Meas 1</td>
<td>X1</td>
<td>Xn</td>
</tr>
<tr>
<td>Meas 2</td>
<td>X1</td>
<td>Xn</td>
</tr>
<tr>
<td>...</td>
<td>X1</td>
<td>Xn</td>
</tr>
<tr>
<td>Meas n</td>
<td>X1</td>
<td>Xn</td>
</tr>
</tbody>
</table>

- Acquisition length is one burst
- Reports multiple measurement results
- Measurement BW is limited by hardware
Sequencer Measurement Concept

Further approach to improve the measurement speed

2nd Approach : Single acquisition multiple measurements (SAMM)

- Acquisition length is n*bursts
- Report multiple measurement results
- No limitation on measurement BW
- Supports frequency fast switch and multi-burst results

Same time, Many More measurements!
There are two independent sequencers in the EXF Wireless Test Set for Femtocell E6650A:

- Source List Sequencer
- Sequence Analyzer List Sequencer

Each sequencer can work individually or in Synch with the other.

- Both sequencers can synchronize with each other by the use of internal triggers
- Both Sequencers can be controlled by a single sequence
Sequence Analyzer Key Parameters

- **Acquisition Parameters**
  - Supports up to 512 pre-configurable hardware states.
  - Each State has:
    - Radio Format
    - Frequency
    - Gain
    - Acquisition duration
    - Transition Time
    - Trigger Type
    - Trigger Delay
    - Output Trigger
    - Max Acquisition length 2GB = 256MSa

- **Analysis Parameters**
  - Up 1000 steps per sequence
  - Defines part of the capture memory to use as a measurement step
  - Each step has:
    - Analysis Offset (from Acquisition start) - Expected Power at DUT
    - Analysis Interval - Measurement Selection
    - Analysis Number
Basic Terminology for Sequence Analyzer

Sequence

Acquisition

Analysis Intervals

Pre-Trigger

Trig Event

Acquisition Duration

Transition Time

Data is returned to App after FPGA analysis here
**Red Bar = Acquisition vs. Blue Bar = Analysis Step**

**Sequence**

<table>
<thead>
<tr>
<th>Acquisition 1</th>
<th>Acquisition 2</th>
<th>Acquisition 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>Step 1</td>
<td>Step 1</td>
</tr>
<tr>
<td>Step 2</td>
<td>Step 2</td>
<td>Step 2</td>
</tr>
<tr>
<td>Step 3</td>
<td>Step 3</td>
<td>Step 3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Step 4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Step 5</td>
</tr>
</tbody>
</table>

- **Conceptual Step**: Beginning = Trig event + Trig Delay
- **Trig delay**:
- **Acq 1 time**:
- **Contiguous samples**: Stored in capture memory
- **Trig event location**: Stored
- **Freq Changed**: Samples gated out (Not stored)
- **Multiple Extractions**: of the same data allowed (and with different lengths)

**Key Points**

- **RFB**:
- **IMM**: E-Atten change Required, hence new Acquisition

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**Page 14**
Source List Sequencer

- Signal is generated in ARB waveform mode
- Setup a waveform sequence with the same or different waveforms to cover one or multiple formats
- Each waveform signal can be configured with a different frequency and amplitude by using a new step in the sequence

– Key Parameters

<table>
<thead>
<tr>
<th>Waveform Sequence</th>
<th>Trigger</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓ Segment</td>
<td>✓ Trigger Source</td>
</tr>
<tr>
<td>✓ Repetition</td>
<td>✓ Trigger delay</td>
</tr>
<tr>
<td></td>
<td>✓ Trigger type</td>
</tr>
<tr>
<td></td>
<td>✓ Polarity</td>
</tr>
</tbody>
</table>
How do you Co-ordinate the Sequencers?

List Sequence from DUT
1. Channel 1 Tx, 0dBm, E-TM 1.1
2. Channel 1 Tx, -10dBm, E-TM 1.1
3. Channel 1 Tx, 0dBm, E-TM 3.1
4. Channel 2 Rx

List Sequence measurements by EXF
1. Channel 1 Power
2. Channel 2 Power, EVM, Spectral mask
3. Channel 3 Power
4. Channel 2 RX Test, -100dBm, FRC A1-1
Source output Uplink signal as a sequence to DUT

Triggers / Synch
Fastest Measurement Speed

Sequence analyzer – LTE 20 MHz LTE-FDD E-TM3.1 example

Test Equipment Setup

EXF sequencer: Typical Testplan

34x faster than MXA one-button application
Increase Test Throughput with Pipeline

“Pipeline” Test Scenario

Serial Test: 2 DUTs

Pipeline: Test DUT1 Tx, DUT2 Rx in parallel; then swap

Time saved
Increase Test Throughput with Ping Pong

“Ping Pong” Test Scenario

On a 16 port Test Set, you can connect 8 two-antenna (1 Tx/Rx, 1 Rx diversity) DUTs.

Diagram showing the test scenario.

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Combination: Ping Pong & Pipeline

TRX1

- DUT 1: Boot, Cal, Boot, Tx, Rx, Unload / Load
- DUT 2: Boot, Cal, Boot, Tx, Rx
- DUT 3: Unload / Load
- DUT 4: Unload / Load

TRX2

- DUT 1: Boot, Cal, Boot, Tx, Rx, Unload / Load
- DUT 2: Boot, Cal, Boot, Tx, Rx
- DUT 3: Unload / Load
- DUT 4: Unload / Load

TRX3

- DUT 1: Boot, Cal, Boot, Tx, Rx, Unload / Load
- DUT 2: Boot, Cal, Boot, Tx, Rx
- DUT 3: Unload / Load
- DUT 4: Unload / Load

TRX4

- DUT 1: Boot, Cal, Boot, Tx, Rx, Unload / Load
- DUT 2: Boot, Cal, Boot, Tx, Rx
- DUT 3: Unload / Load
- DUT 4: Unload / Load
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Traditional Femtocell Tx/Rx Test Setup

MXG + XSA approach

Classic

40 ms TTI Trigger Event

Ethernet

Hub

MXG Signal Generator

10 MHz

Duplexer

Atten

1 to 50 MHz Frequency Ref*

UL

DL

Femtocell

MXA/EXA Signal Analyzer

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New Femtocell Tx/Rx Test Setup for Manufacturing

EXF Wireless Test Set for Femtocell approach
New Femtocell Tx/Rx Test Setup for Manufacturing
Femtocell One-Box Tester approach

Economic

40 ms TTI Trigger Event

1 UP TRX
RFIO 2
RFIO 1
Trig in

Ethernet Hub

EXF E6650A Wireless Test Set for Femtocell

Atten

Ref in

10 MHz Frequency Reference

LAN

Femtocell

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Keysight Femtocell Test Platforms for R&D, DVT & Mfg

R&D and DVT

Signal Generator & Analyzer

EXG/MXG
EXA/MXA

Modular PXI VSG & VSA

M9381A VSG & M9391A/M9393A VSA*

*DL sequencer and chipset control software not available on PXI modular products today

Manufacturing

One-Box Tester (OBT)

E6650A EXF- Accelerate Femtocell Manufacturing

- Lower overall cost of test
- Test multi-format designs
- Compatible with X-Series analyzers and generator code

Reduce engineering test development time

Simplify Signal Creation

Keysight Signal Studio

Fast and Accurate Measurements

X-Series Measurement Applications and Downlink Sequencer

Control, Cal, Test

Chipset Software
Fastest Measurement Speed

Advanced Sequence Analyzer

Flexible & Capable
- Designed for ultra-fast device calibration and verification
- Enables single acquisition with multiple measurements
- Allows precise control of
  - test intervals
  - test levels
  - measurement timing

Execute test plans at the chipset’s highest achievable speed
**Highest Throughput and Yield**

- Maximize throughput with raw HW speed and advanced sequencing
  - Simultaneous control of all TRXs
  - Maximize test throughput with full parallel test
  - Get ultra-fast data processing with quad-core controller and high-bandwidth PXIe backplane
  - Accelerate test execution with advanced sequencing and single acquisition, multiple measurements

- Increase production yield with signal purity and measurement quality
  - Best-in-class power-level accuracy
    - ≤ ±0.4 dB
  - High-margin receiver EVM floor
    - < 1% EVM for 20 MHz LTE carrier
Lowest Cost of Test - Reducing CAPEX Investment

Small form factor – PXI based instrument
- Up to 4 independent TRX
- Each is a fully calibrated VSA&VSG

Flexible License structure
- Apps bundled with mainframe
- Upgrade Freq. & BW (SW lic. only)
- New radio format support (1 lic for all TRX)

Minimise cost of ownership
- 3 year Std Keysight Warranty
- Field upgradeable / replaceable TRX
- Rugged N-Type RF connectors (for MFG)
Accelerate Time to Volume Manufacturing

Manufacturing Test Integration Program

Quickly step your DUT through cal and test modes with chipset software manufacturing test tools

Chipset suppliers’ manufacturing test tools
- Keysight instrument integrated into manufacturing test tools
- Solutions verified by Keysight & Wireless Chipset suppliers
- New chipset models being added to keep pace with latest technology advances

Keysight Chipset Reference Software – ex. TAP
- Save engineering time spent on test development
- GUI and API for chipset control, calibration and verification
- Tailor measurement parameters to your test plan
- Generate graphical test results and logs

Collaboration with Wireless Chipset Suppliers

Keysight Instrument → Wireless Chipset supplier → Production

Chipset Suppliers’ tools
E6650A - EXF Wireless Test Set for Femtocell

- **Fastest, most accurate parallel test**
  - Speed optimized HW and SW applications measurement science
  - Sequence analyzer, SAMM

- **Ultimate scalability and port density on the manufacturing line**
  - Up to 4 independently configurable TRX
  - Modularity: repair, upgrade, extensibility
  - Small MFG. footprint

- **Broad multi-format Support**
  - Cellular + WLAN X-Series Apps (DL only)
  - One SW license for all TRX modules

- **Backward Compatible with Bench Top**
  - Same X-Series Measurement science
  - Same signal studio waveforms
  - Consistent results between R&D & Mfg
Thank You!

Unlocking Measurement Insights for 75 Years
Back up
What are the components that give us the overall test time?

Typical femtocell test plan—Flow chart

- Calibration time
- Mode switch time
- Tx Measurement time
- Rx Measurement time
- Rx sensitivity

Components:
- Cal freq
- Boot
- Switch Antenna
  - Ant# ≤N?
    - Y: Cal power
    - N: Switch channel
  - Ch# ≤M?
    - Y: Tx power
    - N: SEM
- Freq Error
- ACPR
- EVM

DUT, Boot, Cal, Tx, Rx
**What is a Femtocell?**

Femtocells are low-power wireless access points that operate in licensed spectrum to connect standard mobile devices to a mobile operator’s network using residential DSL or cable broadband connections.

*Source: [http://www.femtoforum.org](http://www.femtoforum.org)*
Why Femtocells?
Node B vs. Femtocell (HNB)

Node B

64QAM
16QAM
QPSK

distance

3GPP Femto Cell [Home Node B (HNB)]

64QAM
16QAM
QPSK
FemtoCell (HNB) Architecture, Air Interface, IP network
What is a Femtocell? (in the Smallcell categories)

- **Femtocell** is a low-power wireless access point that operate in licensed spectrum to connect standard mobile devices to a mobile operator's network using residential DSL or cable broadband connections.

http://www.smallcellforum.org/aboutsmallcells-small-cells-what-is-a-small-cell
What is a Femtocell?
(in the Smallcell categories)

<table>
<thead>
<tr>
<th>Specifications</th>
<th>Microcells</th>
<th>Picocells</th>
<th>Public-Space Femtocells</th>
<th>Home use Femtocells</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell radius</td>
<td>2 km max</td>
<td>200 m max</td>
<td>10-100 m</td>
<td></td>
</tr>
<tr>
<td>Output Power</td>
<td>33-36 dBm / 2-5 W</td>
<td>250 mW – 1W</td>
<td>1 mW – 250 mW</td>
<td></td>
</tr>
<tr>
<td>Number of users</td>
<td>More than 100</td>
<td>30 to 100</td>
<td>Less than 20</td>
<td></td>
</tr>
<tr>
<td>Controller signaling protocol</td>
<td>Iu-b</td>
<td>Iu-b</td>
<td>Iu-b / Iu-h</td>
<td>Iu-h</td>
</tr>
<tr>
<td>RRH/RRU option</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>DAS usage</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Application</th>
<th>Microcells</th>
<th>Picocells</th>
<th>Public-Space Femtocells</th>
<th>Home use Femtocells</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low power outdoor sites</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Villages and road sites</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>City centers</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Rooftop sites</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Stadiums</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Tunnel sites (e.g. subway)</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Shopping centers, malls</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>In-building sites (e.g. building / office floor)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Home sites (e.g. room)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Ultimate Scalability

Buy one software license, apply to the platform (1~4 TRX)
- Measurement application
- Waveform packs

• Tailor your TRX’s measurement bandwidth
  - 40 MHz
  - 80 MHz
  - 160 MHz

• Tailor your TRX’s frequency range
  - 380 MHz-3.8 GHz
  - 1.1-1.8 GHz
  - 2.3-2.6 GHz
  - 4.8-6 GHz
  - 380 MHz-6 GHz

Upgrade your TRX hardware capability with license keys
X-Series Benchtop Signal Analyzer Portfolio (excludes PXI)

EXA
Balance the challenges
10 Hz to 26.5 GHz, 160 MHz BW
Real-time spectrum analysis

MXA
Accelerate in wireless
3 Hz to 50 GHz, 160 MHz BW
Real-time spectrum analysis

PXA
Drive your evolution
3 Hz to 26.5 GHz, 510 MHz BW
Real-time spectrum analysis

UXA
See the real performance
9 kHz to 26.5 GHz, 25 MHz BW
Real-time spectrum analysis

89600 VSA software
See through the complexity

CXA
Master the essentials
9 kHz to 26.5 GHz, 25 MHz BW

X-Series Code Compatibility
✓ Backward CC with legacy
✓ Inherent X-Series CC
Keysight Signal Generation Portfolio (excludes PXI)

**MXG**
Pure & Precise
- 9 kHz to 6 GHz RF Vector & Analog
- 9 kHz to 40 GHz uW Analog

**EXG**
Cost Effective
- 9 kHz to 6 GHz RF Vector & Analog
- 9 kHz to 40 GHz uW Analog

**PSG**
Metrology Grade
- 250 kHz to 44 GHz uW Vector
- 250 kHz to 70 GHz uW Analog
- 250 kHz to 9 GHz RF Analog

**UXG**
Metrology Grade
- 250 kHz to 40 GHz uW Analog

**PXB**
Multi-Channel BB Fading & MIMO

**N9310A**
Basic Bench top
- 9 kHz to 3 GHz

**OML and VDI**
mm-wave source modules up to 750 GHz

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