The most important thing we build is trust

ADVANCED ELECTRONIC SOLUTIONS | AVIATION SERVICES | COMMUNICATIONS AND CONNECTIVITY | MISSION SYSTEMS

LTE Base Station Testing using Cobham Wireless PXI Solutions

April 2015

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- Cobham introduction
  - Cobham Wireless
- LTE base station challenges
  - Types of base station?
  - Market drivers?
  - RF test challenges?
  - Test philosophy options?
- Cobham Wireless LTE Base Station Case Studies
  1. Design characterisation & manufacturing
     - French telecommunications equipment company
  2. Maintenance, Support & Commissioning
     - Base station manufacturer headquartered in France

Cobham

- 12,000 people on five continents
- Customers and partners in over 100 countries
- Market leading positions in:
  - Wireless
  - Data
  - Audio & video communications, including satellite communications
  - Defence electronics
  - Air-to-air refuelling
  - Aviation services
  - Life support equipment

Aeroflex into Cobham
Cobham Wireless

COBHAM

- Advanced Electronic Solutions[1] — ~28%
- Aviation Services
- Mission Systems
- Communications and Connectivity — ~40%

AEROFLEX

Aeroflex Microelectronic Solutions (AMS)

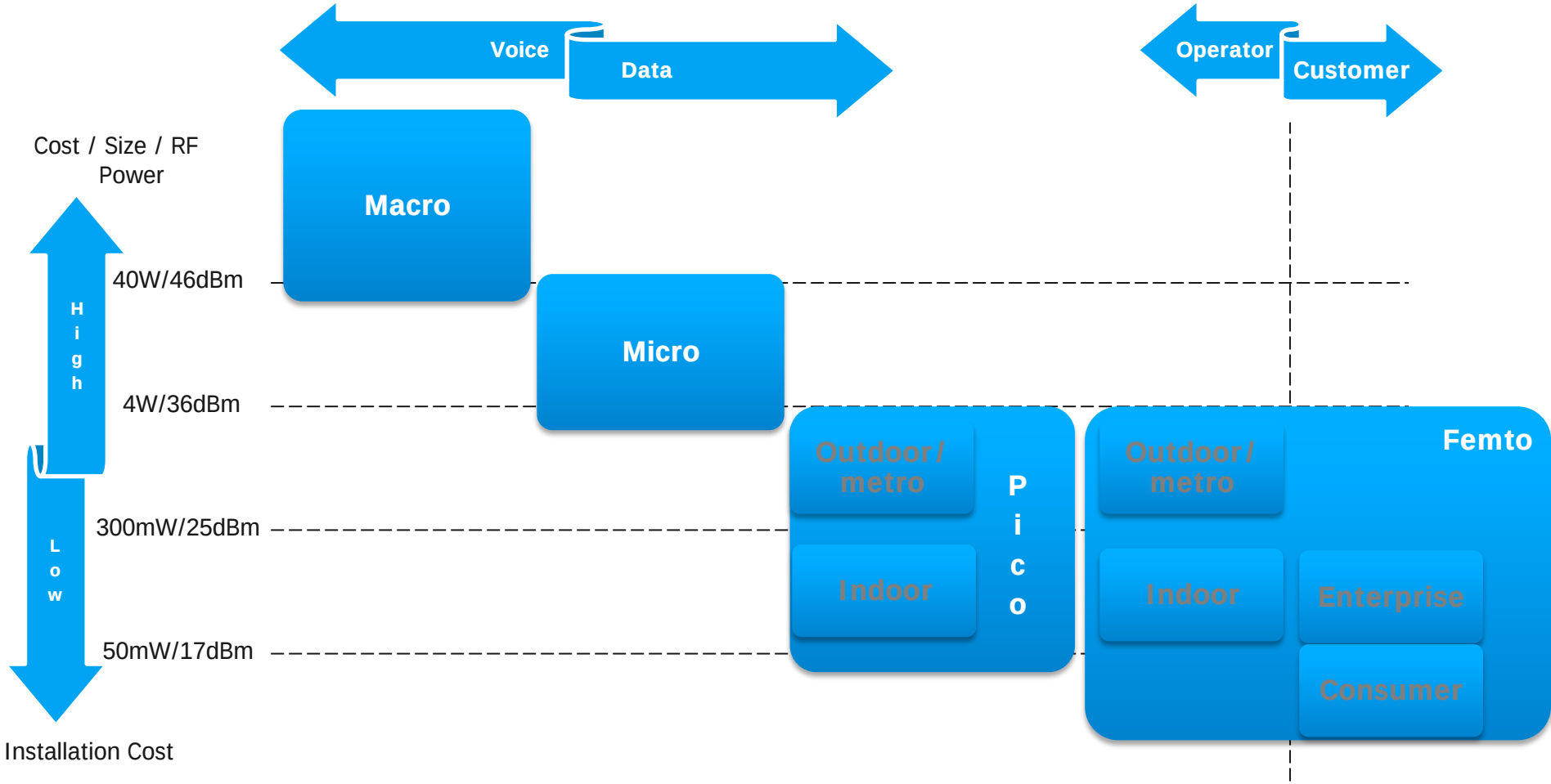
Aeroflex Test Solutions (ATS)

- Cobham Avcomm
- Cobham Wireless

Cobham Wireless

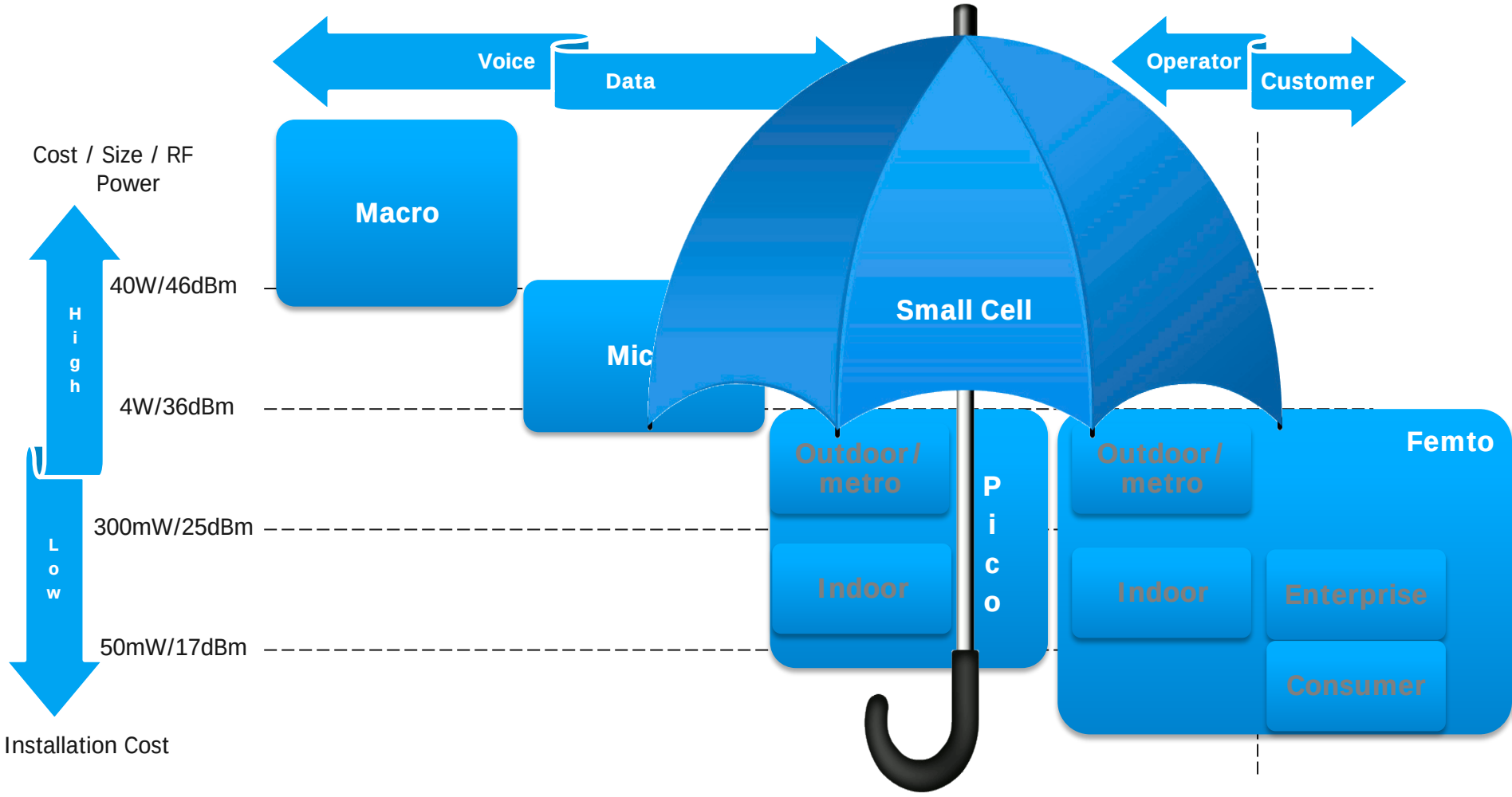
WW locations

Types of Base Stations



Types of Base Stations

Small cell : “umbrella term for an operator controlled, low powered RAN for use in licensed spectrum and unlicensed carrier grade Wi-Fi with a range <1km” [1]



[1] Small Cell Forum

Types of Base Stations

- Products include micro, pico and femto cells to serve a diverse array of use cases
- Cellular technologies include GSM, WCDMA, cdma2000 and LTE

Market Drivers

- In general, both operator & user wants:-
  - Coverage
  - Capacity
  - Reliability
- Hot topic / driver :
  - Small cells

Market Drivers

- Small Cells
  - Demand
    - Driven by a projected x11 increase in traffic by 2018 [1]
  - Cost
    - Reductions being sought (equipment cost per link/per bit, faster & simpler installation & commissioning)
  - Capacity
    - The frequency re-use benefits of deploying small cells are said to improve capacity by up to x1600 [1]
    - Traffic load lighter but burstier
    - Scalable
  - Performance
    - Data offload to improve macro network by >300% [1]

[1] Small Cell Forum

RF Test Challenges

Small Cell

1. Multiple wireless technologies & bands
2. New Designs & Feature Sets
3. Lowering the cost of test

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RF Test Challenges

Small Cell

1. Multiple wireless technologies & bands
   - 3G/4G, WiFi, GNSS
   - Network listening
     - Transmissions from neighbouring cells to manage interference / mobility and support SON
   - Multiple RF bands
     - 43 to 3GPP release 12, (FDD 1-32, TDD 33-44)
   - LTE-U (release 10[1]) / LAA (release 13[1])
     - UNII bands

[1] Country specific

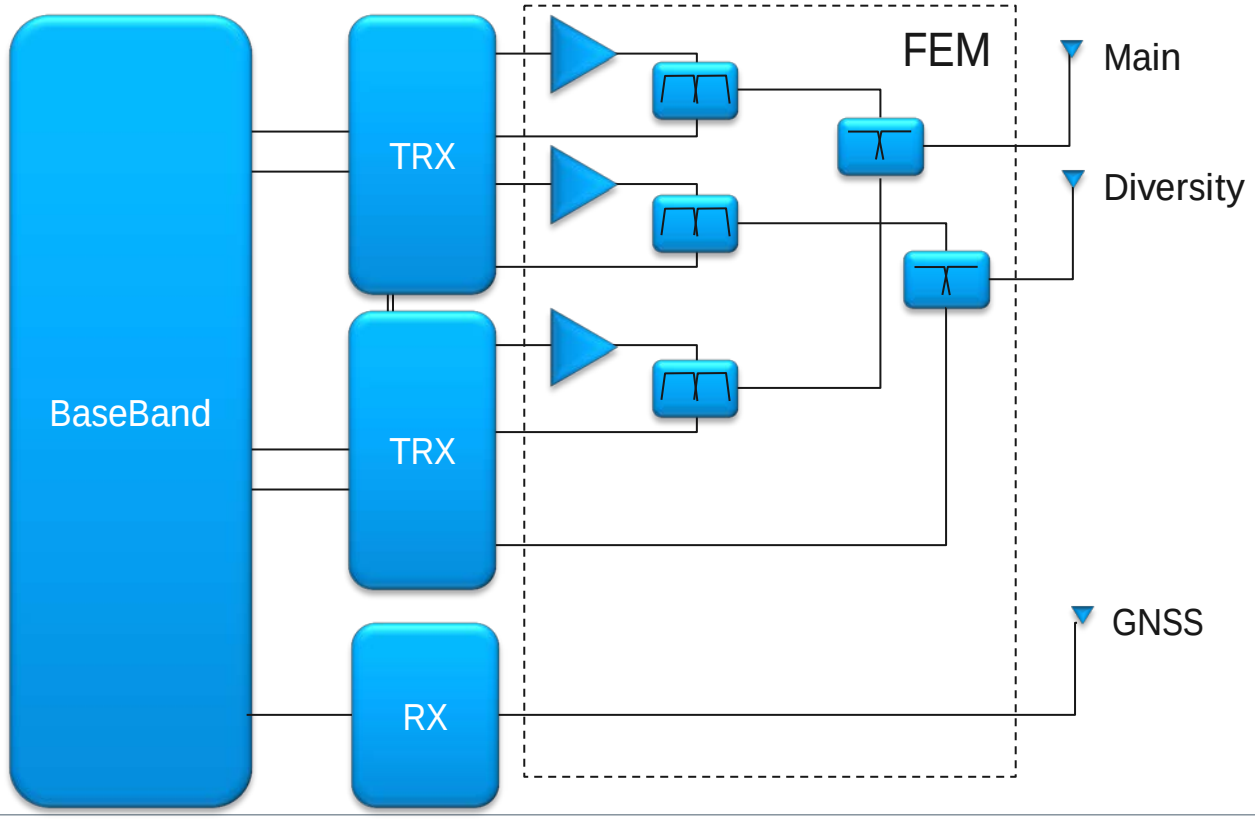
RF Test Challenges

Small Cell

1. Multiple wireless technologies & bands
2. New Designs & Feature Sets
3. Lowering the cost of test

2. New Designs & Feature Sets

- Tighter design integration
  - Single PCB designs
  - Number / nature of paths is influenced by the FEM design



2. New Designs & Feature Sets

- Variety of designs
  - Technology
  - MIMO / Antenna beamforming
  - Digital pre-distortion (DPD)

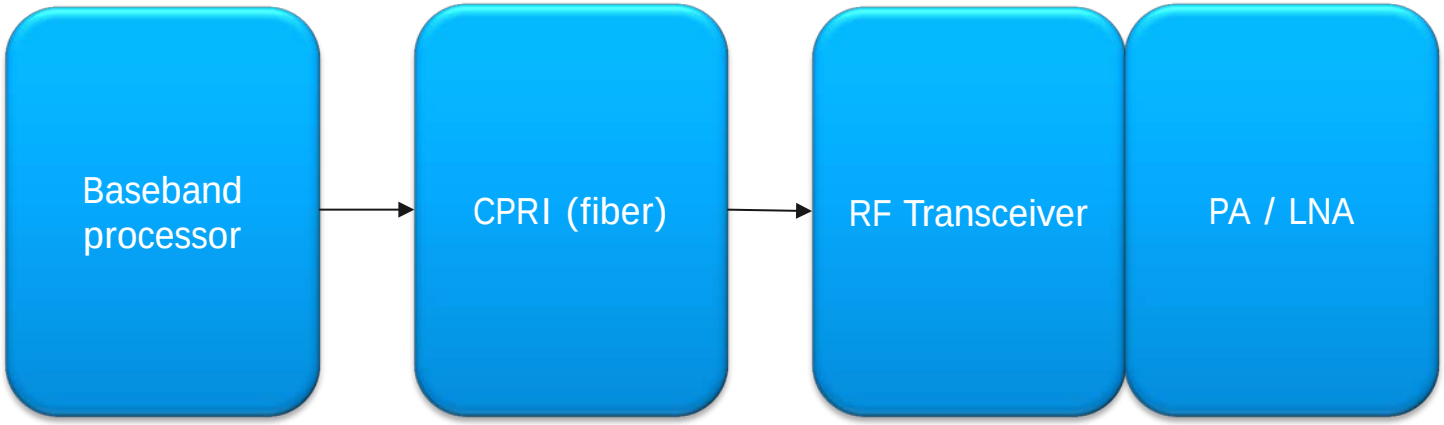
Use Case	LTE FDD/TDD Config	WCDMA Config
LTE+WCDMA 3C Multimode	Single Carrier of upto 20MHz; 2x2	DL: Adjacent 3C, 1 Tx antenna each UL: Adjacent 2C, 2 Rx antenna each
LTE+WCDMA 2C MIMO Multimode	Single carrier of upto 20MHz; 2x2	DL: Adjacent 2C, 2 Tx antenna each UL: Adjacent 2C, 2 Rx antenna each
WCDMA 2C single mode	NA	DL: 3C (2C in Band#1, 1C in Band #2), 1 Tx antenna each UL: Adjacent 2C, 2 Rx antenna each
WCDMA 2C MIMO single mode	NA	DL: 2C (intra or inter-band), 2 Tx antenna each UL: Adjacent 2C, 2 Rx antenna each
LTE 2C Single Mode	Two Carrier (Inter or intra-band) of up to 20MHz; 2x2	NA
LTE 1C 4x4 Single Mode	Single carrier of upto 20MHz; 4x4	NA

2. New Designs & Feature Sets

- Variety of designs
  - Carrier Aggregation (Intra-Band / Inter-Band)
    - Is testing necessary?
      - There are no new 3GPP RF parameters associated with CA
      - However, testing CA could help accelerate test but adds complexity
    - UL, DL or both?
      - Both will emerge but initially led by products supporting DL only
      - Sequential testing using a single channel tester is preferred
    - Inter-band, Intra-band or both?
      - Both are served using sequential testing with a single channel tester
      - Inter-band CA parallel testing requires a 2nd channel
    - Chipset capabilities
      - What control does the vendor offer in non-signaling mode?
    - Which Rx test method is used?
      - Single ended BER – This method is slow and has diminishing popularity
      - BER tests on each TRx synchronously in parallel would save time
      - SNR methods are valid for production test, are fast and easy to implement sequentially

2. New Designs & Feature Sets

- Emergence of Remote Radio Head (RRH)



- Silicon vendor specific alignment methods / device control capabilities

RF Test Challenges

Small Cell

1. Multiple wireless technologies & bands
2. New Designs & Feature Sets
3. Lowering the cost of test

RF Test Challenges

Small Cell

3. Lowering the cost of test
   - Innovate methods for reducing test time
     - DUT & test equipment

RF Test Philosophy

Small Cell

- General RF test philosophy
  - Lower the cost of test
  - Increase efficiency
  - Provide the key measurements required

- This is achieved through control/design of both:
  1. Device (base station)
  2. Test equipment

RF Test Philosophy

Small Cell

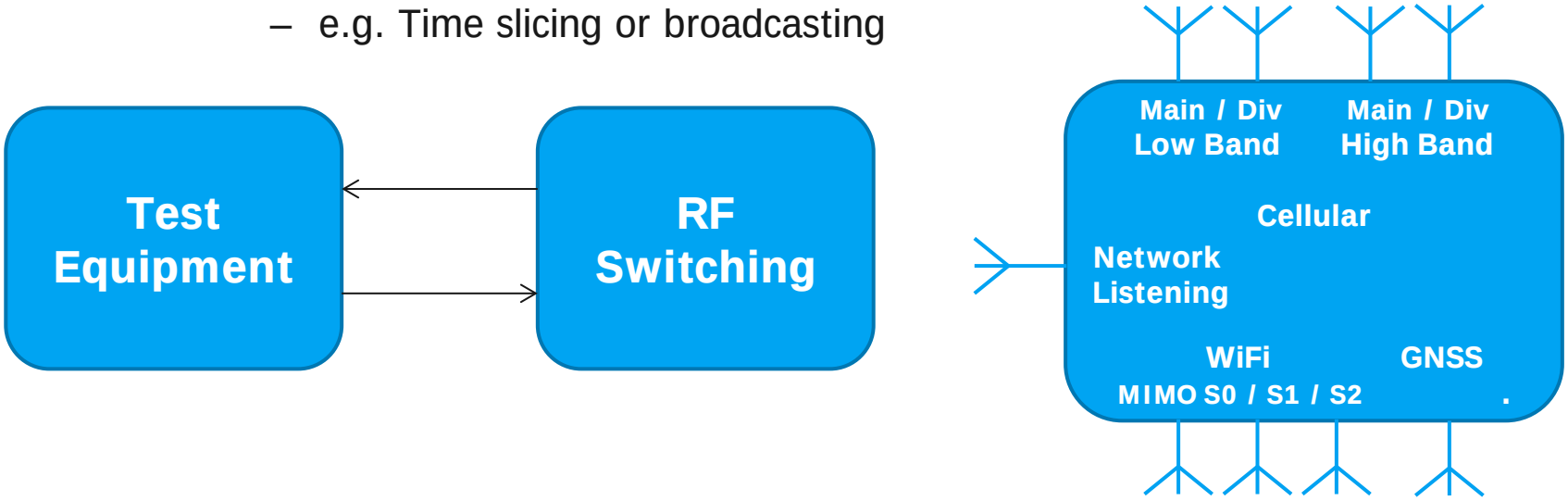
1. The Device
   - Concurrent radios?
   - Non signaling mode of operation?
   - Modular test control API?
     - Overlapping events/actions
     - More control
   - Avoiding reconfigurations
     - BW
     - Power levels

2. Test equipment

- Faster measurements is only part of the solution
- Test utilisation (more important)
  - Minimising idle time
    - Device handling time
    - Device power on / boot cycle time
    - Concurrent Tx and Rx measurements in a single step
  - Multi-DUT testing
- Multi-parameter single measurement steps
  - e.g. Power, modulation spectrum properties of a signal
- Fragmenting a measurement step into multi-threads
  - Decoupling signal acquisition from signal processing

2. Test equipment

- ATE design must provide multiple RF connection paths
- RF Switching
  - Integrating RF switching within test instruments can lower ATE complexity and overall cost
  - Using ‘ping pong’ process control methods are beneficial where device handling time is significant relative to test time
  - Multiplexing instrument resources across multiple devices
    - e.g. Time slicing or broadcasting



RF Test Philosophy

Small Cell

2. Test equipment
   - Multiplexing instrument resources across multiple devices

Cobham Wireless LTE BS Case Study #1

Overview

- French telecommunications equipment company
- Working alongside to provide a small cell manufacturing solution:
  - Calibration
  - Verification
    - 3GPP conformance standard
      - LTE 3GPP TS36.101
      - UMTS 3GPP TS25.141
      - WiFi IEEE 802.11
  - Chipset specific
  - Multi-DUT

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  - **Multi-DUT**

Cobham Wireless LTE BS Case Study #1

Multi-DUT Definitions / Approaches

- Definitions:
  - RF test resource
    1. Signal generator – input stimulus to DUT
    2. Signal Analyser – analysis of DUT output
  - RF channel
    - A combination of 1 and 2 (a pairing)
  - RF conditioning
    - The interconnection between RF test resources and DUT antenna ports
- Multi-DUT approaches with a single instrument:
  1. Multiple RF channels each connected to separate DUTs
  2. RF resources multiplexed sequentially between different DUTs
  3. RF resources shared simultaneously between multiple DUTs
  4. Any combination of 1,2 and 3

Cobham Wireless LTE BS Case Study #1

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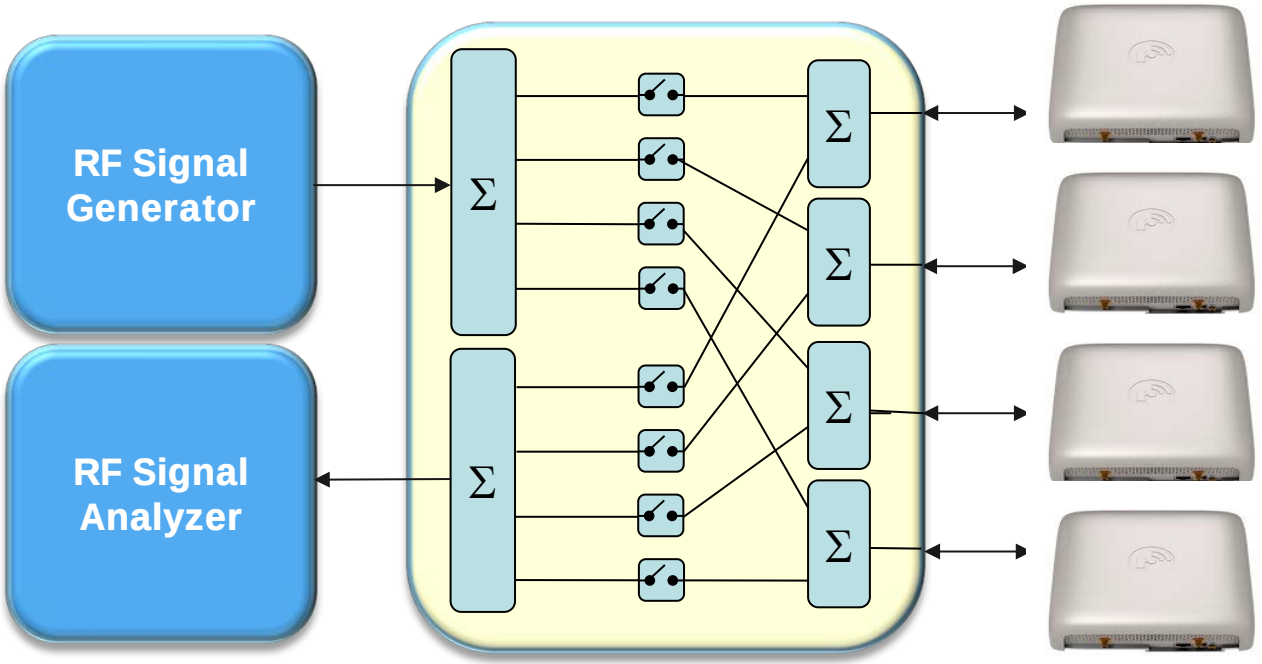
Cobham Wireless LTE BS Case Study #1

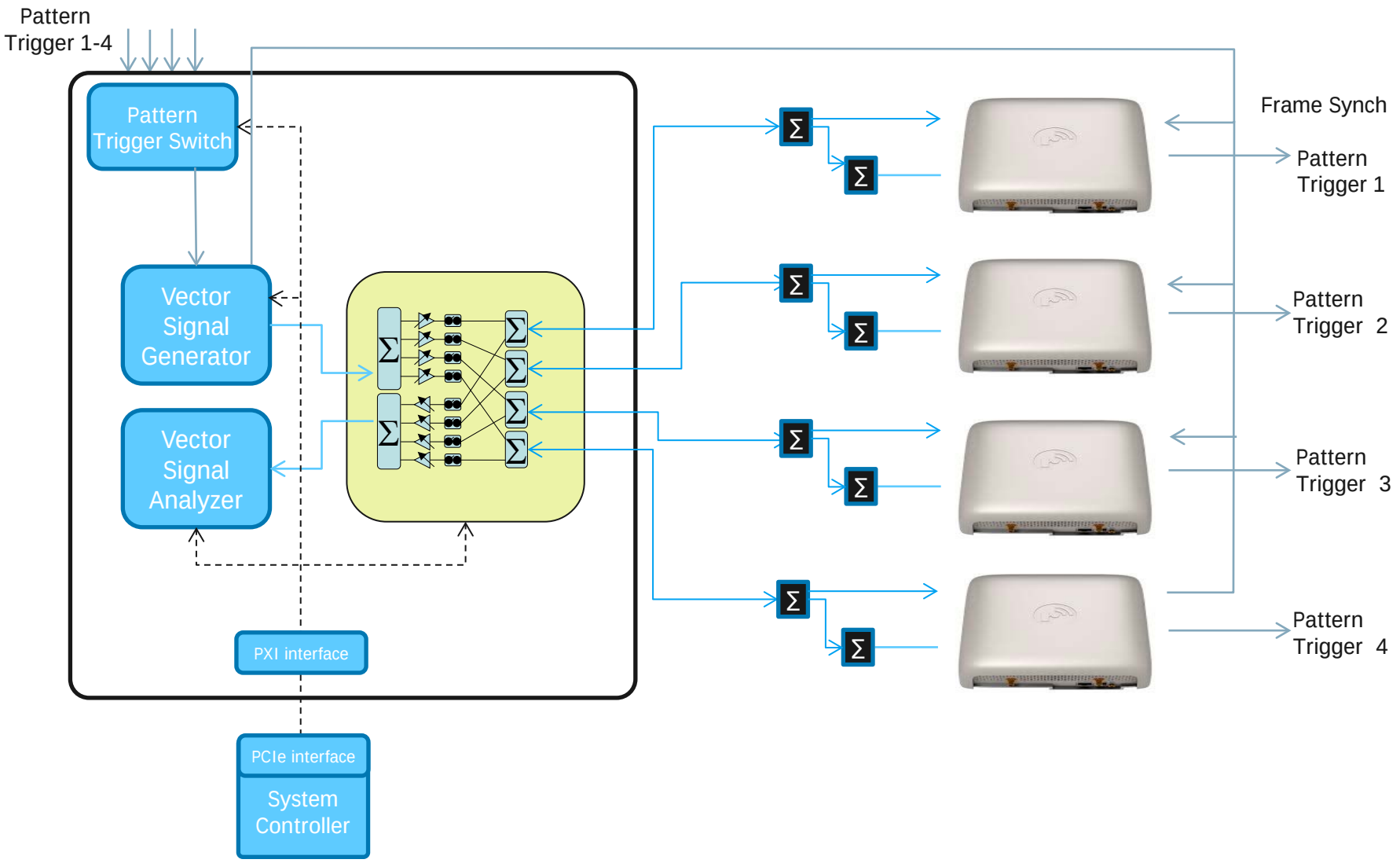
Multi-DUT Approaches #4

- Multiplexed *and/or* shared resources
  - Broadcast to all Rx & switch between all Tx
    - Parallel Rx test & sequential Tx test
  - Switched between each DUT Rx and Tx
    - Sequential test



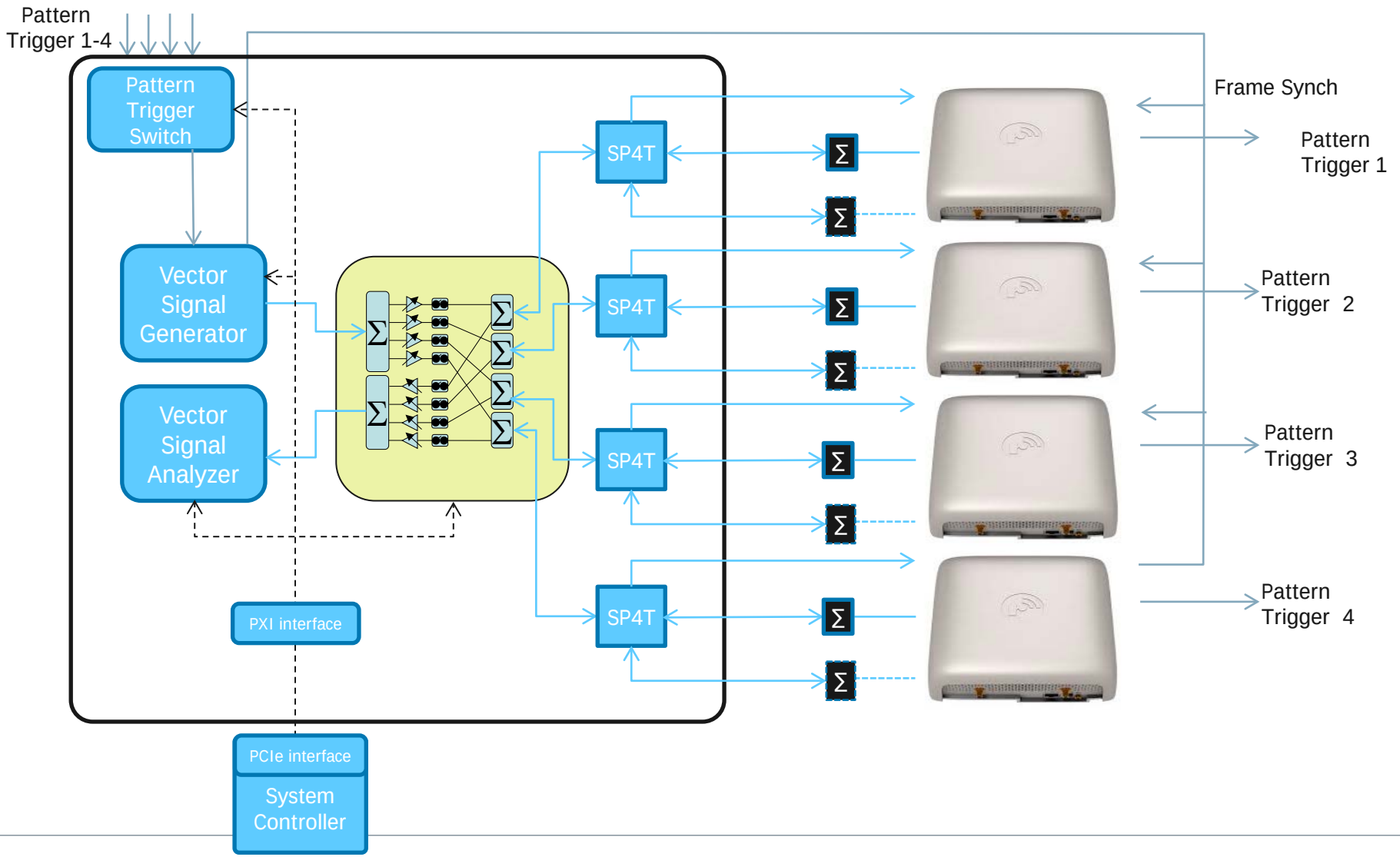
Cobham Wireless LTE BS Case Study #1

Small Cell Devices LTE/UMTS Cellular Transceivers & GNSS / NL



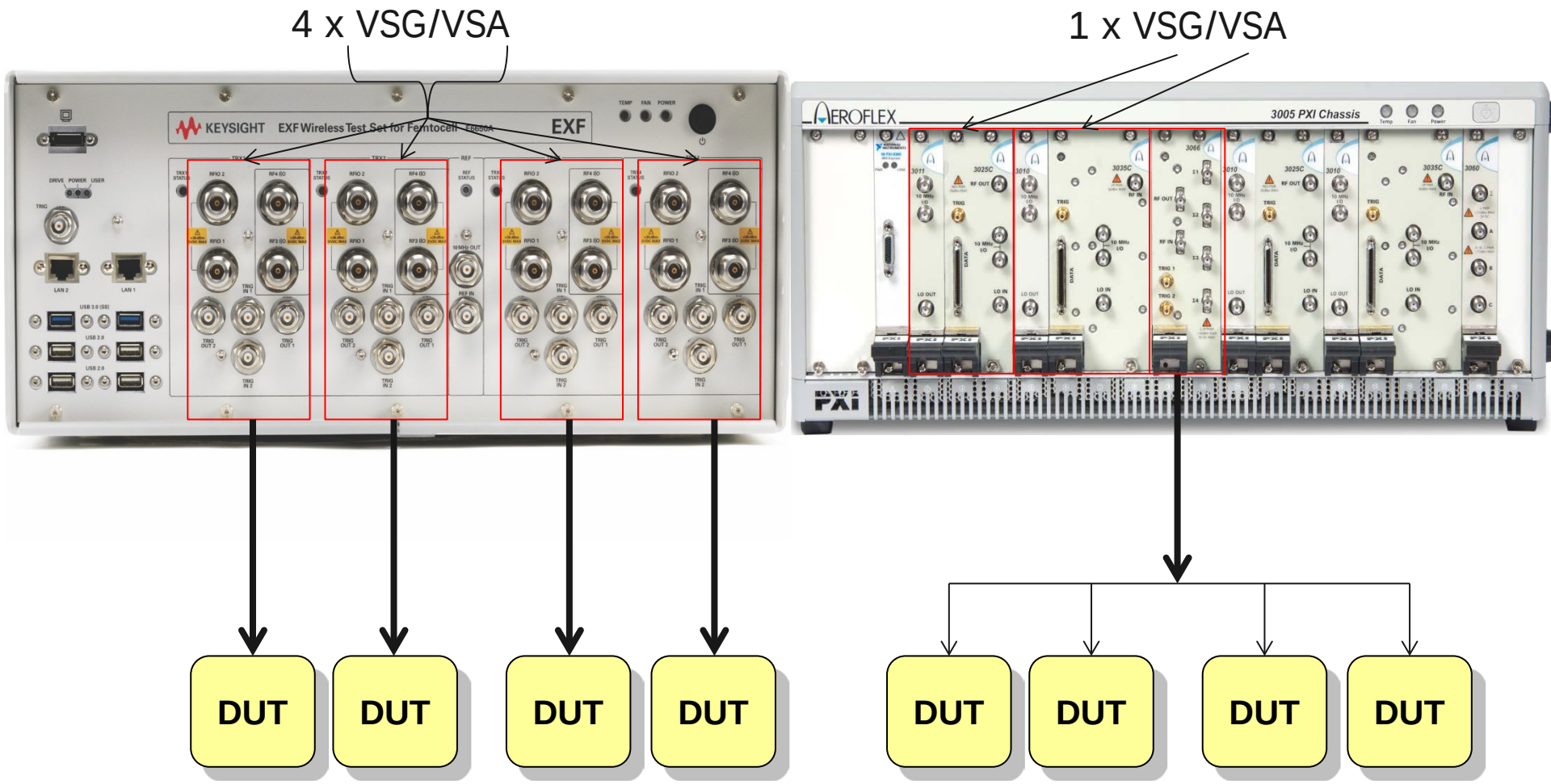
Cobham Wireless LTE BS Case Study #1

Small Cell Devices LTE/UMTS Cellular Transceivers, **WLAN** & GNSS / NL



Cobham Wireless LTE BS Case Study #1

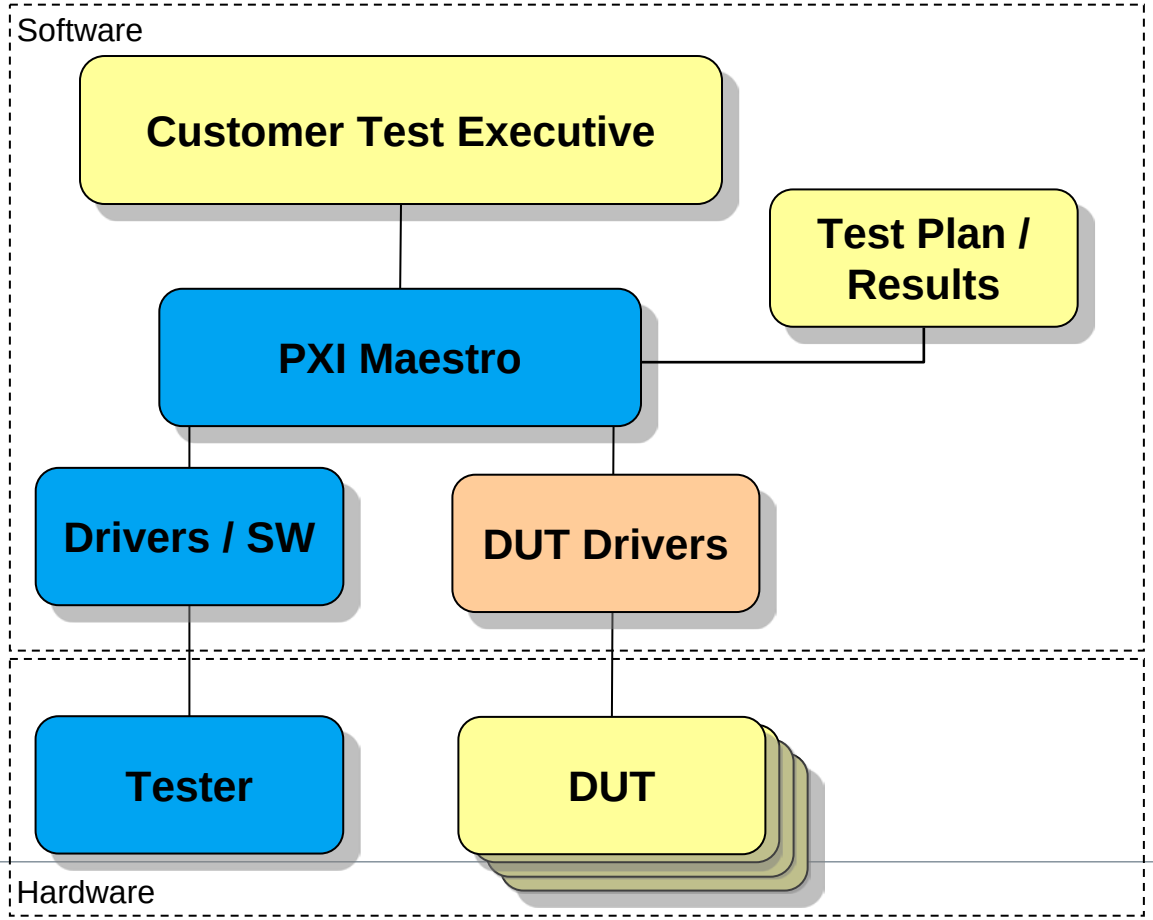
Competitor Approach vs Cobham

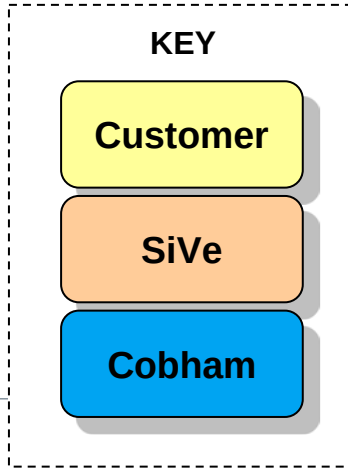


Cobham Wireless LTE BS Case Study #1

Demonstration

- PXI Maestro Small Cell Tester video
  - LTE / UMTS test plan
  - 4 devices





Cobham Wireless LTE BS Case Study #1

Cobham Multi-DUT Approach

- 1 single RF channel testing 4 devices
  - Why is this more efficient?
  - How does it work?

- i.e. How does this lower the cost of test?

Cobham Wireless LTE BS Case Study #1

Test Step Example Key

#1
#2
#3
#4
DUTs

VSA
VSG
PXI VSG or VSA

T1
T2
T3
T4
PC processor threads

Instru-ment

Key

DUT #1
DUT #2
DUT #3
DUT #4

DUT Processes

Wait → Setup → TX/RX

Instrument Processes

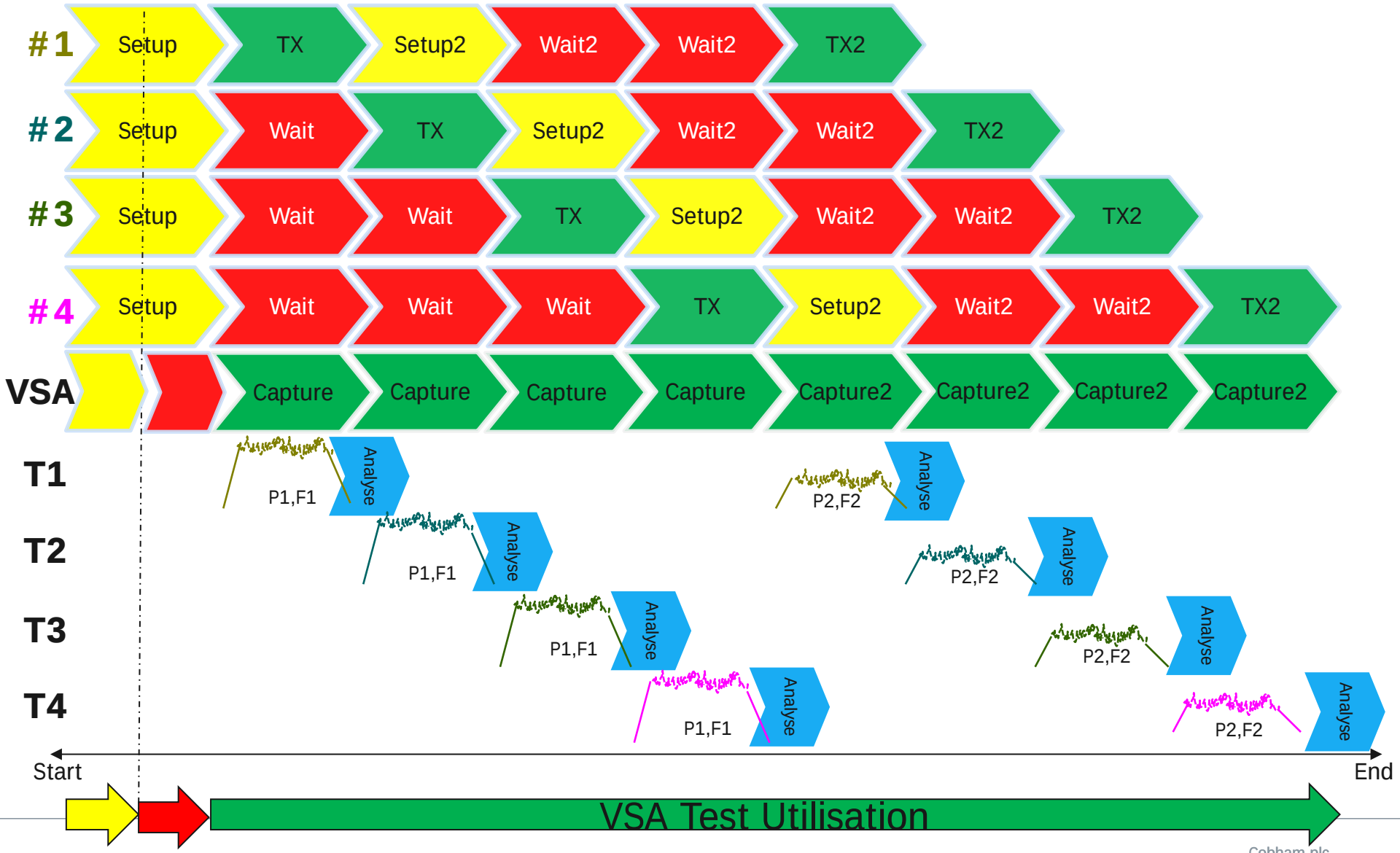
Wait → Setup → Capture/ Playback → Analyze

Start → End

Time

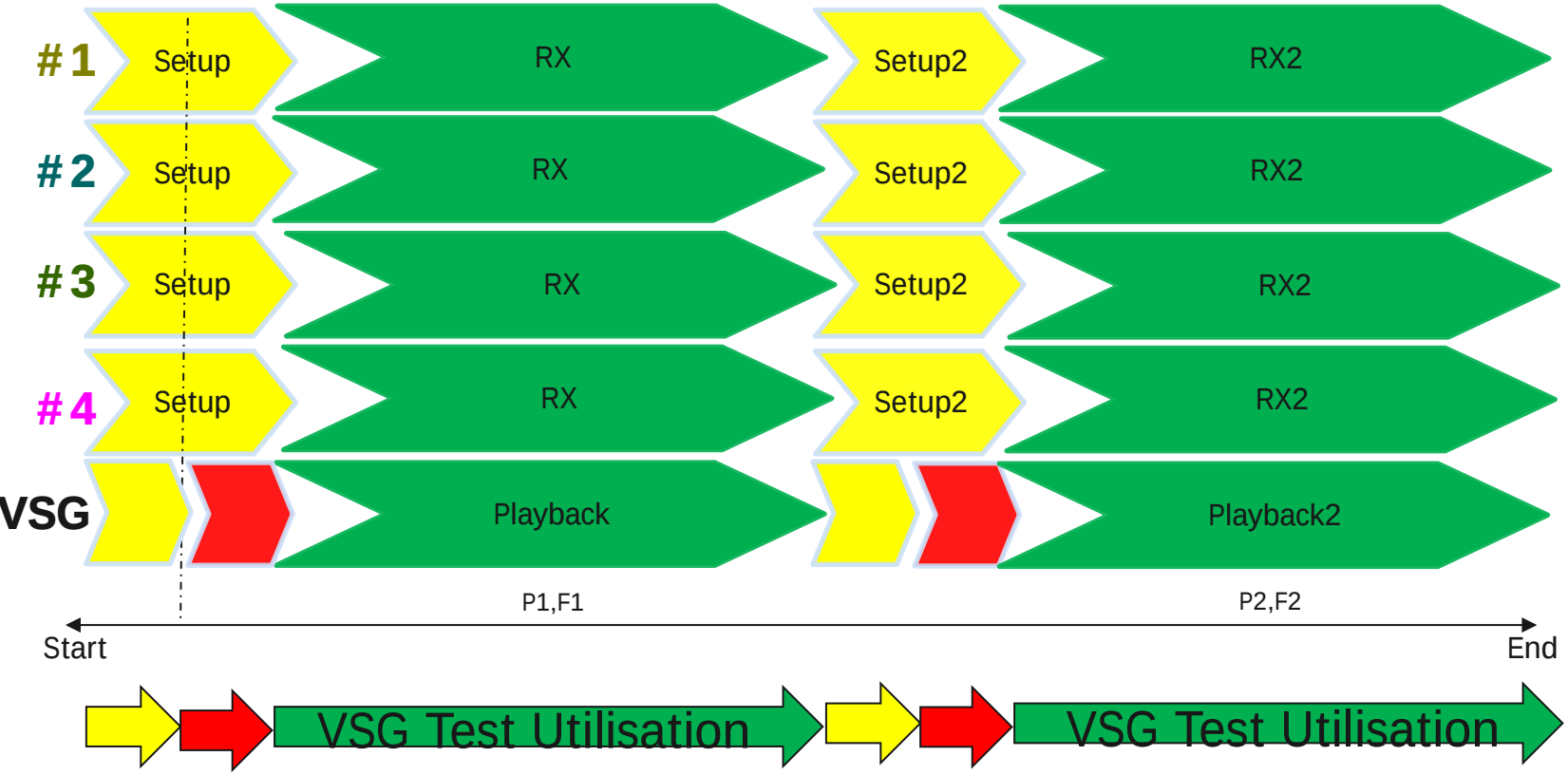
Cobham Wireless LTE BS Case Study #1

TX Calibration / TX Verify Digitiser Test Step Example (LTE / UMTS)



Cobham Wireless LTE BS Case Study #1

RX Calibration (UMTS/LTE) / Rx Verify Signal Generator Test Step Example (UMTS)



Cobham Wireless LTE BS Case Study #2

Overview

- Maintenance, Support & Commissioning BS Tester
  - Major manufacturer headquartered in France
  - Working alongside to provide:
    - Custom test solution
    - Replicated setup to end customers for installation/commissioning
  - Solution
    - LTE & Tetrapol macro cell base station testing
      - Using LTE downlink analysis libraries and Generic libraries (Tetrapol)
    - Small/mobile
      - 6 slot chassis
    - Customised results writing

Summary

- LTE base station challenges
- Small Cell key component
- 2 PXI cases studies in France:
    1. R&D, design characterisation & manufacturing solution
        - PXI Maestro
    2. Maintenance, Support & Commissioning BS Tester
        - Custom solution

LTE Production RF Verification Test Cases

Small Cell

- TS36.101

3GPP Clause	Test Case	Tx or Rx	Comment
6.2	BS Output Power	Tx	E-TM 1.1
6.3.2	Total Power Dynamic Range	Tx	E-TM2 (Min Power) E-TM3.1(Max Power)
6.5.1	Frequency Error	Tx	E-TM 2(Min Power) E-TM 3.1(64QAM) E-TM 3.2(16QAM) E-TM 3.3(QPSK)
6.5.2	Error Vector Magnitude	Tx	E-TM 2(Min Power) E-TM 3.1(64QAM) E-TM 3.2(16QAM) E-TM 3.3(QPSK)
6.6.1	Occupied Bandwidth	Tx	E-TM 1.1
6.6.2	ACLR	Tx	E-TM 1.1, 1.2
6.6.3	Operating band unwanted emissions	Tx	E-TM 1.1, 1.2
7.2	Reference sensitivity level	Rx	FRCA1-3

UMTS Production RF Verification Test Cases

Small Cell

- TS25.141

3GPP Clause	Test Case	Tx or Rx	Comment
6.2.1	BS Maximum Output Power	Tx	TM1,4,5
6.2.2	BS P-CPICH Power	Tx	TM2
6.3	Frequency Error	Tx	TM1,4,5
6.5.1	Occupied Bandwidth	Tx	TM1
6.5.2.1	Spectrum Emission Mask	Tx	TM1
6.5.2.2	Adj. Channel Leakage Ratio	Tx	TM1
6.7.1	Error Vector Magnitude	Tx	TM 1,4,5
6.7.2	Peak Code Domain Error	Tx	TM3
6.7.4	Rel. Peak Code Domain Error	Tx	TM6
7.2	Reference Sensitivity Level	Rx	UL RMC 12.2k

Multi-DUT Concepts

Definitions / Approaches

- Definitions:
  - RF test resource
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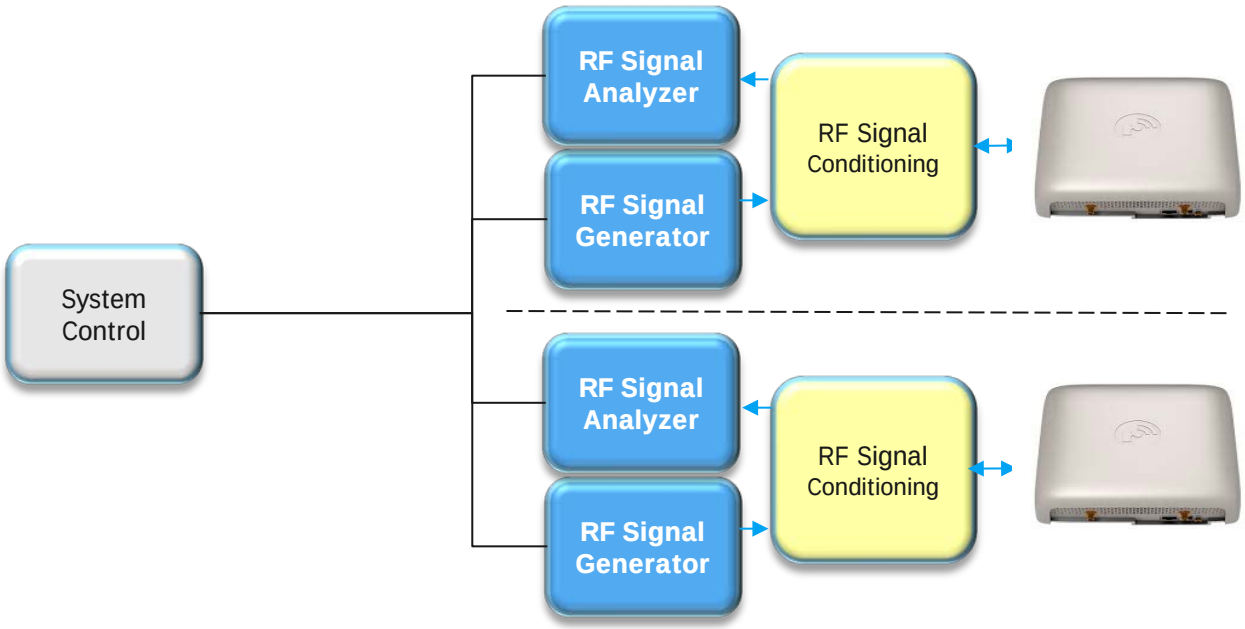
Multi-DUT Concepts

Approach #1: Multiple RF channels

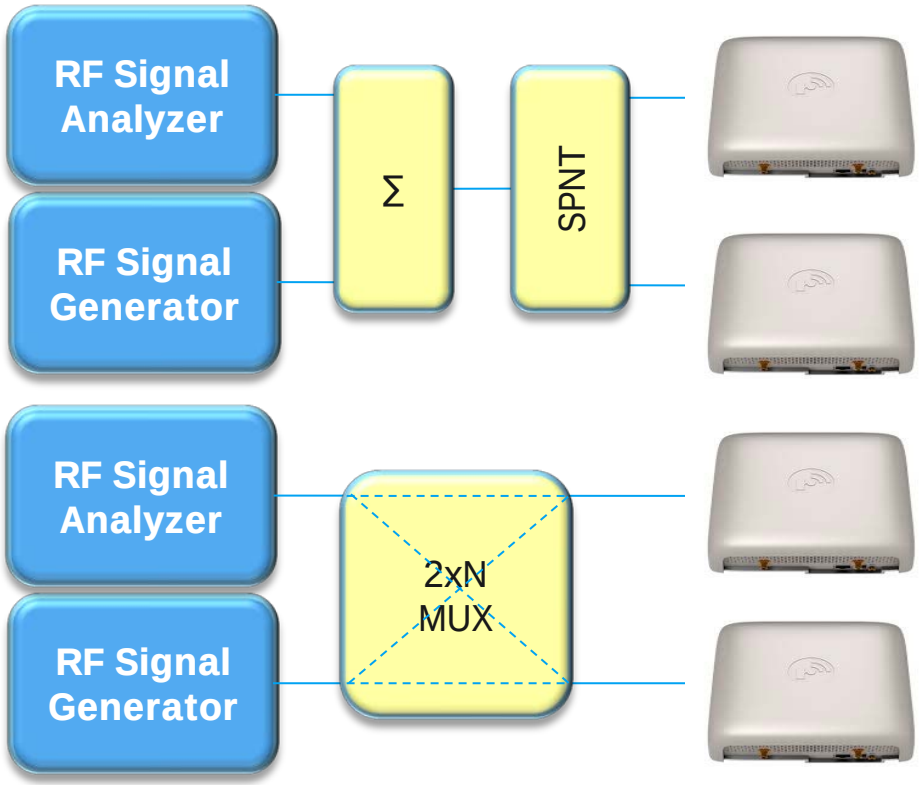
- Multiple RF channels each connected to separate DUTs
  - Can have a dedicated or shared controller/PC
  - Each DUT is operated and tested asynchronously
  - ATE design must account for crosstalk/isolation issues between channels



Multi-DUT Concepts

Approach #2 - Multiplexing

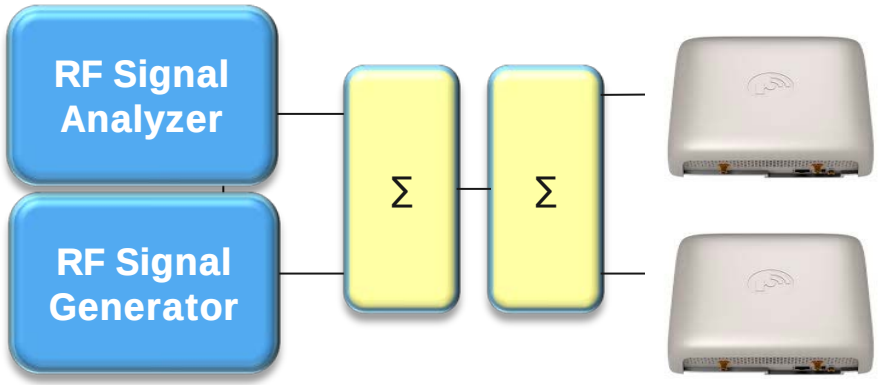
- FDMA
  - Full duplex multiplexing
  - DUTs tested sequentially
  - Ideal when Tx and Rx can be tested concurrently
- TDD/TDMA
  - Half duplex multiplexing
  - DUTs tested in parallel
    - Tx/Rx ping pong
- Benefit
  - Lower cost
  - Single PC
  - Common boot time



Multi-DUT Concepts

Approach #3 - Shared resources

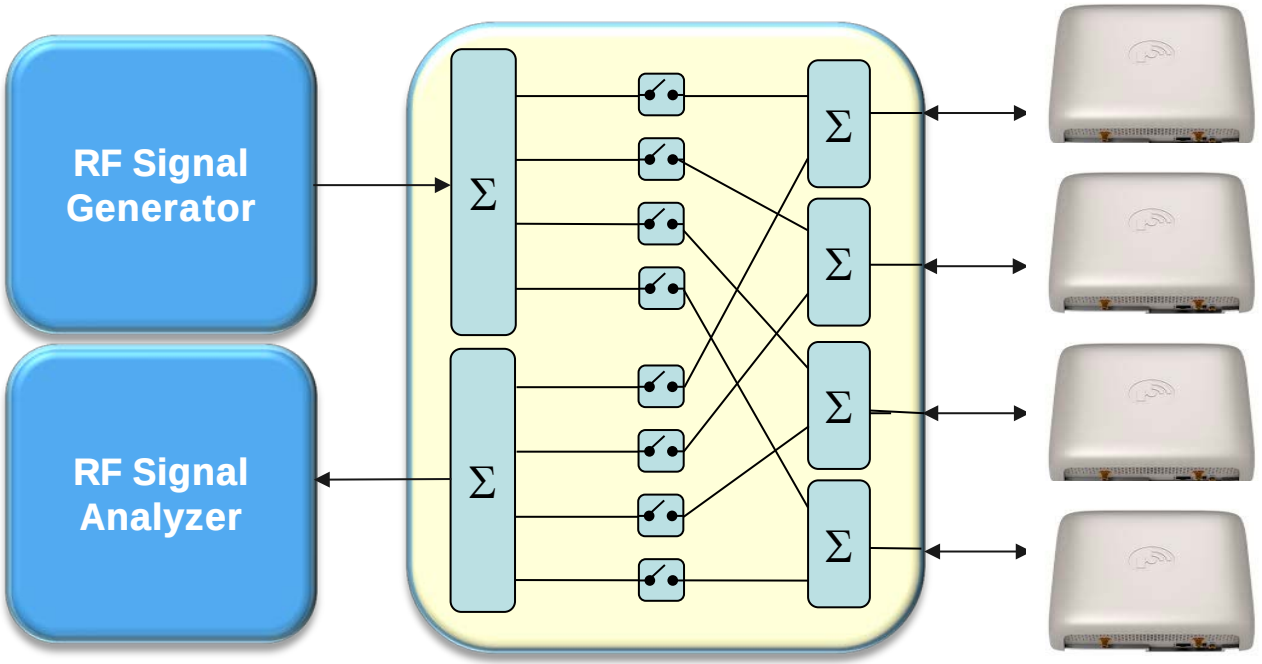
- RF resources are available to DUTs at the same time
- Broadcast
  - Signal generator transmit to all DUTs at once (synch to all DUTs)
  - Signal analyser receiving from all DUTs
- Benefits:
  - True parallel test
  - Single PC
  - Common boot time



Multi-DUT Concepts

Approach #4 - Combination

- Multiplexed *and/or* shared resources
  - Broadcast to all Rx & switch between all Tx
    - Parallel Rx test & sequential Tx test
  - Switched between each DUT Rx and Tx
    - Sequential test



Multi-DUT Concepts

Design Considerations for RF signal conditioning

- Frequency range
- VSWR
- Amplitude flatness
- Input power handling
- Port isolation
- Temperature stability
- Low insertion loss
- Path loss equalisation
- Switching time