무선 기지국 시스템 설계의 새로운 접근 – Samana 기반 통합 플랫폼 구조

ADI 한민석 과장

Senior Field Application Engineer

Radio Access Network (RAN) Building Blocks and Partitioning

RAN Architecture

Three blocks: **RU** (Radio Unit), **DU** (Distributed Unit), **CU** (Central Unit)

Split Trade-off

Higher splits → more fronthaul throughput and tighter latency

4G / LTE (Split-8)

Time-domain I/Q samples sent via CPRI protocol to the baseband unit (DU + CU). A single 20MHz carrier in 4Tx/4Rx configuration needs 5Gbps

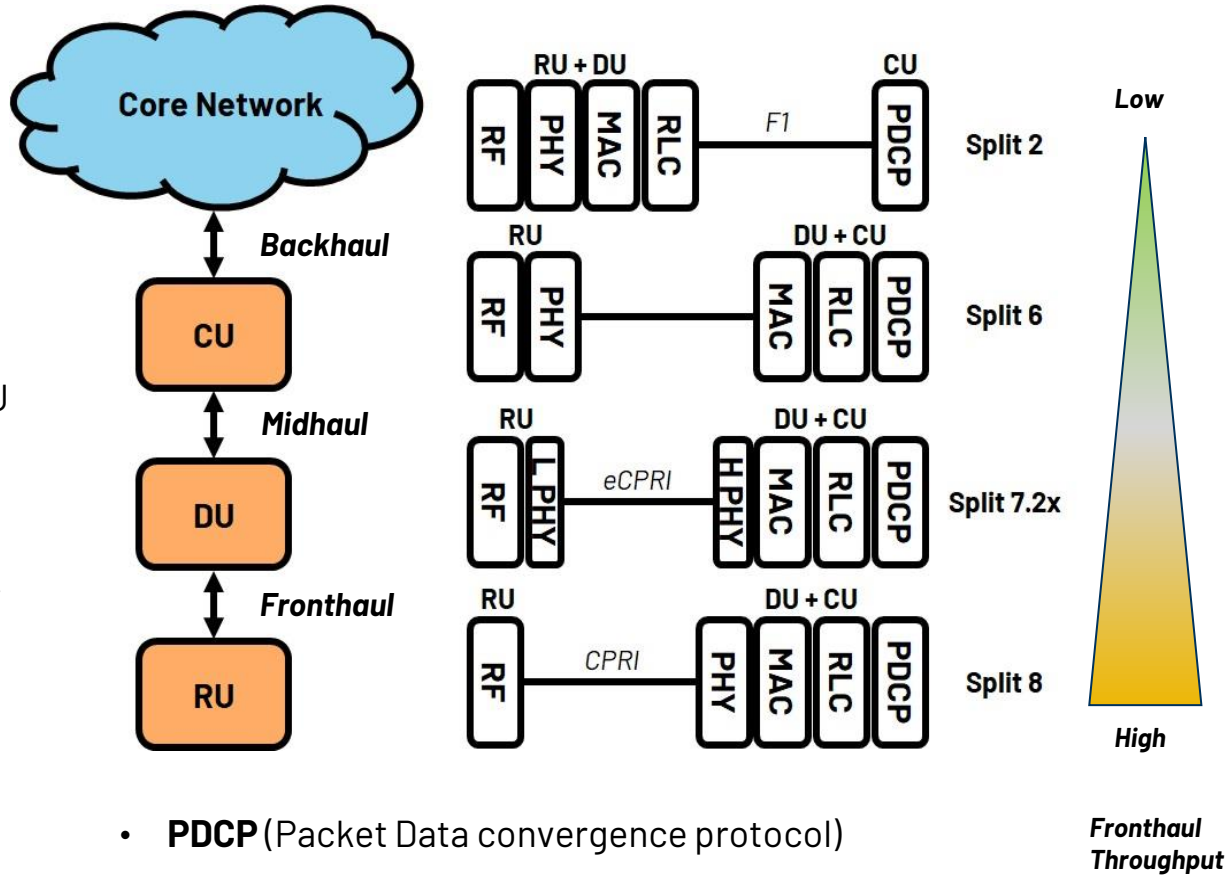
5G Macro / Massive MIMO (Split 7.2x)

Split-8 impractical for wider channel BW and more Tx/Rx chains in 5G. By moving the low-PHY processing from DU to RU, the fronthaul throughput is significantly reduced.

In Split 7.2x, frequency domain I/Q samples are transferred via eCPRI protocol between the DU and RU.

All-in-One Small Cell Radios (Split 6)

For a self-contained small cell with limited coverage and capacity it may makes sense to put RU and DU in the same box.



- **PDCP** (Packet Data convergence protocol)
- **RLC** (Radio link control)
- **MAC** (Media Access Control)
- **PHY** (Physical layer)

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Formation of the Open Radio Access Network (O-RAN)

Mission: Transformation of the RAN into an Open, Intelligent, and Virtualized system

O-RAN ALLIANCE

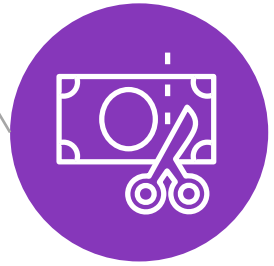
- Over 300 Members
- 32 Mobile Network Operators
- Over 147 unique Technical Titles

Supply Chain Diversity

Open & Interoperable Interfaces Enables RU, DU and CU purchase from Best-in-Class Vendors

Increased Innovation

Separate Hardware & Software Enables Large Community of Innovators



Lower Costs

RAN Virtualization (mainly in DU and CU) Enables Use of COTS Servers, similar to Data Centers

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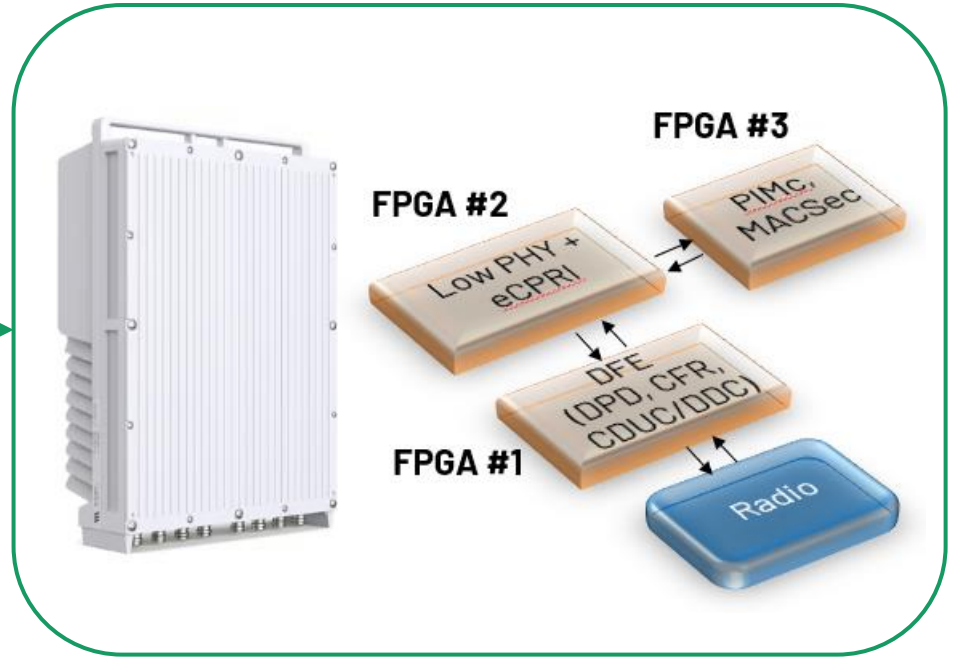
ADRV906x (Samana) – Full Featured Radio on a Chip – No FPGAs!

4G/5G Macro Radio Unit

Implementation with FPGAs



Samana

Radio on a chip

Total Power 15W*

Application requirements

- Small & Lightweight
- Low Power
- Cost Optimised

Challenges with FPGAs

- FPGAs drive **High Cost** & **Power** (>50W)
- Power drives **Weight**
- High IP integration effort for customers

Samana provides

- **Low Power** Consumption RU SoC (***15W****)
- Full System Integration into single IC
- Up to **30% BOM cost savings** by eliminating FPGAs

*15W is for TDD 4Tx/4Rx, 200MHz Carrier BW and 70/30 DL/UL ratio

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Introduction to O-RAN Open Front Haul Interface

ADRV906x (Samana) integrates an eCPRI fronthaul interface compliant with O-RAN split 7.2a standard

eCPRI – enhanced Common Public Radio Interface: Standard Ethernet based protocol for transferring data and control signals between RU and DU. O-RAN Open Fronthaul Interface complies with eCPRI and further specifies:

User Plane (**U-Plane**): messages containing frequency domain I/Q data samples that are transmitted or received.

Control Plane (**C-Plane**): real time control information regarding handling of User Plane data such has how to map the IQ samples to each antenna port.

Synchronization Plane (**S-Plane**): Precision Time Protocol (PTP) messages based on IEEE1588 to synchronize the RU to the rest of the network.

Management Plane (**M-Plane**): slow control and **radio configuration** information **(USE CASE CONFIG)**

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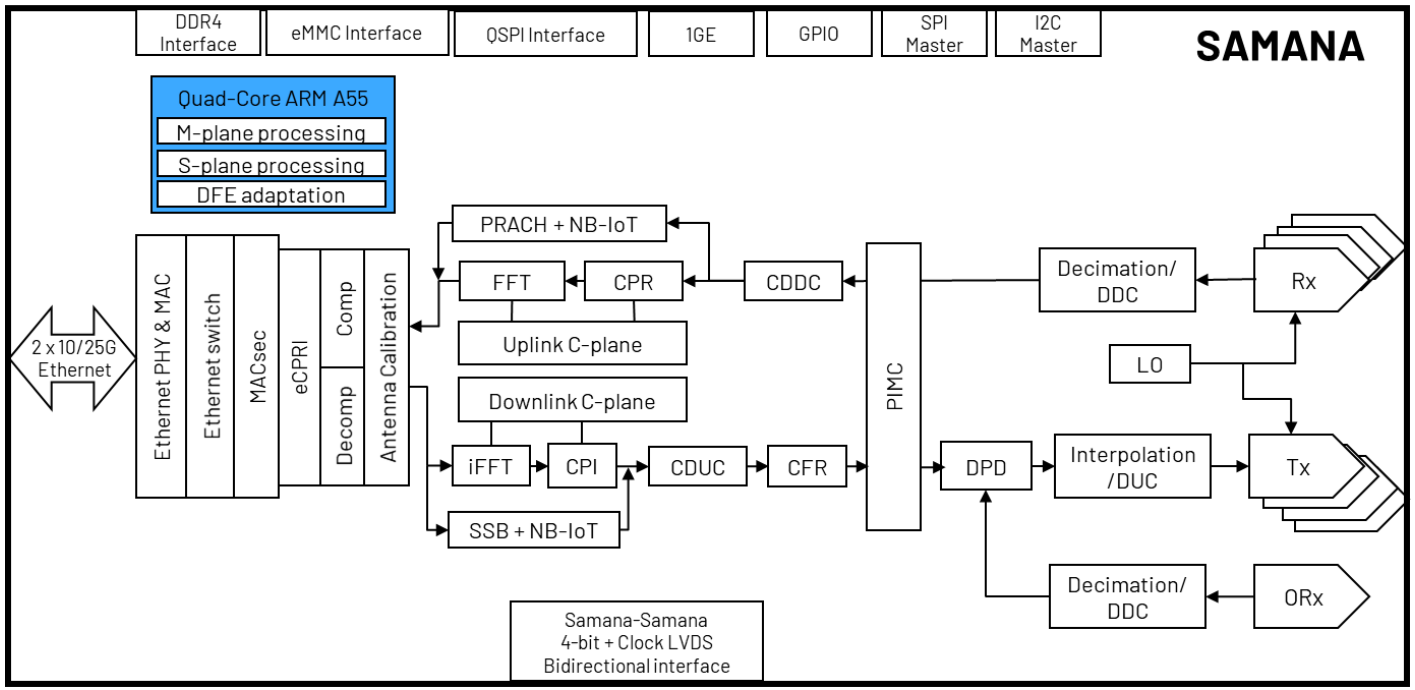
Samana – 4T4R / 8T8R Radio + DFE + Low PHY

Feature	Support
Antennas	4T4R (expandable to 8T8R) – 16nm
Air Interface	NR FR1, LTE, NB-IoT
Functional Split	7.2x cat A, no beamforming
Duplexing	TDD and FDD (including PIM cancellation)
Instantaneous BW	660 MHz
Occupied BW	400 MHz
Synchronization	IEEE1588 PTP or 1 pps + ToD; SyncE
Processor	Quad-core ARM A55
DPD sub-system	DPD Gen6 - LDMOS/GaAs/GaN PAs, > 40 W
External Memory	DDR4, NAND flash, NOR flash
Fronthaul Interface	2 x 10/25G ethernet, O-RAN compliant eCPRI
RF Interface	4T4R10, 400 MHz to 7.125 GHz



- Adds more processing at the edge (on the Radio)
- Reduces the BW that needs to be sent to DU/CU – Frequency domain data + on-chip compression
- Adds Machine learning performance optimization at the edge

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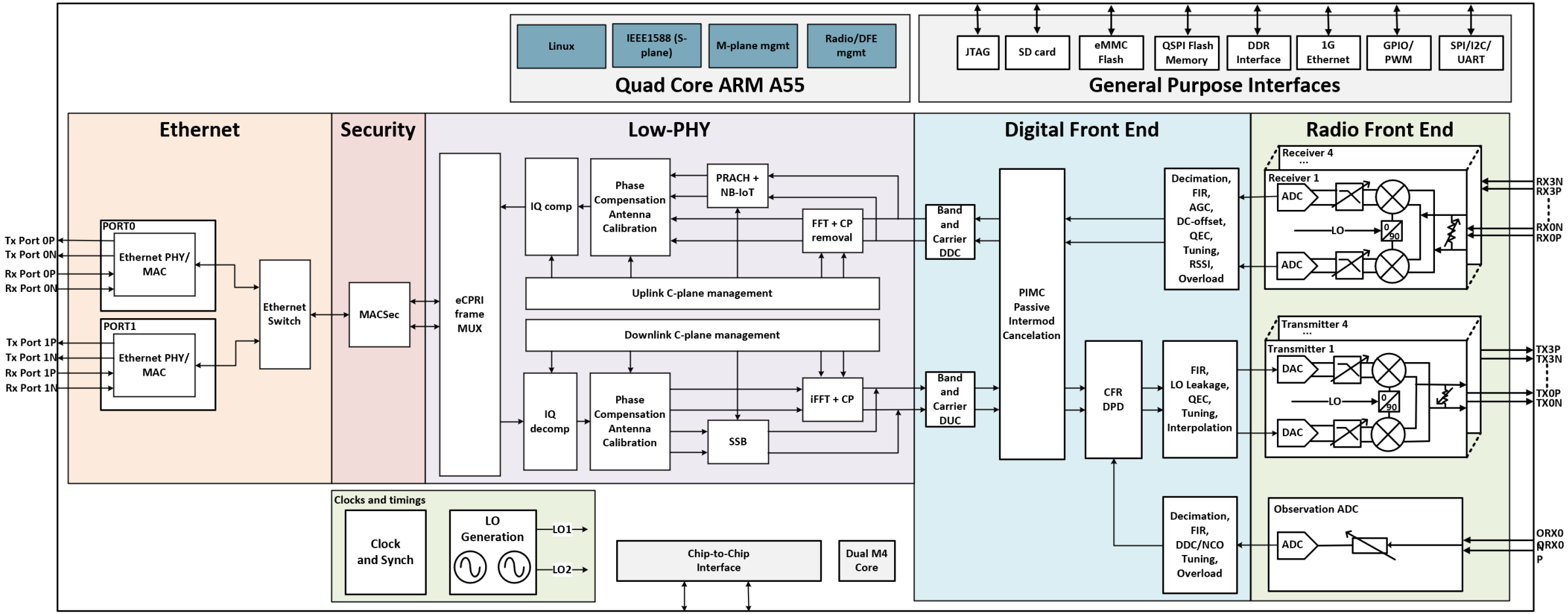
Samana Detailed Block Diagram



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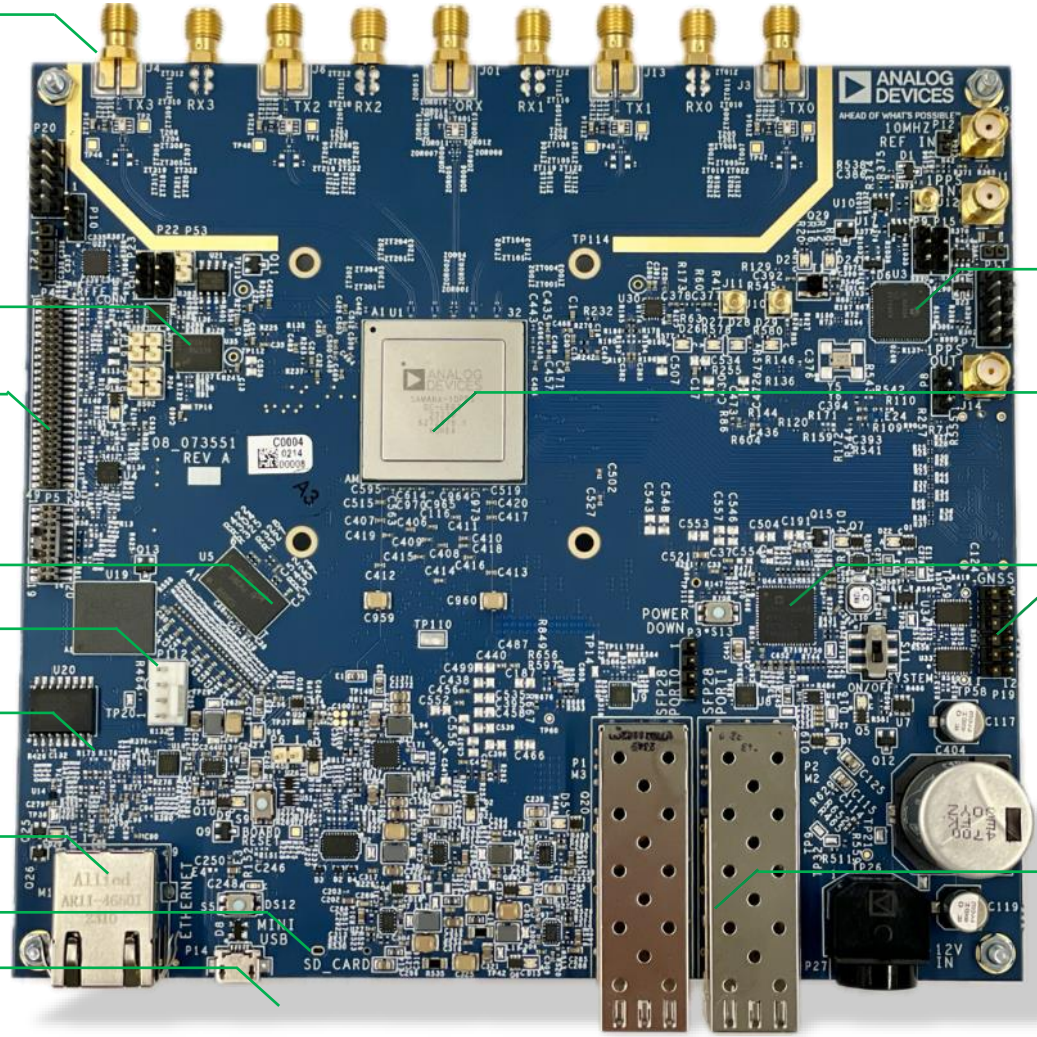
Complete Radio Board Design with Samana



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Samana Multi band Use Case Support

Samana enables far greater flexibility in use case planning with a single transceiver device

When layered with the LO distribution capabilities more frequency band combinations can be supported.

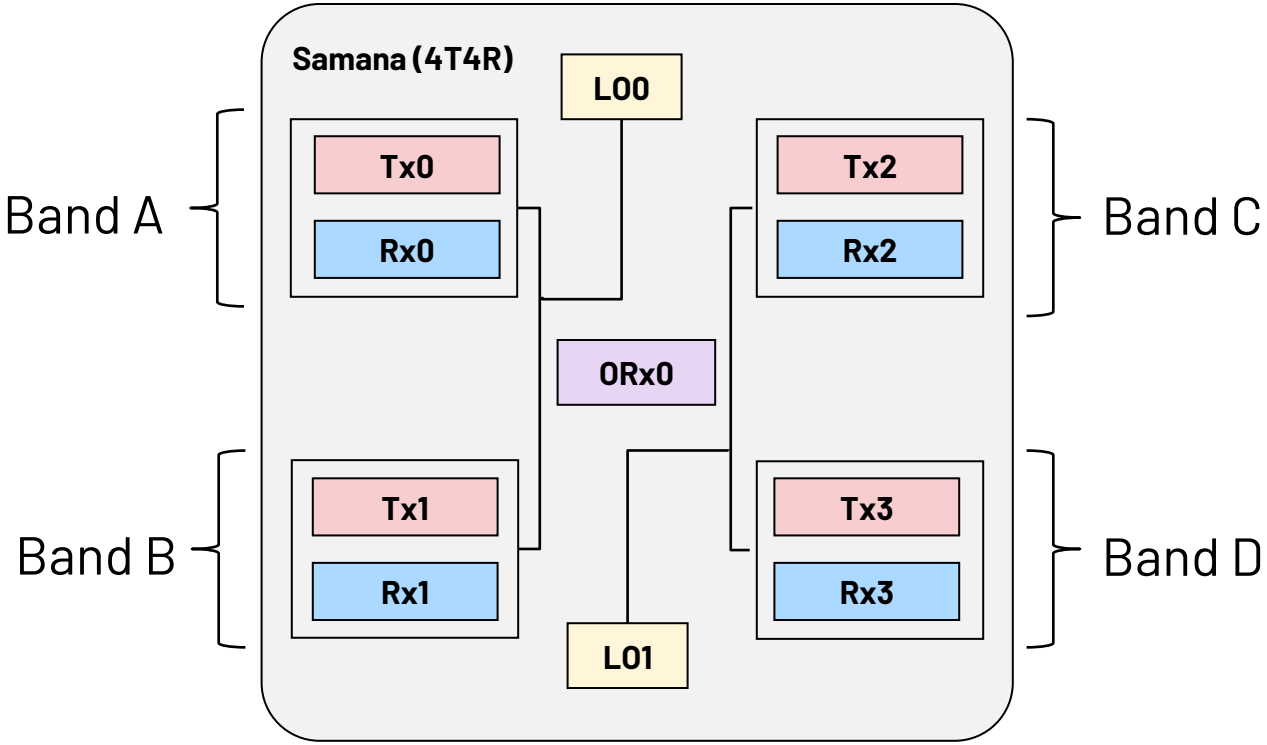
- **Mixed mode TDD and FDD is supported**

With an 4T4R device, up to 4 “band profiles” can be supported within a single use case:

- 1 x 4T4R → Common profile deployed on all Rx, Tx, ORx channels
- 2 x 2T2R → Can use Tx/Rx[0,1] for 100MHz application and Tx/Rx[2,3] for 400MHz application
- 4 x 1T1R → Can use a different use case for each pair of Tx/Rx channels

Allows 4 individual “band profiles” (>400MHz IBW) to be used in the device

LO0-LO1 – 400M-7.125G



- Above example shows support for 4 Bands with single Samana 4T4R
- Flexibility in LO0/LO1 routing
- Multi band support limited by RF Frontend bandwidth and power

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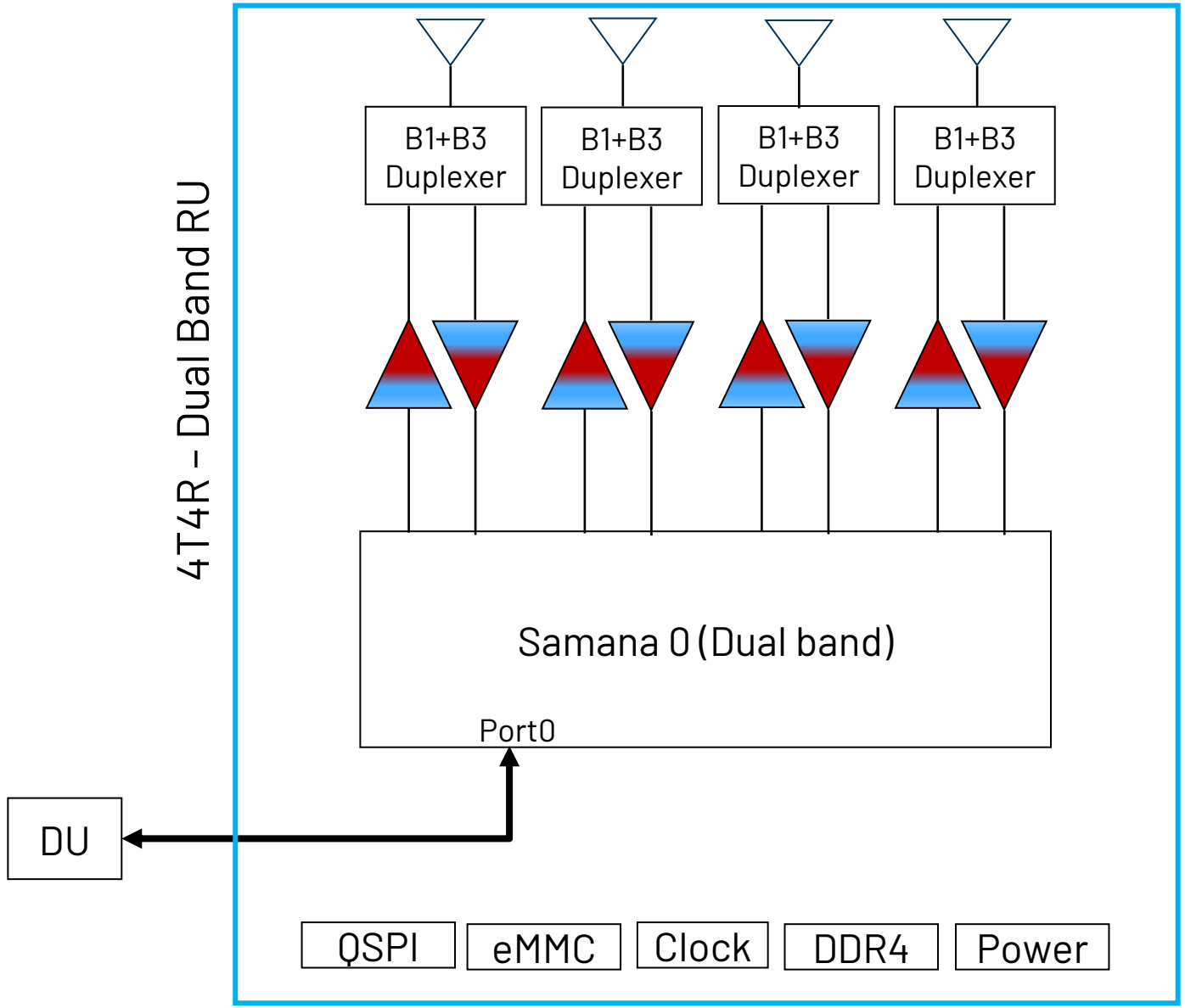
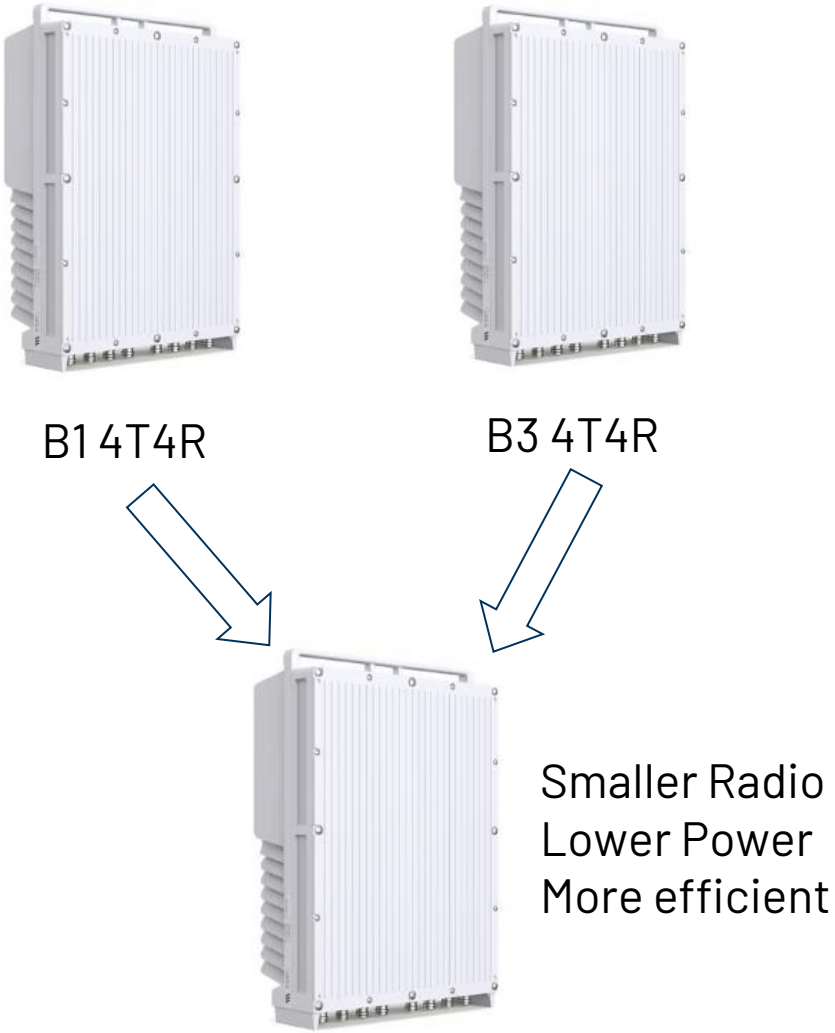
Samana Dual-Band use case example (B1+B3 – 4T4R)





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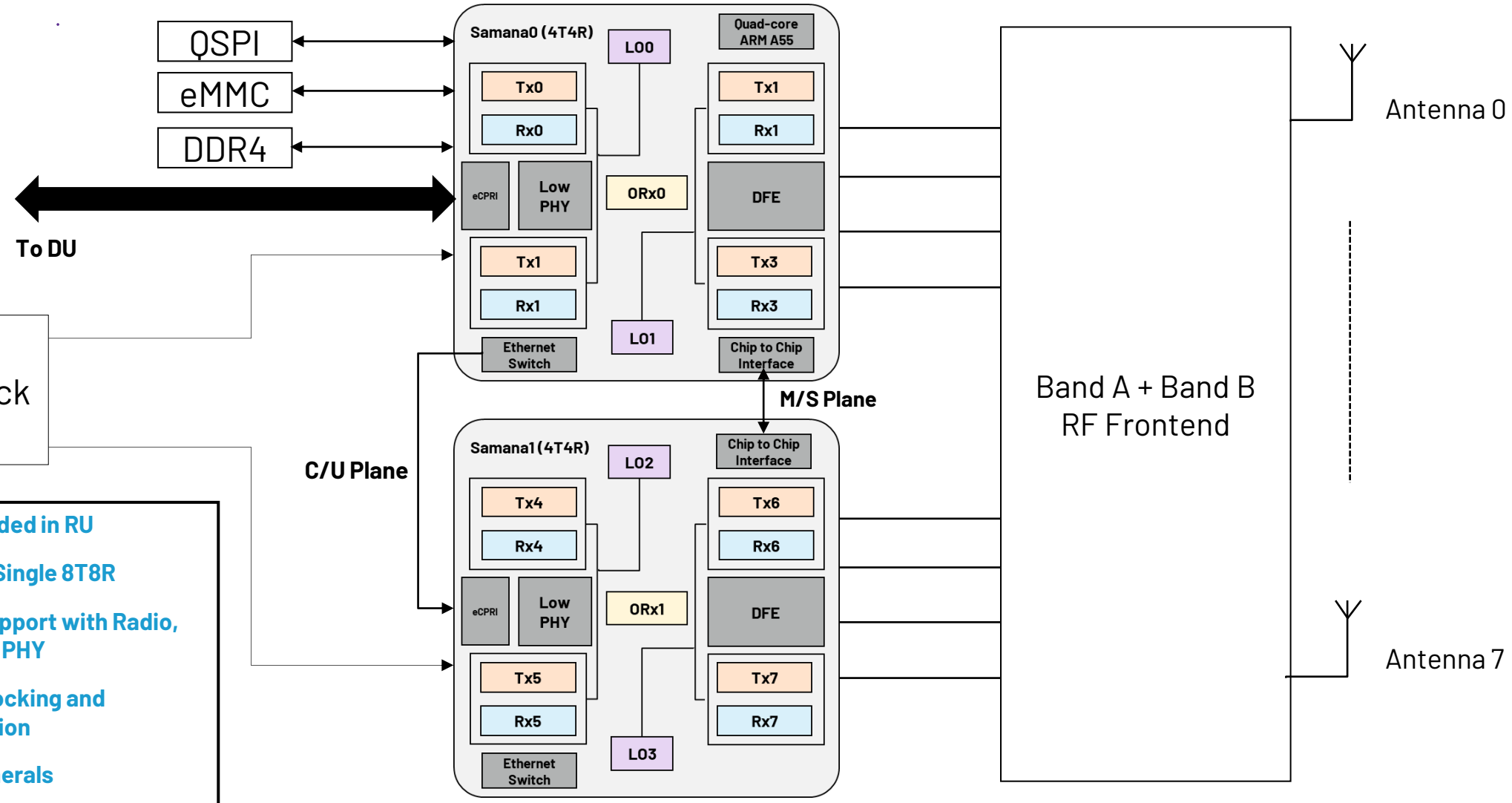
Samana Multi band Use Case Support (8T8R Tiling)



- No FPGA needed in RU
- Operates as Single 8T8R
- Multi band support with Radio, DFE and Low PHY
- Simplified clocking and synchronization
- Fewer peripherals
- >400Mhz IBW supported

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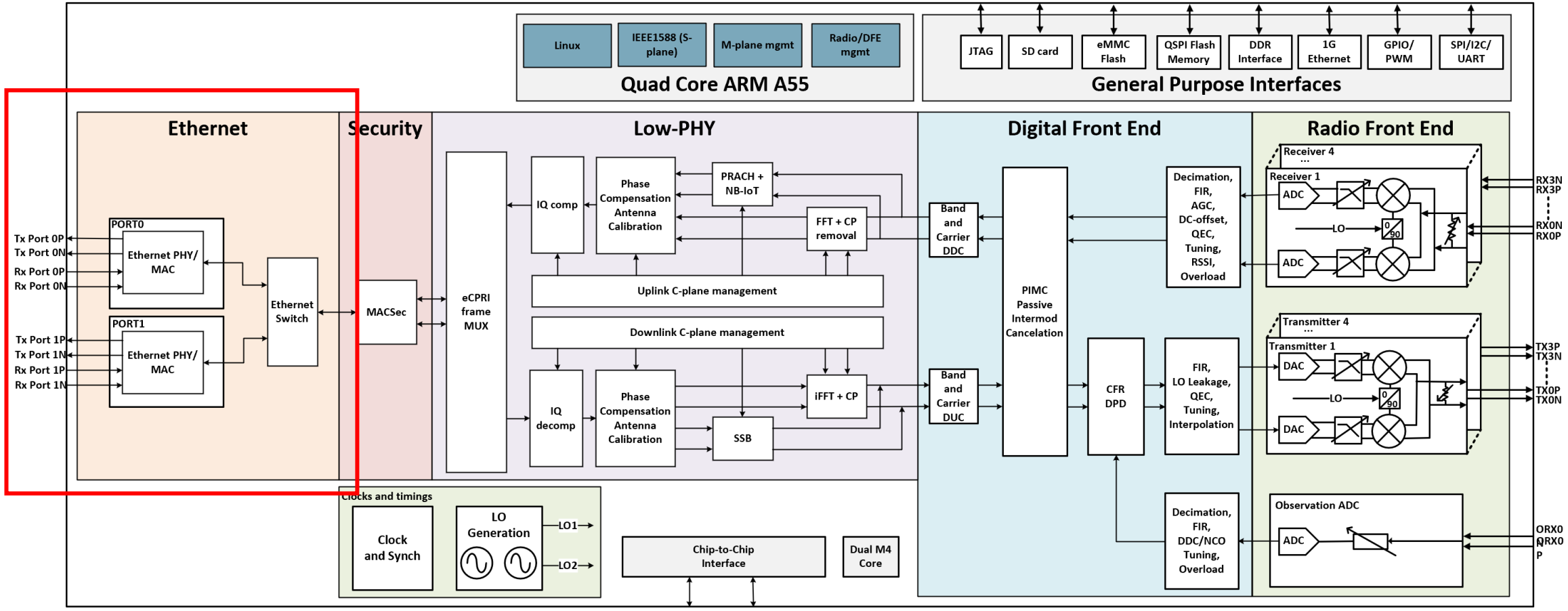
Samana Block Diagram – Ethernet Switch



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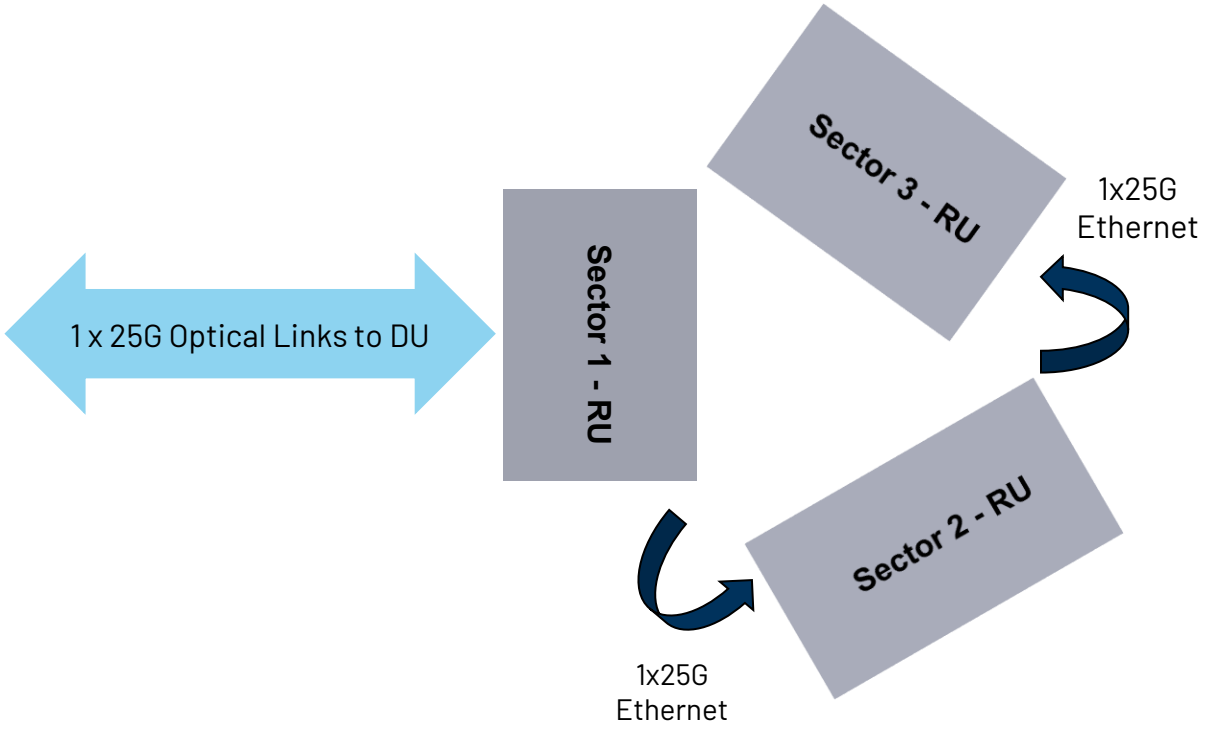
Fronthaul Daisy Chaining Use Case

Supporting 3 sectors with one Optical Connection

- Each cell tower typically consists of 3 sectors, and each served with one RU
- Assuming the carrier bandwidth for all 3 RUs fits on a single 25Gbps fiber, a single fiber can serve all 3 sectors.
- Single optical port assigned to primary Samana
- Internal switches in Samana to the other sectors (CUSM planes)
- 2 uSec packet delay across two hops
- Samana for sector 1 and sector 2 act as boundary clock



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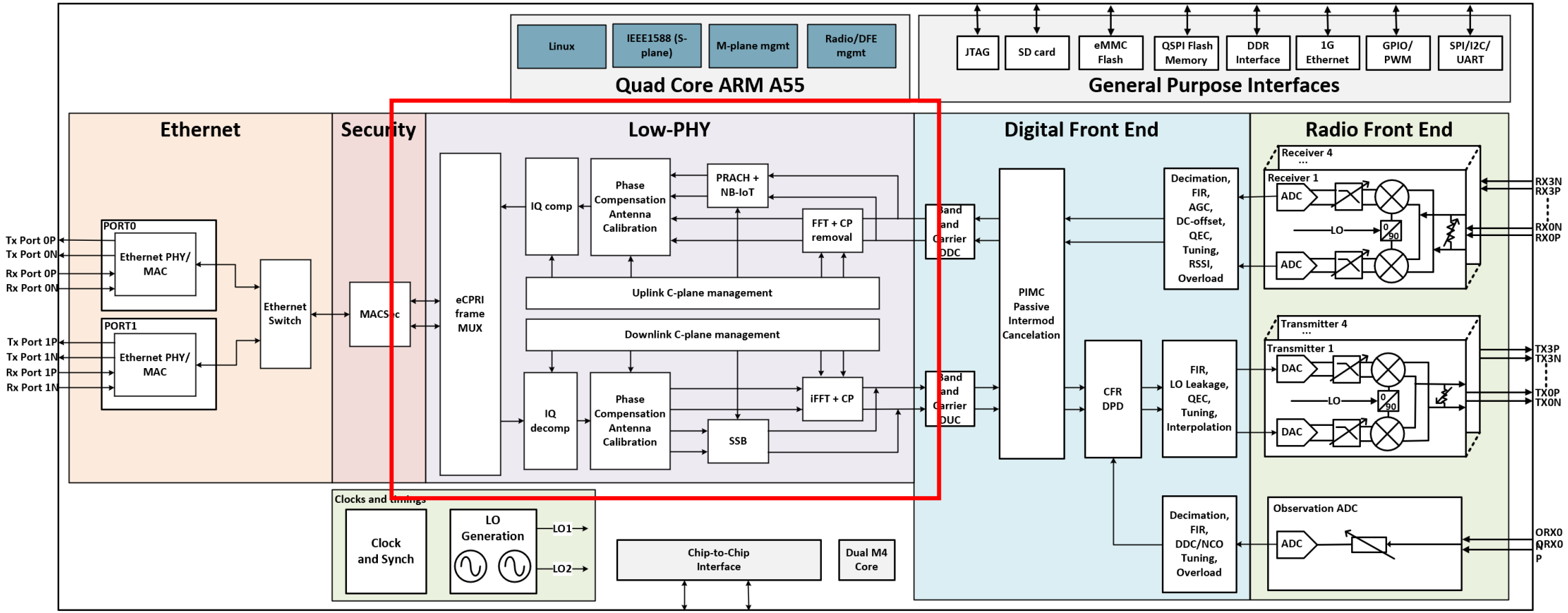
Samana Block Diagram – LowPHY



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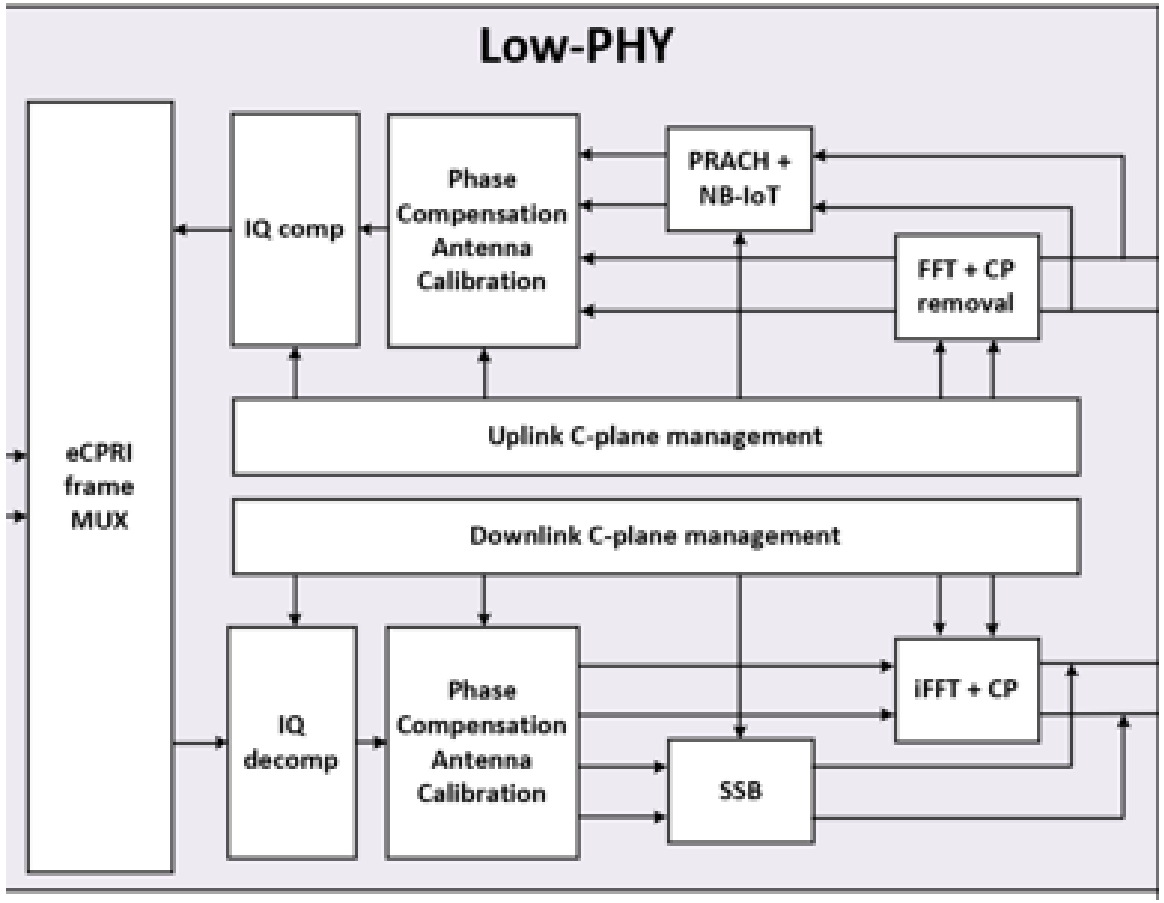
LowPhy Functionality

- Translates data from frequency domain to time domain and vice versa
- Interface between C/U plane ethernet data to Tx/Rx controls on the radio side
- Adds compression to reduce throughput requirement on the Ethernet interface
- Allows for phase compensation
- Adds support for NB-IoT
- Integrates real time autonomous antenna cal



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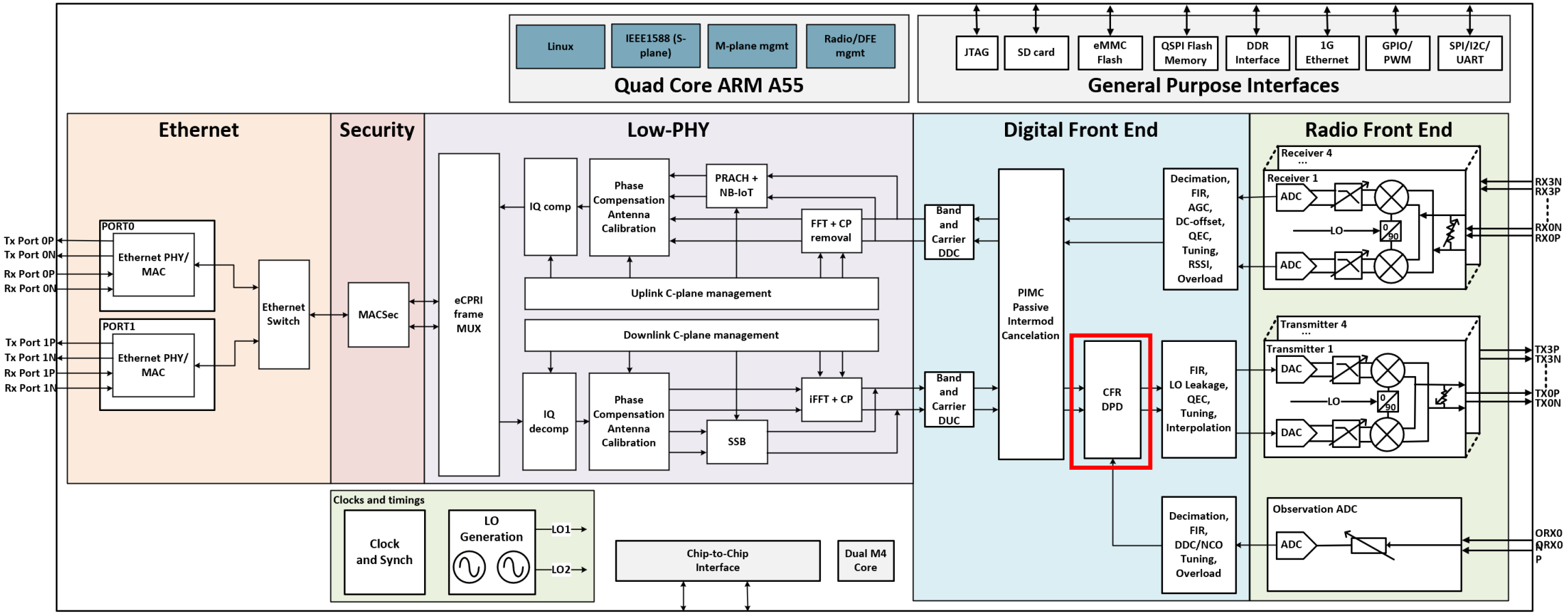
Samana Block Diagram – CFR and DPD Blocks



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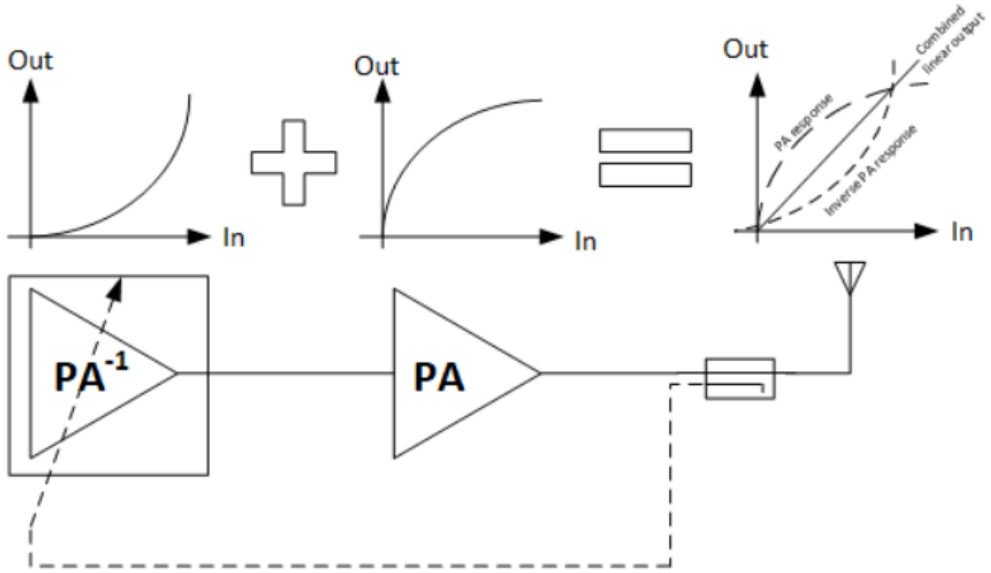
DPD Principle of Operation



- Why do we need DPD?
  - Having DPD enables use of highly efficient non-linear PAs such as Doherty
  - Base station can transmit more RF power to cover larger area while using less power
  - Reduces heat generated in the system allowing for reduced weight and thermal solution

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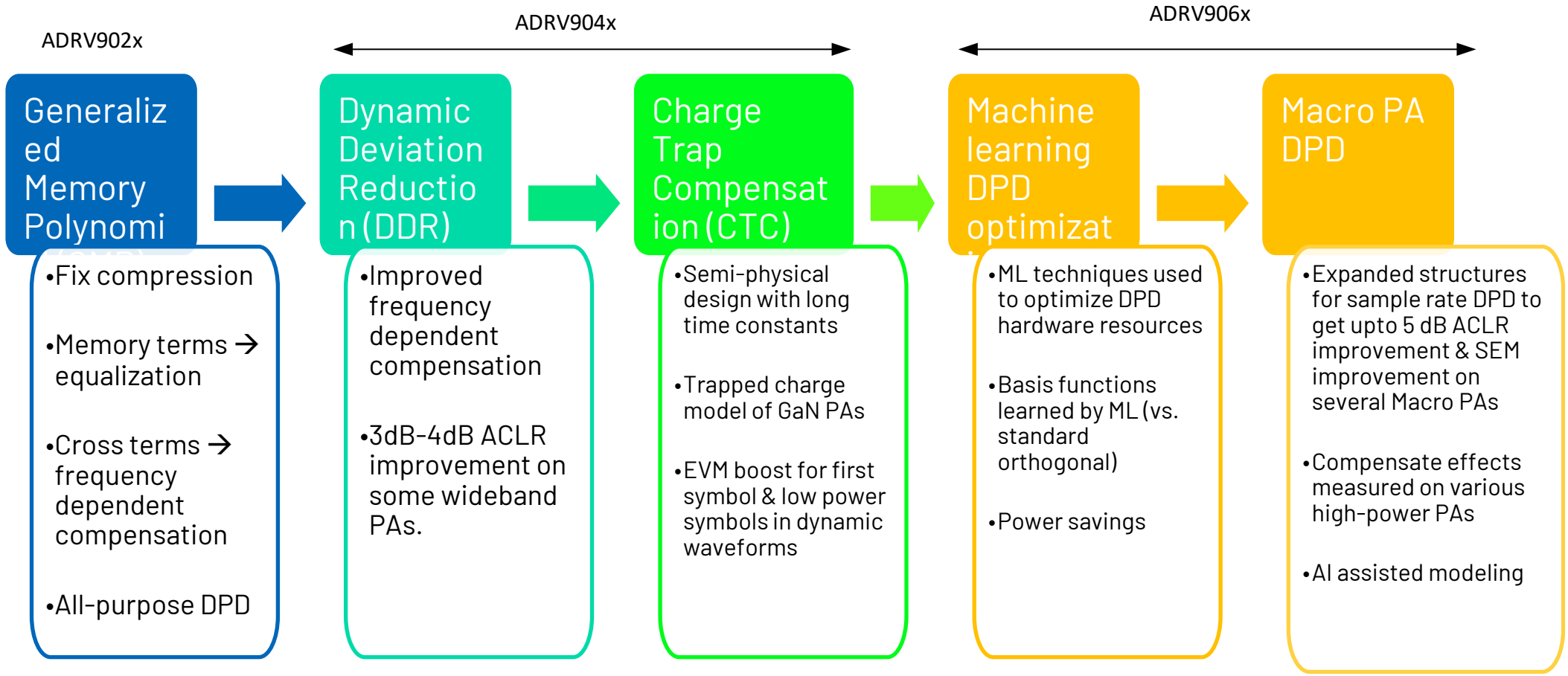
Evolution of the ADI DPD over Generations



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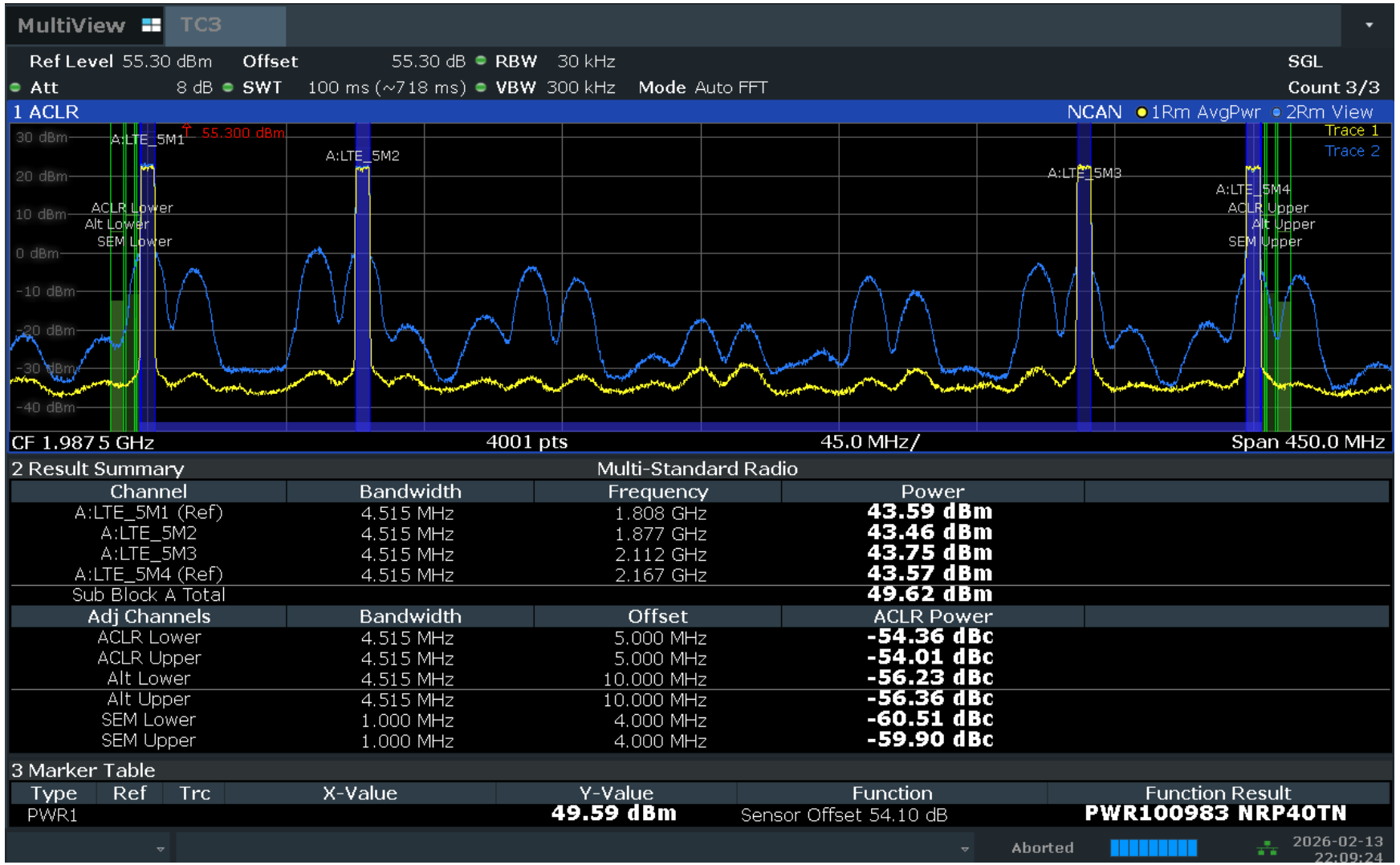
DPD performance on B1+B3 Wideband PA for Macro Cells

ADI DPD results:

Pout = 49.59 dBm
PA Drain Eff = 55.5 %
Lineup Eff = 51.5 %
DPD results: -54.0 dBc



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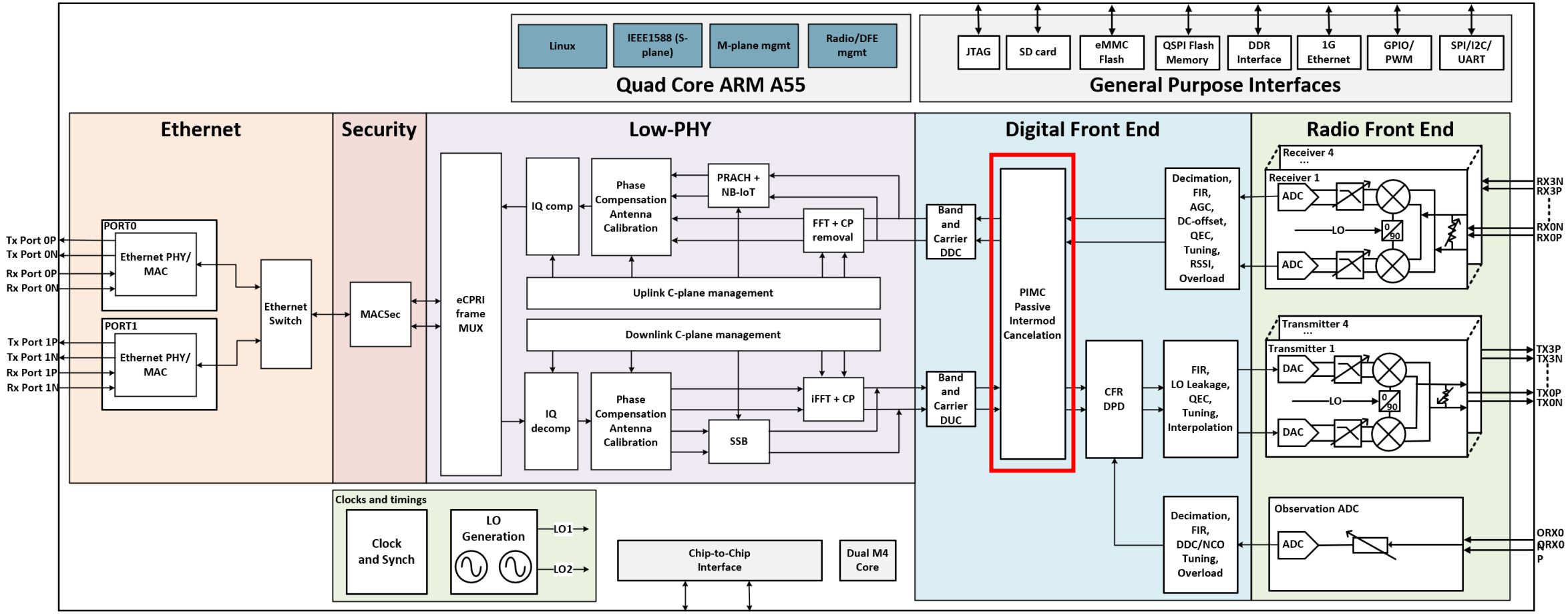
Samana Block Diagram – Passive Intermodulation Correction



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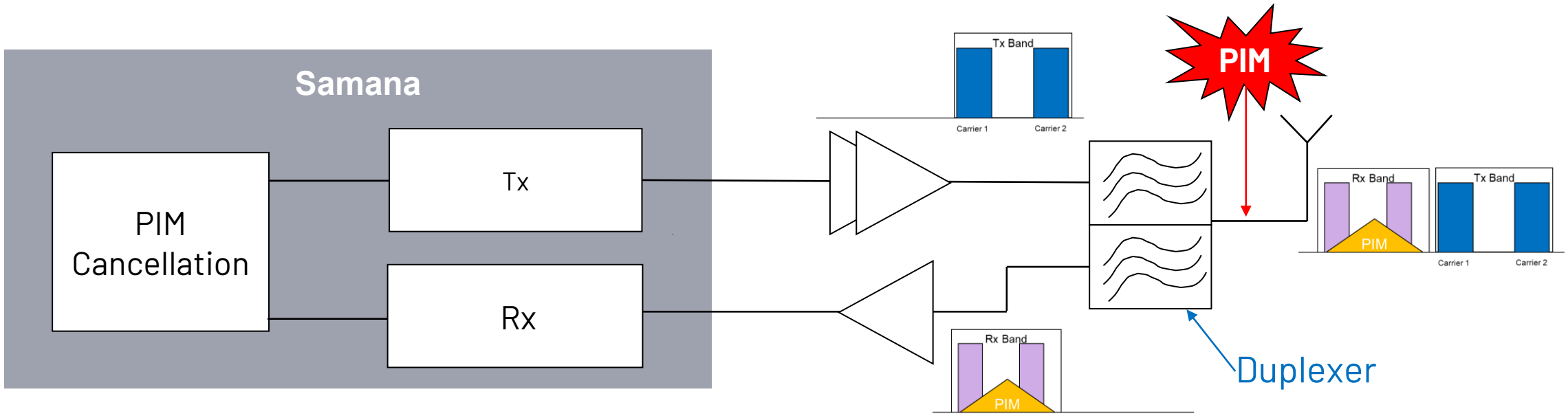
PIM Cancellation and Detection



- Passive Intermodulation (PIM) product falls in Rx band, and it will desense Rx
- PIM cancellation in TRx helps to maintain Rx performance
- Firmware can *detect* "**Assembly**" and "**Beyond the antenna**" PIM excursions
- This is key for Multiband Macro high power PAs to ensure optimum Rx performance
- ADI PIM on Samana helps with both Interband PIM and Intraband PIM

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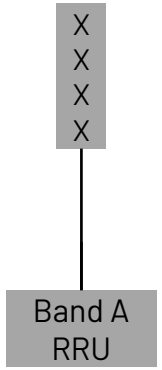
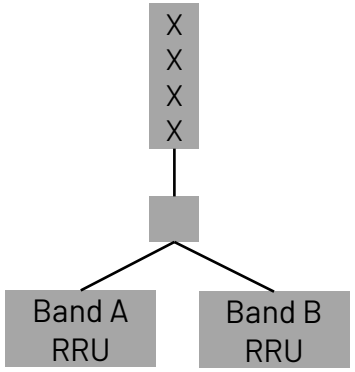
Supported Scenarios for PIM Cancellation

Single band



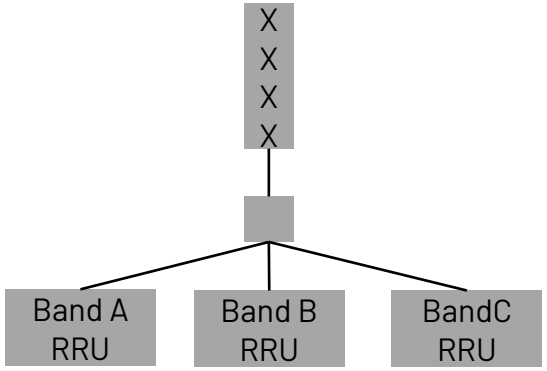
Dual band



Possible band combinations

B20+B8
B28B+B8
B1+B3
B1+B7
B29+B5
B66+B70

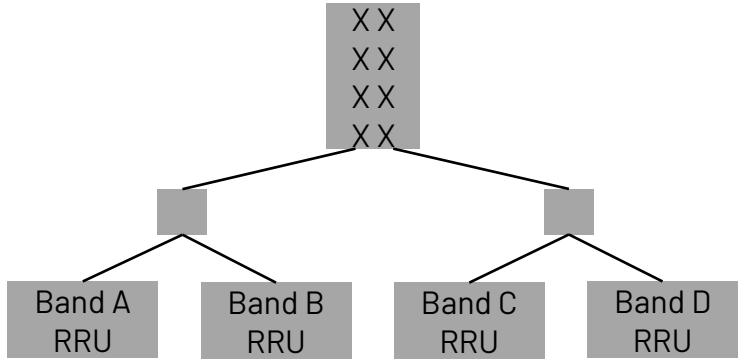
Tri-band



Possible band combinations

B28B+B20+B8
B1+B3+B7
B26+B29+B71

Multiple profile



Where Band C and Band D can be any dual band combination (cannot exceed 4 Tx channels)

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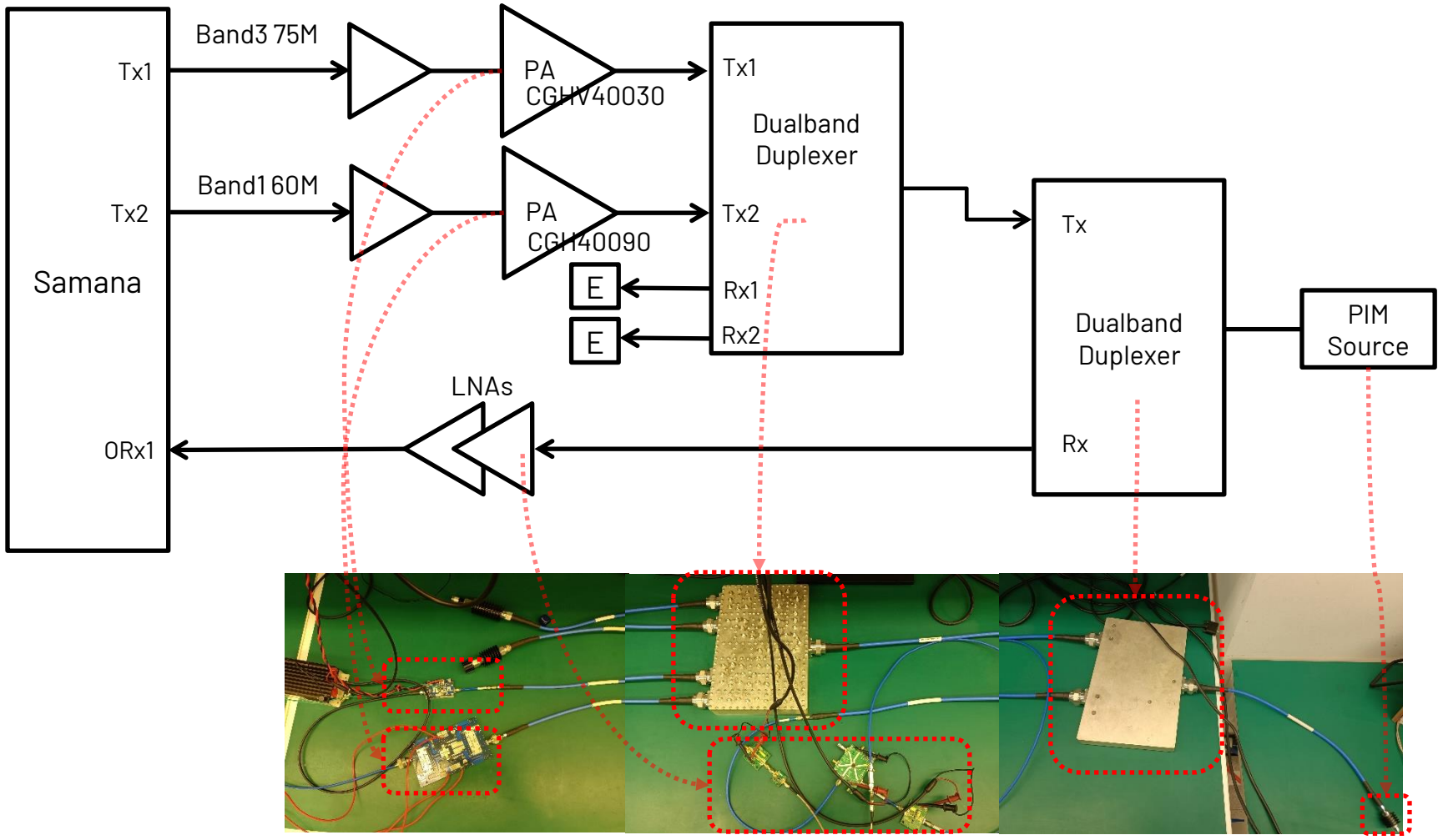
Example PIM Cancellation Test Setup



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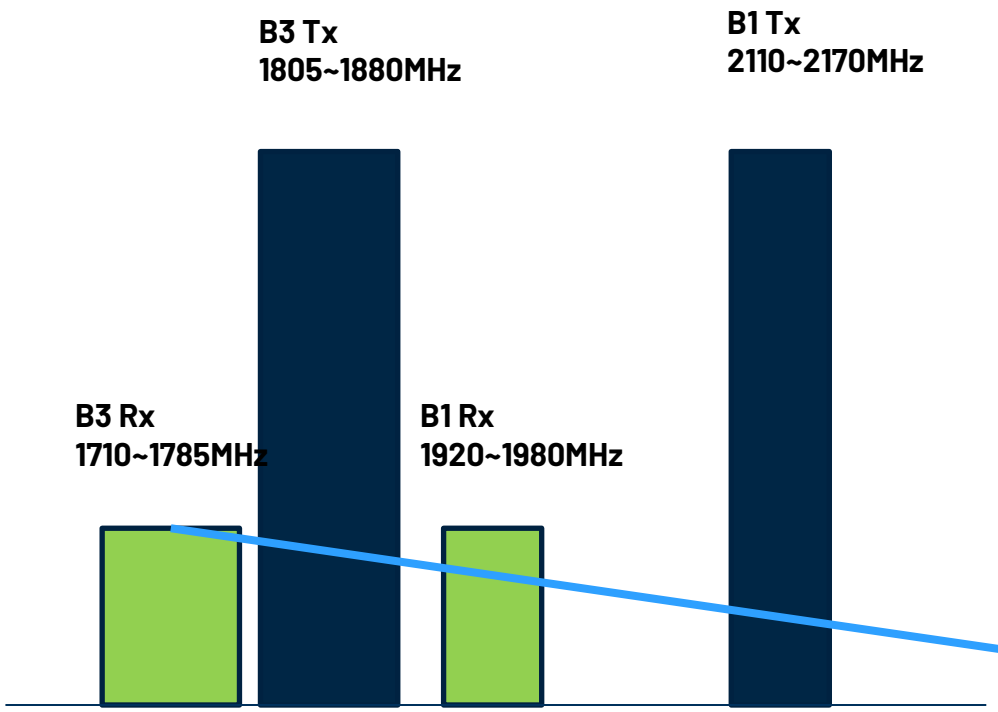
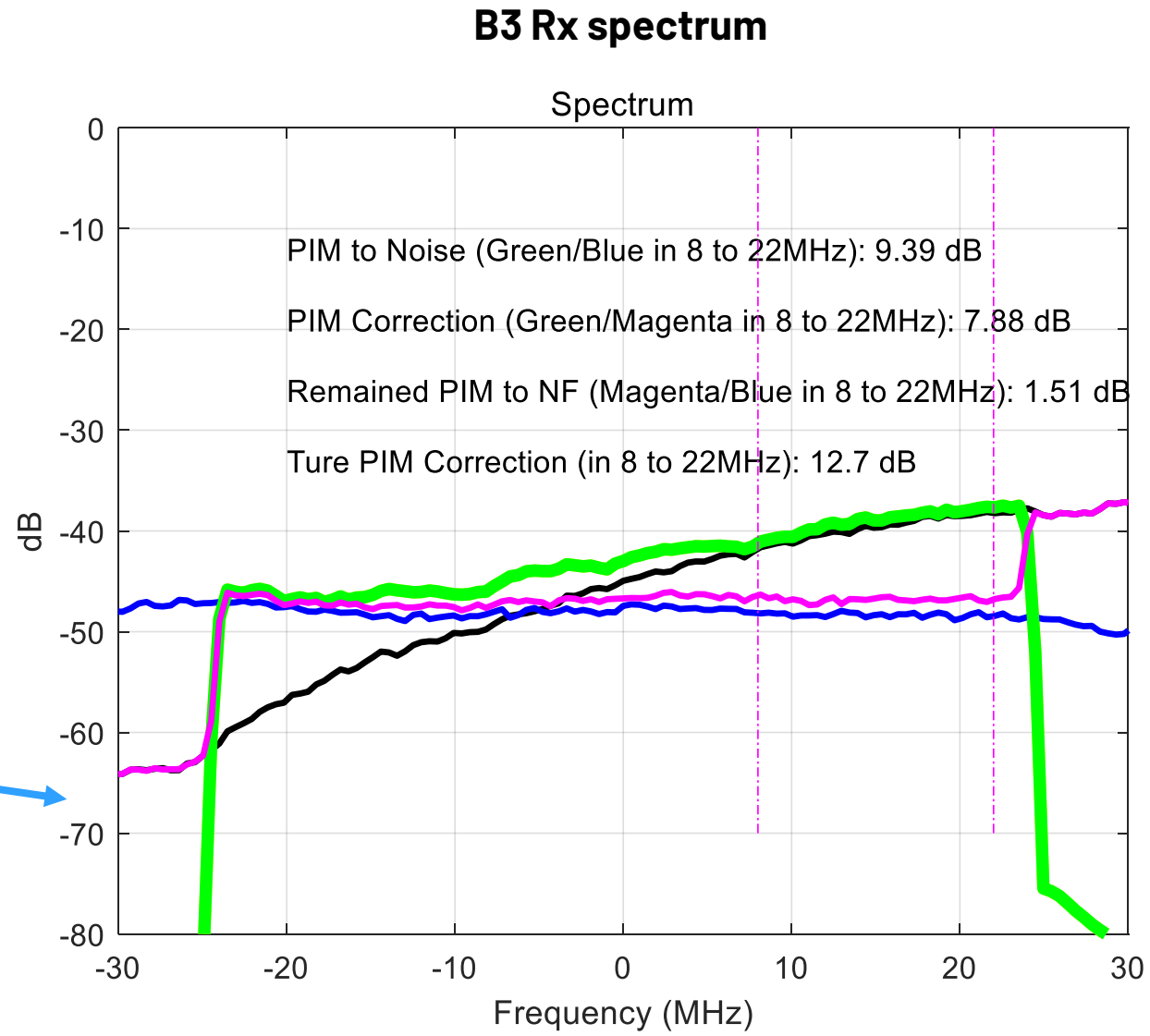
Example PIM Cancellation Test Results





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Thank you

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