Synchronisation Challenges in Next Generation RRUs

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Advanced Timing for High Speed Connectivity

Contents

- Traditional Base Station Sync
- Evolution of 5G and Front-Haul technologies
- Sync Architectures for next generation RRUs
- Air Interface clocking for 5G RRUs

4G Base Station Clocking functions

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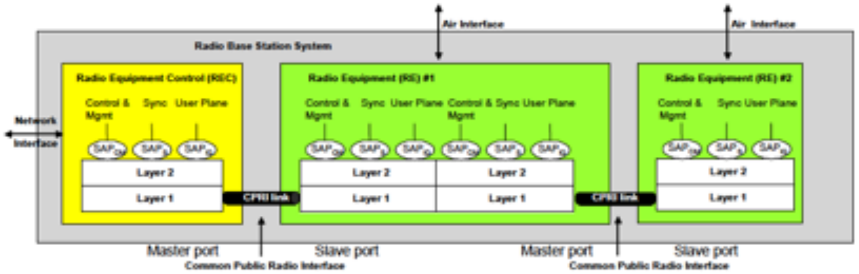
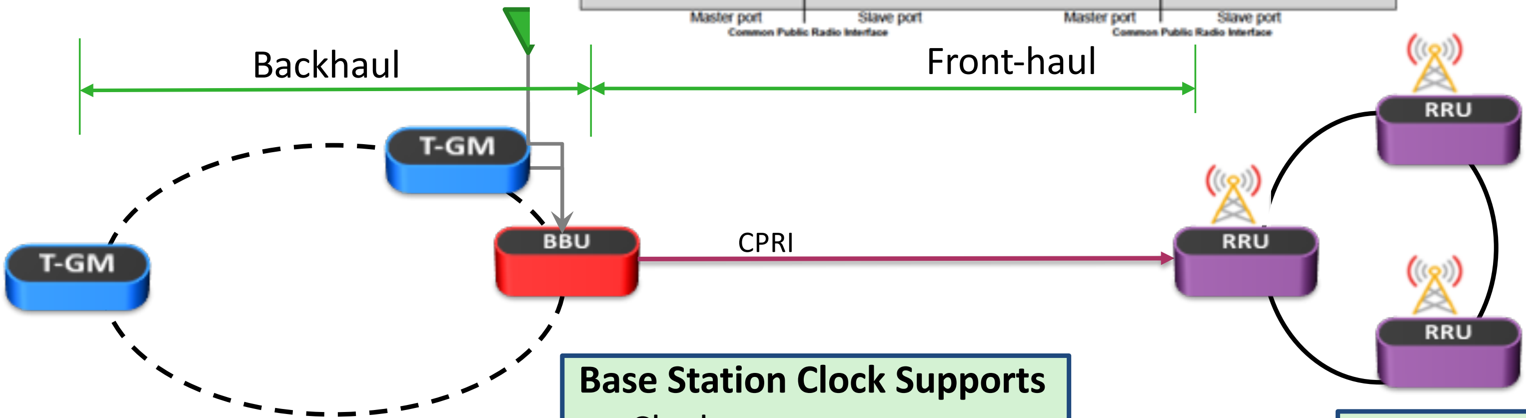


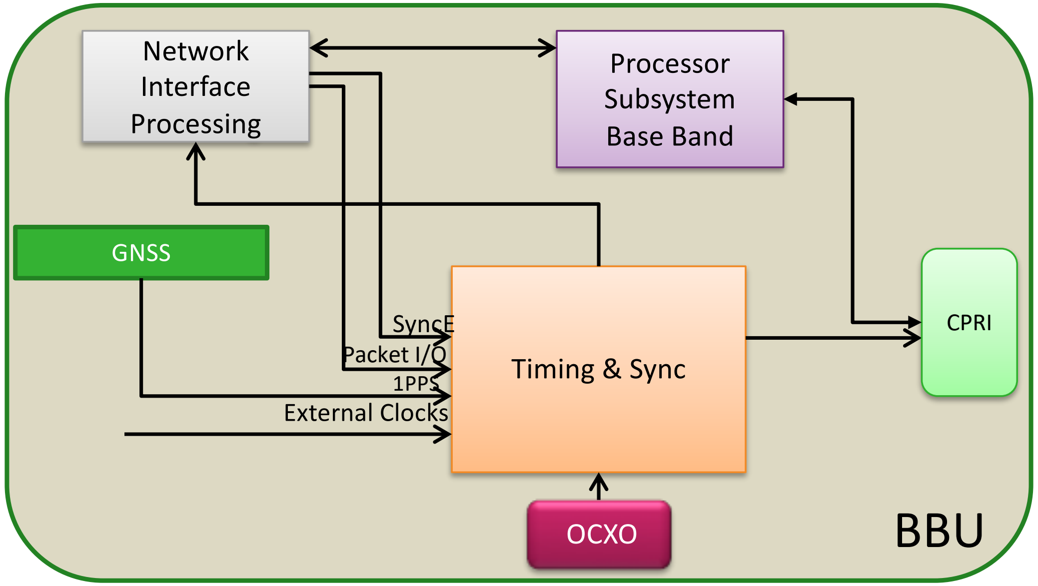
T-GM - Telecom Grand Master,
BBU – Base Station Unit,
RRU – Remote Radio Unit

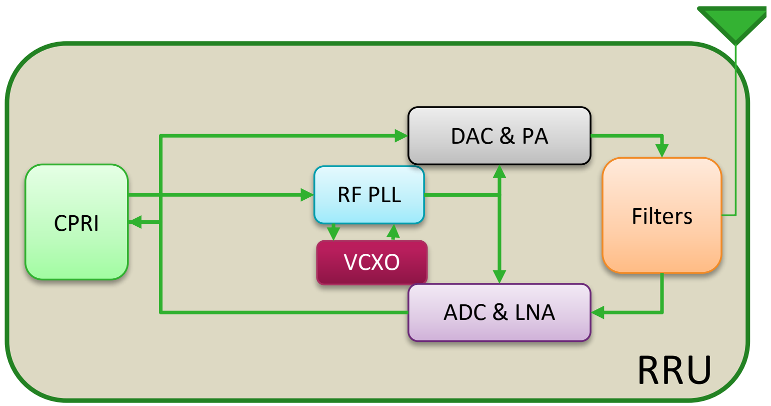


Base Station Clock Supports
- Clock recovery
  - GNSS
  - Physical Layer
  - Packet Layer
- Holdover

Radio Clock Supports
- Clock recovery
  - CPRI layer
- Air Interface requirements

Traditional Clocking Implementations





Next Generation - Physically disconnected RRUs

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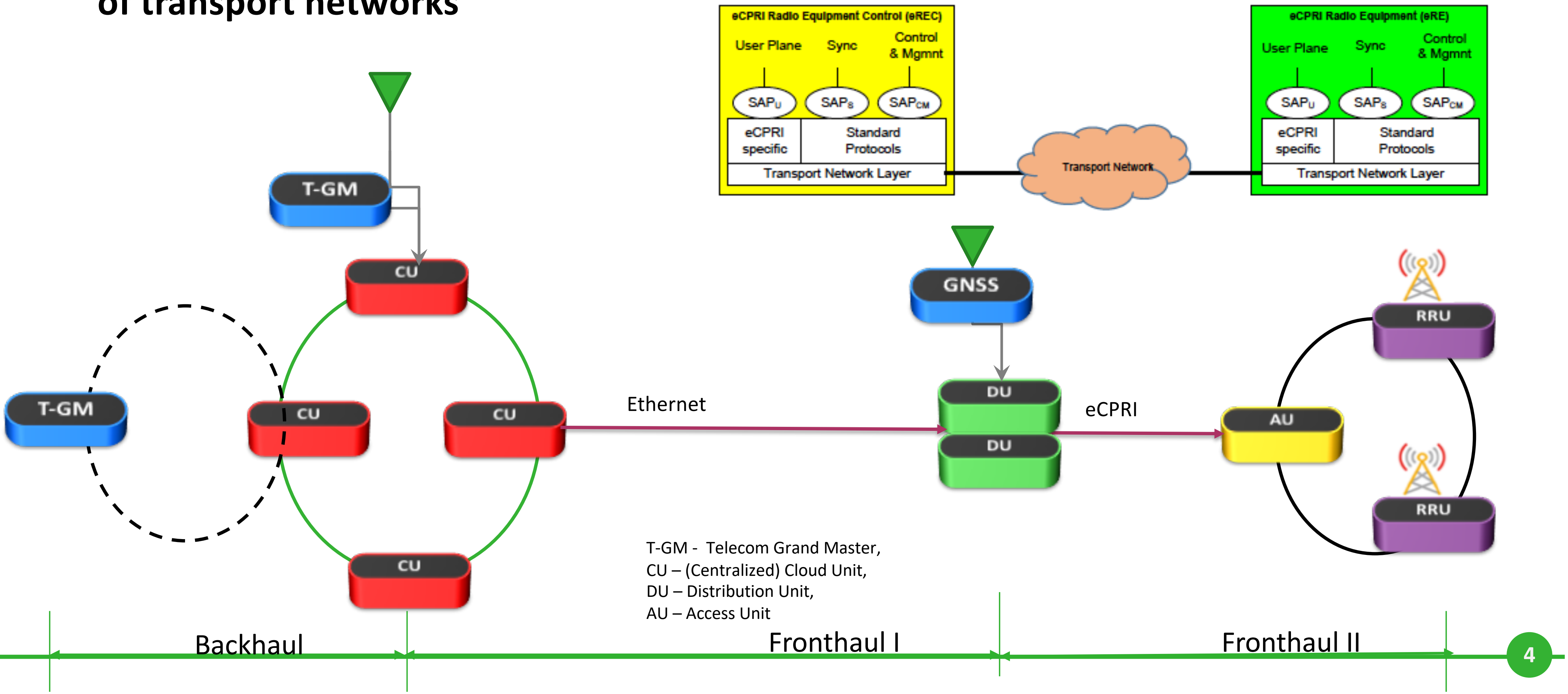
- eCPRI supports Ethernet-switched IP-routed front-haul networks, or similar types of transport networks



5G Cellular Synchronisation requirements

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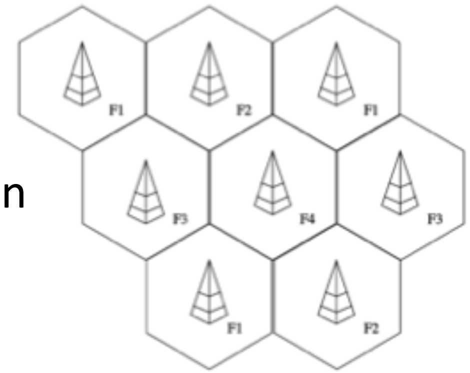
3GPP requirements

- Air Interface

LTE (FDD and TDD)	Wide Area	50ppb		3GPP TS 36.104 [7] Clause 6.5.1	Frequency accuracy at the air interface, over one sub-frame period (1ms)
	Med. Range	100ppb			
	Local Area	100ppb			
	Home	250ppb			
LTE-TDD	Wide area, >3km radius		10µs	3GPP TS 36.133 [8] Clause 7.4.2	Maximum deviation in frame start times at the air interface (for cells on the same frequency with overlapping coverage areas)
	Wide area, ≤3km radius		3µs		
	Home BS, >500m rad.		1.33 + T_{prop} µs		
	Home BS, ≤500m rad.		3µs		

[1] T_{prop} is the propagation delay between the Home BS and the cell selected as the network listening synchronisation source

- Network Interface
  - 16ppb



Holdover

- Hold previously known
- For x hours/days

Advanced features

- COMP, ICIC

5G will use the 4G synchronisation requirements for now

Transport Network requirements - Sync

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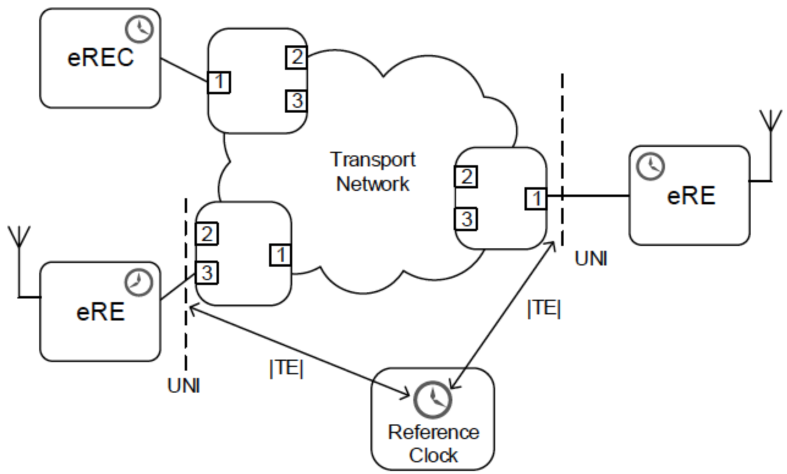
- **Transport Network Synchronisation**
  - Packet Sync Mechanisms such as IEEE1588
  - With or without SyncE
- **2 Cases for Deployment Scenarios**
  - Case 1 : Packet clock integrated into eRE
  - Case 2 : Packet clock at the network edge
    - 1PPS/ToD to eREs



Category	|TE| for case 1& 2	Applications Details	TAE proposed by IEEE801.CM		TAE (for Application)
			Case 1	Case 2	
A+	TBD	MIMO or TX diversity transmissions, at each carrier frequency	-	20ns	65ns
A	TBD	Intra-band contiguous carrier aggregation, with or without MIMO or TX diversity	60ns	70ns	130ns
B	TBD	A & Inter-band carrier aggregation, with or without MIMO or TX diversity	100ns	200ns	260ns
C	1100ns	3GPP LTE TDD	1100ns	1100ns	1500ns

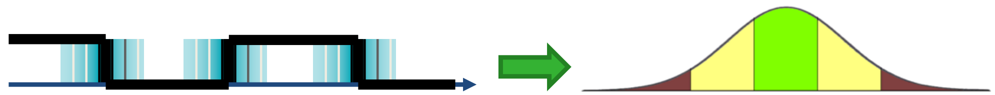
Challenges

- **Packet based timing recovery**
- **Environmental Aspects**
  - Higher temperatures of operation
  - Higher shock and reliability requirements
- **Higher Air interface spectral frequencies**

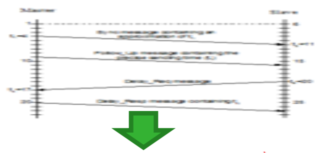
Packet Based timing recovery

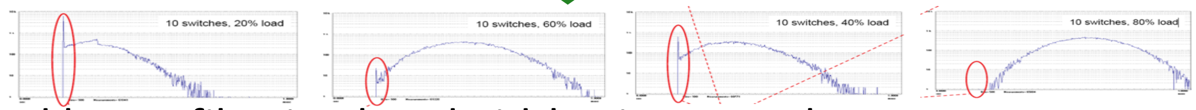
Physical vs Packet clock timing recovery

- Physical clocks -> stationary in nature with defined pdf



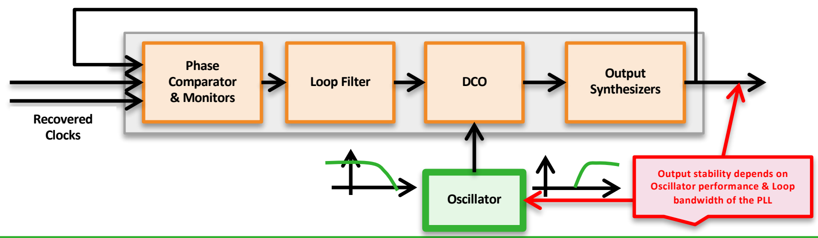
- Packet clocks -> Not stationary signals





- Packet clocks -> “Packet selection” and lower filtering bandwidths, in general

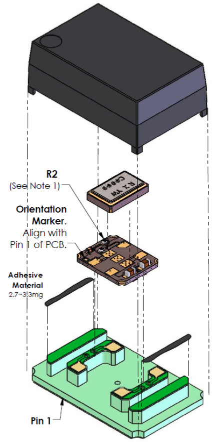
- For given error, lower bandwidths necessitates a more stable reference clock

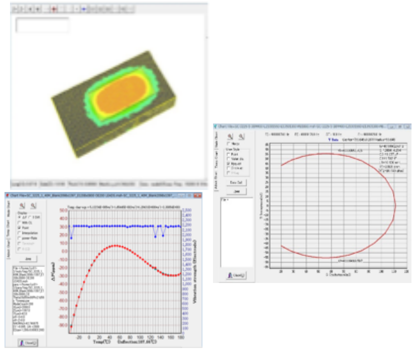


Environmental Effects

- **Higher Temperatures of operation**
  - Densification demands modular equipment configurations
- **Weatherproof outdoor equipment**
  - Fan-less, sealed enclosures designs
- **Massive MIMO RRUs**
  - Higher Power consuming radios
  - PCBs getting hotter > 85degC
- **Outdoor deployments**
  - Lamp posts & structures
  - Requires low shock & vibration

- **Reference Clocking challenges**
  - Higher temperature of operations
    - All IC, special process solutions

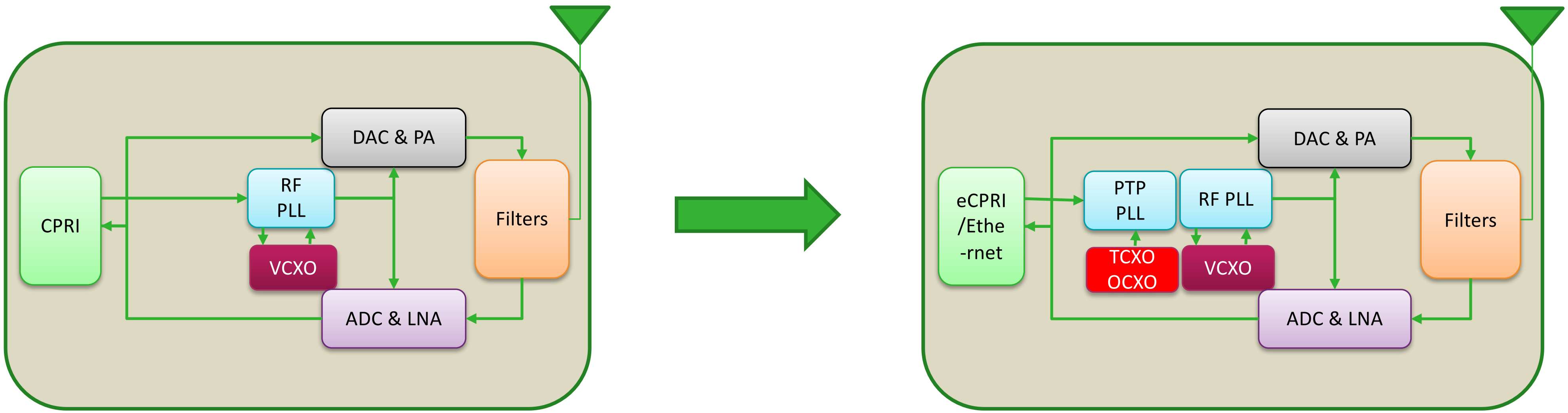




- **Reference Clocking challenges**
  - Special designs resilient to shock & Vibration
    - SC-cut strip crystal with G-sensitivity < 1ppb/G
    - Enhanced performance in vibration prone environments

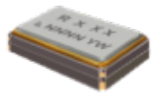
5G RRU timing evolution

- Packet interface into RRU necessitates protocol layer timing recovery



- Packet timing recovery needs TCXO or OCXO

RRU Synchronisation solutions

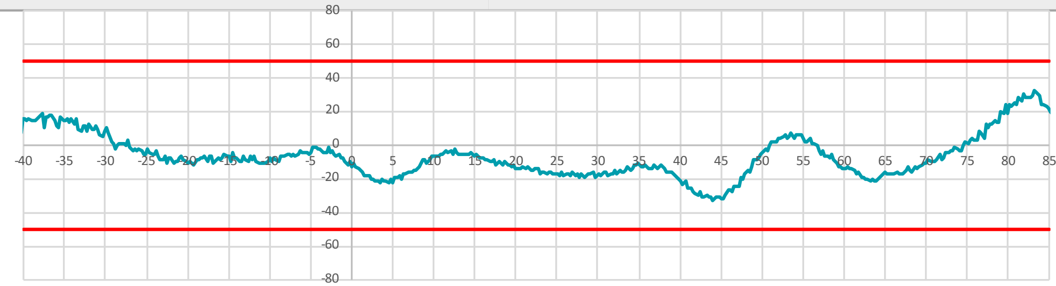


50ppb TCXO

Key Features:

- Temperature stability : +/-50ppb (-40 to 85C)
- High temperature ranges : -55 to 105°C available
- 7mmX5mm & 5mmX3.2mm

	Frequency (Package size)	**Stability** (Temperature range)	**Slope** (ΔF/ΔT)	Aging (10 years)	**Phase Noise** (Typ. @ 19.2MHz)
TCXO	10 – 40 MHz (5.0 x 3.2 mm) (7.0 x 5.0 mm)	**±50 ppb (-40 to 85°C)** **±100 ppb (-40 to 105°C)**	±20 to ±10 ppb/°C	3ppm	-123 dBc/Hz @100Hz -155 dBc/Hz @10kHz -156 dBc/Hz @ 100kHz

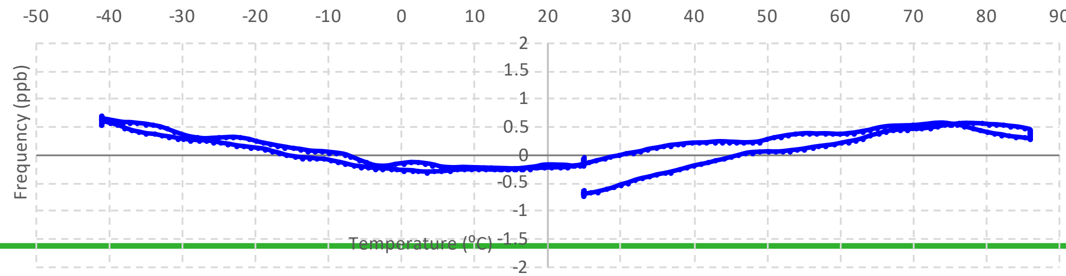


Mini OCXO

Key Features:

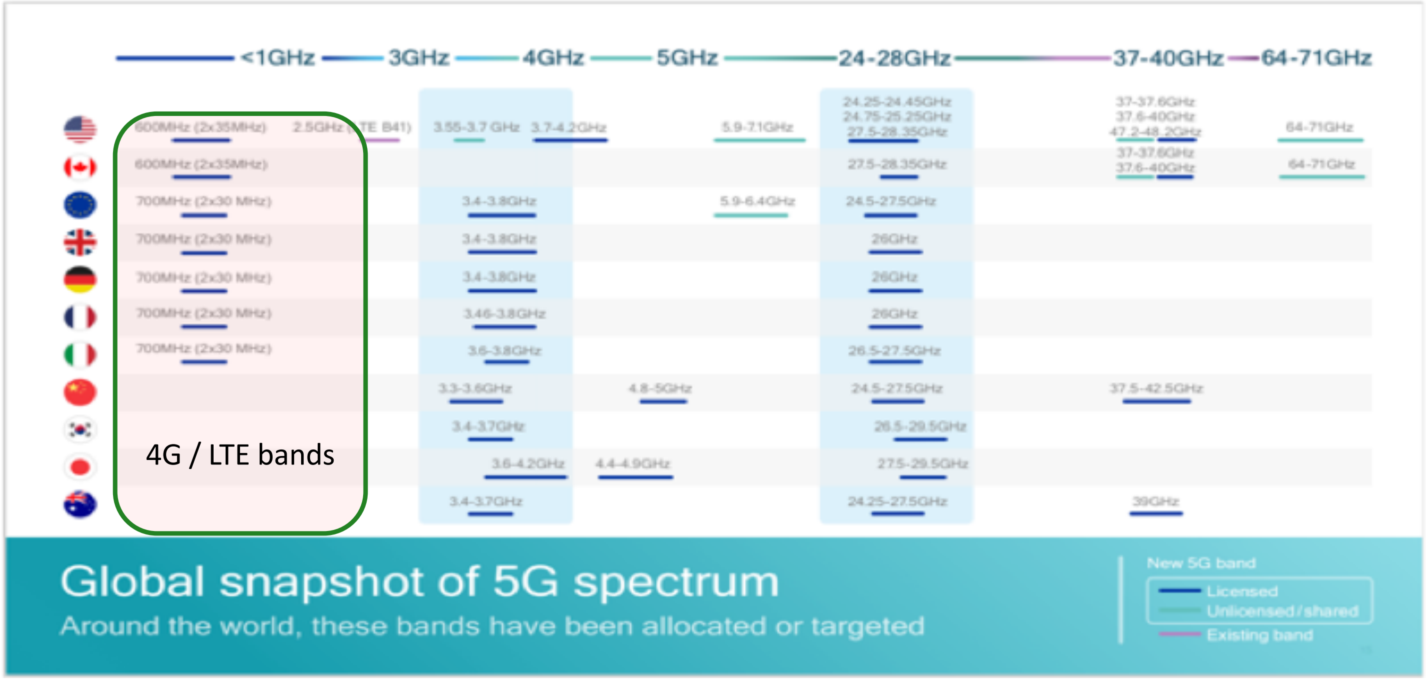
- +/-10ppb (-40 to 85C) temperature stability
- 9mmx7mm, 7mmx5mm next generation
- <1ppb/degC temperature slope
- High temperature ranges : 105°C available
- Fast Start-up times

	Frequency (Package size)	**Stability** (Temperature range)	**Slope** (ΔF/ΔT)	Aging (10 years)	**Phase Noise** (Typ. @ 50 MHz)
Mini OCXO	10 – 50 MHz (9.7 x 7.5 mm) (7.0 x 5.0 mm)	**±10 ppb (-40 to 85°C)** **±20 ppb (-40 to 95°C)**	±1 to ±1.5 ppb/°C	3ppm	-148 dBc/Hz @100Hz -154 dBc/Hz @10kHz -156 dBc/Hz @ 100kHz



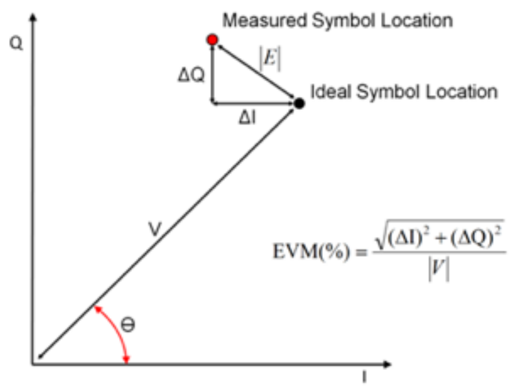
Radio Clock reference challenges

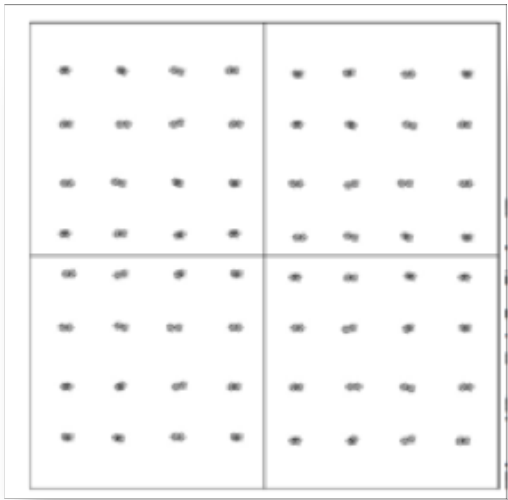
- **4G clocks cover up to 2.4GHz frequencies**
- **5G covers high spectral frequencies**
  - Up to 100GHz



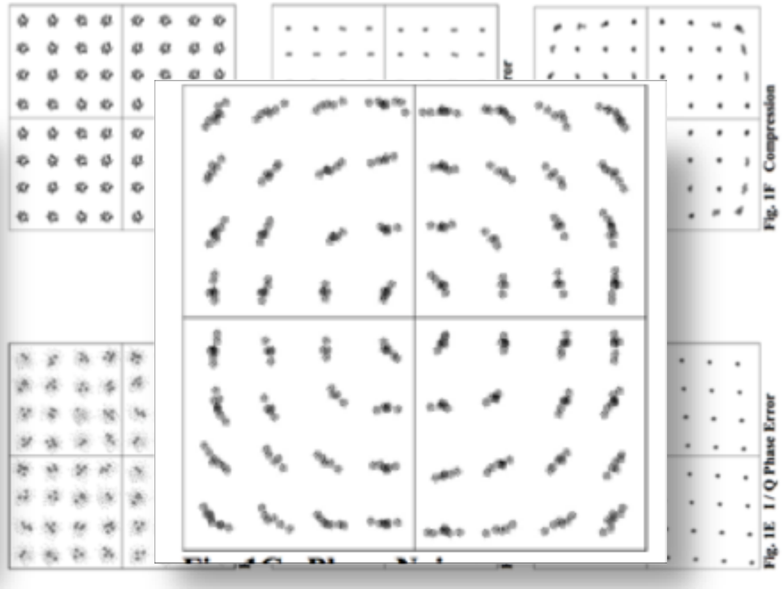
Contribution to EVM - Phase noise

- **Reference clock phase noise contributes to EVM**
  - As the modulation level increase (like 256 QAM) the constellations are dense, minimal close-in noise desired





Ideal Constellations



Constellations with high phase noise

RF References for 5G

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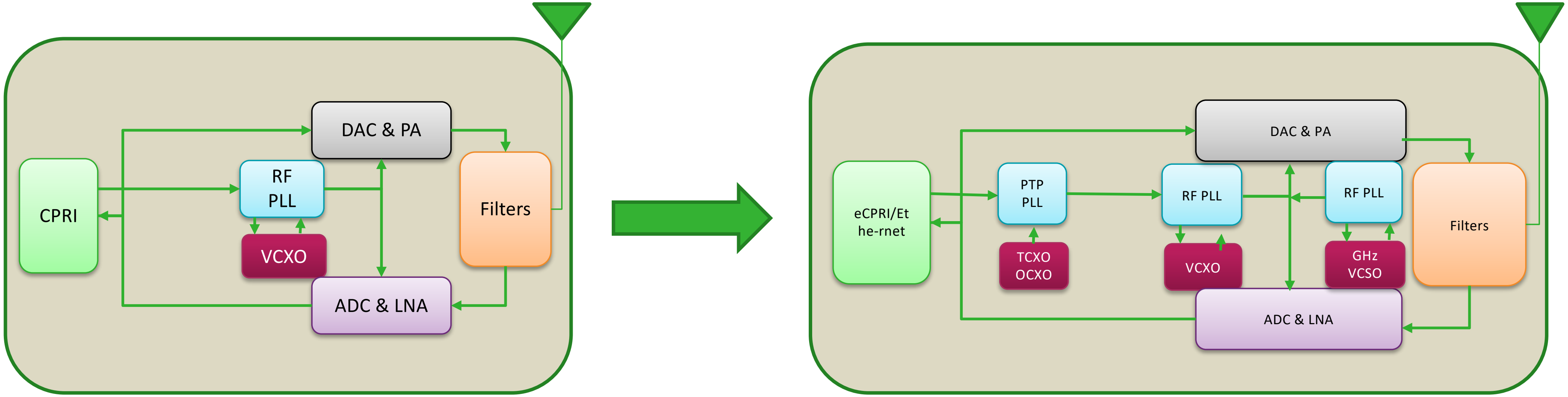
- Higher spectral frequencies need low phase noise reference clocks – GHz VCXOs

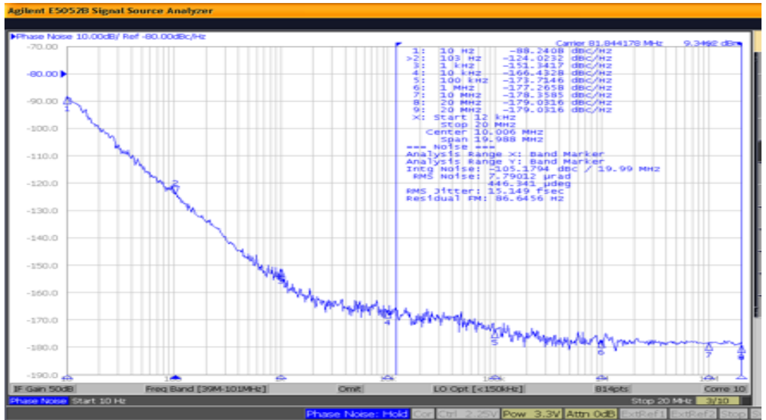


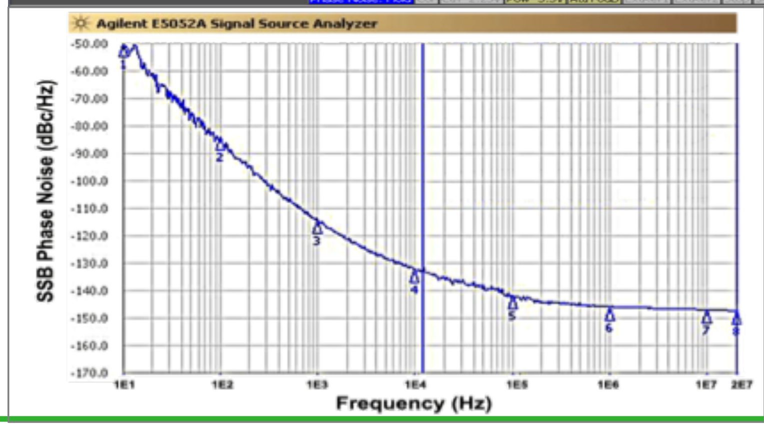
High frequency clock references

- **Two clocking reference options**
  - Ultra low phase noise, low frequency
  - Low phase noise, GHz frequency

- **Ultra low phase noise solutions**
  - 122.88M VCXO

- **GHz frequency solutions**
  - ~2.5GHz VCXO solutions





Conclusion

- Next Generation Base station architectures poses synchronisation challenges for RRU implementations
- Network clock recovery will be based on packet clock recovery methods, needs more stable reference clock than current
- Environmental effects are critical
- Higher spectral frequencies requires very low noise reference clocks for superior performance

References

- IEEE P802.1CM/D2.2 Draft Standard for Local and metropolitan area networks—Time-Sensitive Networking for Front-haul
- eCPRI Interface Specification: eCPRI Specification V1.1 - Common Public Radio Interface
- CPRI Interface Specification : CPRI Specification V7.0 Common Public Radio Interface
- eCPRI Transport Network D0.1 - Common Public Radio Interface: Requirements for the eCPRI Transport Network
- IEEE1914.3/D3.2 : Draft Standard for Radio over Ethernet Encapsulations and Mappings

Acknowledgements

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Thank you

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