

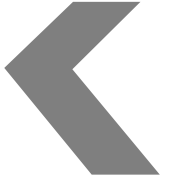
Ultra Low Phase Noise Clocks for next generation cellular applications

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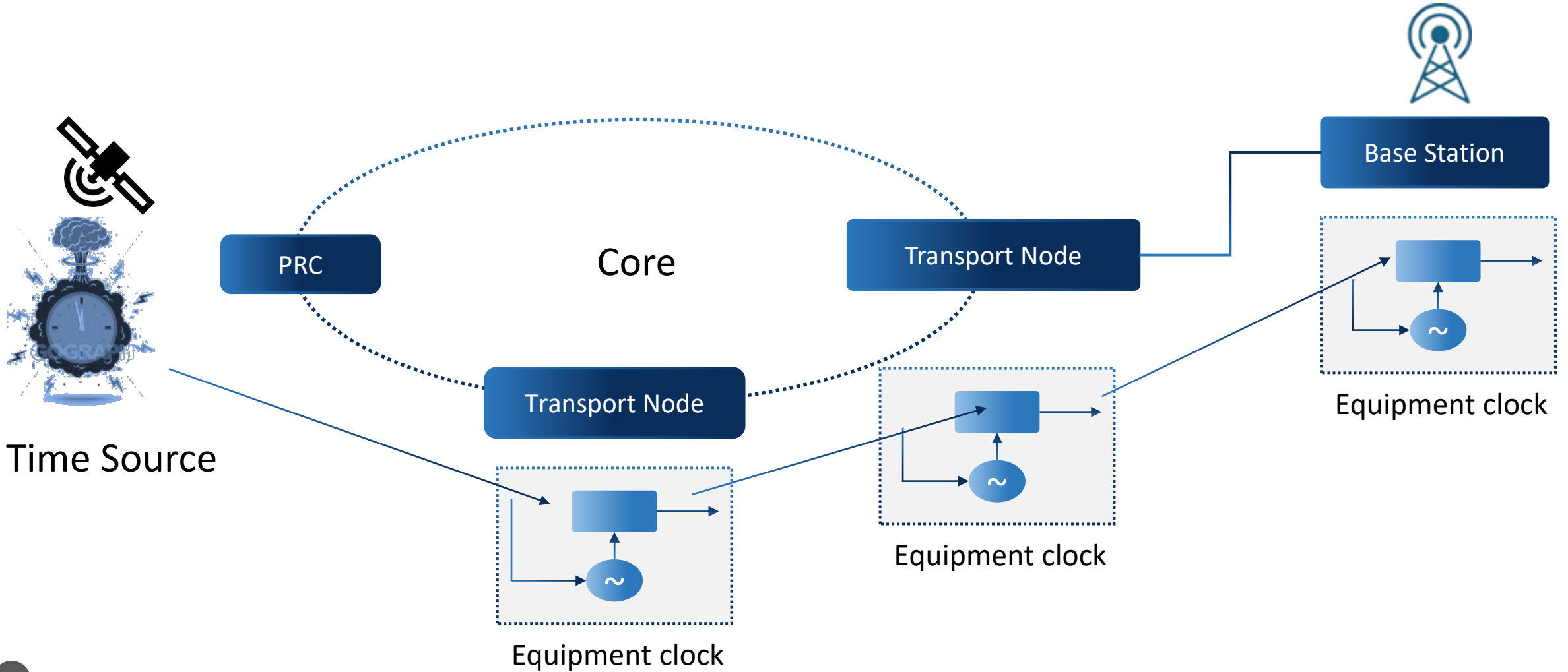
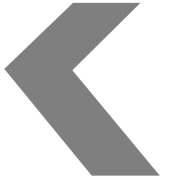
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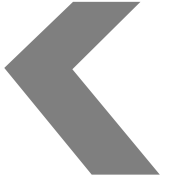
Contents

- Cellular Sync Architectures
- Phase noise basics
- Impact on Transport and wireless systems
- Conclusion

Network Synchronisation



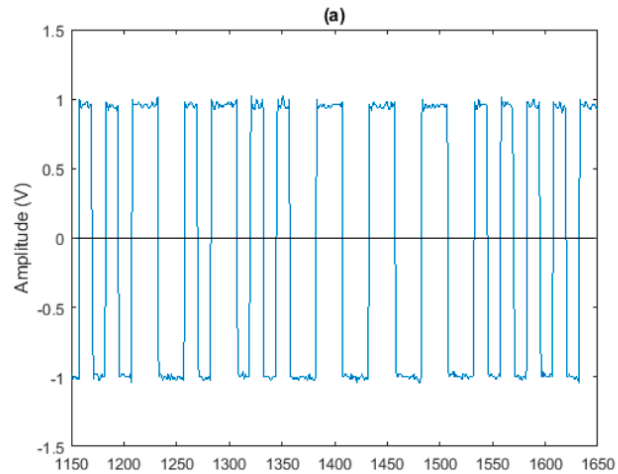
Transport Network



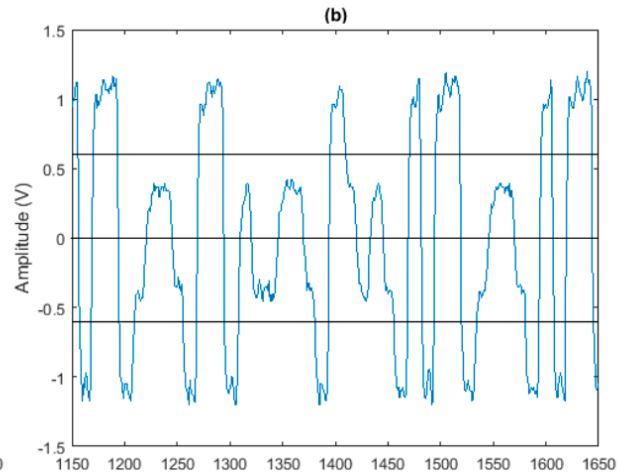
Higher transmission rate

- Higher modulation

On-OFF Keying

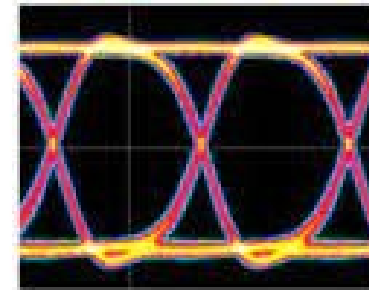


PAM-4

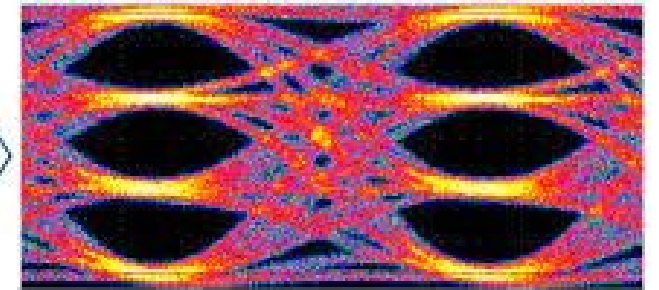


Higher transmission rate

- Eye diagrams

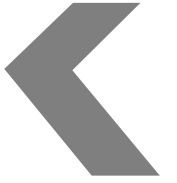


NRZ

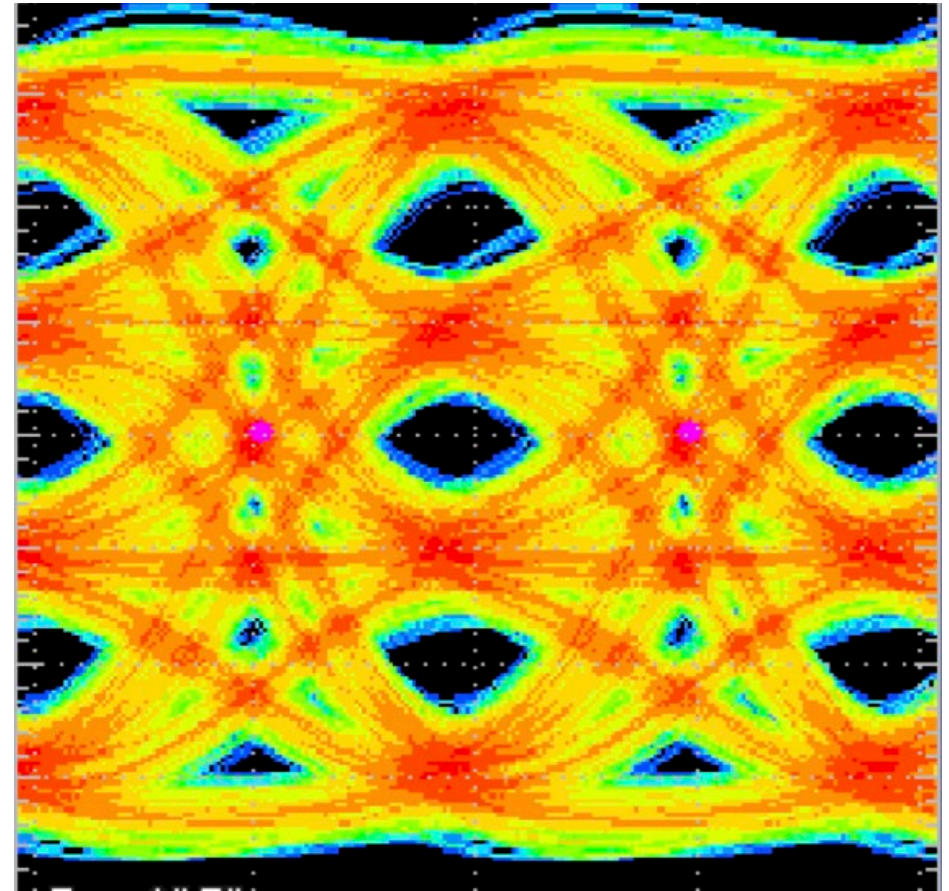
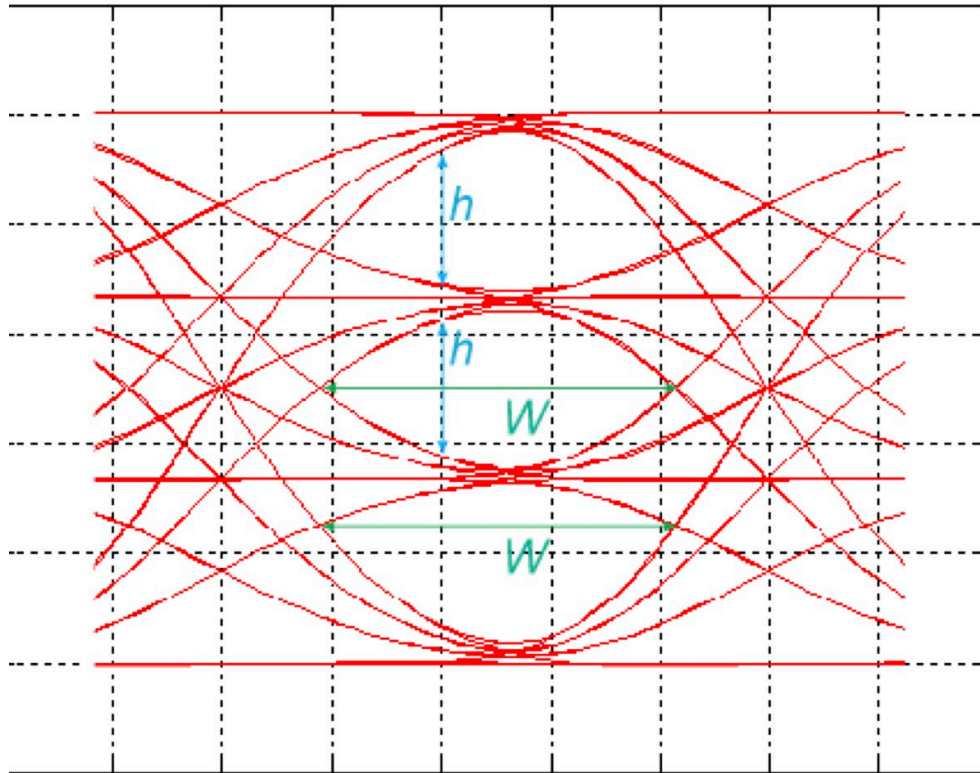


PAM4

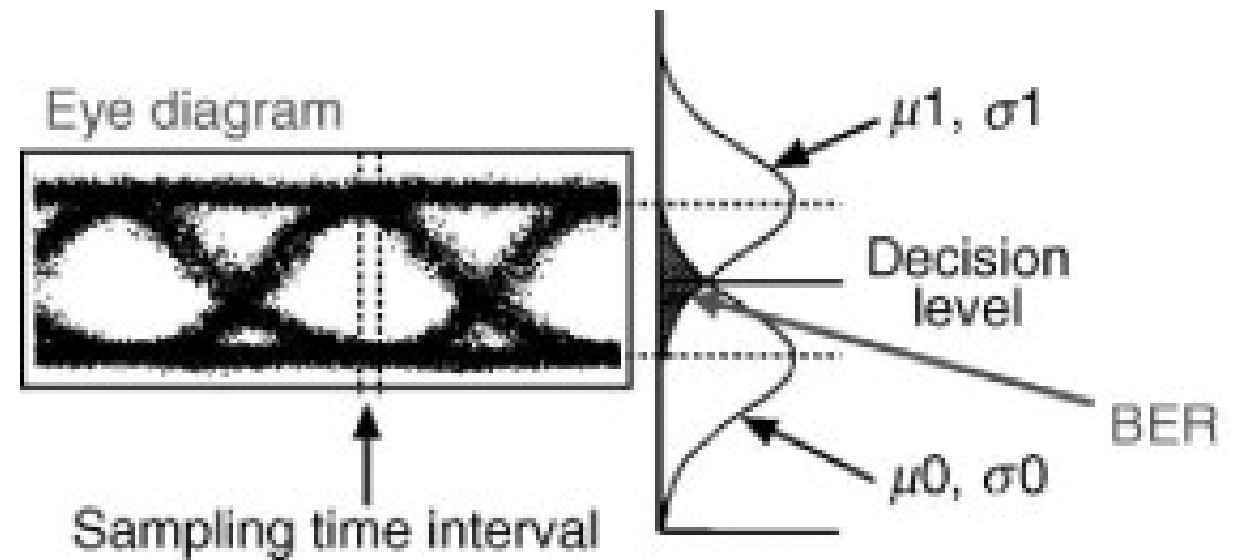
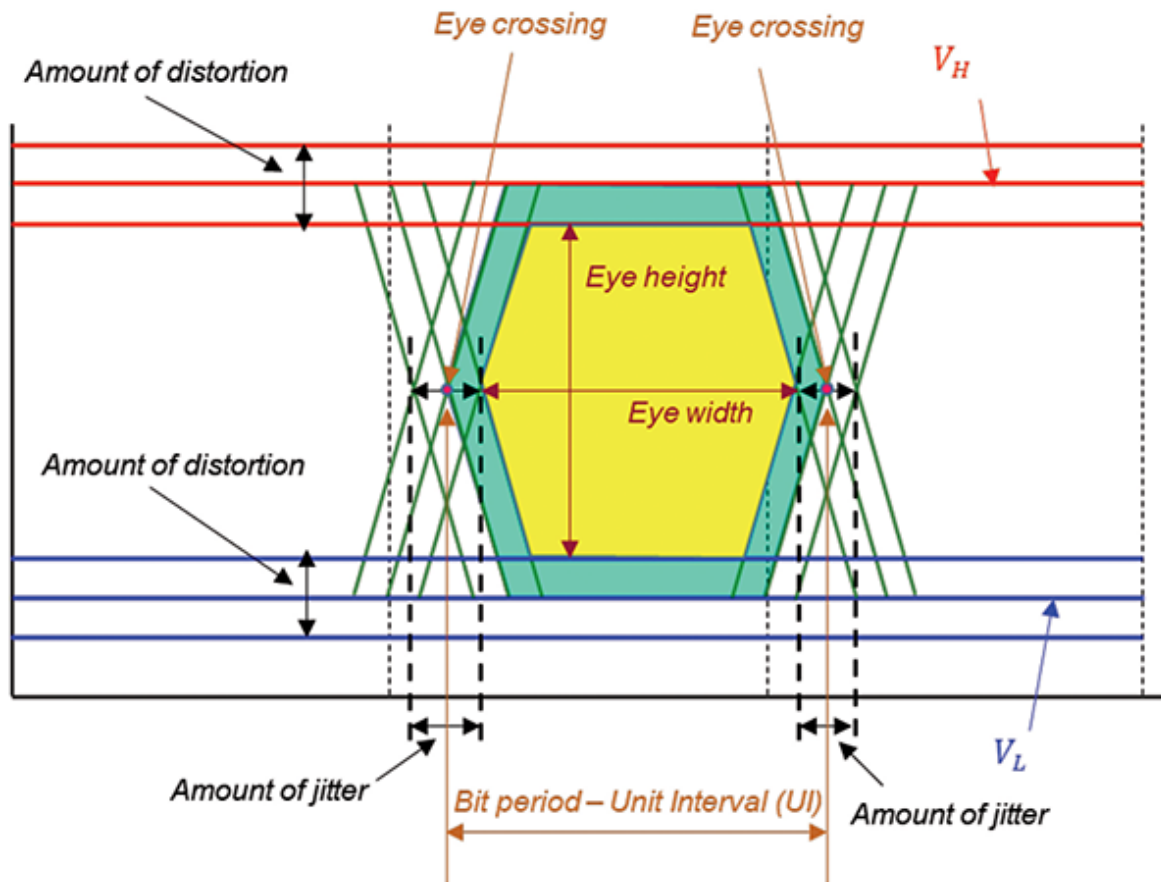
Eye Diagram directs to error



The height and width of the eye diagram matters



Eye Diagram parameters

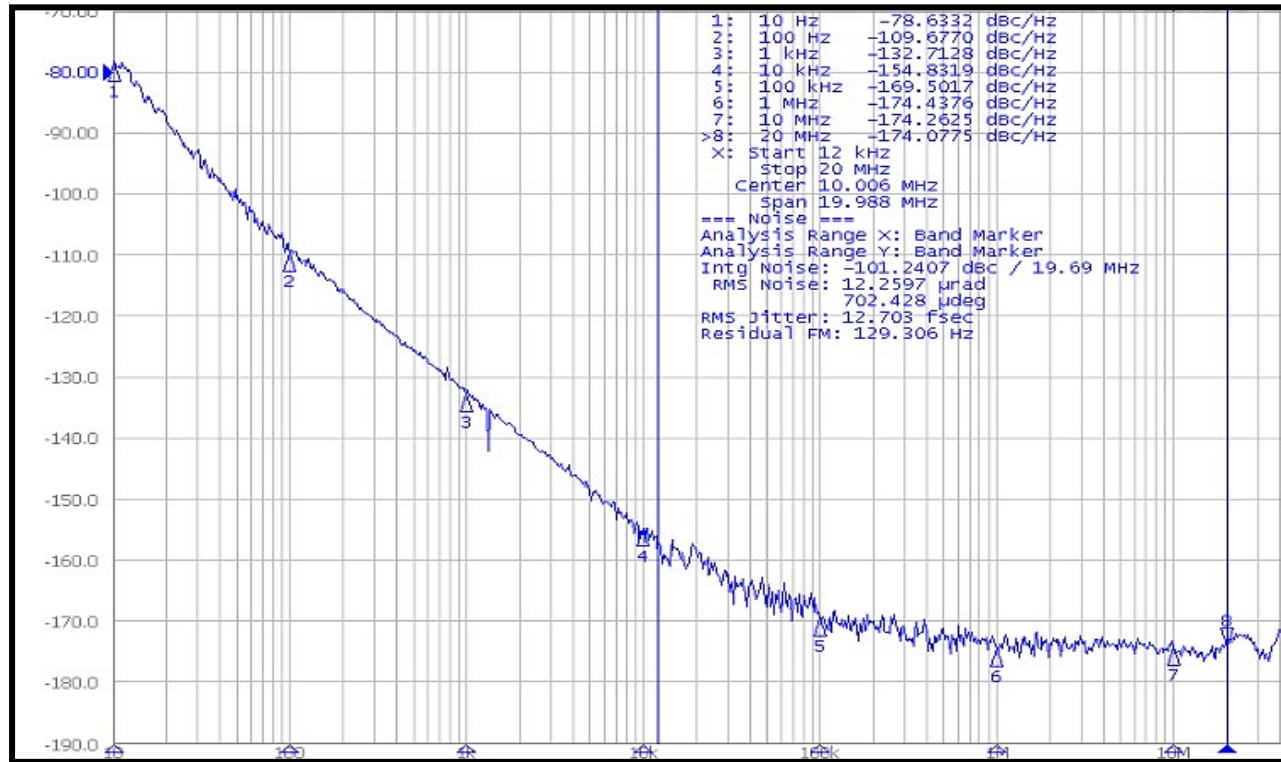


Low jitter requirement



Jitter requirement

- ~ 100 fs (4 MHz – TX PLL BW($<F_{ref}/10$)) , $F_{ref} = 156.25$ MHz



Mean Time between Errors as a Function for Multigigabit Data Rates

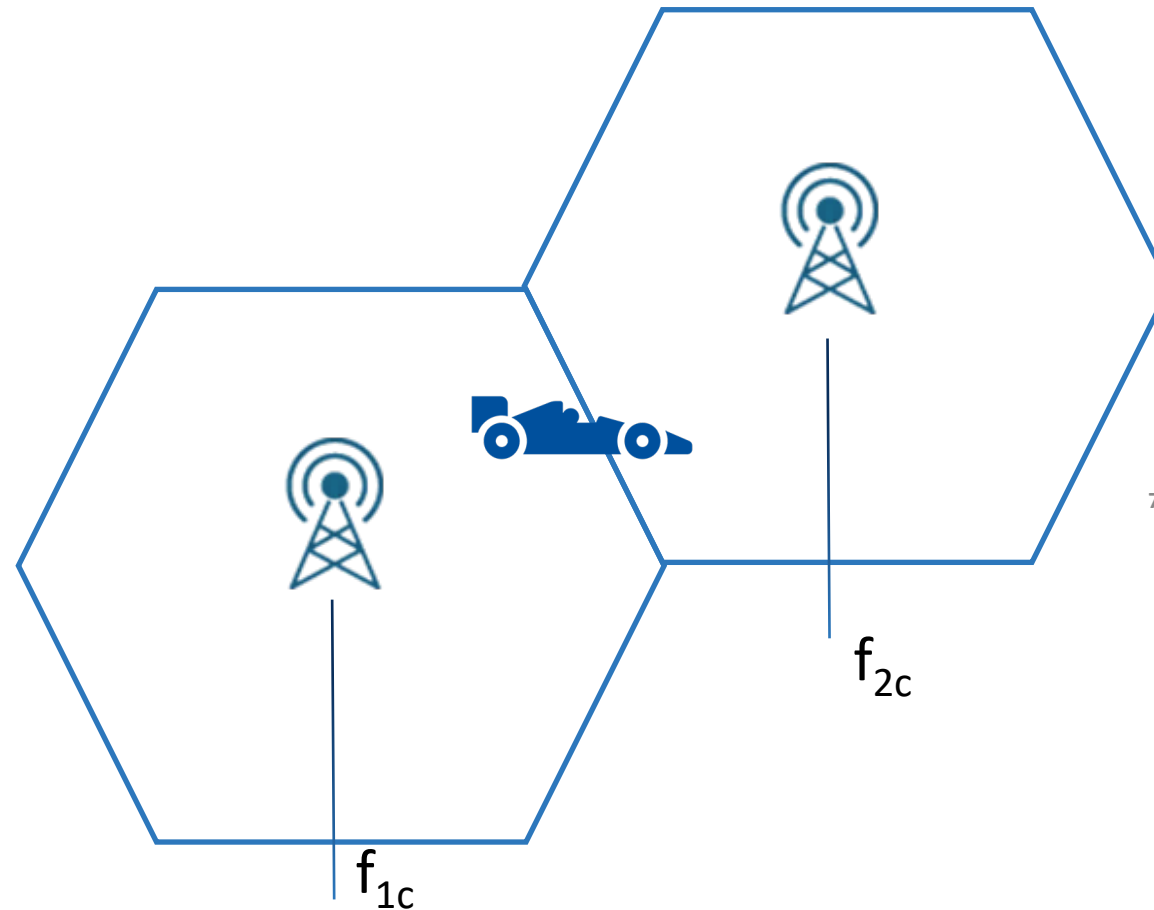
BER	1 Gbit/s	2.5 Gbit/s	5 Gbit/s	10 Gbit/s	40 Gbit/s
10^{-8}	100 ms	40 ms	20 ms	10 ms	2.5 ms
10^{-9}	1 s	400 ms	200 ms	100 ms	25 ms
10^{-10}	10 s	4 s	2 s	1 s	250 ms
10^{-11}	1.66 min	40 s	20 s	10 s	2.5 s
10^{-12}	16.67 min	6.67 min	3.33 min	1.67 min	25 s
10^{-13}	2.78 h	1.11 h	33.3 min	16.67 min	4.17 min
10^{-14}	1.16 d	11.11 h	5.56 h	2.78 h	41.67 min
10^{-15}	11.57 d	4.63 d	2.31 d	1.16 d	6.94 h
10^{-16}	3.86 mo	1.54 mo	23.15 d	11.57 d	2.89 d
10^{-17}	3.17 y	1.27 y	7.72 mo	3.86 mo	28.93 d
10^{-18}	31.7 y	12.7 y	6.34 y	3.17 y	9.64 mo

Source: D. Derickson and M. Muller, "Digital Communications Test and Measurement", Prentice Hall, 2007

Low jitter requirement



- Cells should support moving UE
- Support for 250 kmph



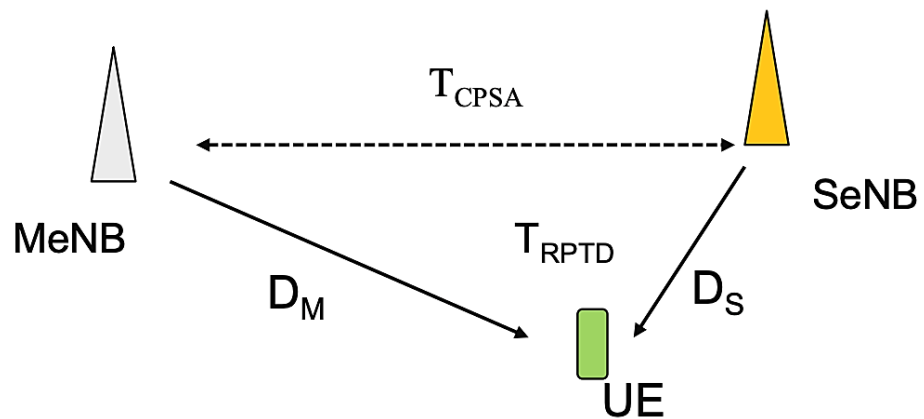
BS class	Accuracy
Wide Area BS	± 0.05 ppm
Medium Range BS	± 0.1 ppm
Local Area BS	± 0.1 ppm

Phase Sync for collaboration



Dual connectivity

- UE utilise radio resources from multiple eNB

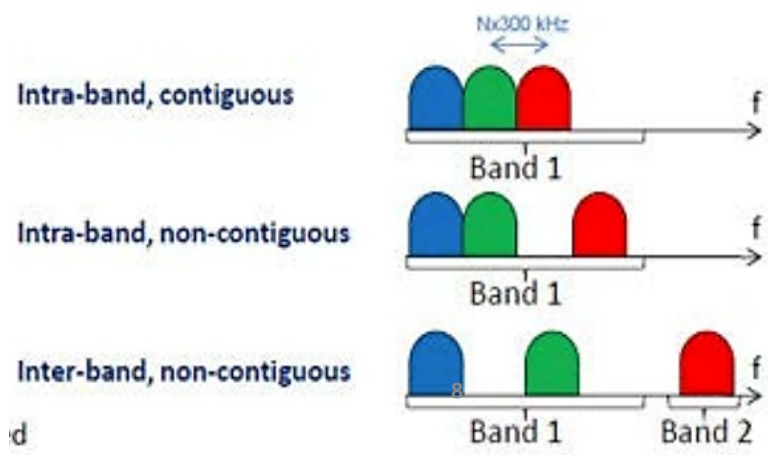


TRPTD: absolute propagation time difference between MeNB and SeNB of UE

TCPSA: the sum of absolute timing accuracy values

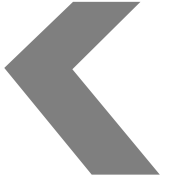
Carrier Aggregation

- Aggregate bands for high throughput



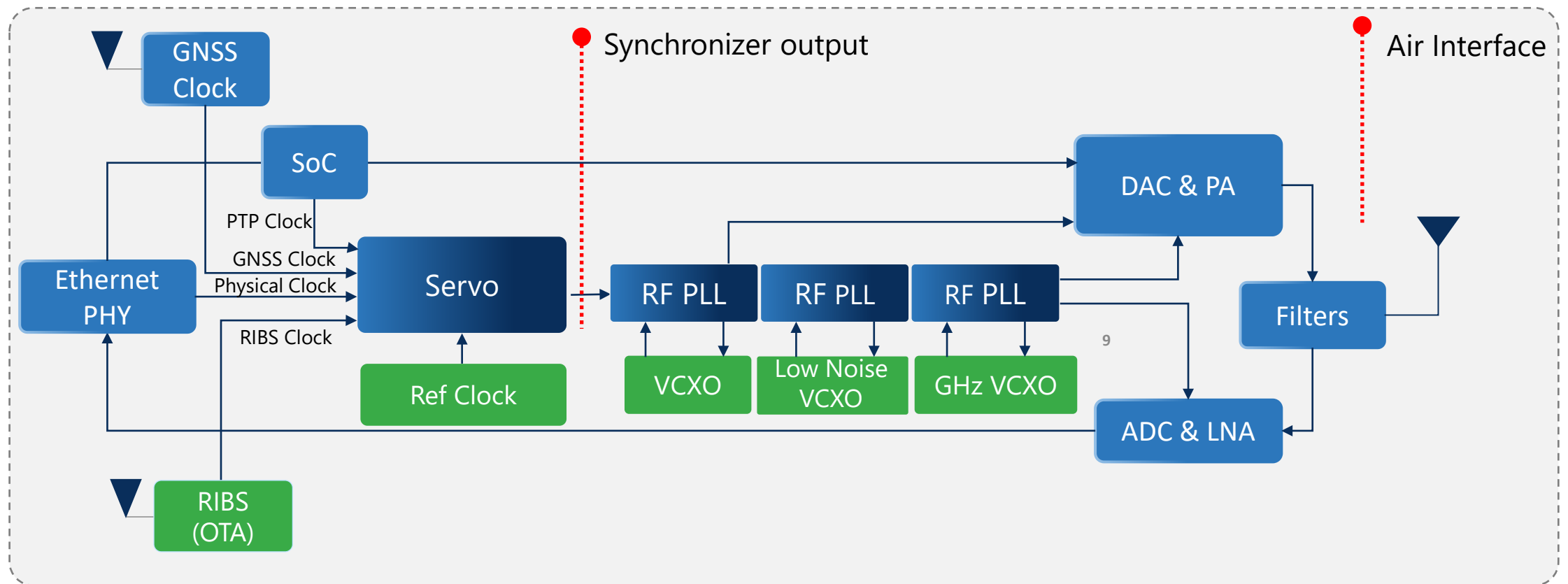
MRTD/MTTD: Maximum Received/Transmitted Timing Difference

Synch Architectures for Radios



Network references need stable clocks

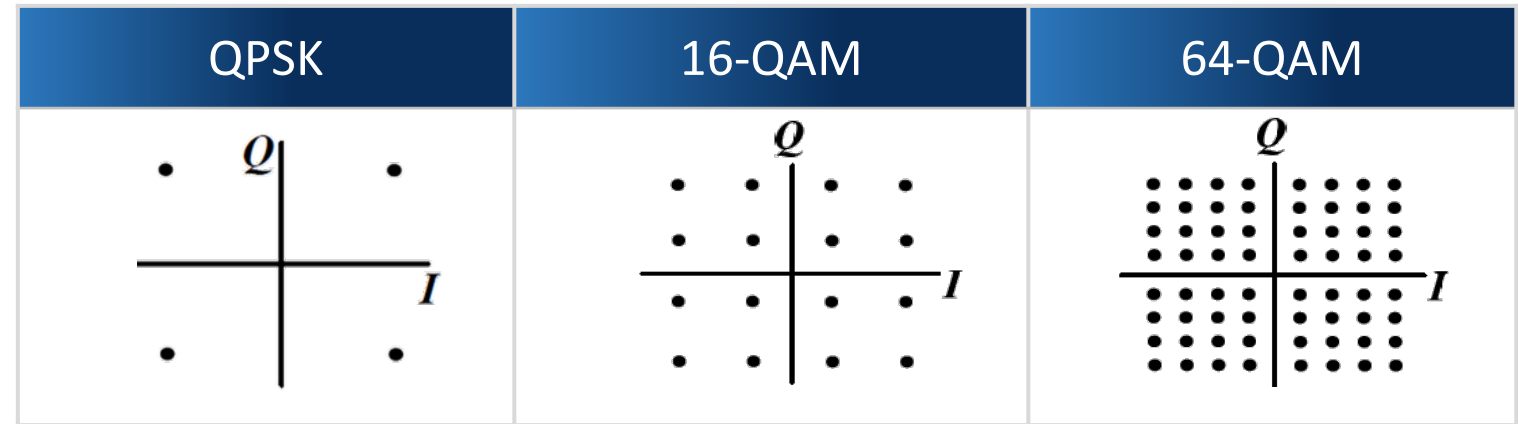
- Radio clocks need low phase noise



Air Interface : Error Vector Magnitude



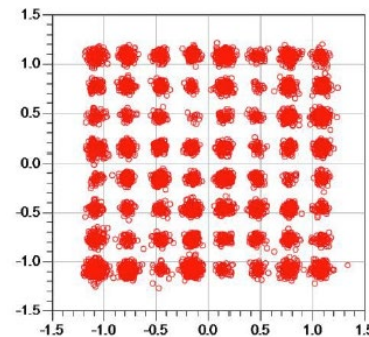
More and more bandwidth
= faster download/upload



Poor Phase Noise
vs Good Phase Noise

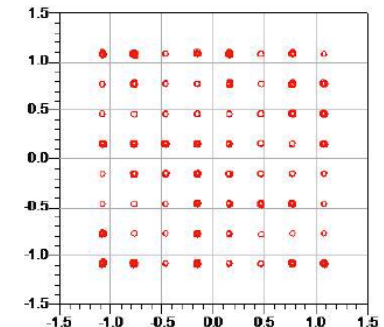
Poor Phase Noise

Hard to decode (EVM = -28dB; EVM = 2.28°)



Good Phase Noise

Easier to decode (EVM = -40dB; EVM = 0.56°)



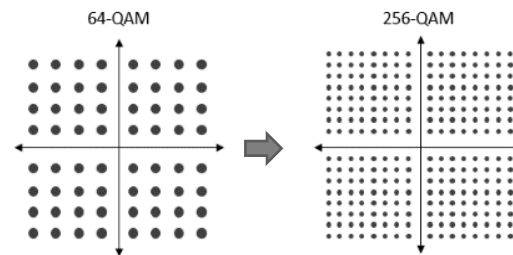
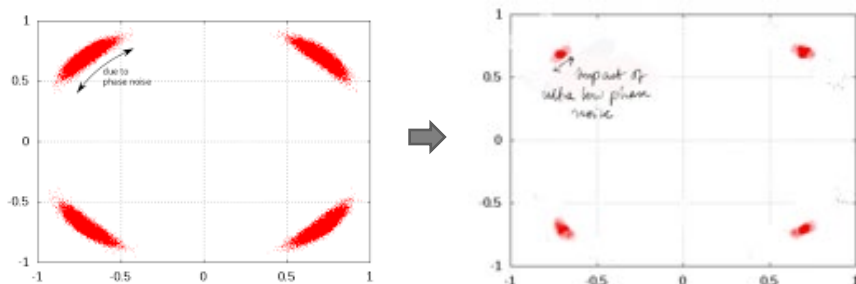
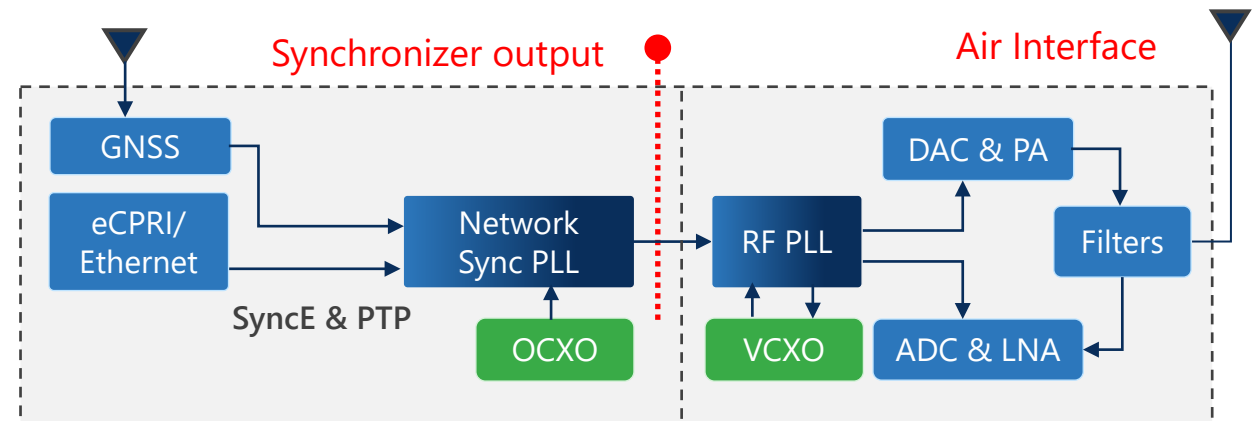
Radio Interfaces need low noise clocks



Phase noise is critical in higher QAM rate applications

- Higher Data Rates \leq Higher Modulation Rates
- Higher Modulation Rates \leq Packed constellations
- Packed constellations \leq Low EVM
- Low EVM \leq Low phase noise

- Lowest phase noise possible



Reduced contribution to EVM
(Error Vector Magnitude)

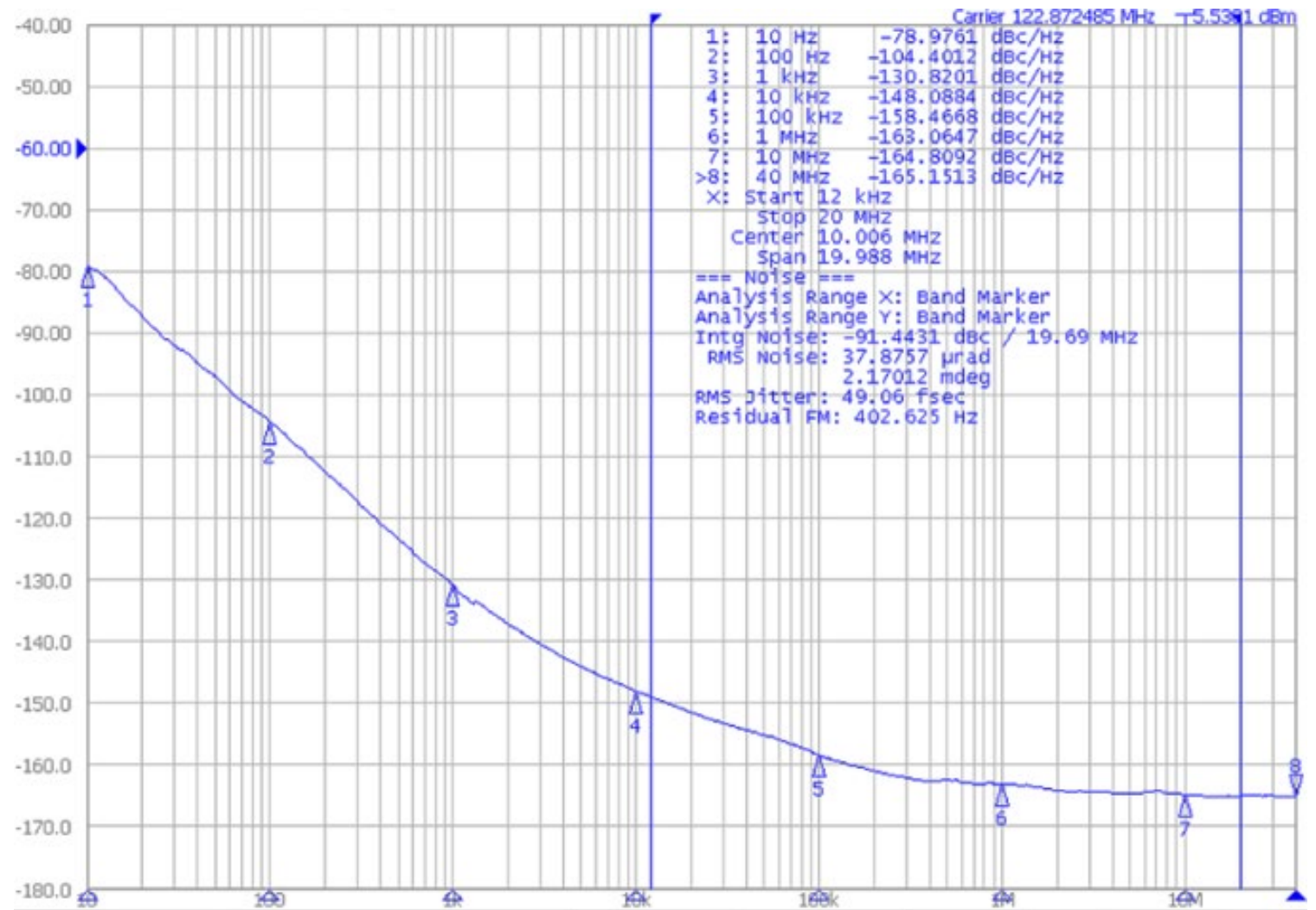
- Higher modulation rates
=> Higher throughput

Phase noise contributions



Contributors to phase noise

- Different elements of the system contribute to various components of the spectrum

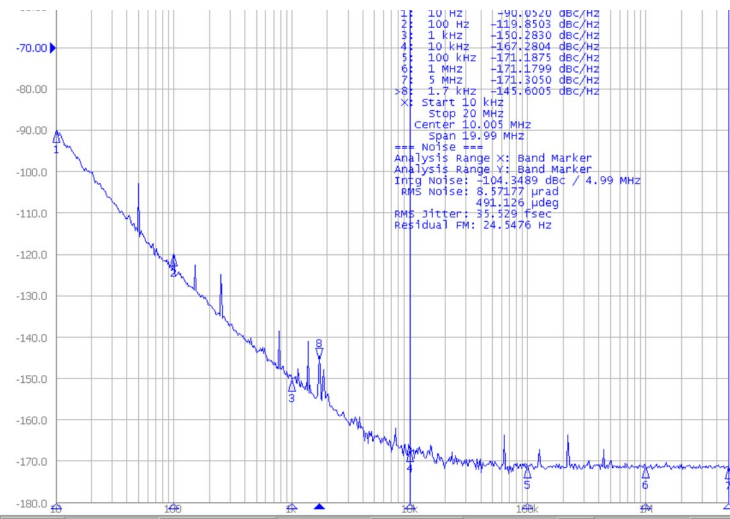


Reference clocks with Stability and low phase noise

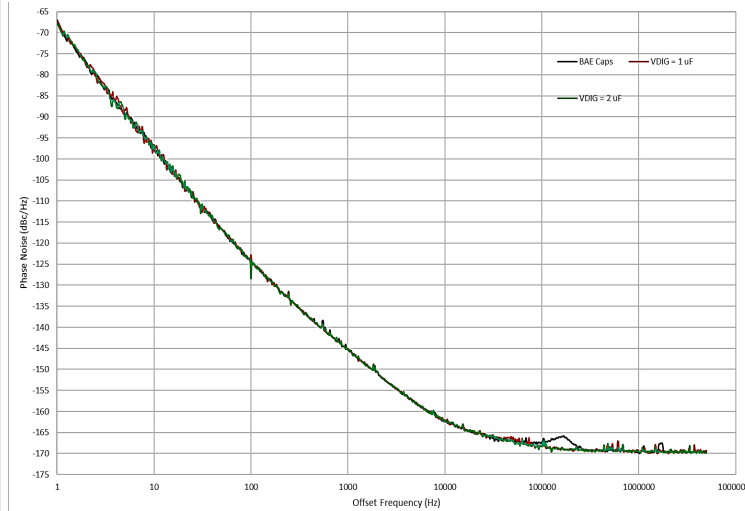


Stability combined with phase noise

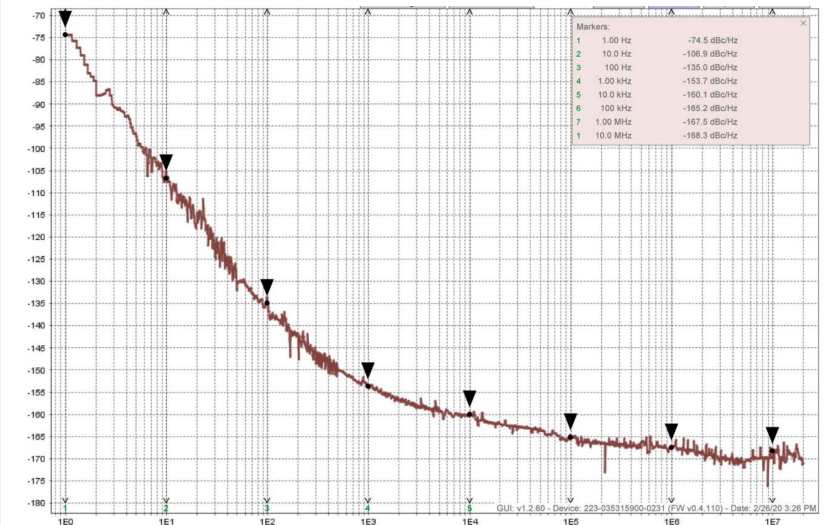
300 ppb FvT
38.88 MHz Phase Noise



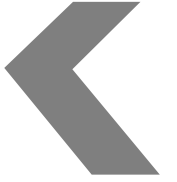
20 ppb FvT
38.88 MHz Phase Noise



3 ppb FvT
38.88 MHz Phase Noise

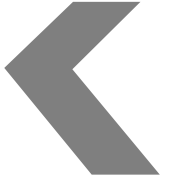


Summary



- Transport, Interconnect and Radio Interfaces are moving up in data rates
- Phase noise and jitter becomes key enabler for high data rates

References



- PAM4 signals for 400 Gbps: acquisition for measurement and signal processing; John Smith, Applications Engineer, Tektronix
- Experimental Comparison of Pulse-Amplitude and Spatial Modulations for Vehicle-to-Vehicle Visible Light Communication in Platoon Configurations, BASTIEN BÉCHADERGUE et al

Thank you



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