Light Rabbit

Implementing a White Rabbit node on COTS AMD development boards without relying on external VCXOs

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[18]

6G-ICAS4Mobility[23]

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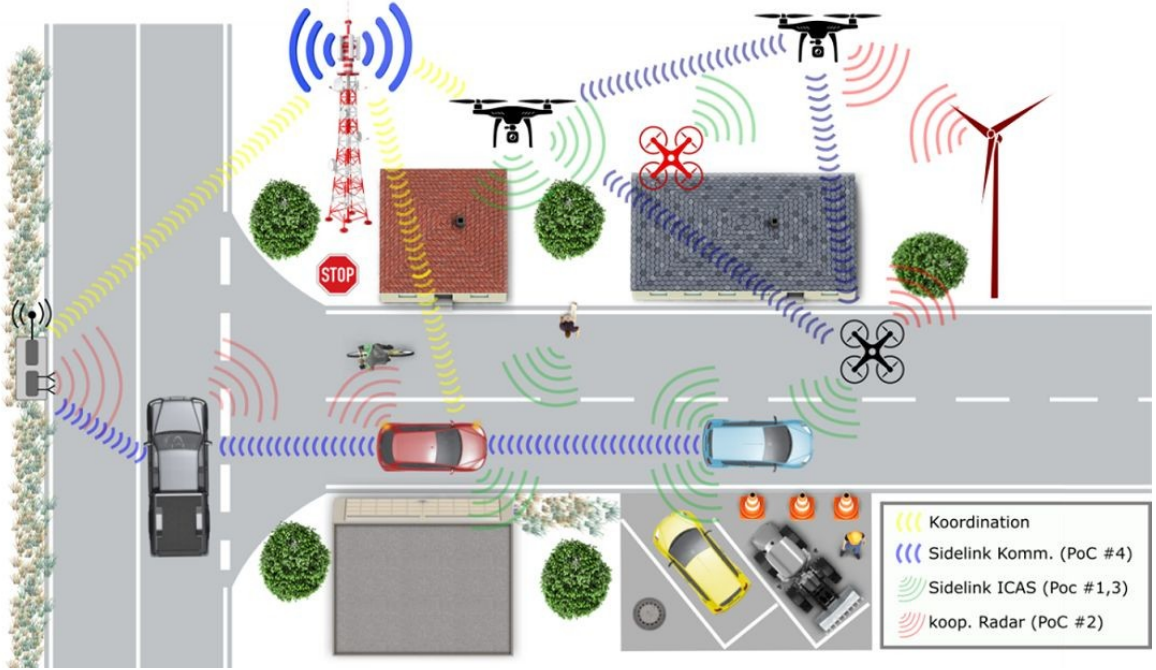
6G-ICAS4Mobility: Scenario

[23]

Integrated Communication and Sensing in 6G for stationary and mobile nodes



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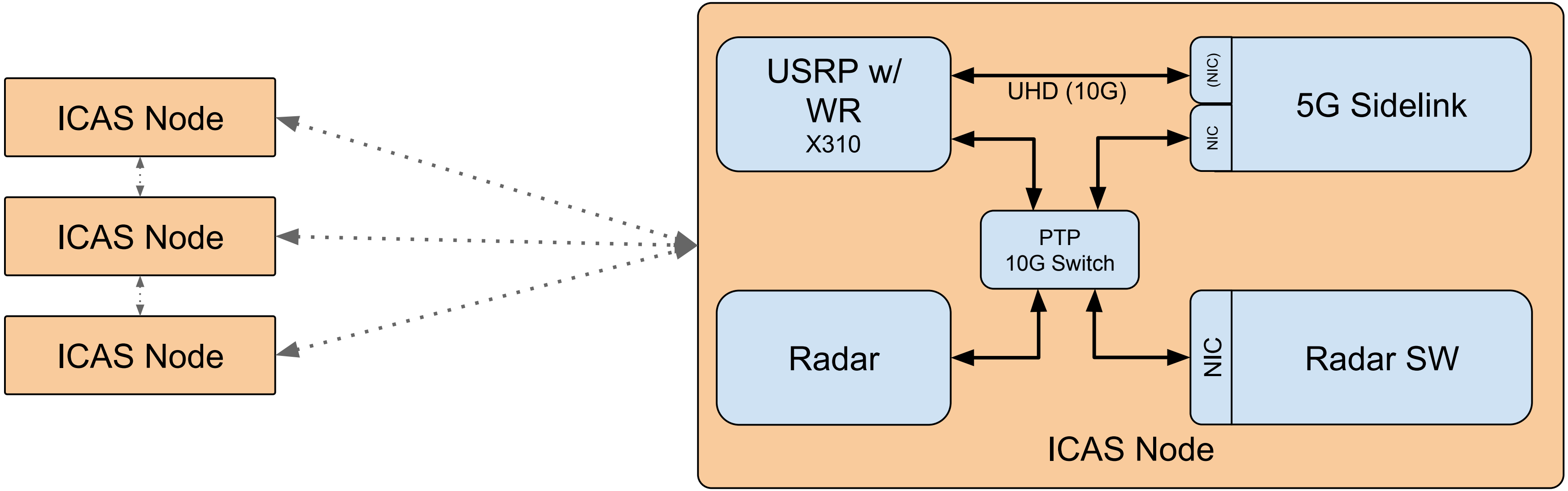
6G-ICAS4Mobility: An example node structure



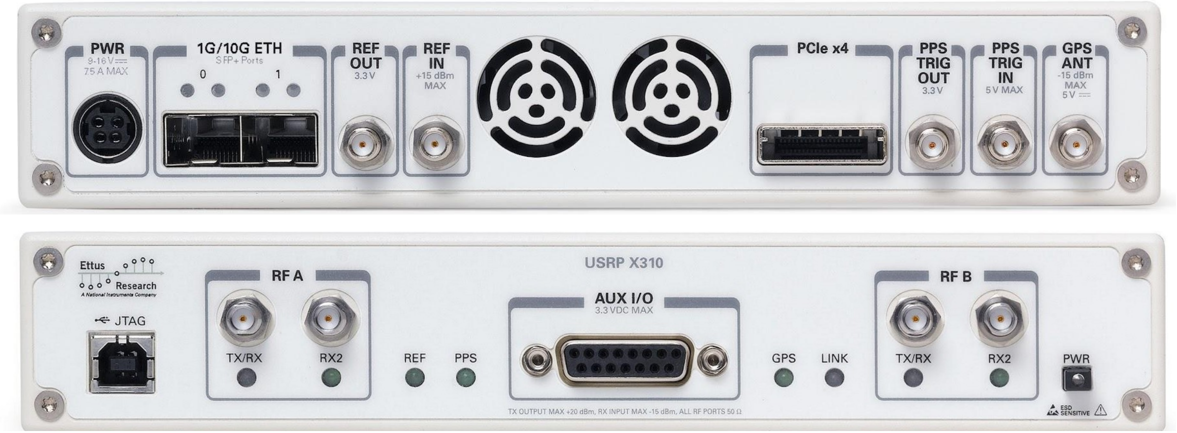
White Rabbit … on an Ettus X310 USRP

- AMD Kintex-7 XC7K410T FPGA
- PCIe
- 2x SFP+ (10G or 1G)
- Optional GPSDO
- DA-15 GPIO port
- 2x RF Front-End Daughter Board slots

⇒ **No VCXOs!**

⇒ **No QPLLs with FRAC-N support!**

⇒ **7Series fabric ⇒ use MMCMs!**



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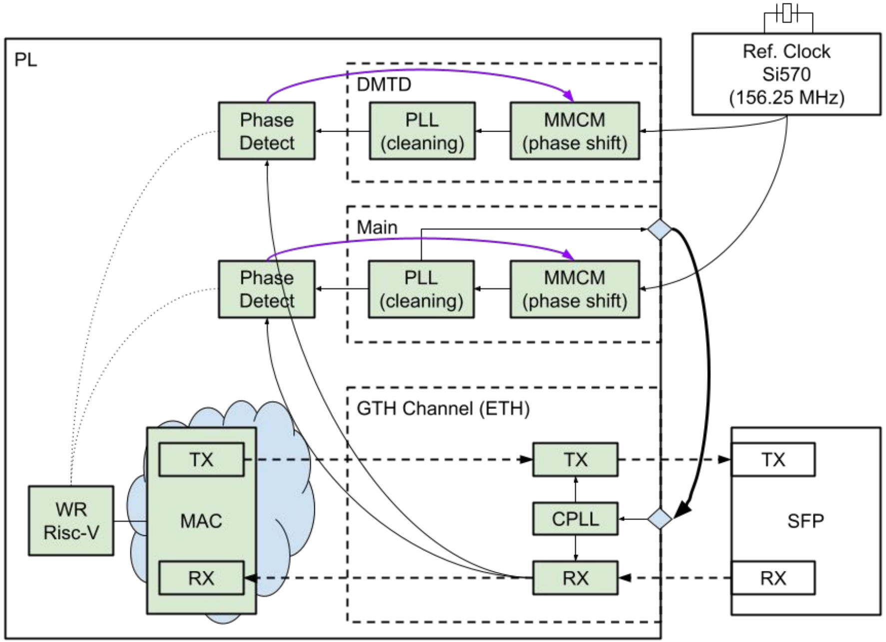
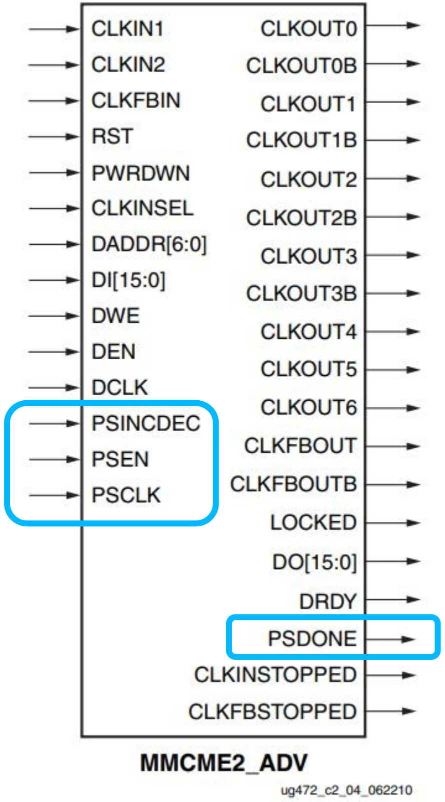
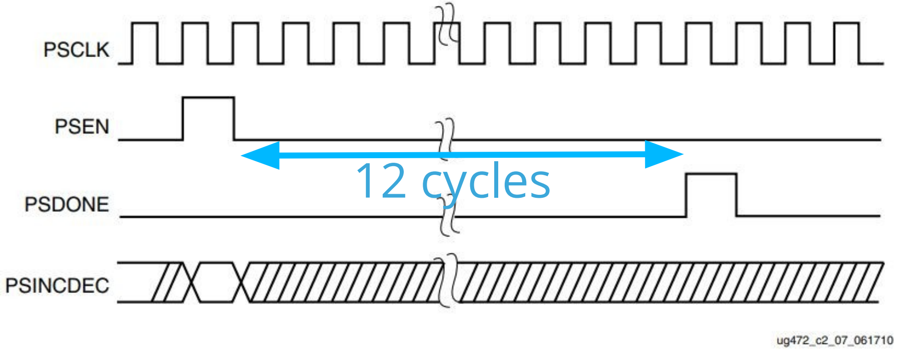
MMCM-based Implementation

- Clock oscillator can have any reasonable frequency
- Frequency is adjusted by repeated phase shifts
- PLL for cleaning chained behind phase-shifting MMCM



MMCM: Dynamic Phase Shift Interface



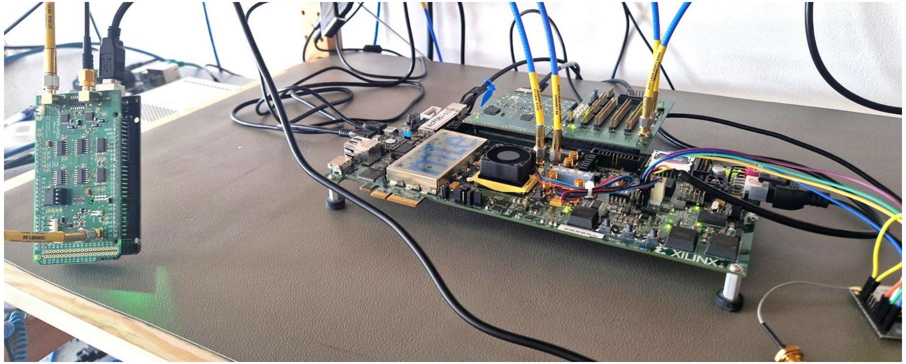


- Add up (unsigned part of) 16 Bit DAC value every 12 cycles
- Sign bit → PSINCDEC
- On wraparound → PSEN = ‘1’
- Shift by 1/56 th of a VCO period

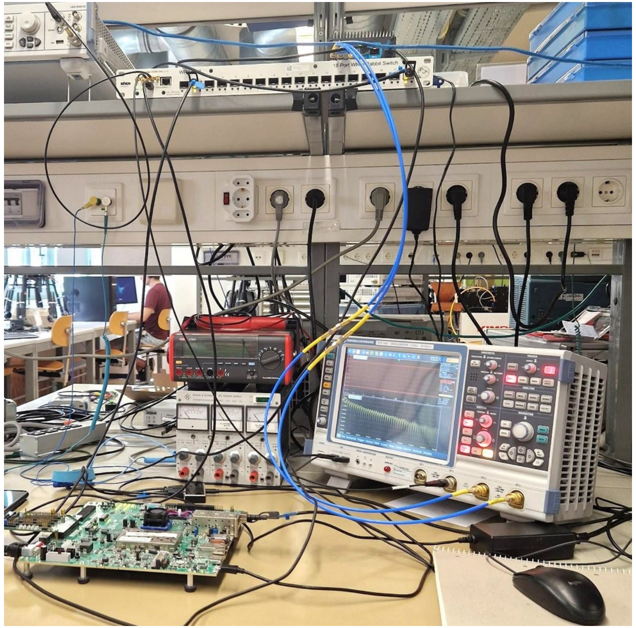
https://docs.amd.com/v/u/en-US/ug472_7Series_Clocking

Measurement Setups

TAPR-TICC (PPS), D-DMTD on ZC706 (10 MHz)



R&S RTO1044

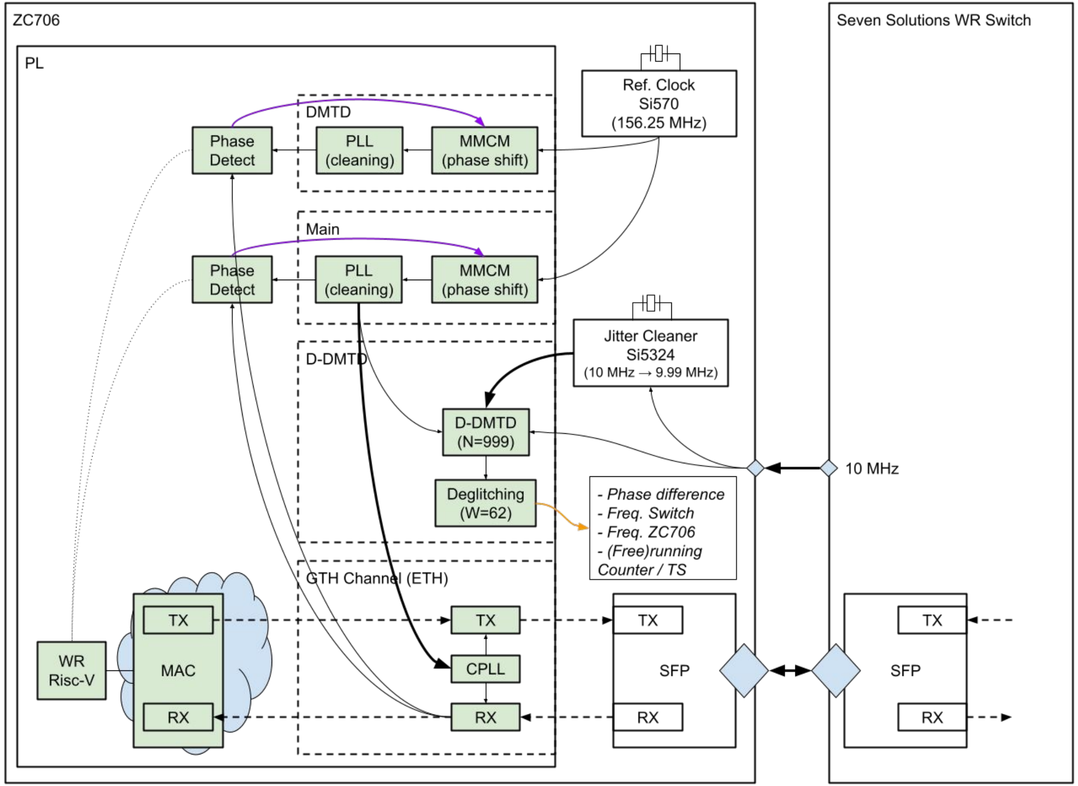


D-DMTD based Measurement Setup: 10MHz

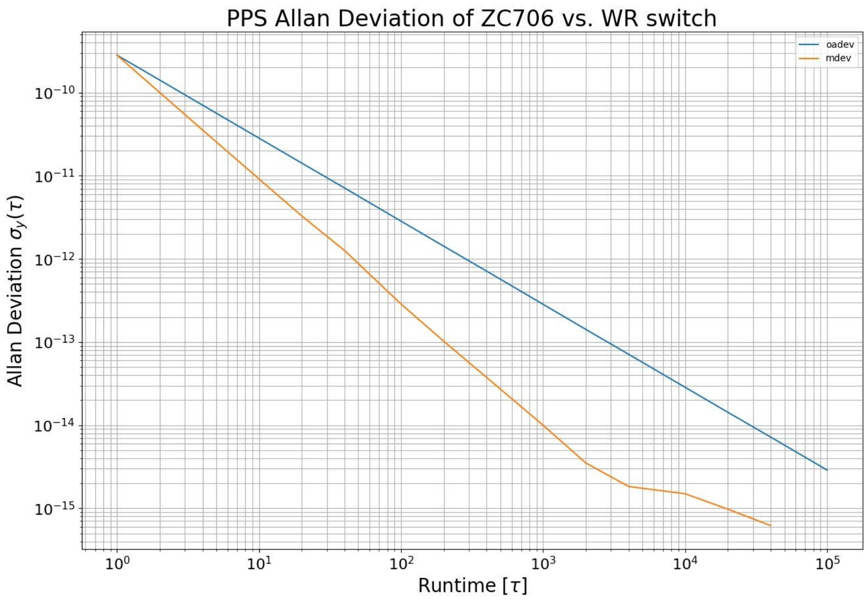
- Employ D-DMTD again
  N = 999
  W = 62
  ⇒ 10ps resolution

- Compare to *Seven Solutions* WR switch

- Gather phase and frequency information

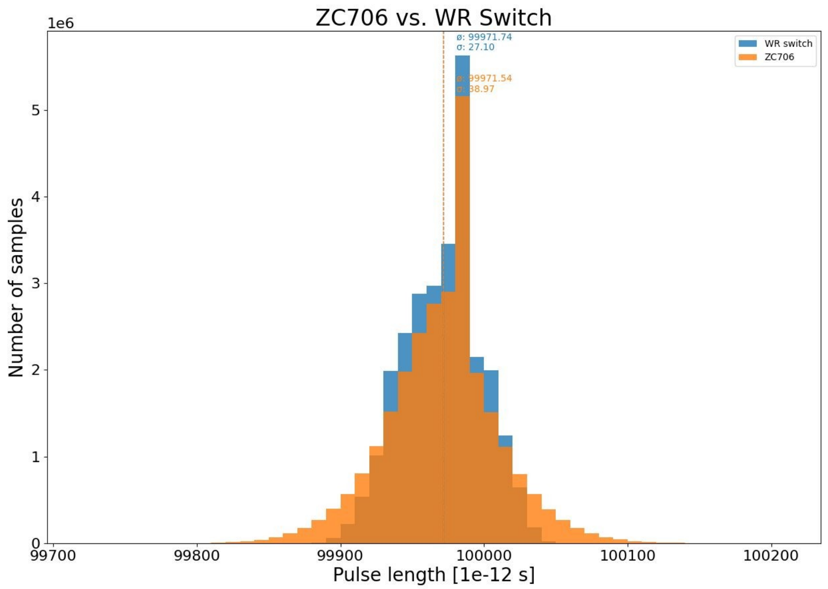


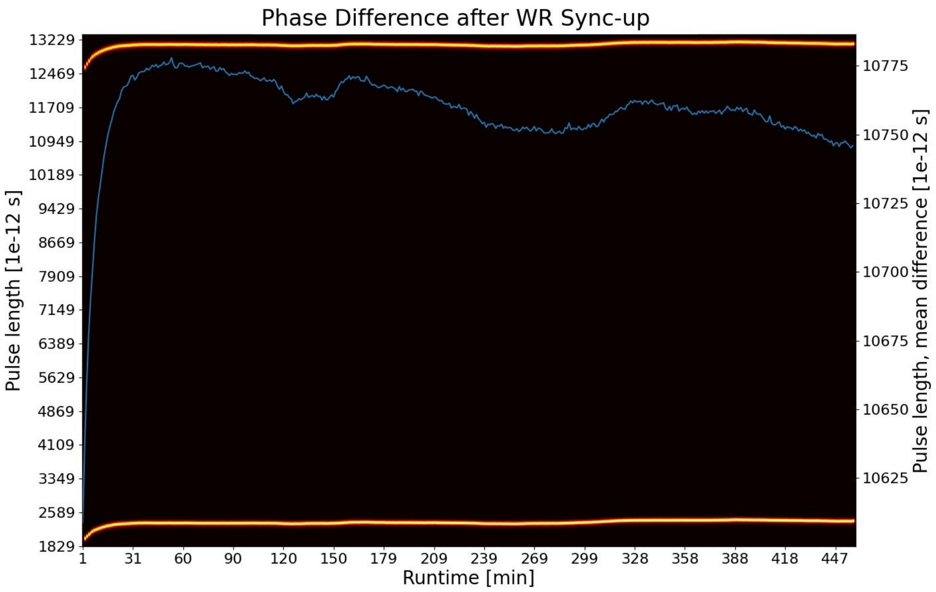
Allan Deviation: MMCM-based



TAPR-TICC based Measurement Setup

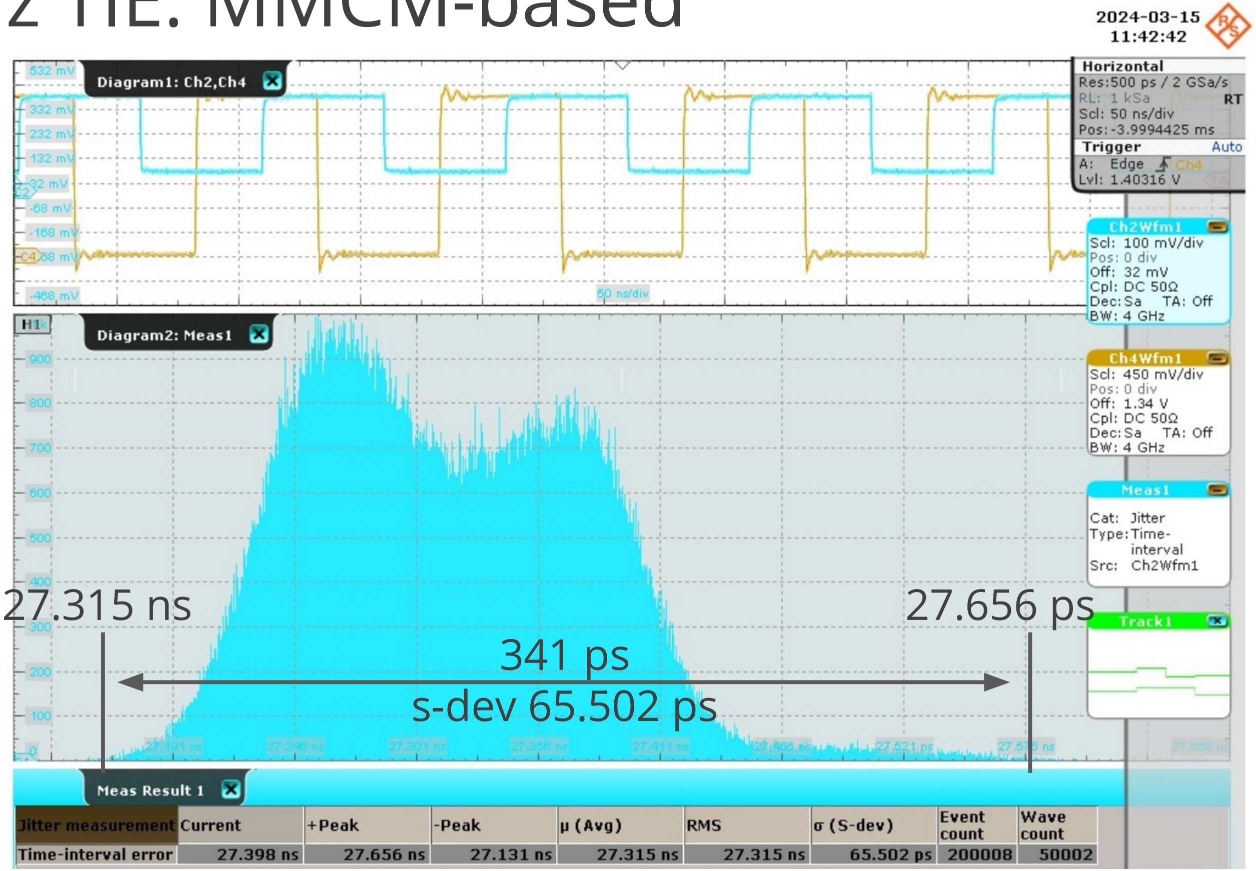
Histogram: MMCM-based





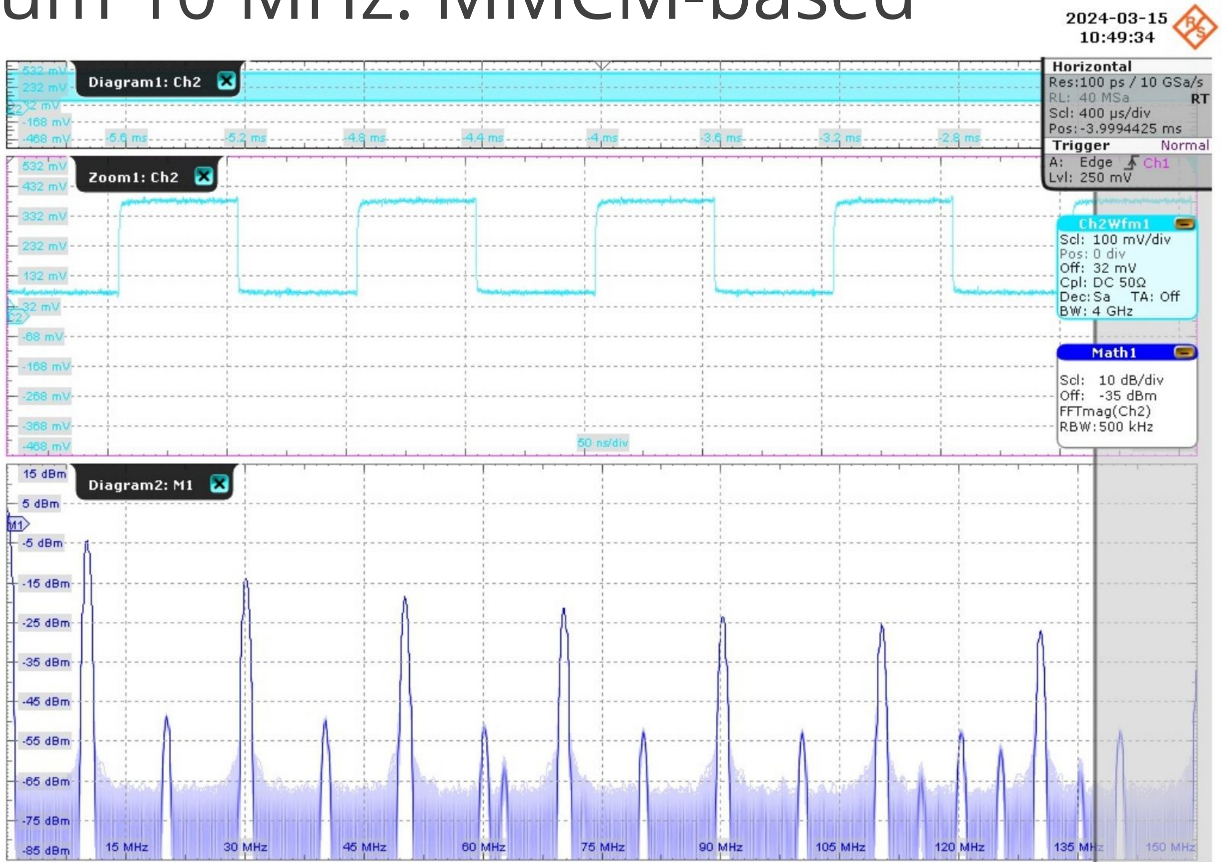
D-DMTD based Measurement Setup

10MHz TIE: MMCM-based



R&S Jitter Wizard
R&S RTO1044

Spectrum 10 MHz: MMCM-based



R&S FFT
R&S RTO1044

VERANO: In-vehicle Radar Networks

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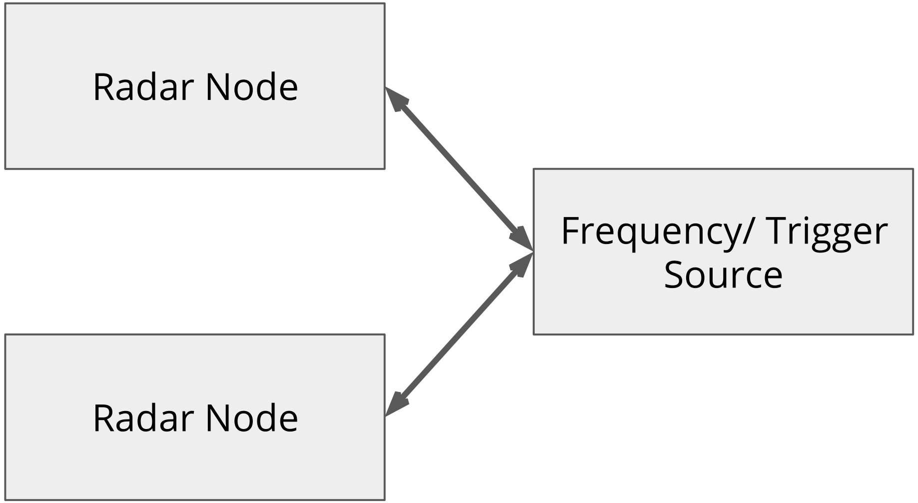


Radar Network Demonstrators

- AI based Radar Image Processing
- Radar Image Compression
- OFDM Radar, etc.
- Radar Imaging
- Front-end research

Frequency/ Trigger Distribution via

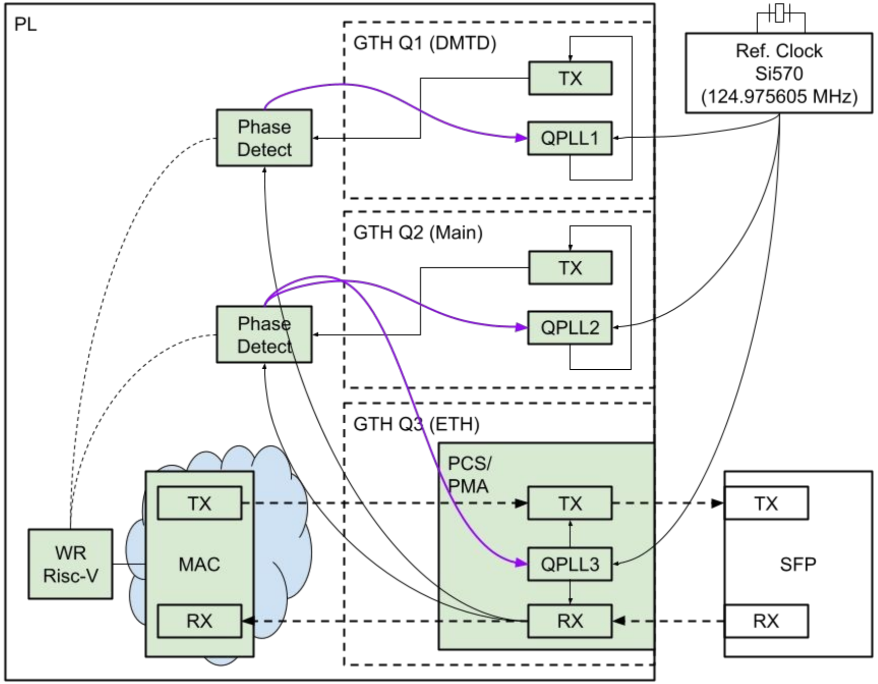
- Coax cable
- Ethernet with PTP v2.1
- Wireless LO distribution

VCXO Technologies (Dormouse FMC Card)

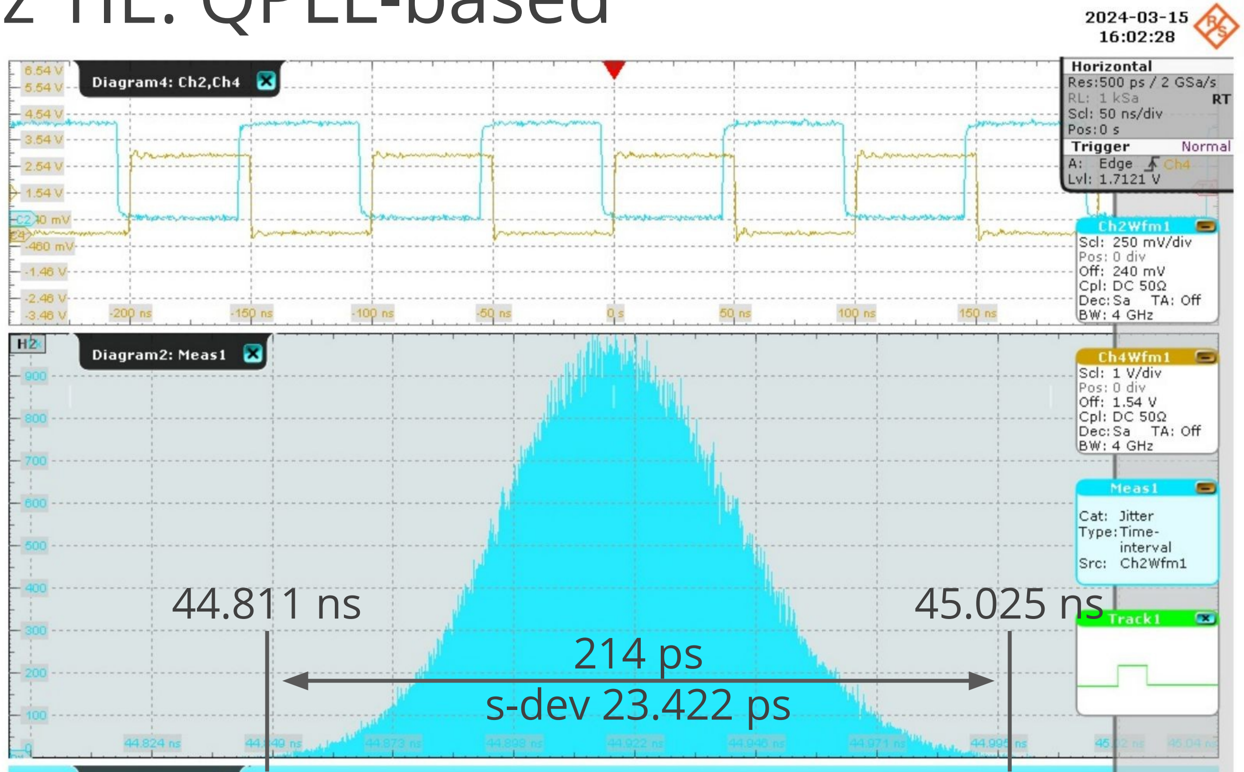
- AMD ZUP/RFSoC GTHe4/GTYe4 QPLL
- SiT3521

QPLL-based Implementation

- Multiple GTH Quads
- External fixed GTH reference clock slightly below 125 MHz
- QPLL output clock needs to pass through a channel TX to be available in fabric
- Frequency is adjusted using the QPLL "SDM" feature



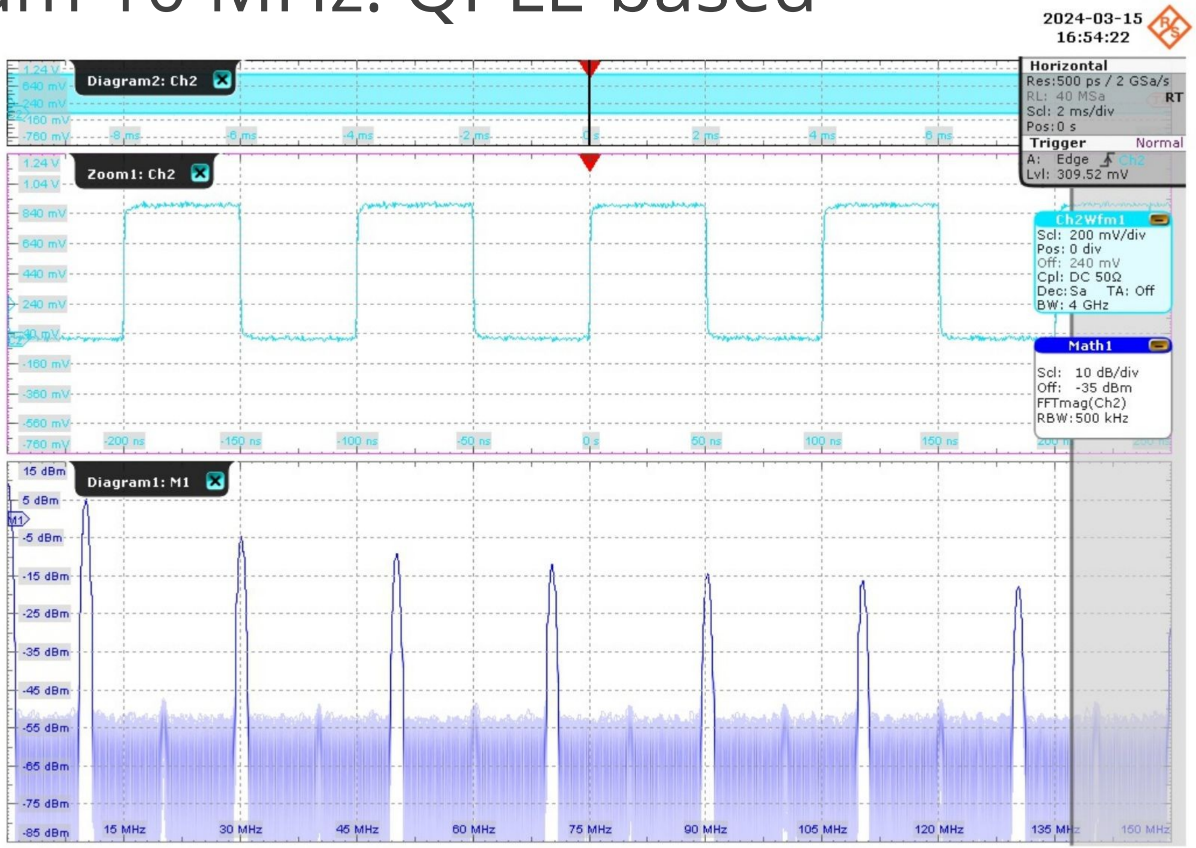
10MHz TIE: QPLL-based



Jitter measurement	Current	+Peak	-Peak	μ (Avg)	RMS	σ (S-dev)	Event count	Wave count
Time-interval error	44.874 ns	45.025 ns	44.811 ns	44.92 ns	44.92 ns	23.422 ps	215828	53957

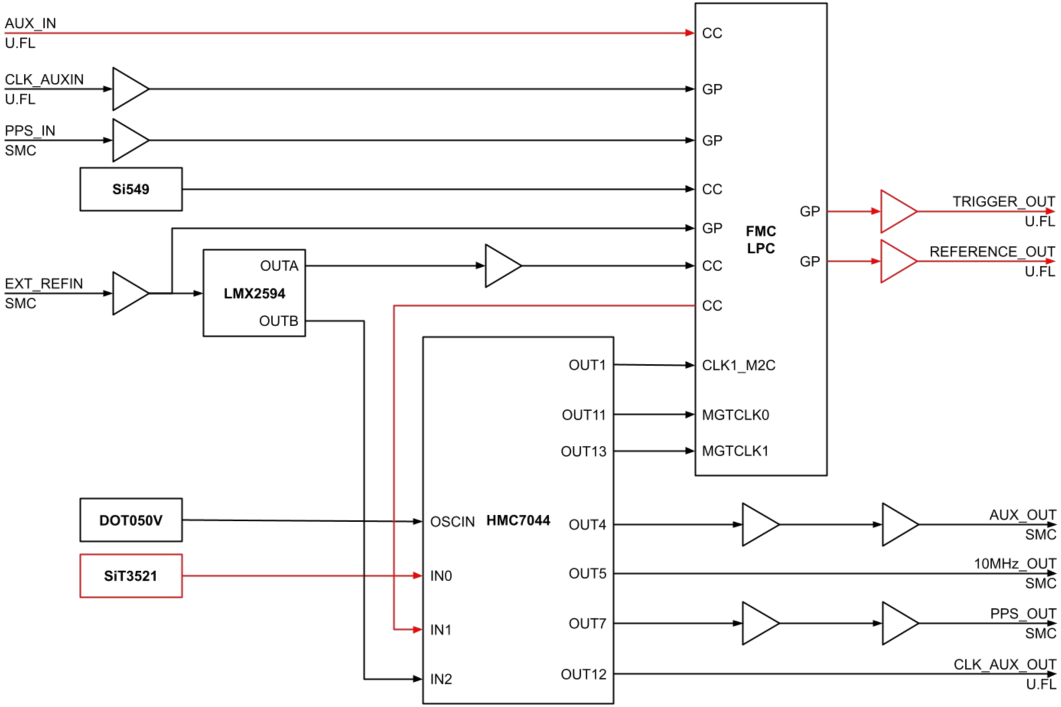
R&S Jitter Wizard
R&S RTO1044

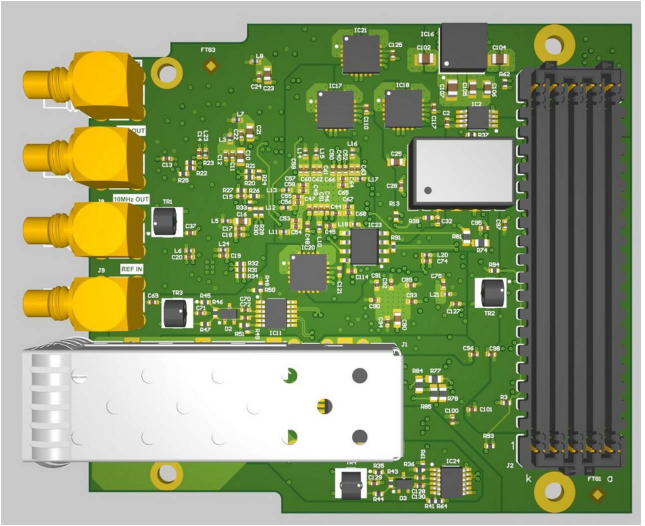
Spectrum 10 MHz: QPLL-based



R&S FFT
R&S RTO1044

Dormouse: an FMC Card based on the FCWR Card





Conclusion

- Loss of accuracy compared to “conventional” VCXOs
- QPLL (Ultrascale fabric) has higher precision and accuracy (than MMCM)
- MMCMs are more widely available, requires less resources

⇒ **What’s next? Work-in-progress…**

- Absolute Calibration with the special SFP Loopback Module
- Measure FPGA-internal (bitstream) delays and jitter effects
- Investigate effects of phase-shifting MMCM
- Investigate reset and power-on randomness

Thank You!

- DESY for providing loaner of a White Rabbit Switch
- U Ulm for supporting the measurements, e.g. with their R&S RTO, etc.
- BMBF for funding the 6G-ICAS4Mobilitx and VERANO projects

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