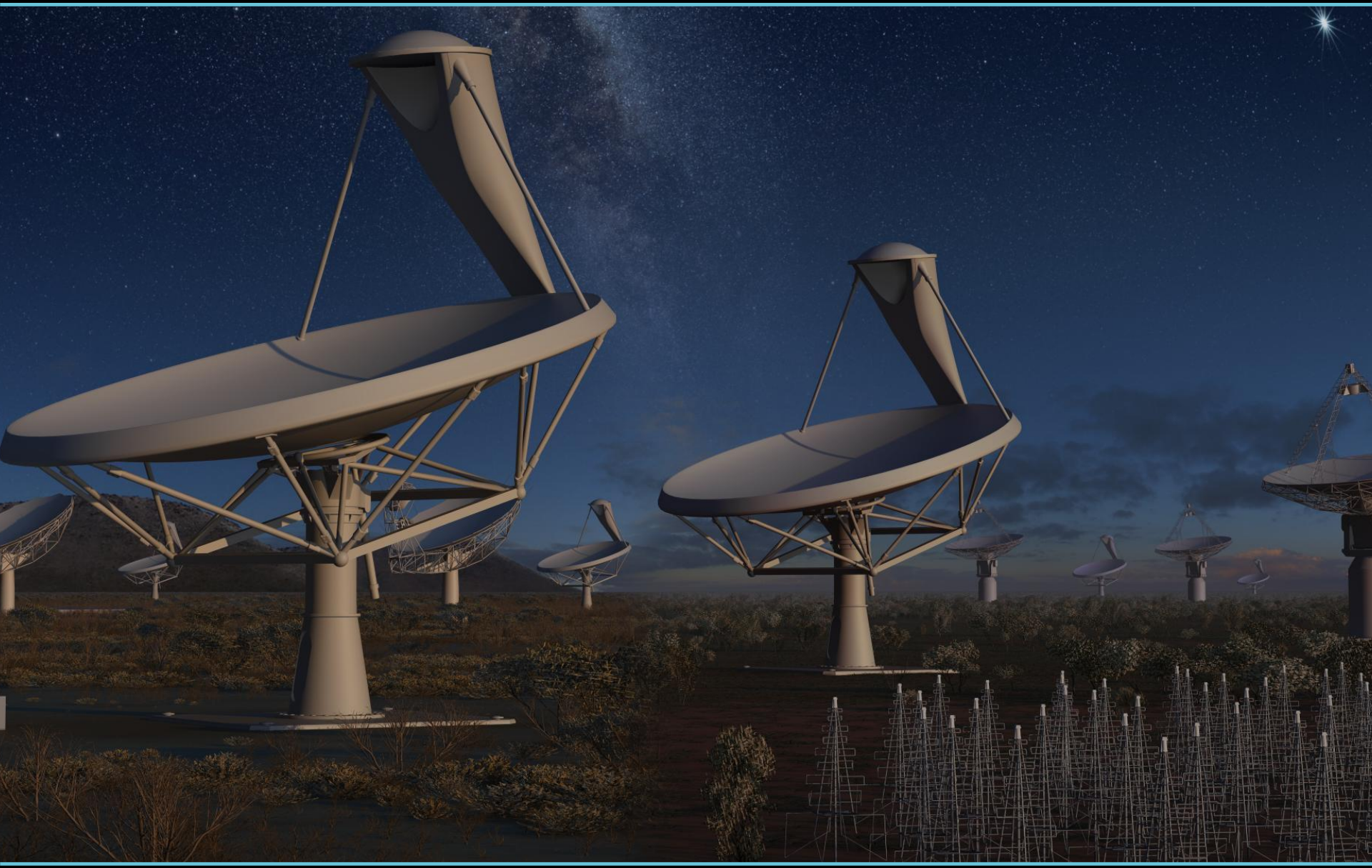
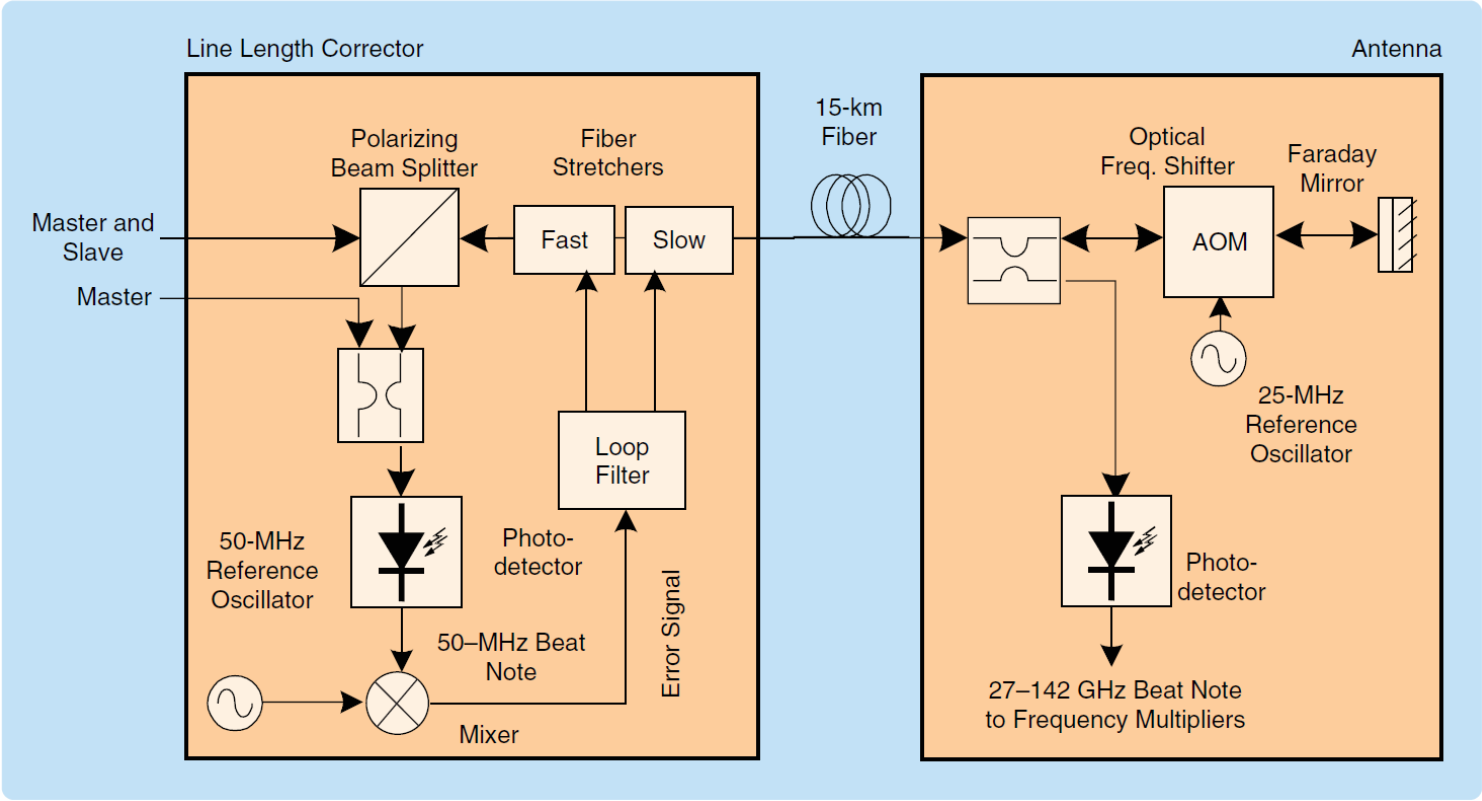
Stabilized frequency transfer for the SKA



Phase coherence for antenna arrays

- Round trip phase measurement — e-MERLIN, ATCA, JVLA
- Active phase compensation — DSN, ALMA, SKA

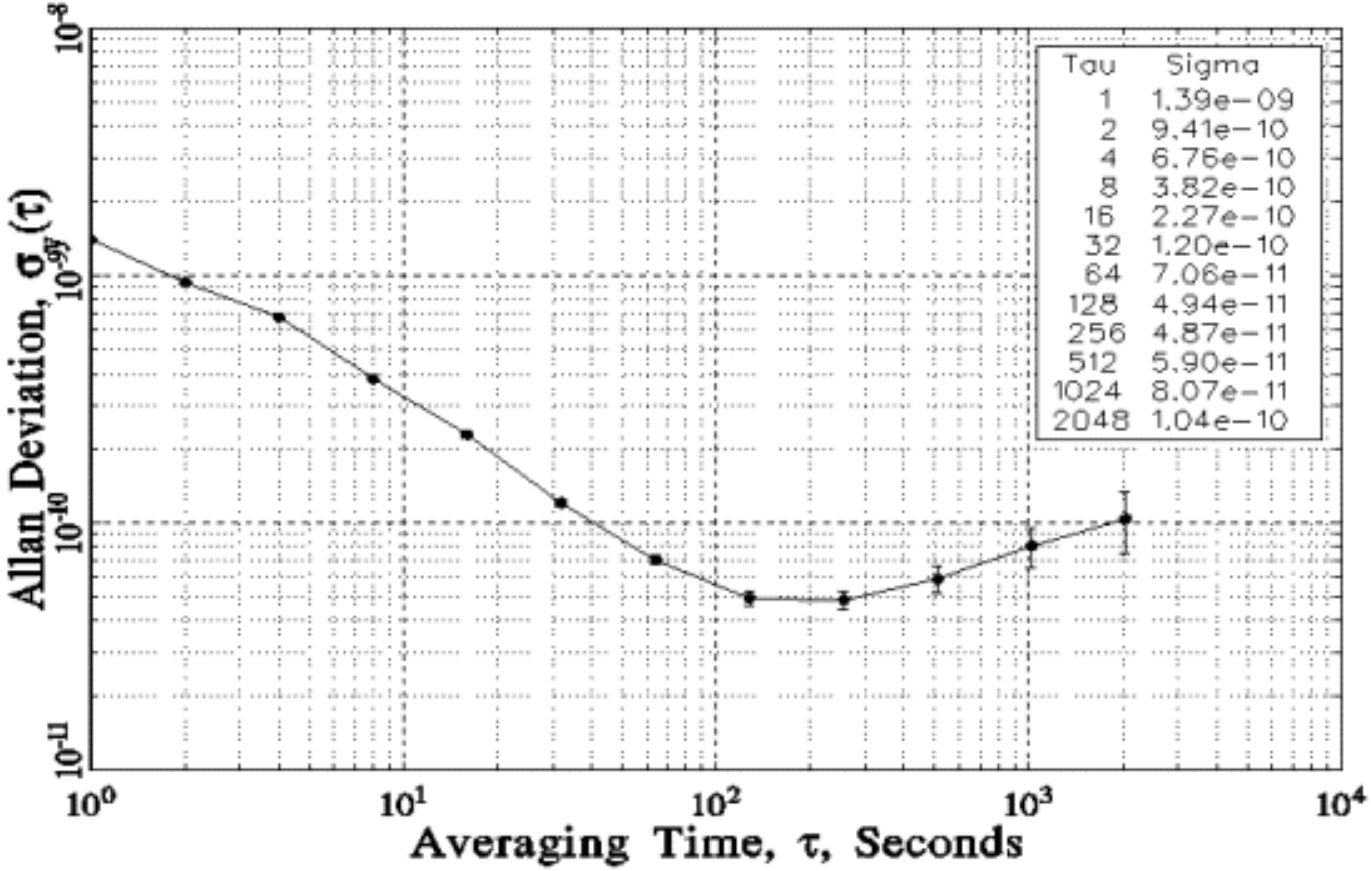


SKA stability requirements

- REQ-2268: max 1 sec coherence loss = 0.2 rad
  → Adev: 2.31×10^{-12} over 1 sec
- REQ-2692: max 60 sec coherence loss = 0.2 rad
  → Adev: 3.84×10^{-14} over 60 sec
- REQ-2693: max phase drift < 1 rad over 10 min
- Link length — up to 173 km
- Other reqs — cost, scalability, glass-box, RFI, etc

Allan deviation

- From Allan (two-sample) variance
- Measure of frequency stability of oscillators

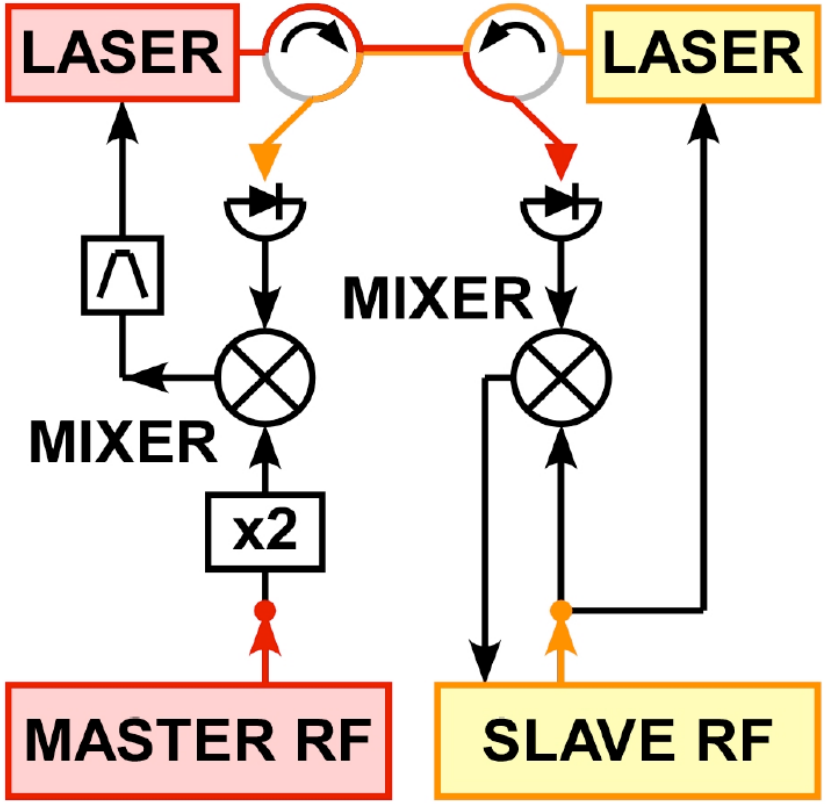


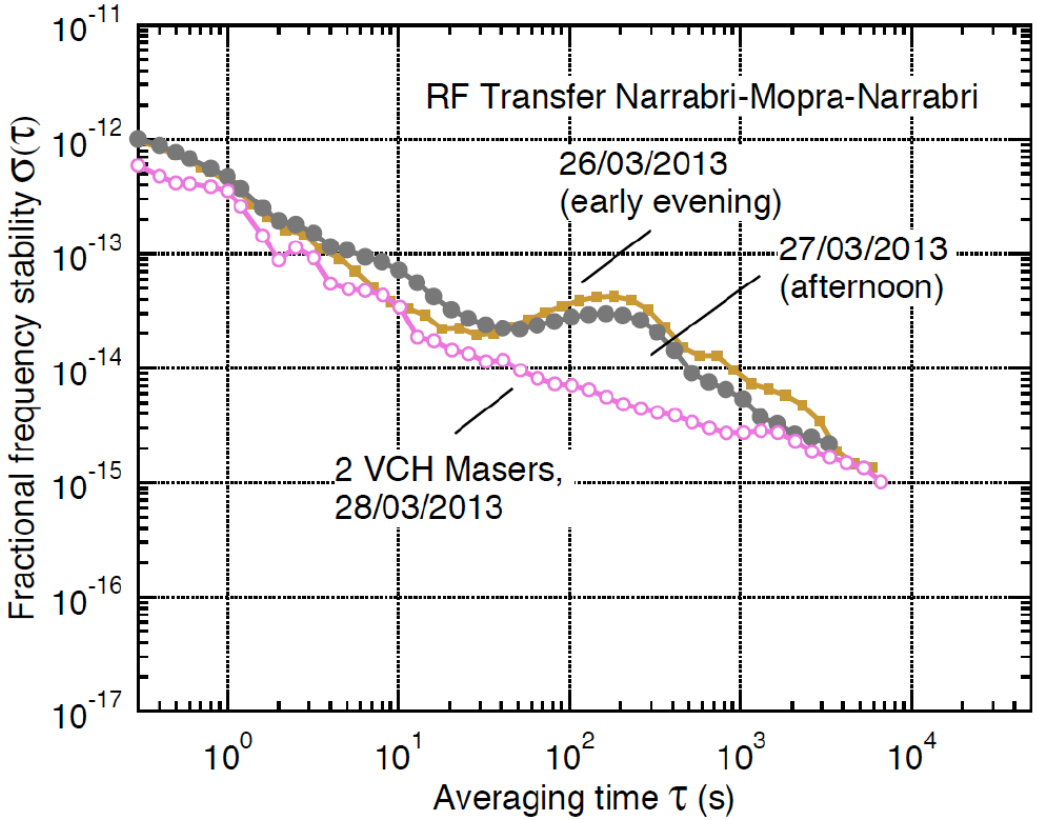
Other SKA.STFR concepts

- University of Manchester — upgraded e-Merlin
- PC — passive, phase conjugation technique
- Tsinghua University (THU) — client-side 1f-2f technique
- UWA — optically-sensed RF/MW transmission

Other concepts — PC

- 310 km link, Mopra-Narrabri-Mopra

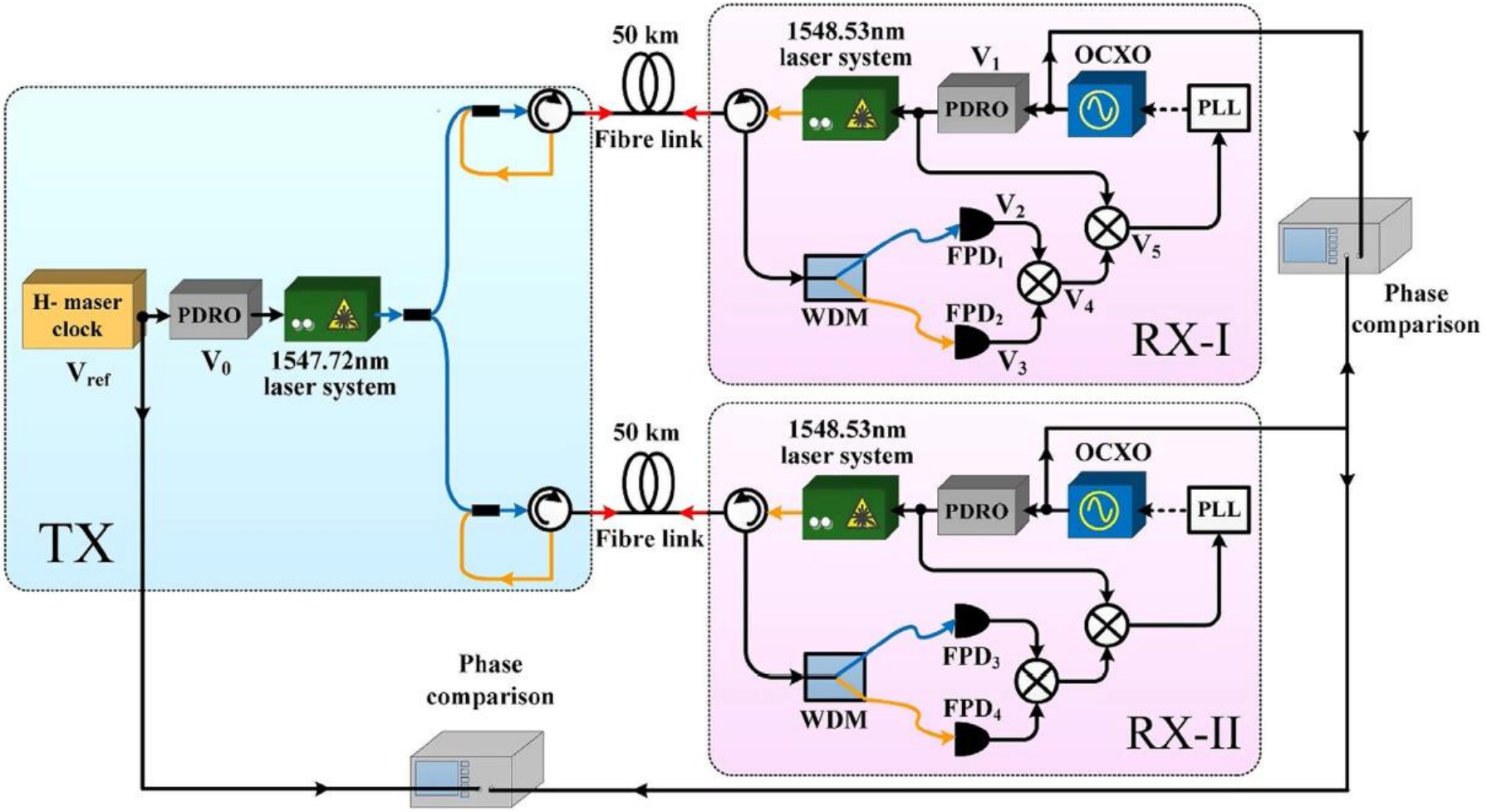




(Baldwin et al. *Phot. Fiber Tech. Congress* 2016)

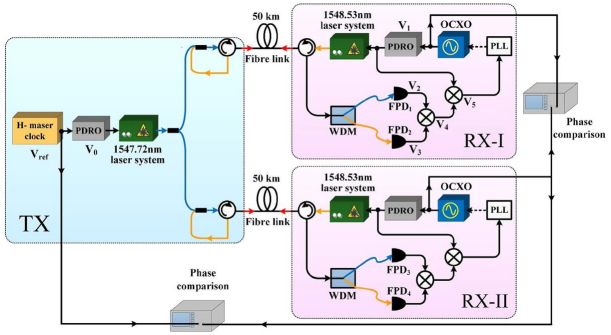
Other concepts — THU

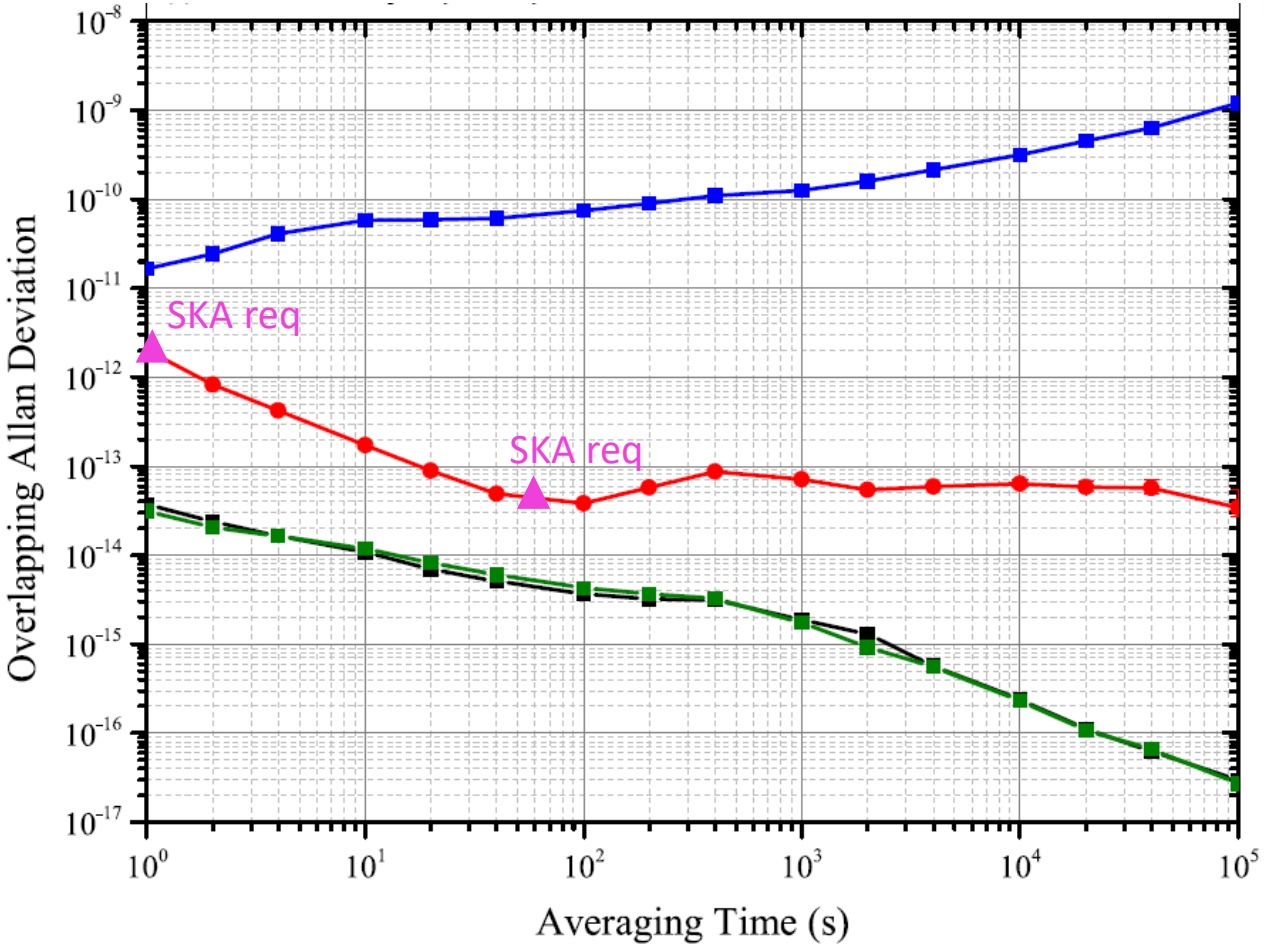
- Tsinghua University



Other concepts — THU

- Tsinghua University

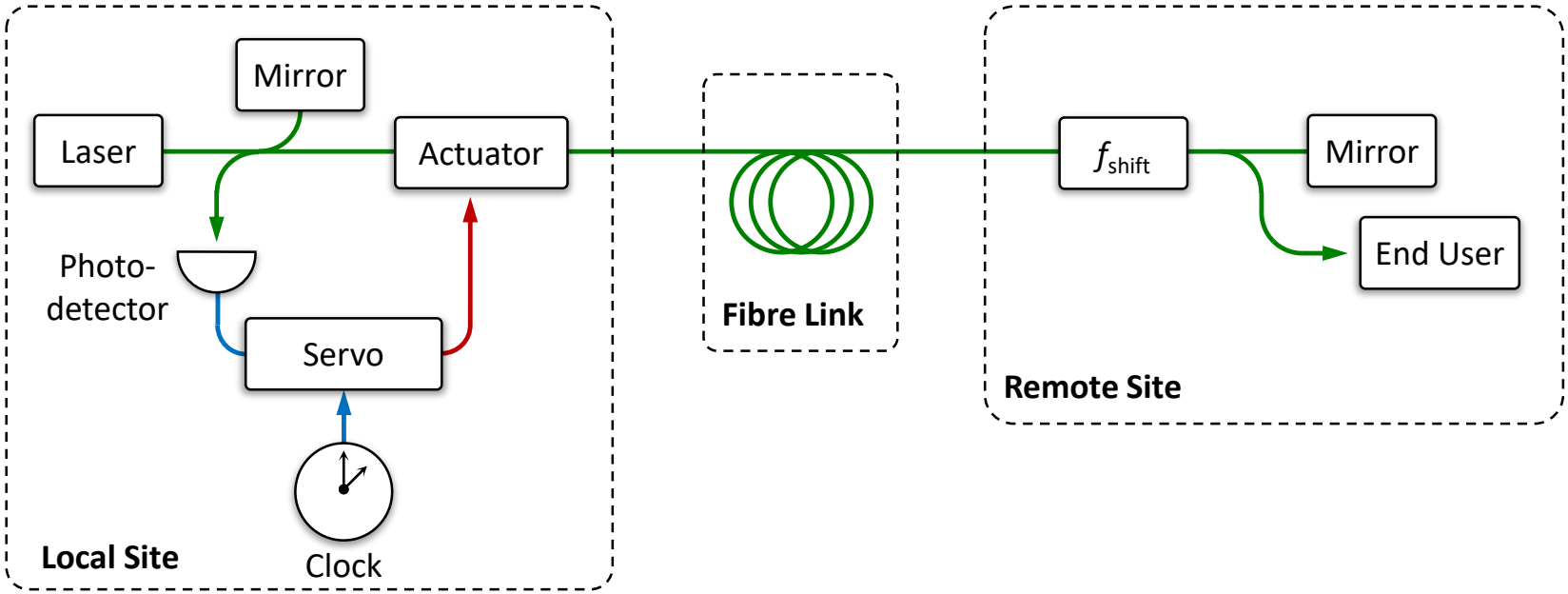




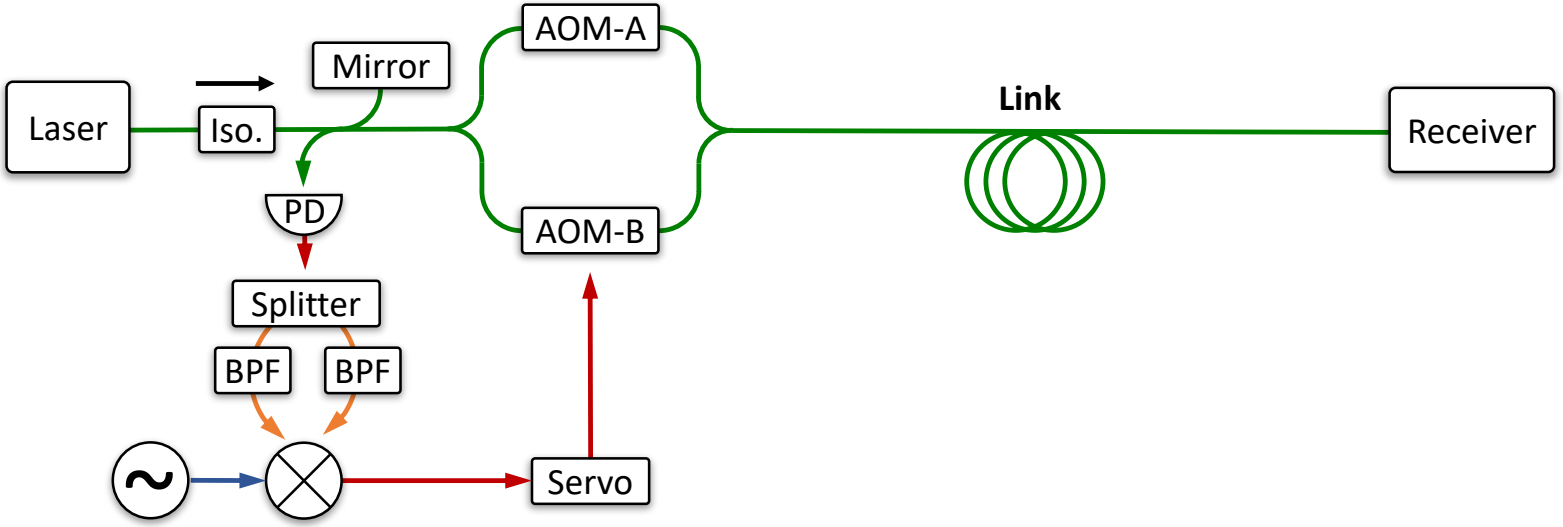
(Wang et al. *Sci. Reports* 2015)

UWA SKA.STFR Concept

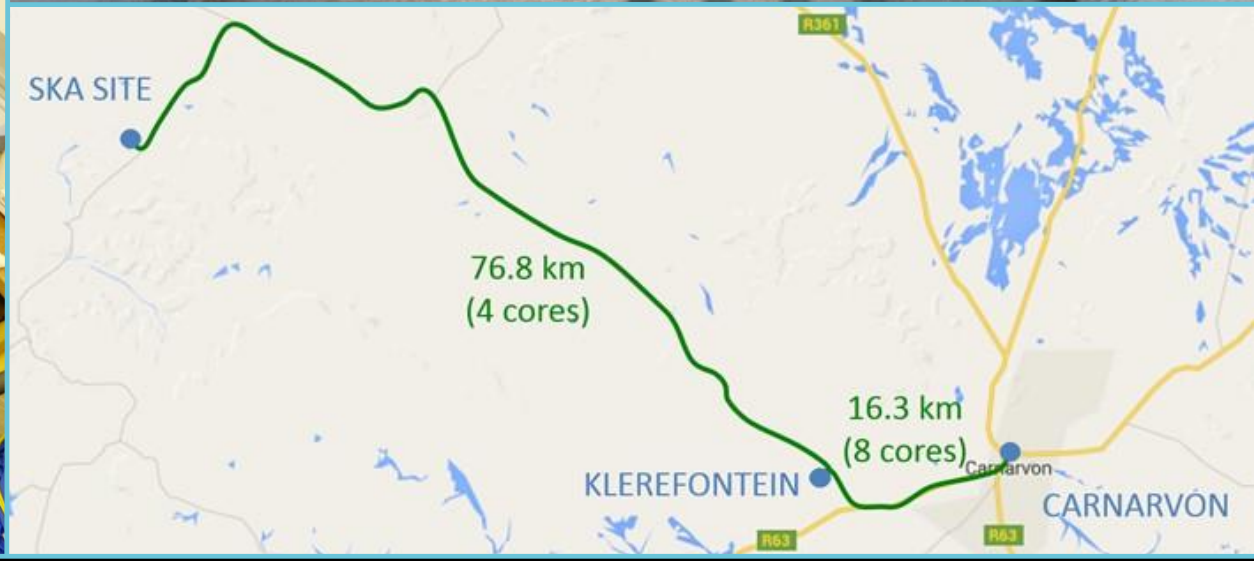
- Transmitted signal reflected back from remote site
- Self-heterodyned
- Actuator pre-compensates outgoing signal



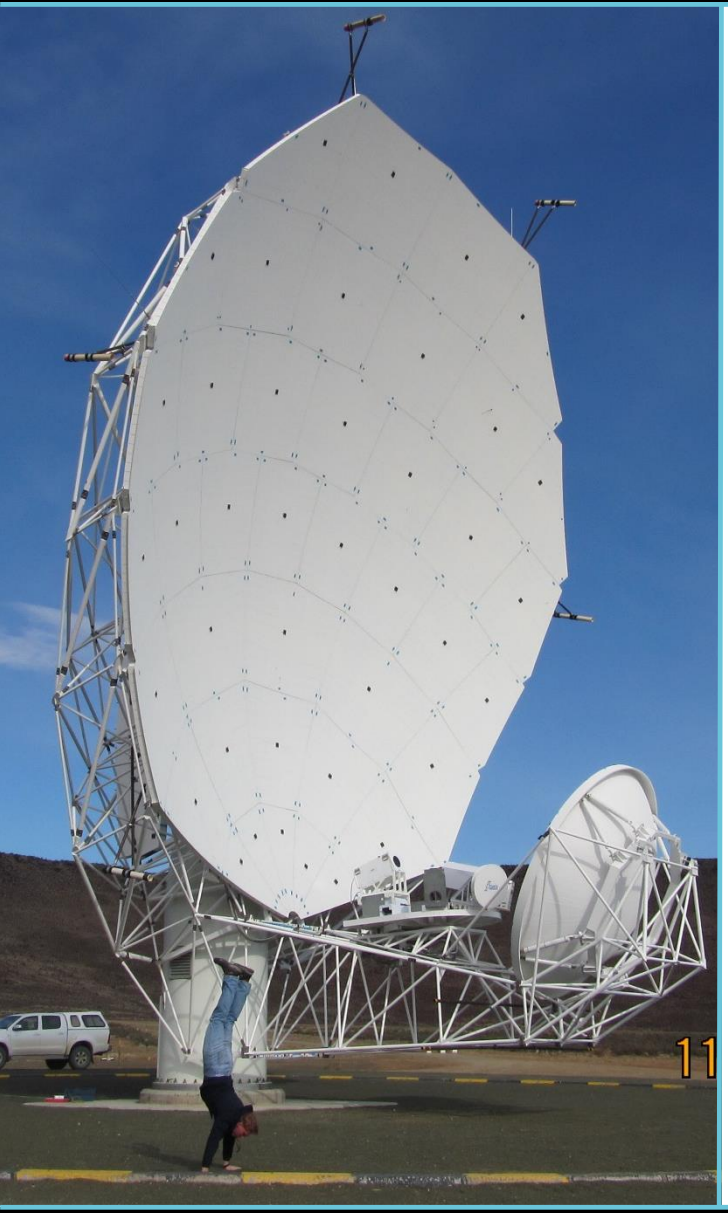
UWA SKA-Low

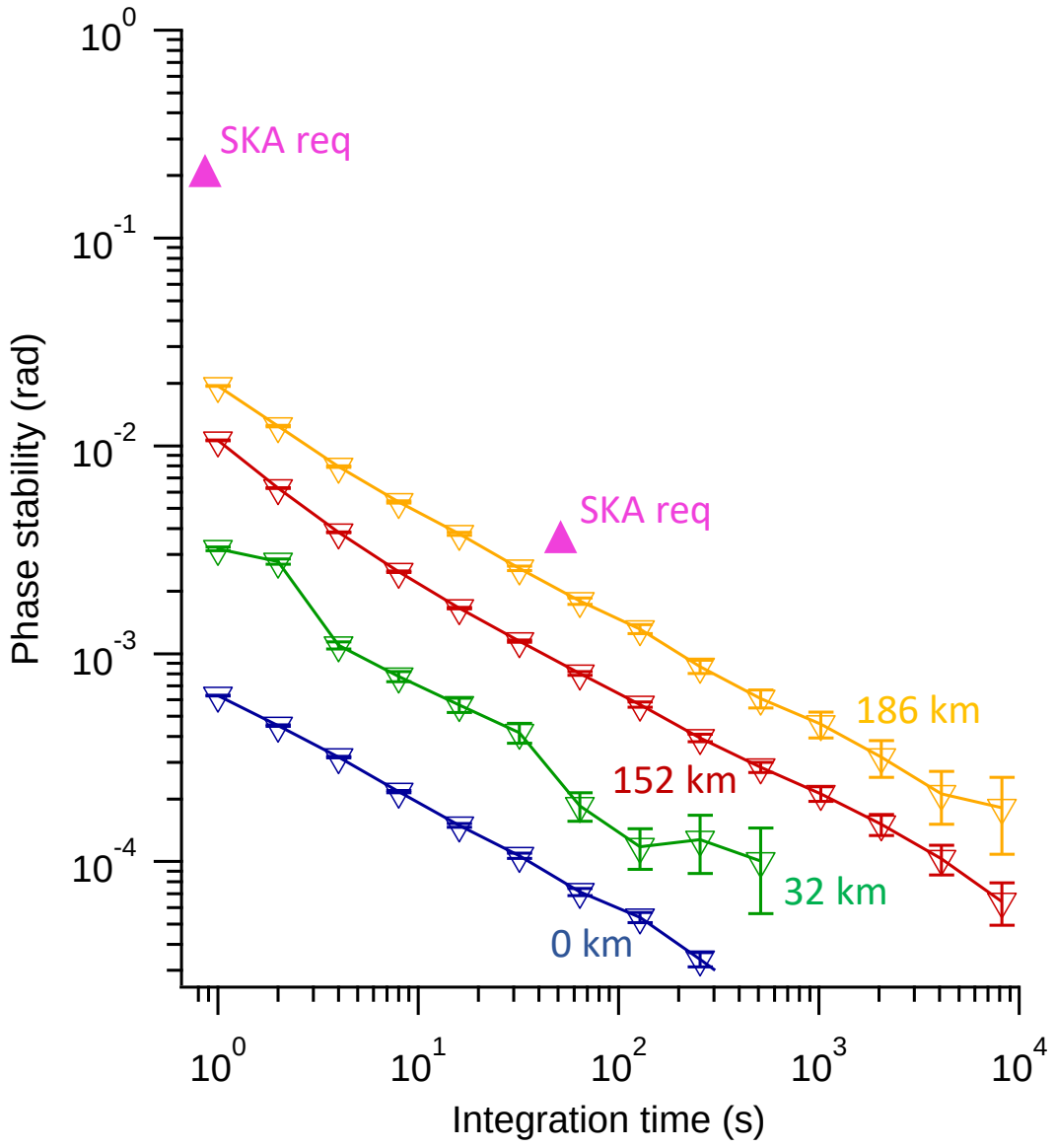

Laser
Iso.
Mirror
AOM-A
AOM-B
Link
Receiver
PD
Splitter
BPF
BPF
Servo

UWA SKA-low tests

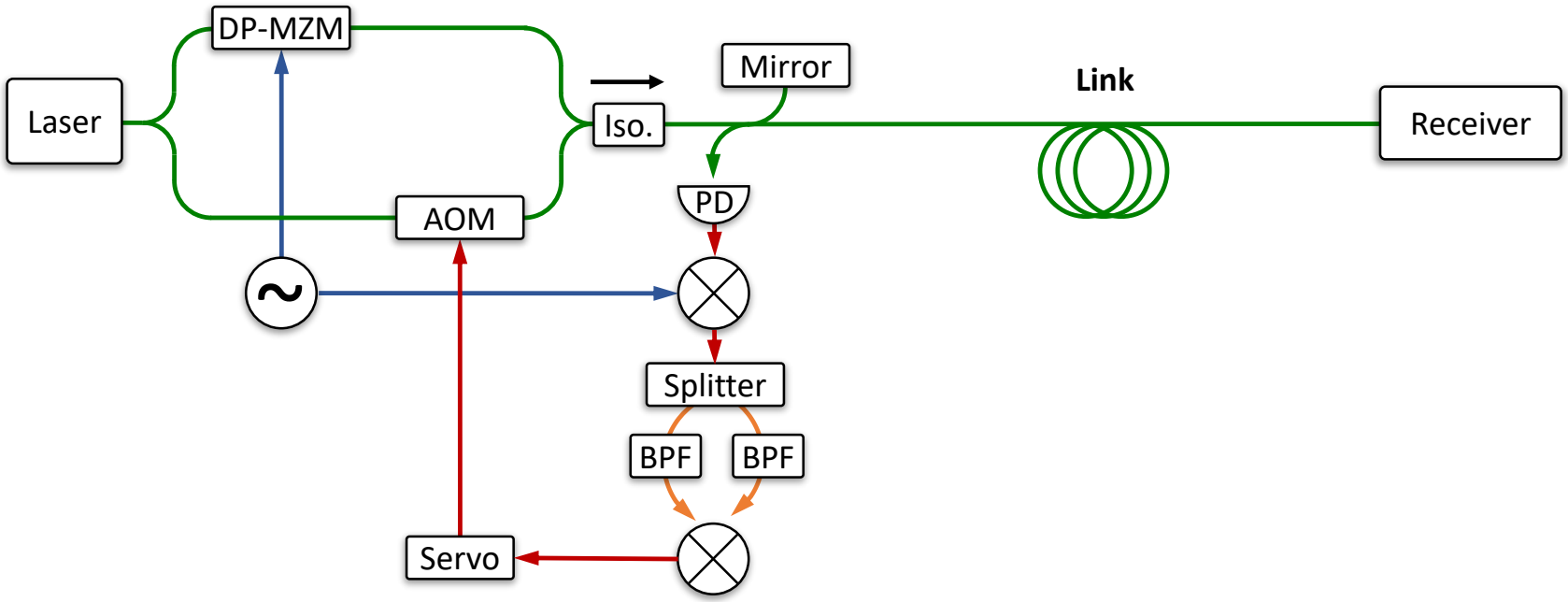


UWA SKA-low tests

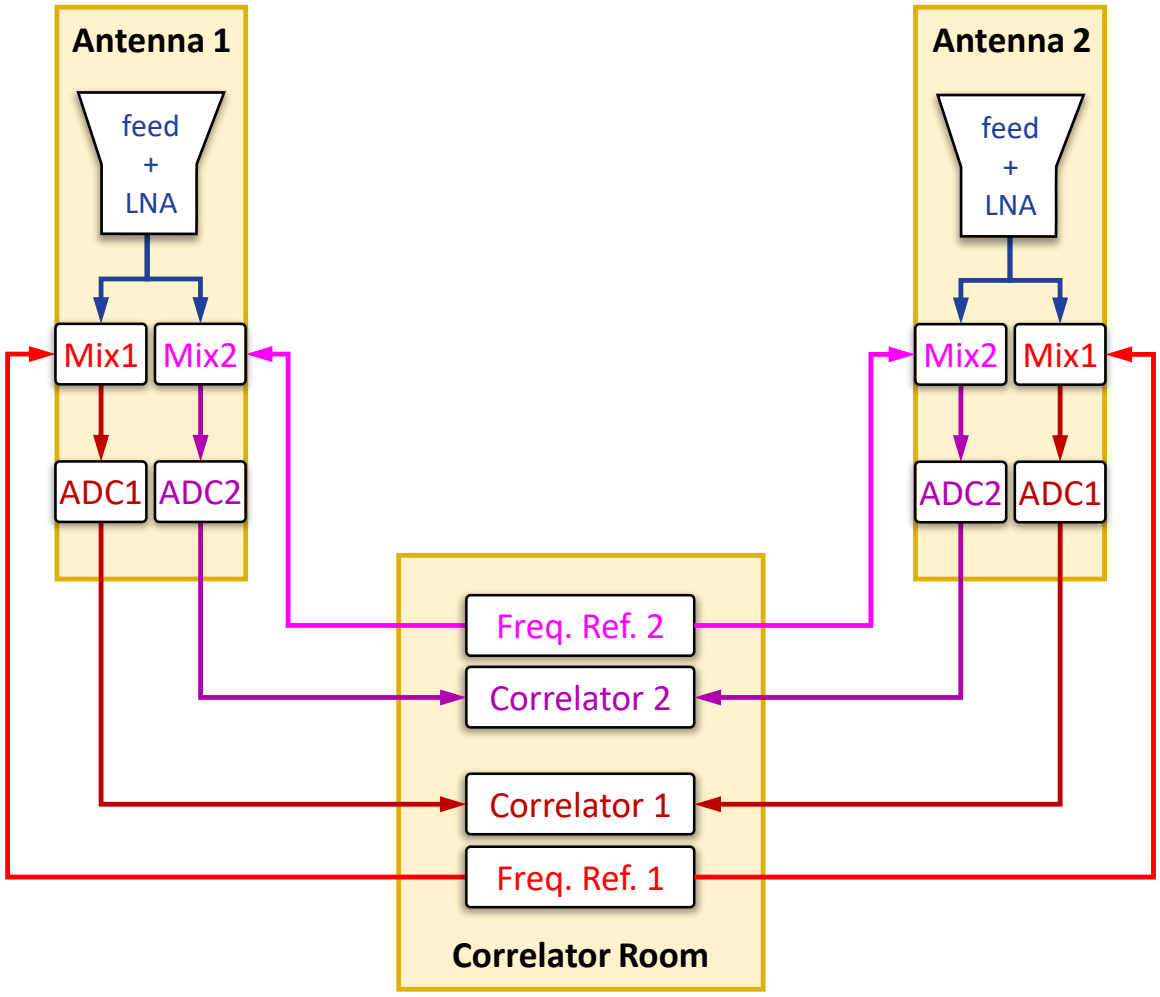




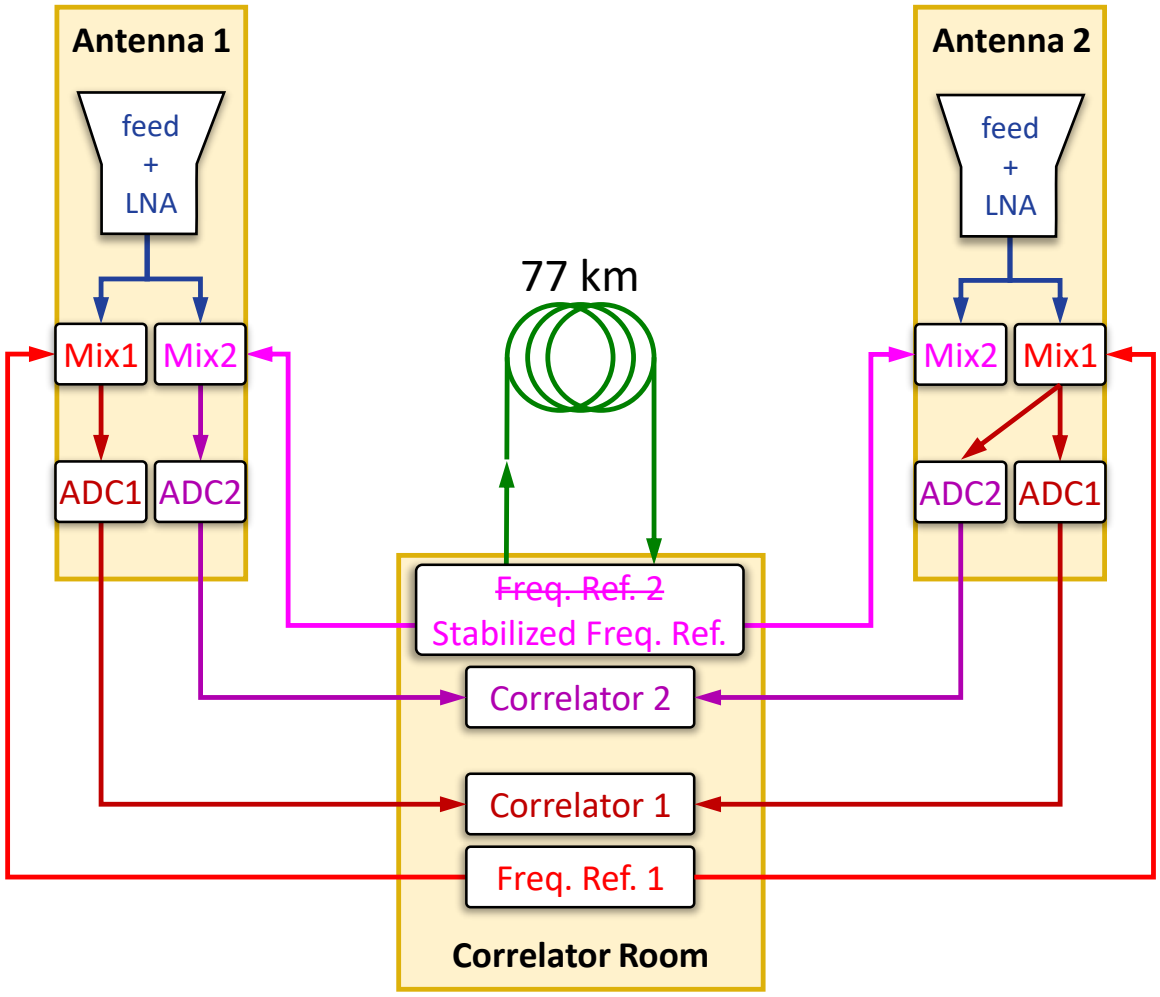
UWA SKA-Mid


DP-MZM
Laser
Iso.
Mirror
Link
Receiver
AOM
PD
Splitter
BPF
BPF
Servo

ATCA Tests


Antenna 1
feed + LNA
Mix1
Mix2
ADC1
ADC2
Antenna 2
feed + LNA
Mix2
Mix1
ADC2
ADC1
Freq. Ref. 2
Correlator 2
Correlator 1
Freq. Ref. 1
Correlator Room

ATCA Tests


Antenna 1
feed + LNA
Mix1
Mix2
ADC1
ADC2
77 km
Antenna 2
feed + LNA
Mix2
Mix1
ADC2
ADC1
~~Freq. Ref. 2~~
Stabilized Freq. Ref.
Correlator 2
Correlator 1
Freq. Ref. 1
Correlator Room

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ATCA Test Setup

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ATCA Tests

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ATCA Tests

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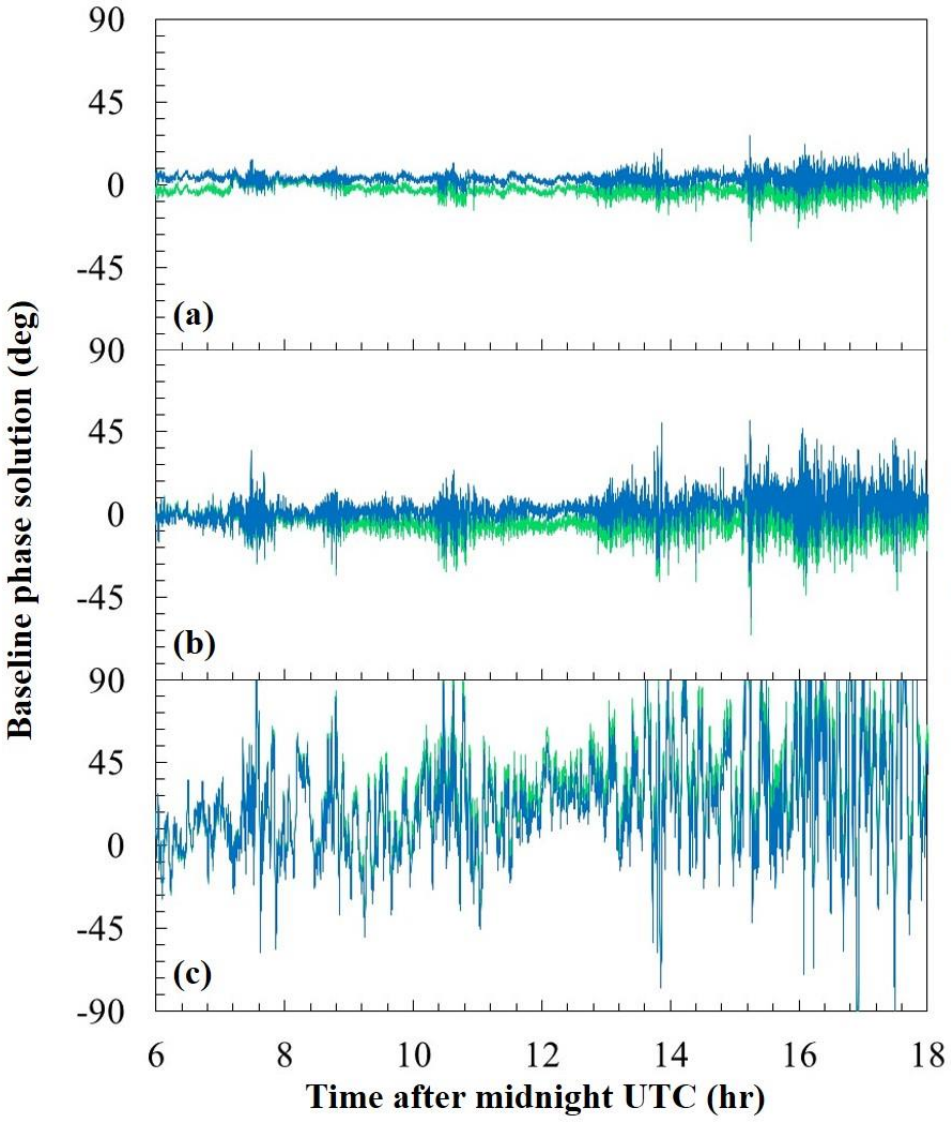
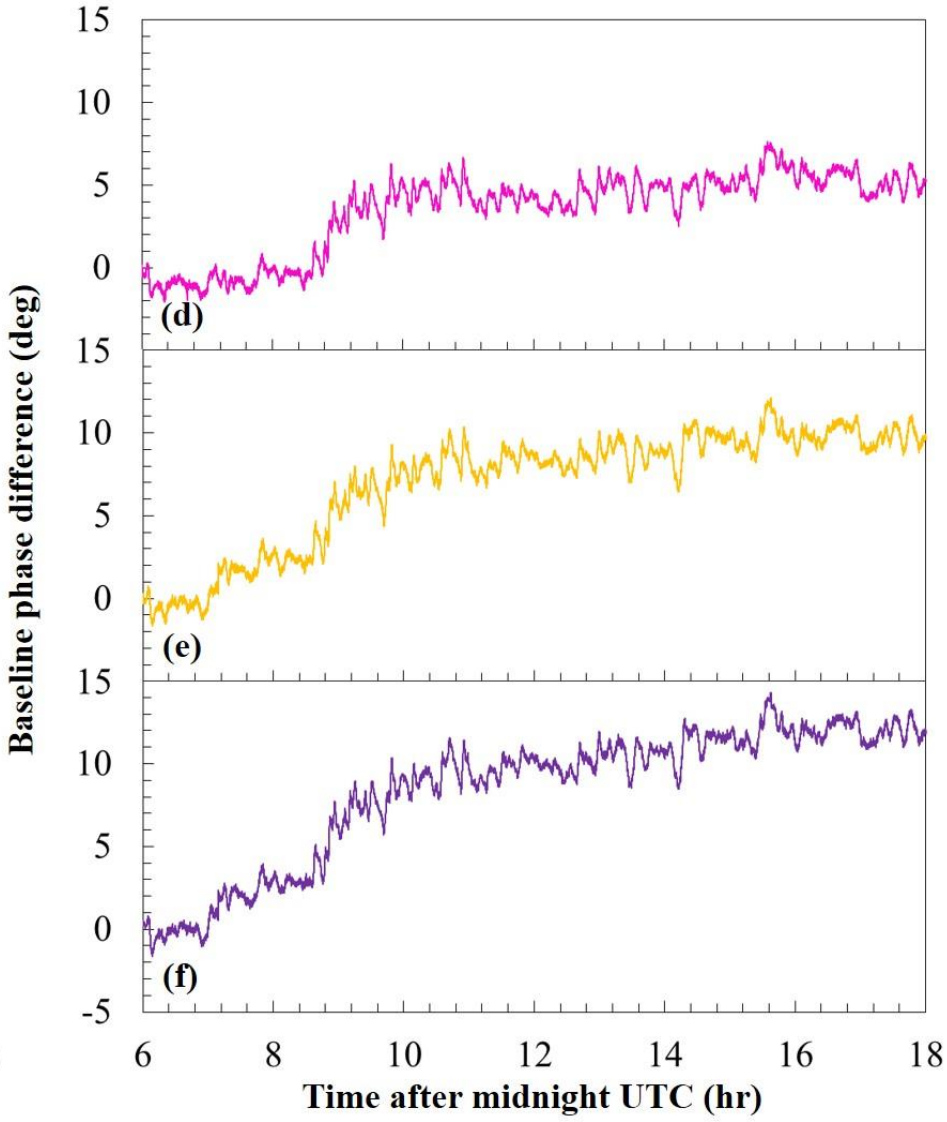
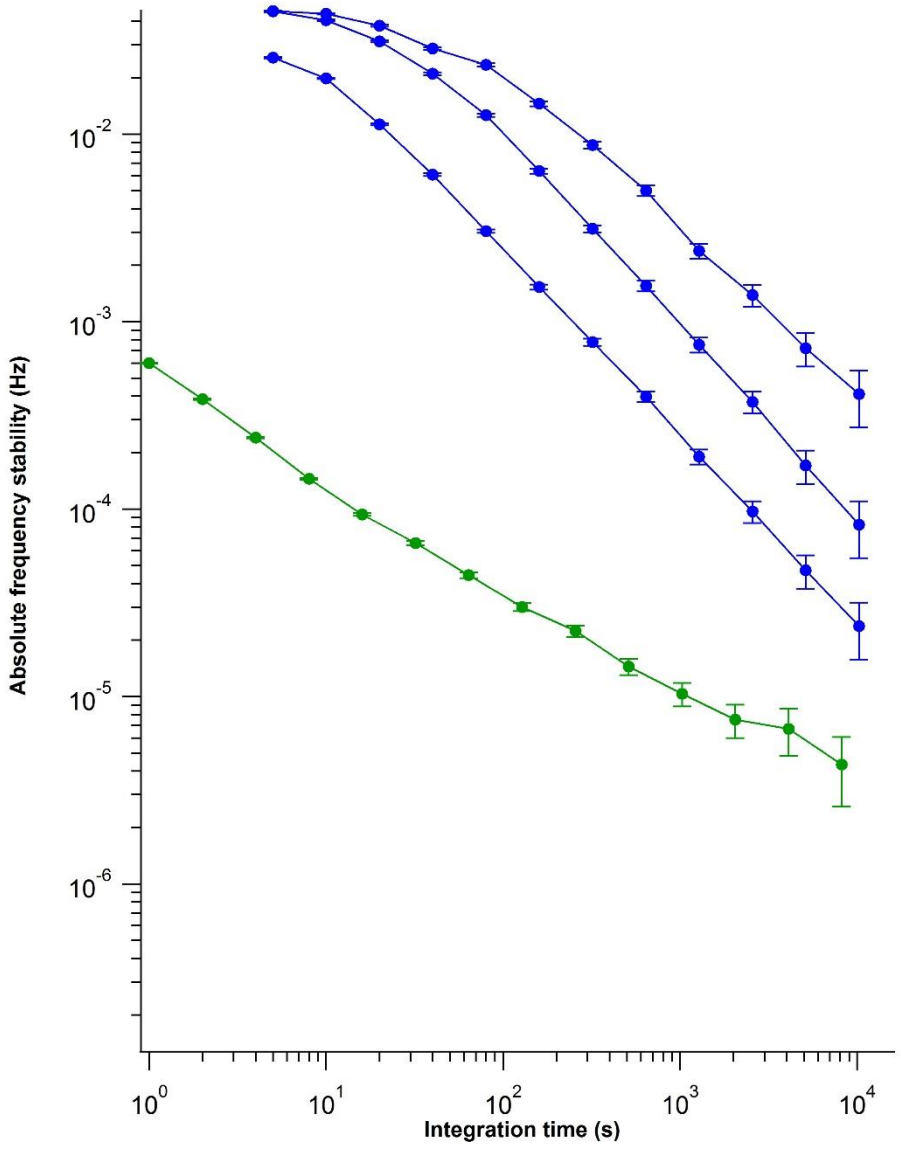
ATCA Tests

Analysis


Baseline phase solution (deg)
90
45
0
-45
-90
(a)
(b)
(c)
6
8
10
12
14
16
18
Time after midnight UTC (hr)


Baseline phase difference (deg)
15
10
5
0
-5
(d)
(e)
(f)
6
8
10
12
14
16
18
Time after midnight UTC (hr)

Analysis


Absolute frequency stability (Hz)
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}
Integration time (s)

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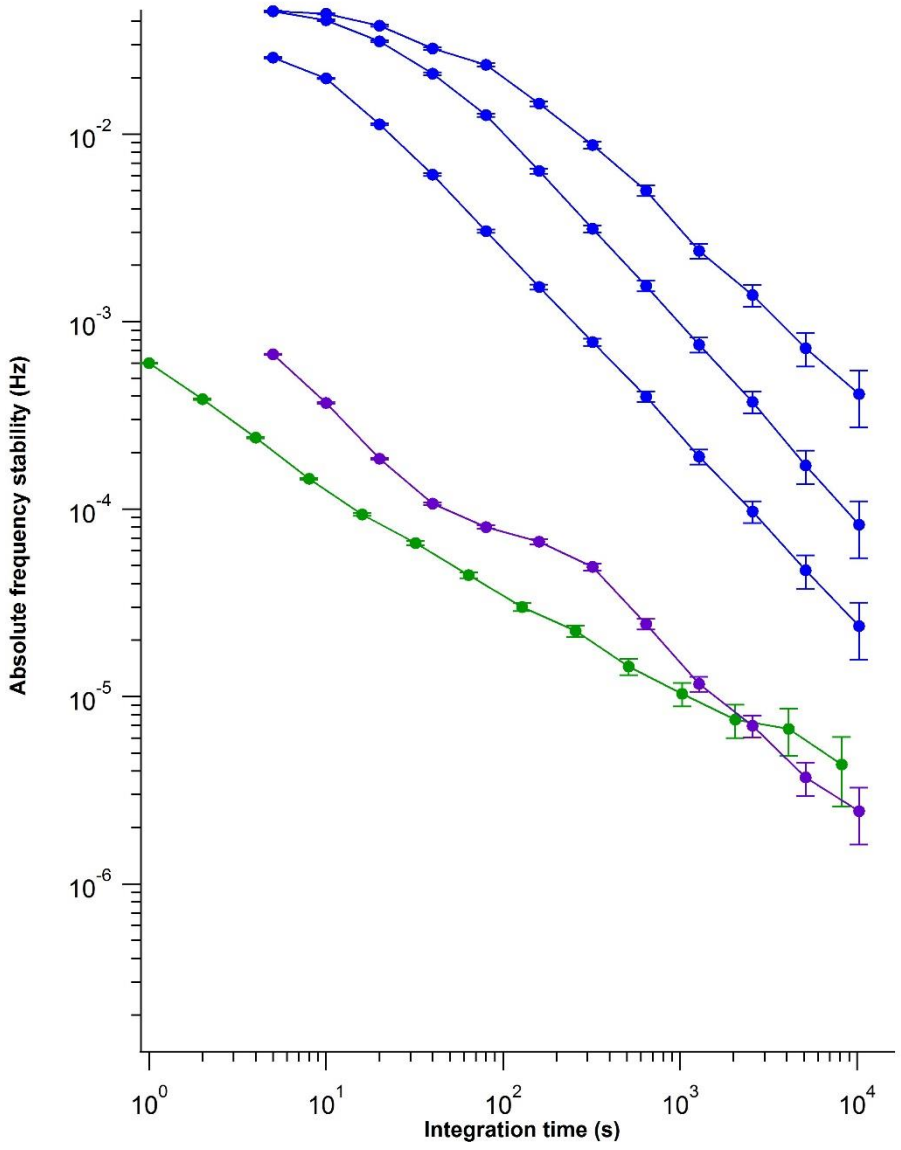
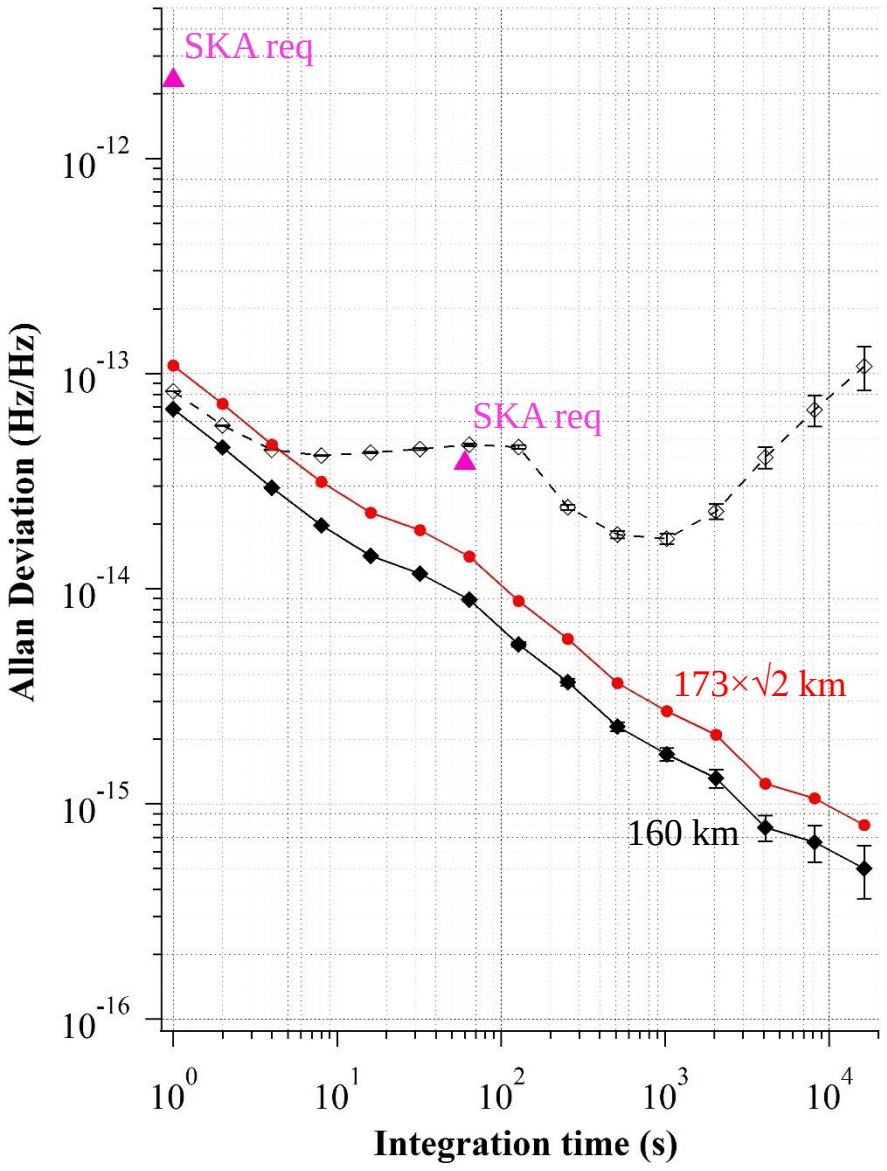
Analysis

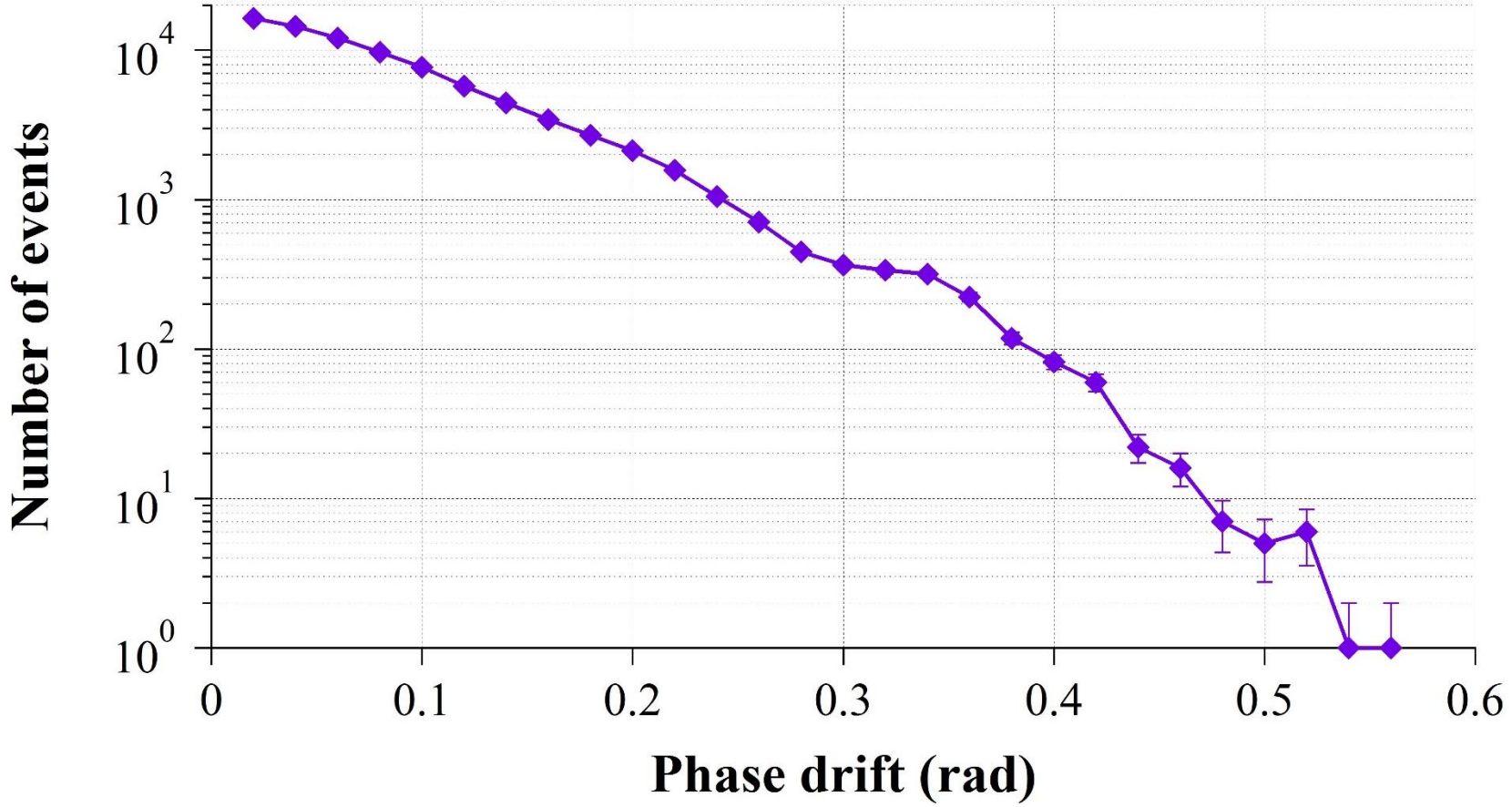


SKA requirements



SKA requirements

- 600s phase drift < 1 rad
- 42hrs data, drifts < 0.08 rad (1 s.d.)



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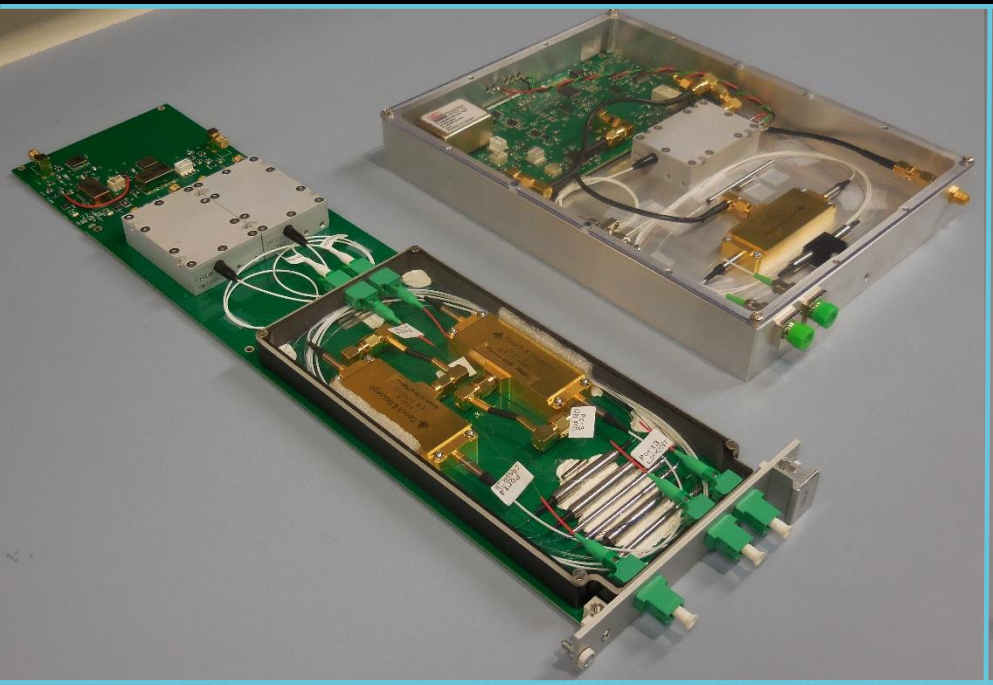
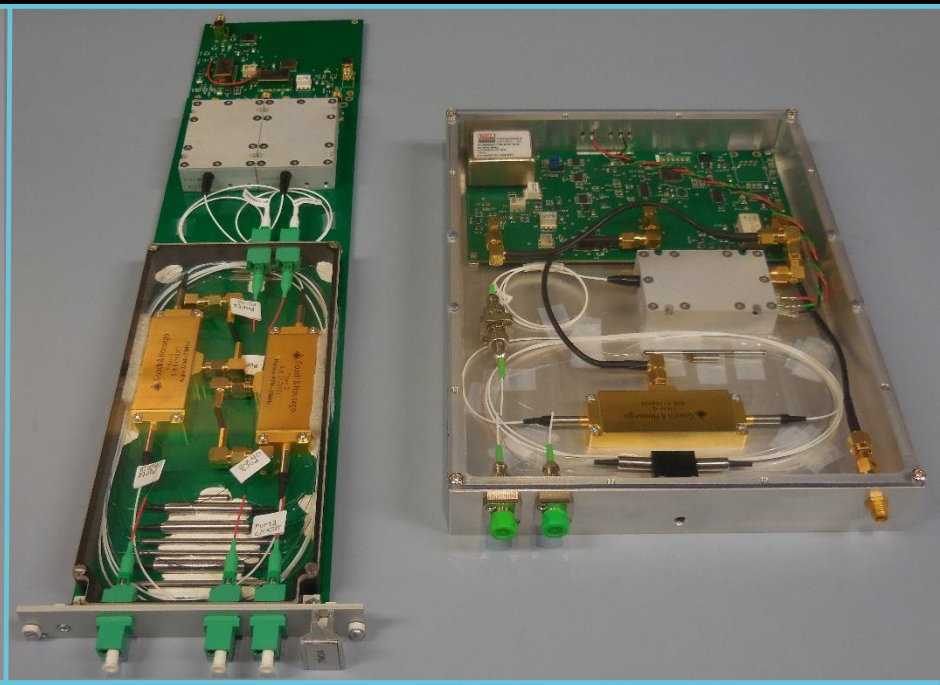
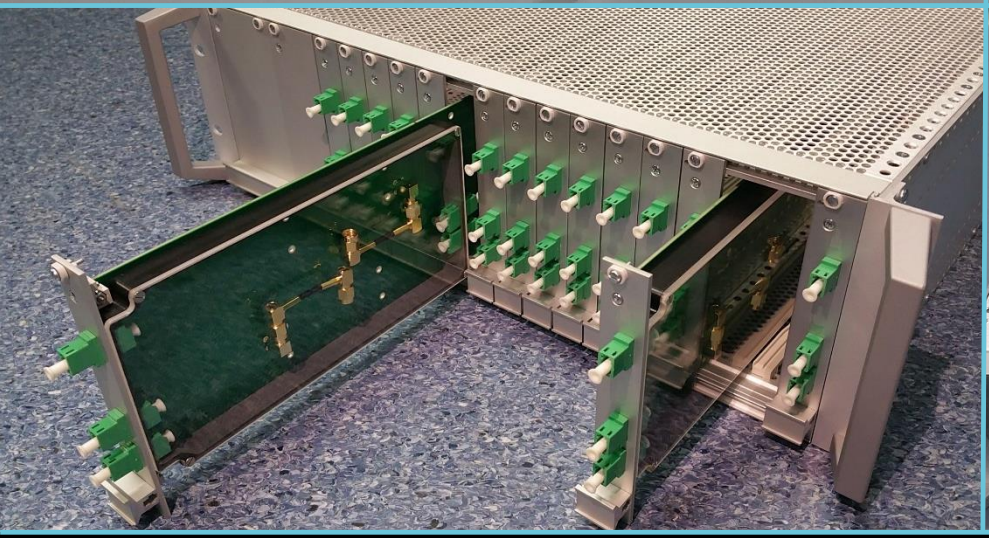
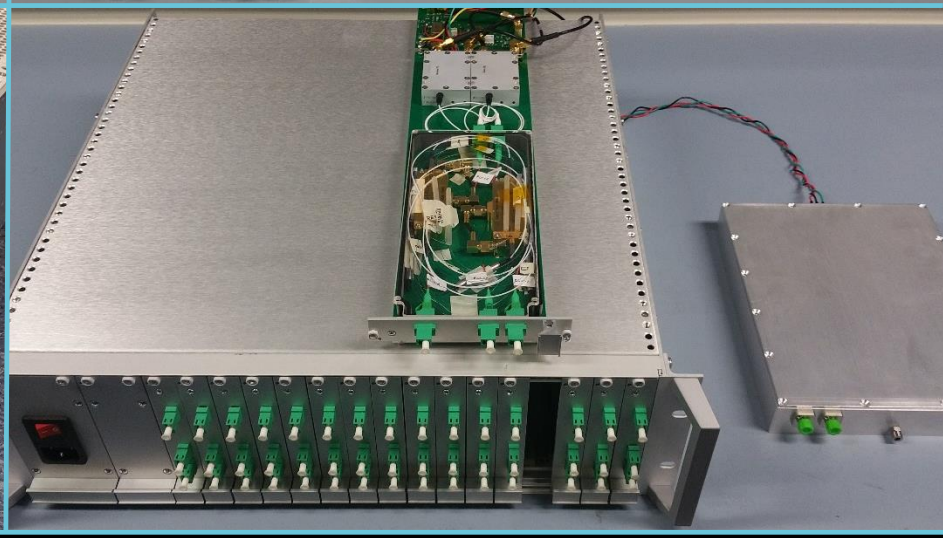
Design to Manufacture









Conclusions and future work

- UWA stabilized frequency transfer system meets SKA requirements under observing conditions
- Work progressing on design-to-manufacture
- Working towards AAVS1 and MeerKAT integration and end-to-end testing

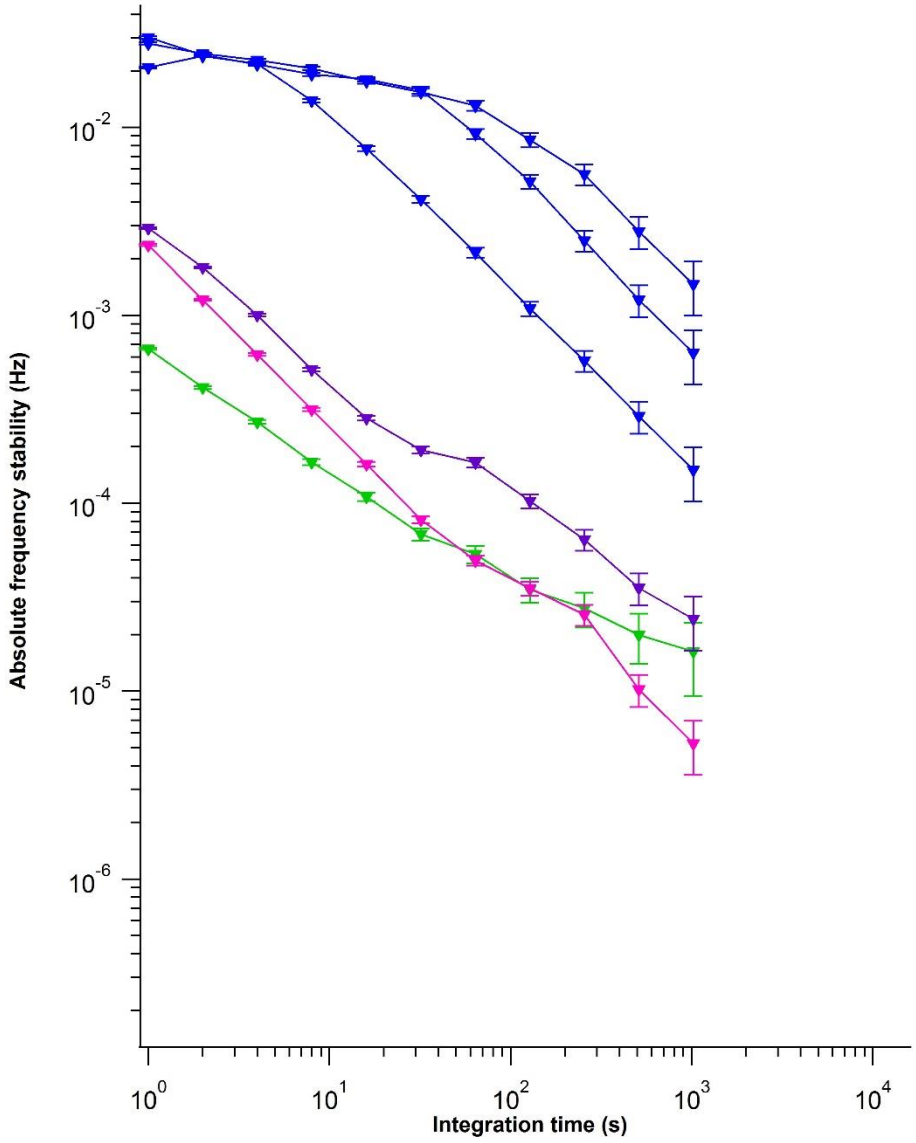
Acknowledgements

Many thanks for the hard work and effort of:

- Sascha Schediwy & Simon Stobie at UWA
- Richard Dodson and Maria Rioja at ICRAR
- Jamie Stevens, Mike Hill, Jock McFee, Peter Mirtschin & Brett Lennon at CASS

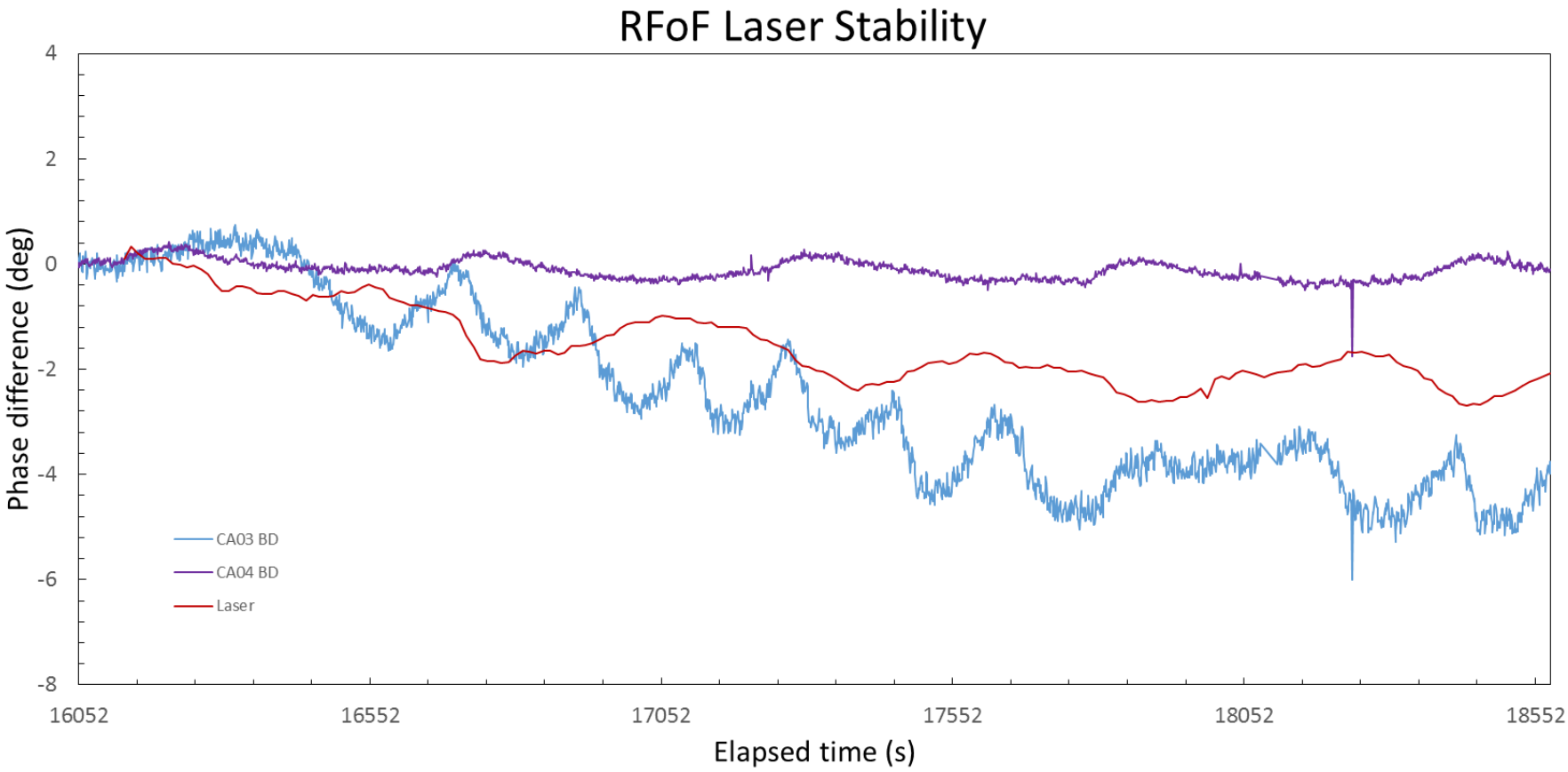
Extra Information

1-second logged data



Noise investigation

- Non-coherent noise investigation - laser stability



Noise investigation