

# **Some thoughts and options about Refurbishing the Timing System at the Radio Telescope Effelsberg**

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## Outline: Refurbishment in which areas? Which goals?

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- The source
  - Maser performance improvements
    - Short term frequency
    - Long term frequency
    - Options
- Time-Keeping
  - How to generate local time?
  - To what performance?
- The link to the observed radio signal
  - Can we allow to sacrifice source performance via the link?
  - How to bring the full source performance to the radio signal?

## What can we do to the Maser source itself? Organise with T4S

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### Maser Refurbishment Options

- Get more than 1 very good maser (trivial, but fact)

### What to do with old masers?

- Improve thermal stabilisation (boxes)
- Trade in old cavities, get re-newed units
- Renew old units with actual electronics / oscillators
  - New 5 MHz OCXOs (RAKON 8E-14 @ 1s): now
  - New 5 MHz low noise floor option: wait until 2019
  - Low phase noise 100 MHz oscillator replacements (-140 dBc @ 100 Hz offset or better, made by Axtal): 2019
  - Replace 1pps generator: today few ps jitter

Improve on short term stability (just use masers)

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## Anything which can be done with masers alone?

- **Yes, but most involve dedication & efforts**
  - Observation and Monitoring (phase comparator & time interval counter)
  - Combination: 2 equal sources improve performance by  $\sqrt{2}$
  - Disciplining of 2 or 3 sources: generate a Time-Scale
  
- **A well-kept Time-Scale is always better than the „best source“**

Improve on long-term stability (just use masers, local)

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**Optimise local Time-Keeping, while not using „fancy“ sources like „Sapphire“, „Rb-Fountain“, „Optical“ sources (there are more...)**

- **Solution: The ONLY way is to compare to UTC**
  - UTC is more stable than any maser after 5 days
  - USNO:
    - „Rb fountain #7 is more stable than the whole UTC system generated by BIPM
    - „If we eliminate all Cs clocks from UTC computation, UTC will become more stable“
    - This is politics, but shows the dimension and capabilities of masers compared to „fancy“ clocks.

Where is UTC? “UTC is NOT directly available”

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## **Task: generate a Physical Realisation of the local estimate of UTC**

### **Prerequisite**

- **Regular Link to UTC**
  - PTB is the only legal and accepted laboratory
  - A link (better: multiple links) provides stability
- **Calibrate this link at regular intervals**
  - Calibration provides uncertainty (traceability)
- **The local estimate is always worse than the source**
- **PTB ranks at 1.2 ns (circular-T)**

## Candidate Links to UTC (apart from relative VLBI-VLBI)

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### Link to UTC

**Best GNSS based links: „integer PPP“, iPPP**

- **Requires two corresponding receivers at Effelsberg and PTB**
- **Must be „geodetic grade“,**
  - Septentrio
  - GTR 53
- **Daily computation of the difference to UTC (effort), apply correction**

**Dream: a Fiber link to PTB**

## UTC Link calibration to reach „Uncertainty“

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### Simple solution: Use PTB's calibration services

- **There are calibration methods to secondary labs at the level of 1.5 ns calibration uncertainty, which could guide the activities here**
  - Effelsberg is NOT a secondary lab in the metrological sense, but the methods and error models could be used
  - Based on PTB's travelling receiver
  - Might be our mobile 2-Way station, but complex
- **Calibrate twice per year (needs some thought)**
- **Others say every three months...**
- **Deal directly with PTB (Andreas Bauch)**
- **Harmonise with Wettzell**



## Several time-scales can co-exist

- All based on the same sources, but different outputs
- Different control- and steering options
- Different & redundant hardware
- Outputs can be synchronous (SYRTE is doing so)
- Ready for fail-over in case of malfunction (needs human effort!)
- Can be on 1pps (time) only, 100 MHz (frequency) or both

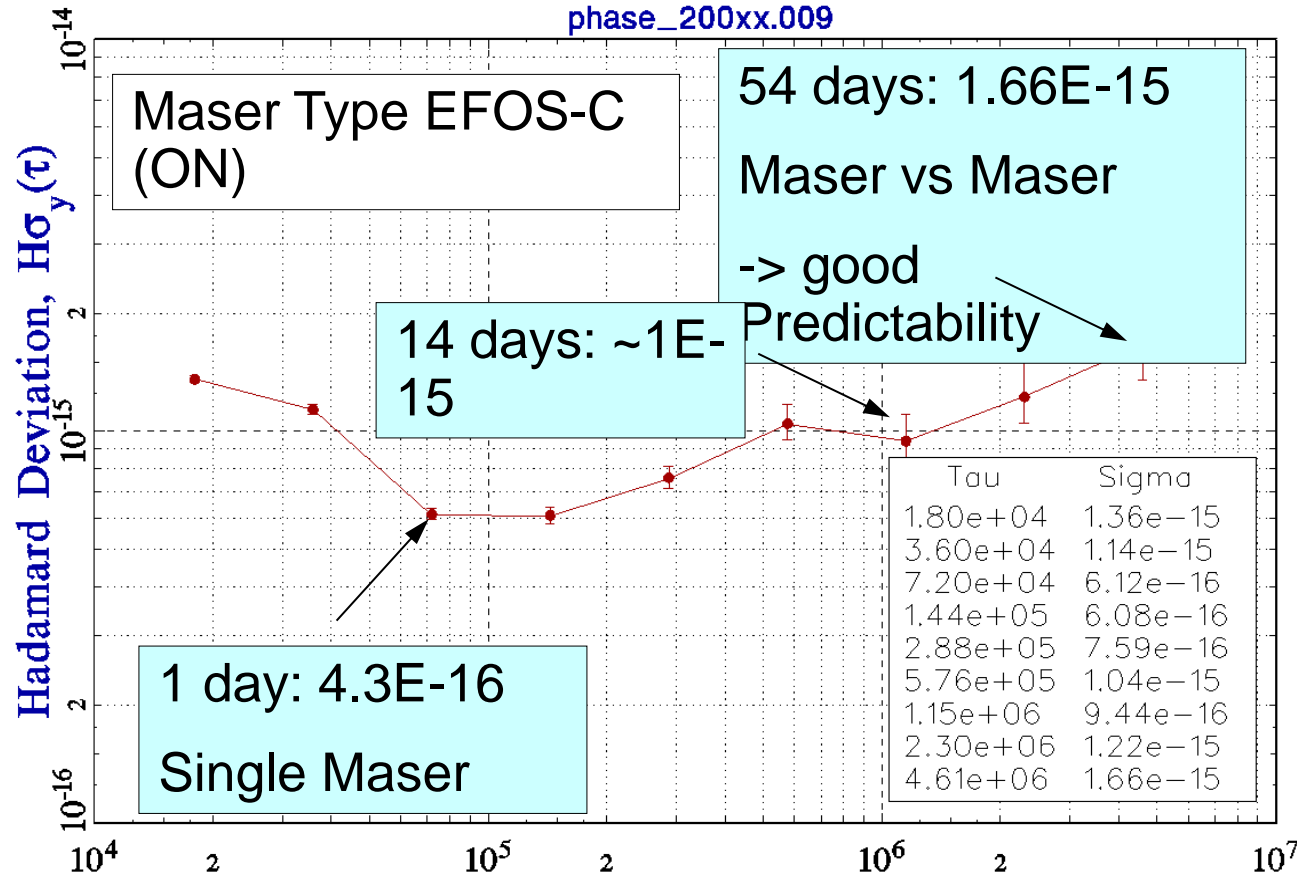
## Steering options (needs a dedicated workshop)

- Control the masers (people say: dont touch masers)
- Use High Resolution Offset Generators (HROG)
- Use Steppers (I dont like this for frequency steering, may be good for time steering)
- Have Time & Frequency Signals Coherent (tbd)

# New Norcia: HDEV Maser-1 vs Maser-2

## “predictability of maser drift”

### FREQUENCY STABILITY



Question: Which one is better? Cannot be solved with two clocks.  
 HDEV: „Capability to predict a maser frequency“ used for steering



# What to do with the link?

## Cables:

Cable	TK at 5 MHz	TK at 10 MHz	TK at 100 MHz
Huber-Suhner Multiflex 141 10m	51.3ppm/K	-6.0ppm/K	-25.2ppm/K
RG-223 10m	-141.2ppm/K	-131.9ppm/K	-125.9ppm/K
Semiflex Cable 8.18m	6.6ppm/K	-11.5ppm/K	-28.6ppm/K
Huber-Suhner 10m	-6.9ppm/K	-8.6ppm/K	-11.1ppm/K
Times Microwave LMR-240 10m	17.1ppm/K	-3.4ppm/K	-24.0ppm/K
Times Microwave SFT-205 10m	15.4ppm/K	7.7ppm/K	-4.3ppm/K
Meggitt 2T693 SiO <sub>2</sub> 7m		30.6ppm/K	4.3ppm/K
Andrew FSJ-1 12m	25.0ppm/K		7.1ppm/K
Andrew FSJ-4 20m	10.0ppm/K		1.3ppm/K
Andrew LDF-1P-50-42 10.6m	15.1ppm/K	2.8ppm/K	-10.4ppm/K
Andrew LDF4-50A 10.6m	7.2ppm/K	4.7ppm/K	0.6ppm/K
Times Microwave TF4FLEX 30m			6.4ppm/K
Phasetrack PT210 6m			2.0ppm/K

- **Suggestions**

- Use 100 MHz for main distribution (coherent to 1 pps...)
- LDF4-50A for the rigid part („its really cheap“)
- Phase-Track for the moving parts (50 m cost €4000)

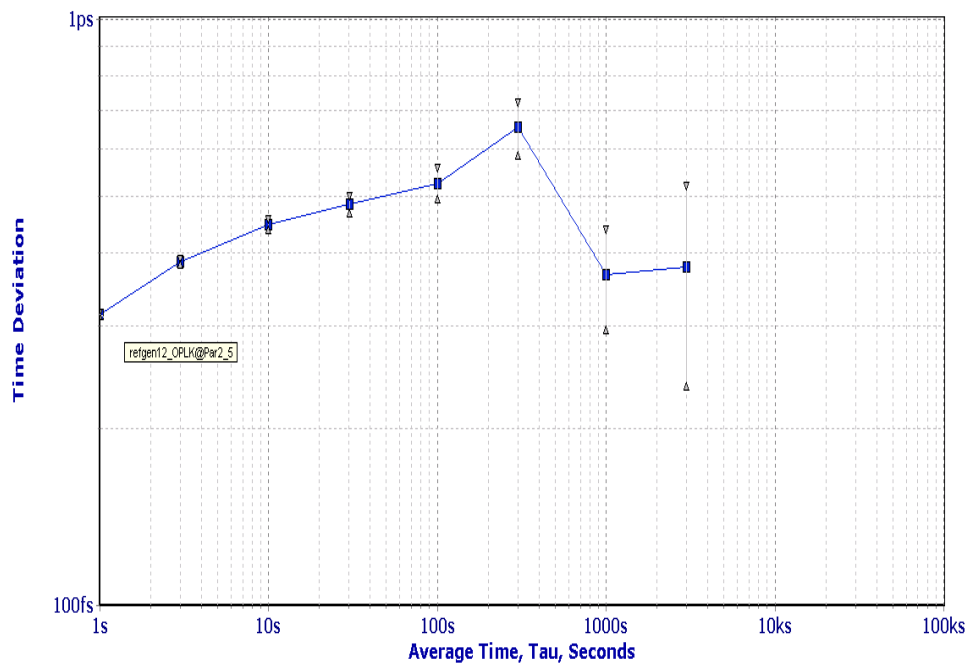
**Monitor existing link(s) with TimeTech's**

**„Remote Phase Comparator“ via 300m opt fiber**

# Remote Phase Comparator performance

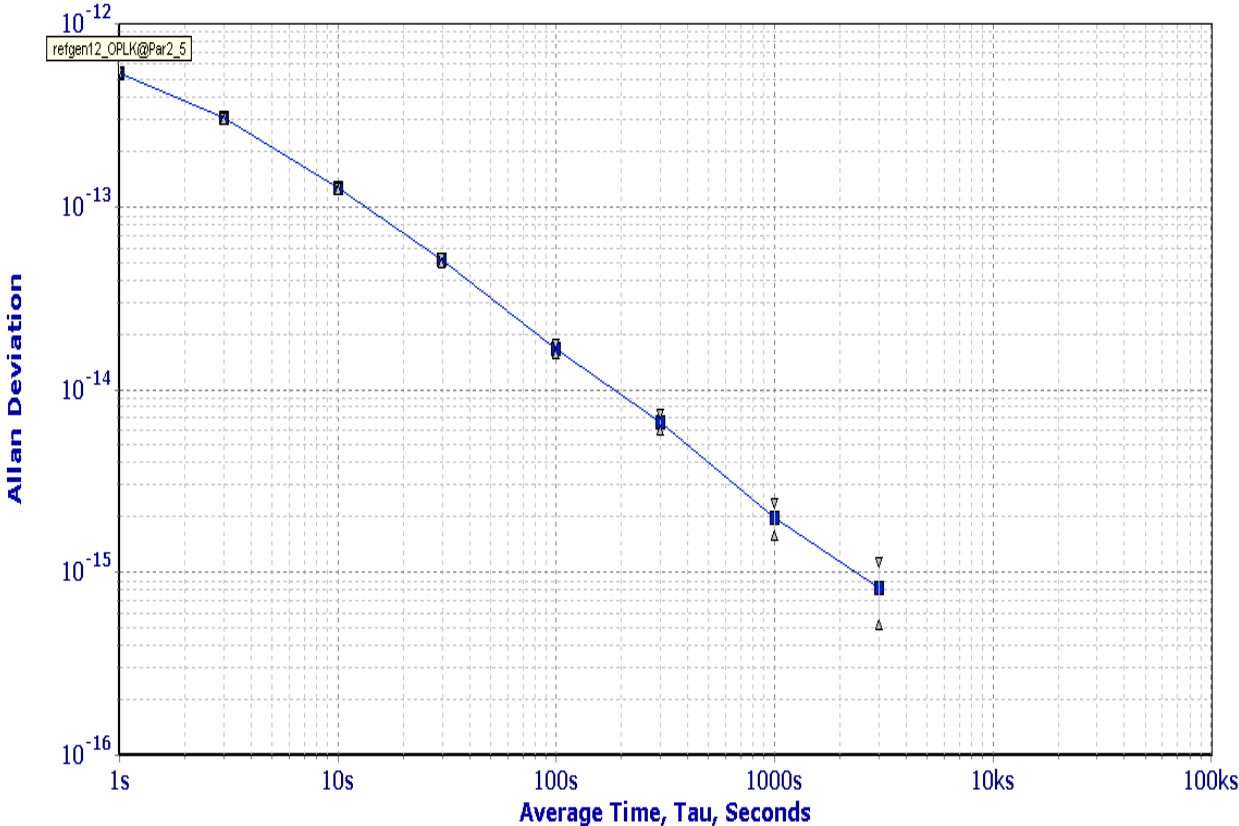
## Idea:

- Characterise existing links, non compensated links, etc. then apply corrections based on observations
- Accepts 5/10 or 100 MHz, both ends
- Can be done „soon“, i.e. within weeks
- TDEV below, 300m spool, bidirectional fiber



Time Deviation vs. Tau	
2018/07/04 20:00 - 07/05 04:00	
Instrument: OP_TEST_1	
Source: refgen12_OPLK@Par2	
Remarks: none	
No Averaging	
Noise: White FM	
1s	3.14E-13
3s	3.86E-13
10s	4.47E-13
30s	4.83E-13
100s	5.26E-13
300s	6.54E-13
1000s	3.67E-13
3000s	3.78E-13

# Remote Phase comparator, ADEV



Allan Deviation vs. Tau	
2018/07/04 20:00 - 07/05 04:00	
Instrument: OP_TEST_1	
Source: refgen12_OPLK@Par2	
Remarks: none	
No Averaging	
Noise: White FM	
1s	5.44E-13
3s	3.07E-13
10s	1.26E-13
30s	5.13E-14
100s	1.69E-14
300s	6.69E-15
1000s	2.00E-15
3000s	8.30E-16

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