Research on VLBI Application for Time and Frequency Transfer in NICT

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1.Introduction.

Development of optical frequency standards is progressing rapidly and its accuracy (uncertainty of the absolute frequency) is reaching about 10^{-16} in fractional frequency. Current atomic time standard with Cs atoms will be replaced by optical frequency standards in the near future. Inter-comparison of the generated frequency are necessary for each laboratory in order to make next time-scale defining sources. However these frequency standards are operated in a carefully controlled environment in each laboratory, and thus cannot be moved and compared directly against a clock on another site. Optical fiber-linked frequency transfer has been realized for distances around 100km, and its frequency comparison precision is better than 10^{-15}(Fig.1). However, high precision time & frequency (T&F) transfer over intercontinental distances does not reach sufficient precision to support such a clock performance. T&F transfer techniques have been used for inter-comparison of locally generated UTC among independent laboratories for maintaining national time standards. In this paper, several technologies used for T&F transfer are introduced, and we propose to use VLBI as an additional tool for T&F transfer.

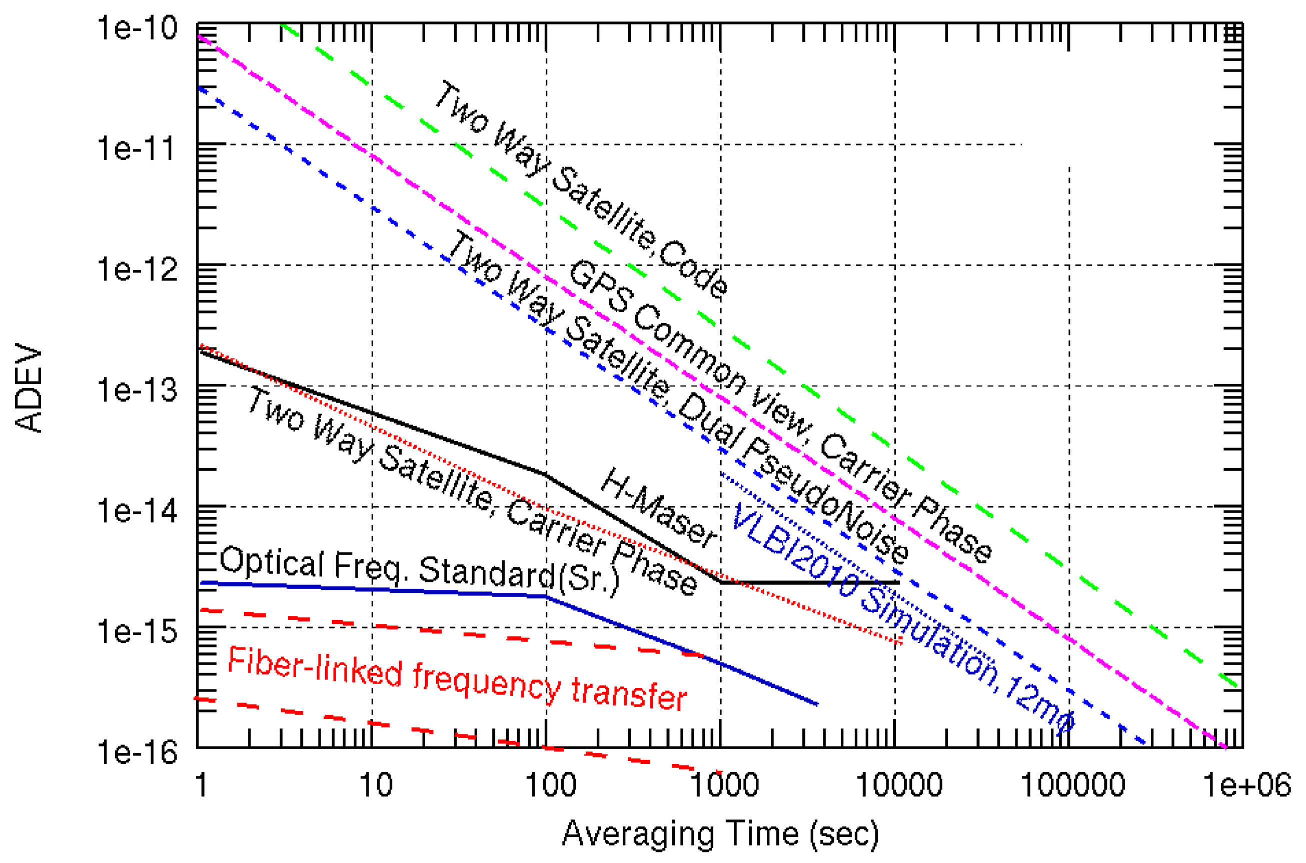


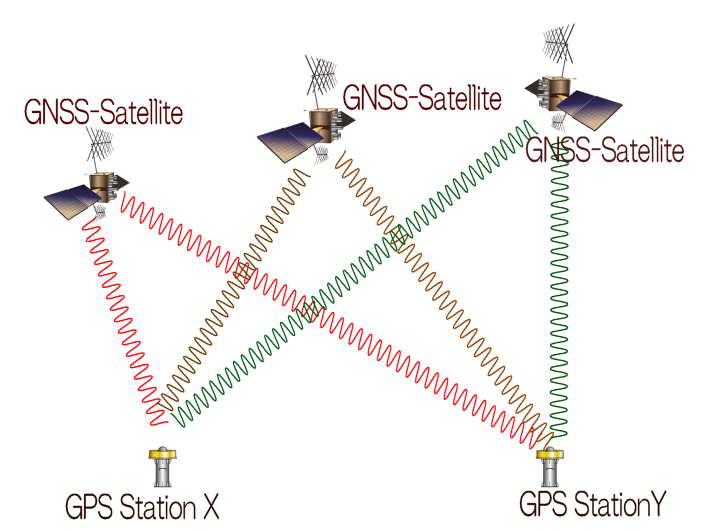
Fig.1: Typical stabilities of long distance T&F transfer techniques and stabilities of atomic time standards.

2.T&F Transfer Techniques

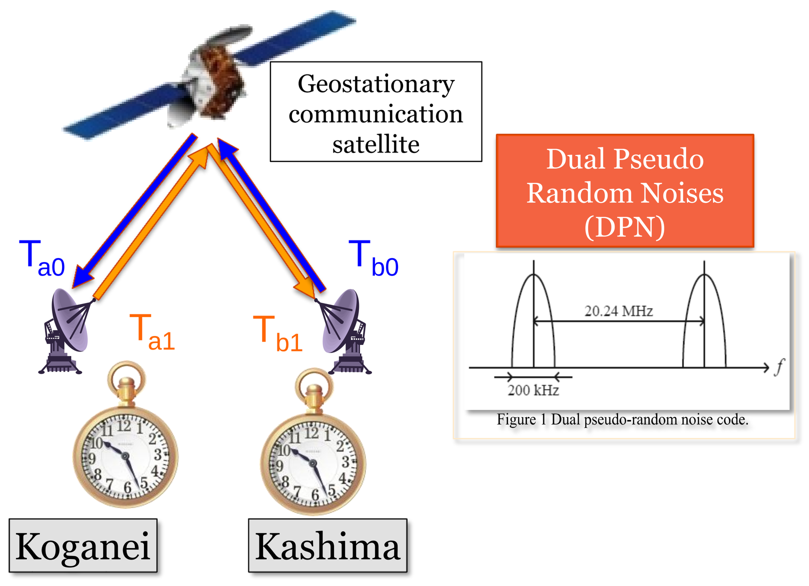
NICT has been developing several techniques for T&F transfer. Fig.2 gives an overview of three currently used techniques. Typical time comparison stabilities for each techniques can be taken from Fig.1. Two examples of actual comparison experiments are presented below.

[EXP2010Aug] An experiment for comparison of time transfer capabilities was organized in August, 2010 between Kashima Space Technology center and Koganei headquarter. Overview of the campaign is displayed in Fig.3, and time comparison results are presented in Fig.4. Since absolute comparison of time is not subject at present, offsets for each comparison techniques are removed. A 2nd order polynomial obtained by least square fitting to ETS-8 data was removed from all the data, because data of ETS-8 is thought to represent the real clock behavior of the two atomic standards. In this experiment, the H-maser signal for Kashima 11m station was provided from via a coaxial cable over a distance of 500 m.

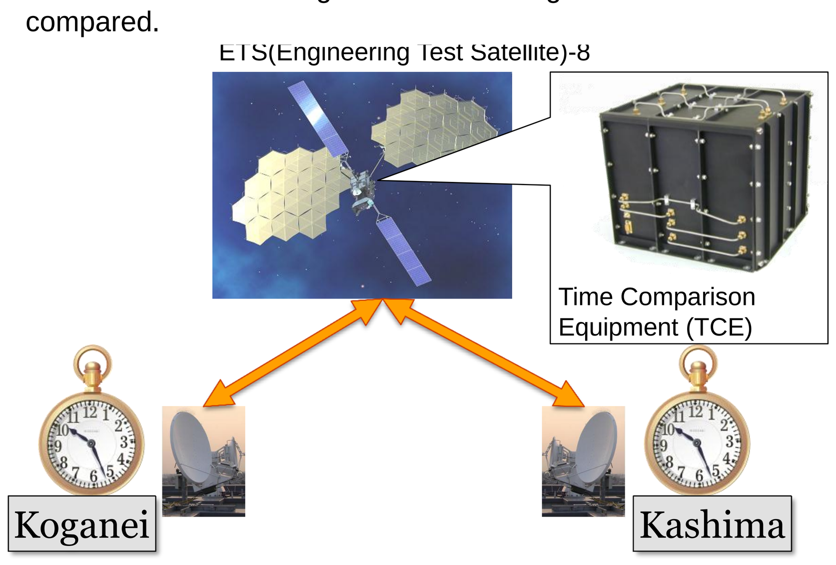
[EXP2012Feb] Portable H-maser was installed at Kashima 11m station in Nov. 2011. Thus, reference signal fluctuations caused by the 500m coaxial cable line transmission are reduced. Results of clock comparison experiment on 19-21 Feb. are shown in Fig.5.



(a) GNSS Common View is a technique of T&F transfer by observation of GNSS satellite with GNSS receivers running with reference signal to be compared.



(b) Two way satellite T&F transfer (TWSTFT) is send and receive timing signals each other. Most of the delay component in the signal paths are cancelled out, thus higher precision is expected. NICT has developed a technique of Improved time resolution by using dual pseudo random noise (DPN) signal, which is the same principle with bandwidth synthesis used in VLBI.



(c) ETS-8 is Japanese engineering satellite with time comparison equipment (TCE) on board. TCE is special device designed for time comparison between Ground-Ground , and Ground-Satellite.

Fig.2: Techniques for T&F transfer to distant remote sites. NICT has conducted research on these three techniques.

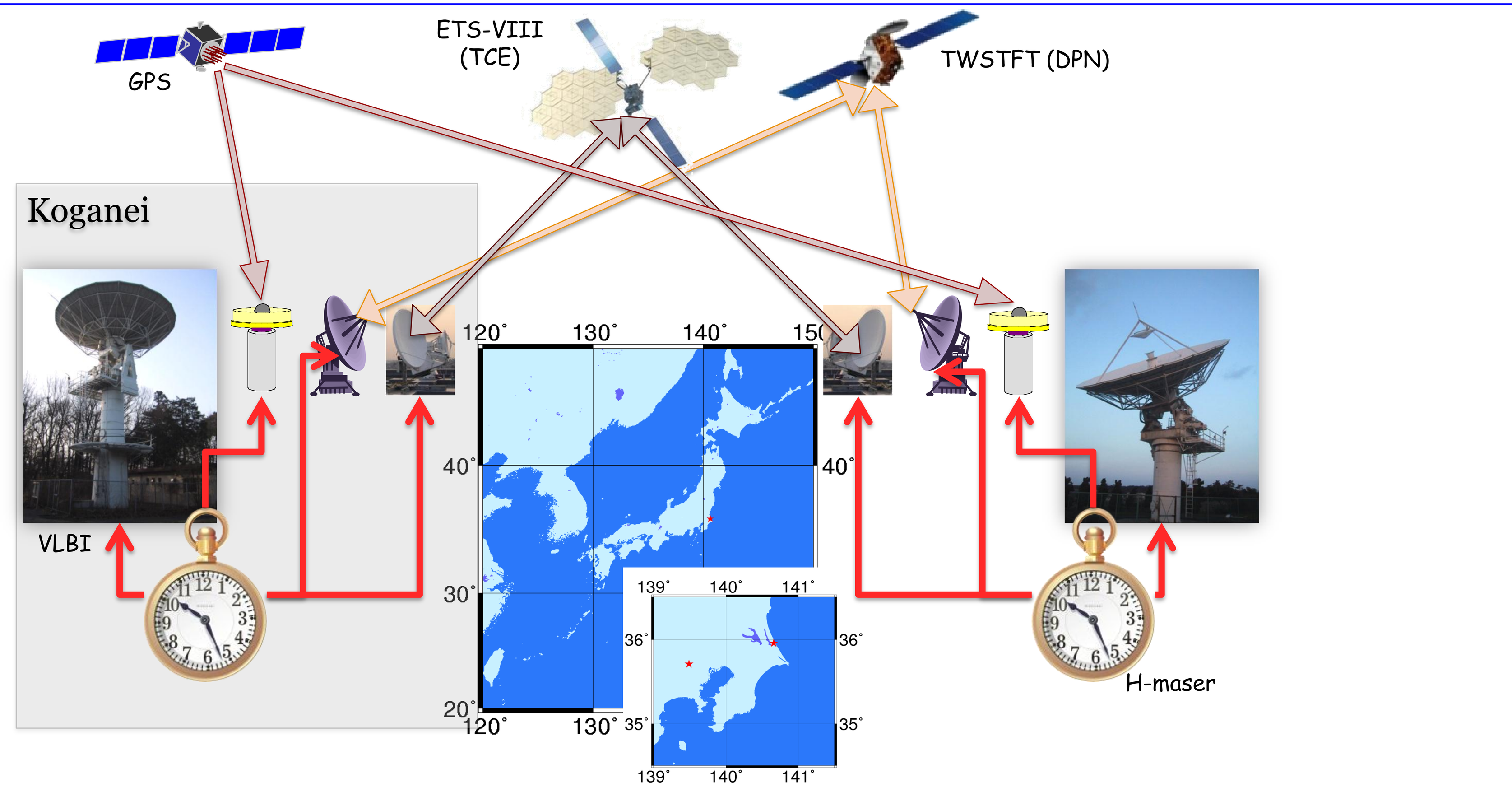


Fig.3: Experiment for comparison of the T&F transfer between Kashima 11m site and Koganei headquarter was organized in August 2010. TWSTFT, GPS common view observations, ETS-8 T&F transfer, and VLBI observations were made simultaneously for comparison of H-maser atomic time standards at Kashima and Koganei.

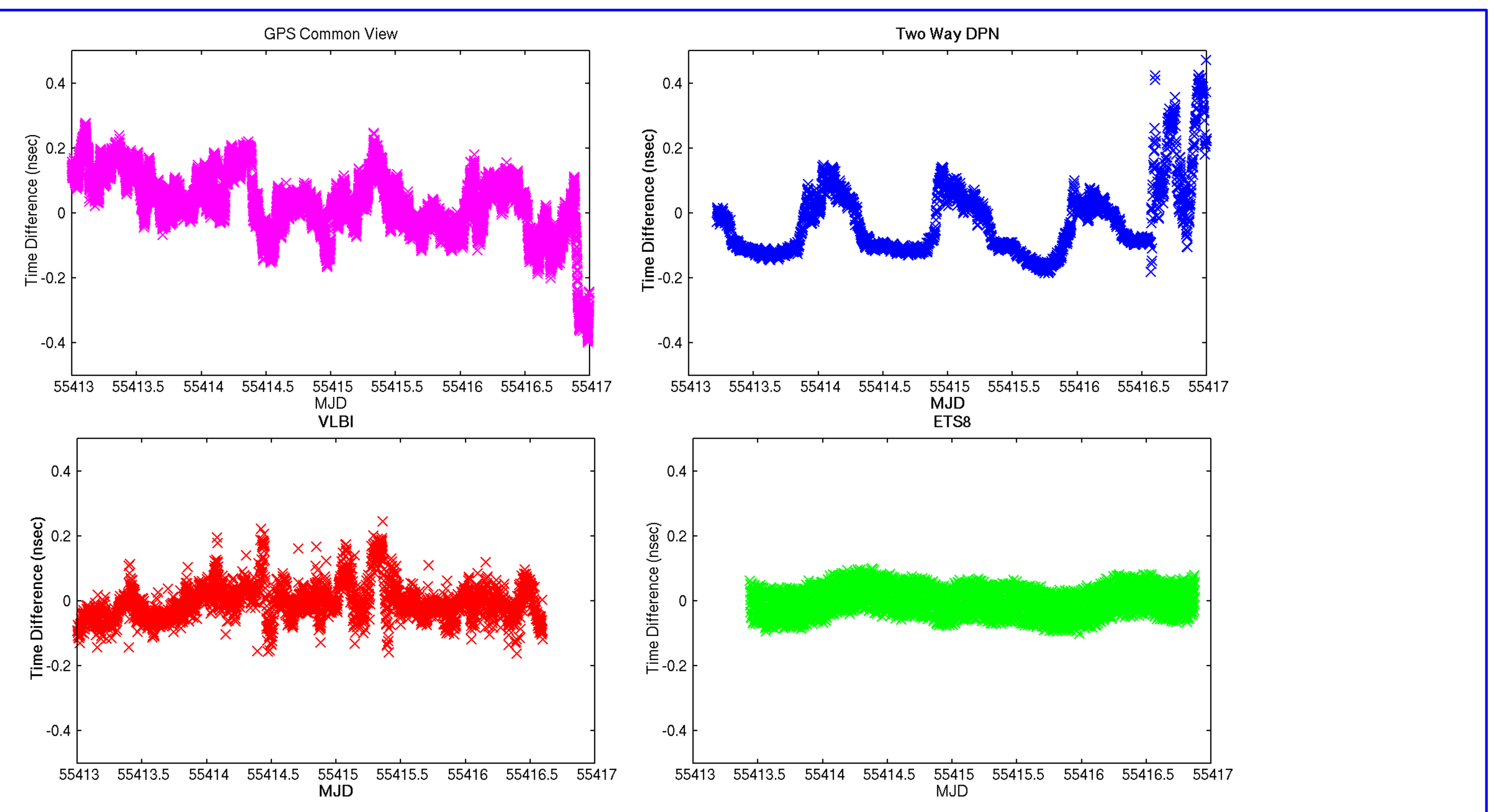


Fig.4: Clock comparison results from each technique are presented. Offsets have been removed separately and a 2nd order polynomial was removed from all data as it basically represents the clock behavior. Horizontal and vertical scale are same in all plots.

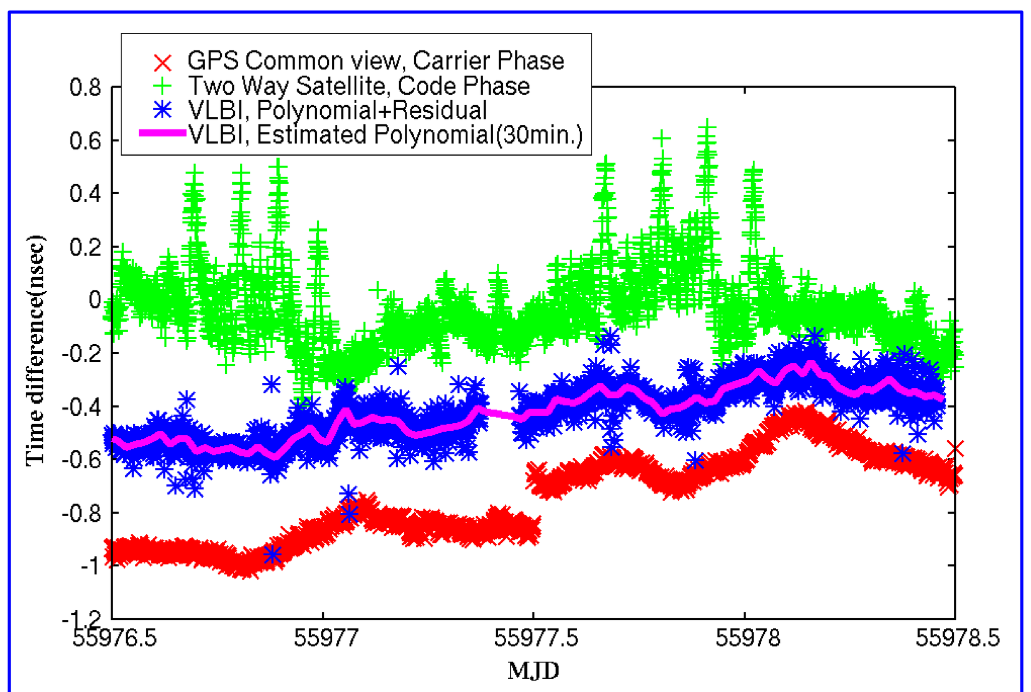


Fig.5: TWSTFT, GPS-CV, and VLBI are compared on the Kashima11m-Koganei11m baseline. A parabolic trend is removed from all data.

3. Prospect of VLBI2010

Our project goal is to use a portable small diameter antenna for T&F transfer at remote site. NICT has been developing a 1.6m diameter small antenna (MARBLE) system [Ishii et al, 2010] for baseline validation. Fig.6 shows simulation results based on VLBI2010 compliant antennas.

Our target is to enable the MARBLE system(Fig.7) for full VLBI operation and test it on T&F transfer experiments.

A wide-band recording system, RFI mitigation, and a linear polarization correlation system are our tasks to be realized for the reaching our goal.

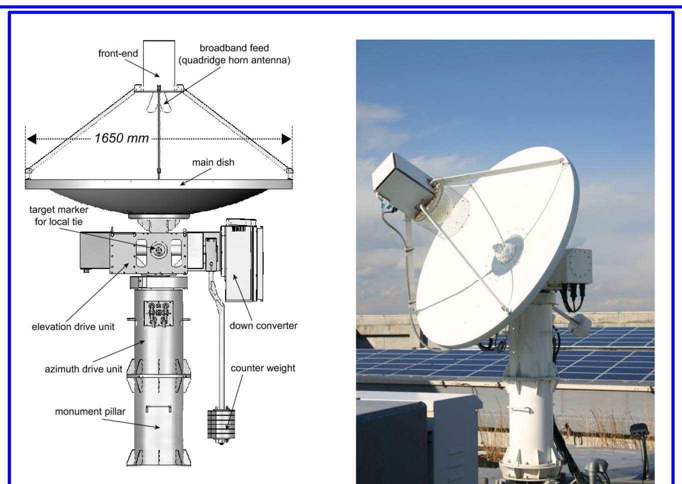


Fig.7 Illustration of MABLE 1.6m antenna

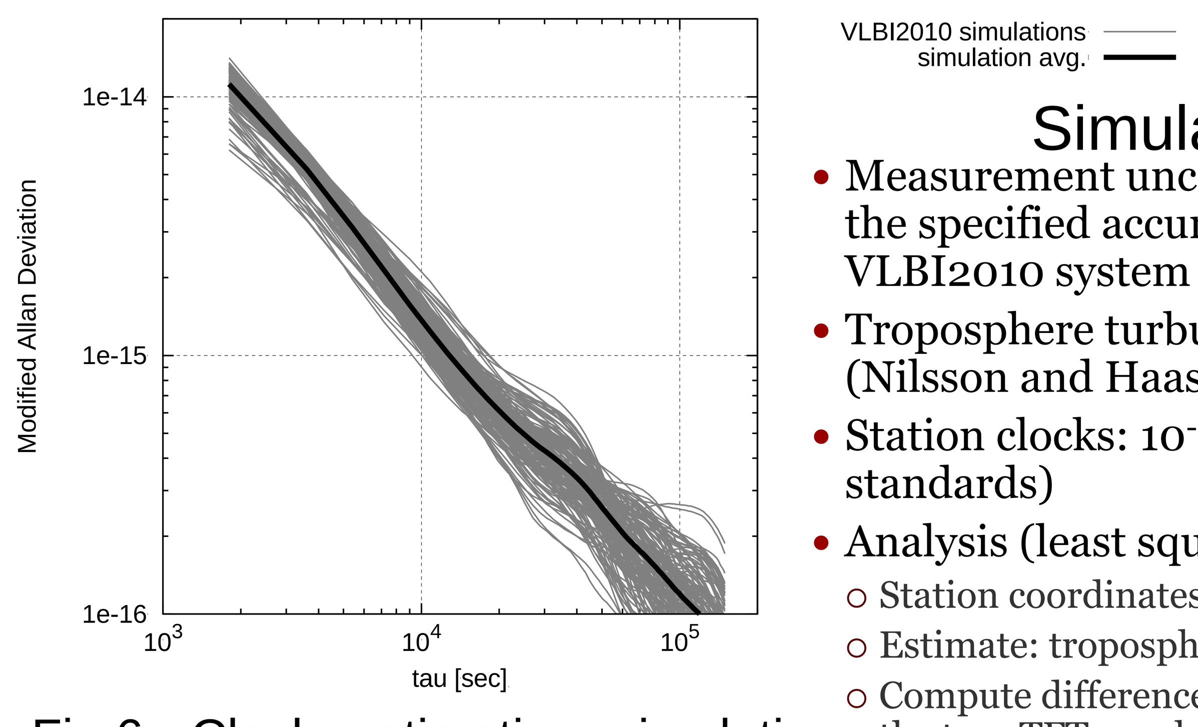


Fig.6: Clock estimation simulation with VLBI2010 compliant antennas.

Simulation Condition

- Measurement uncertainty 10 ps (white noise), i.e. 3x the specified accuracy of the fully operational VLBI2010 system
- Troposphere turbulence with $C_n = 10^{-7}$, H=2000 m (Nilsson and Haas [2008])
- Station clocks: 10^{-16}@1d (Next-generation freq. standards)
- Analysis (least squares adjustment):
  - Station coordinates fixed
  - Estimate: troposphere and station clocks
  - Compute difference estimated – simulated clock (i.e. access the true TFT capability)
  - Derive freq. stability over all possible baselines