GNSS time and frequency transfer through national positioning infrastructure

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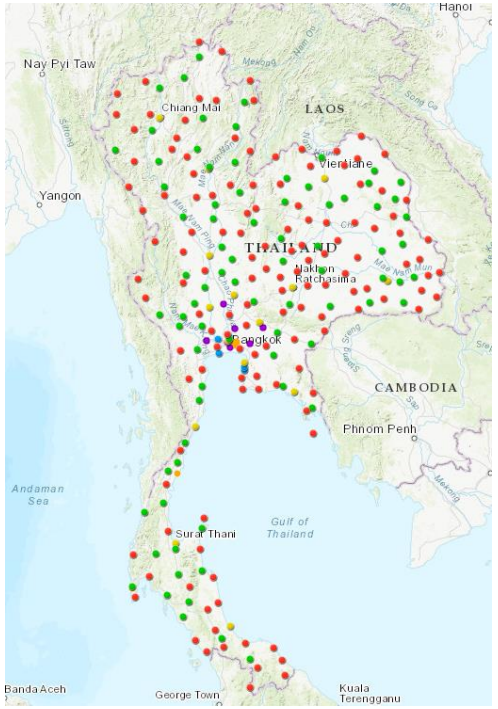
Outline

- Introduction
- NIMT GNSS timing station
- Measurement scenarios
- GNSS time transfers
- Research methodology
- Results
- Conclusions

Introduction

- GNSS ground station network: around 250 stations
- Real-time GNSS positioning services
- Geodetic grade and a choke-ring antenna to observed multi-frequency and multi-GNSS measurements
- Receivers operates with a rubidium vapour cell and crystal oscillators to generate periodic signals



Introduction

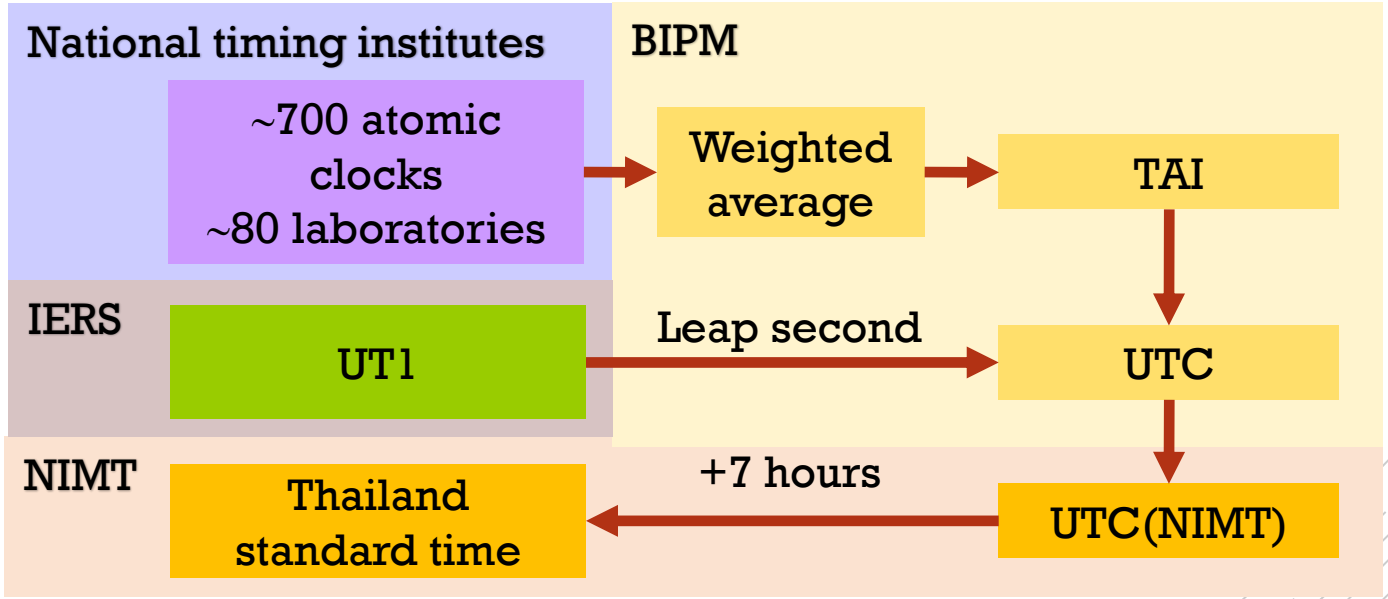
- This national PNT infrastructure is used to support high accuracy real-time positioning applications at the improved reliability, with lower operation costs and provide faster results for both positioning and timing solutions
- GNSS civilian users have been working on crustal deformation, geodesy, land-based mapping and surveying, atmospheric studies, machine control, attitude determination and precision agriculture
- Official time realisation operates through time transfer to set civilian clocks nationwide to be respected to an atomic time standard

Introduction

- Precise timing information provided by this GNSS PNT infrastructure could be used to
  - synchronise timing system
  - provide time tag to telecommunication industries including mobile phone networks, electrical power networks, computer networks including internet of things and banking operations
- GNSS users require precise timing information in real time and can rely on the world official time based upon a prediction of UTC

Introduction

- NIMT time and frequency laboratory is the sole local realisation of UTC in Thailand providing international time link to UTC; named UTC(NIMT)
- Time differences between the true UTC and predicted UTC(NIMT) along with their corresponding uncertainties are reported in a weekly to ensure the measurement traceability of participated laboratories on their atomic time scale realisations



Introduction

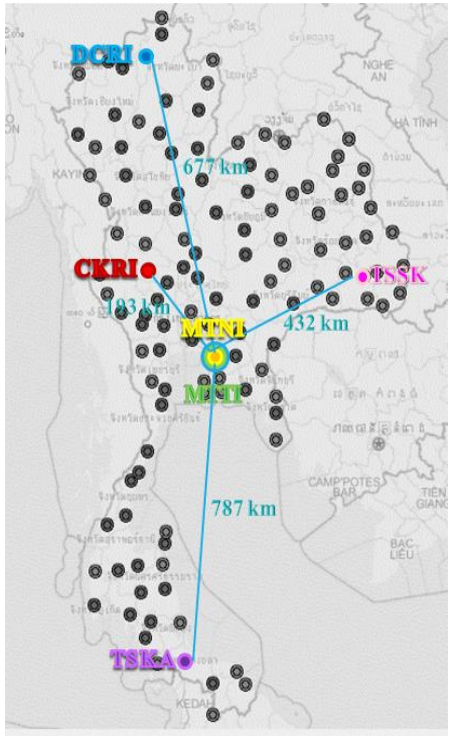
- UTC(NIMT) time is realised by an ensemble of one active hydrogen-maser (AHM) and three caesium frequency standards as primary standards
- This atomic time scale is daily measured and steered to the International Atomic Time (TAI) scale by applying the GNSS common-view time transfer method to assure the traceability of generated time and frequency to the SI second realised by UTC

Measurement scenarios

- Two types of GNSS receivers; geodetic and time transfer receivers, are operated at NIMT in order to provide both international and national time link
- The time transfer or timing receivers provide a specific optimal estimation algorithm in order to determine the clock offset and frequency offset between available navigation system time scales and synchronised to UTC as well as positioning capabilities as defined in the geodetic receivers

Measurement scenarios

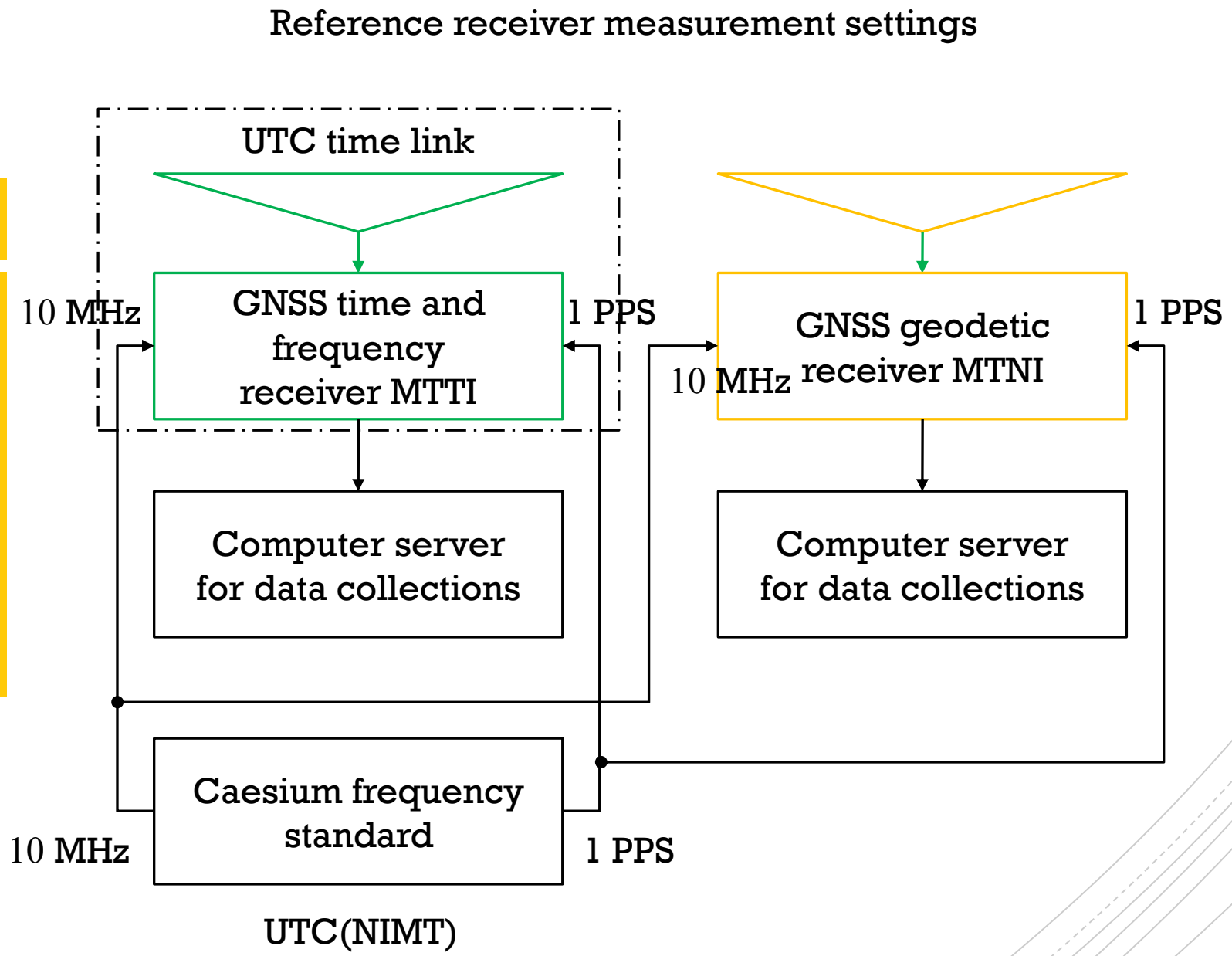
- Four ground stations are selected to determine in order to define the timing accuracy and frequency stability of these receiver internal clocks and to provide measurement traceability to UTC
- Two ground stations at NIMT are MTNI and MTTI
- Four referenced ground stations used in this study are located in furthest distances in the north, east south and west within this national geodetic network



GNSS time transfers

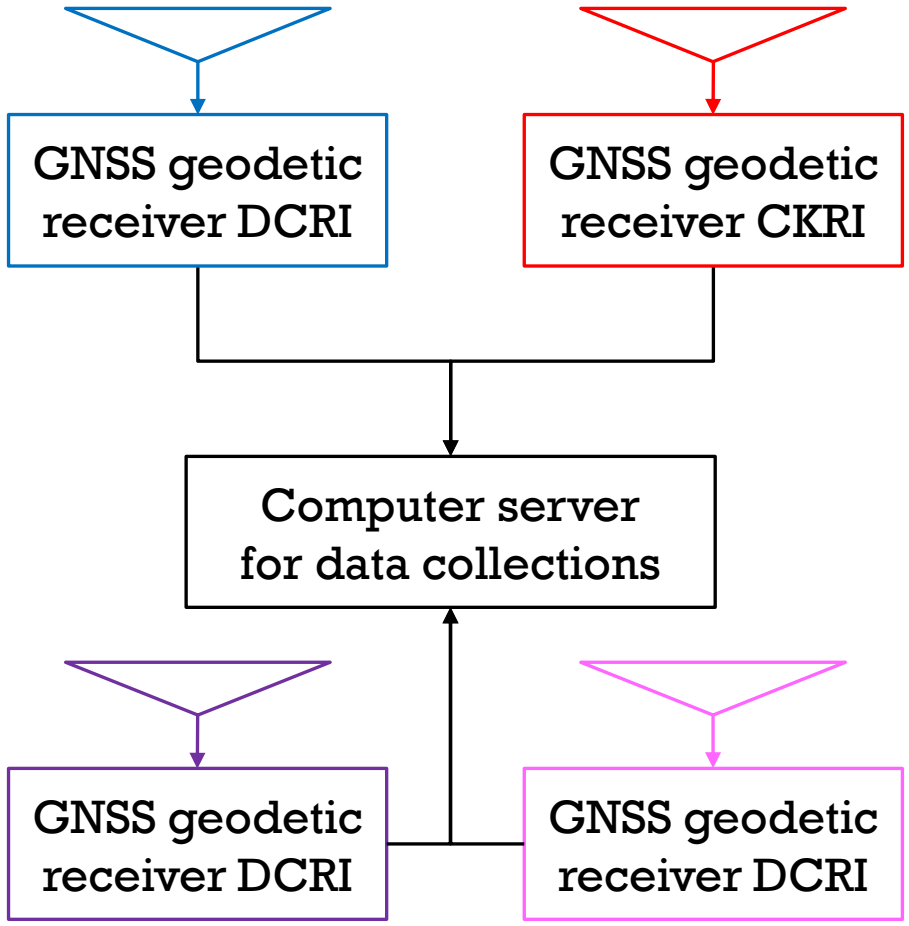
- GNSS time transfer technique
  - determine the synchronisation error; time differences between two clocks or time scales, between the ground station clock and GNSS reference time scale
  - find out the time differences between the two ground station clocks computed from simultaneously observed satellites (common-view)
- GNSS time transfer methods employed in this work are based on code measurements
- They are converted into the common GNSS generic time transfer standard (CGGTTS) version 2E covering GPS, GLONASS, Galileo, BeiDou and QZSS.
- The time differences between the receiver clock and GNSS reference time scale (REFSYS)
- The tracking epoch is 780 seconds (13 minutes)
- It is noted that the receiver clocks and coordinates are initially set to align with GPST and ITRF2014
- Known receiver positioning are fixed into the observation equation

Research methodology

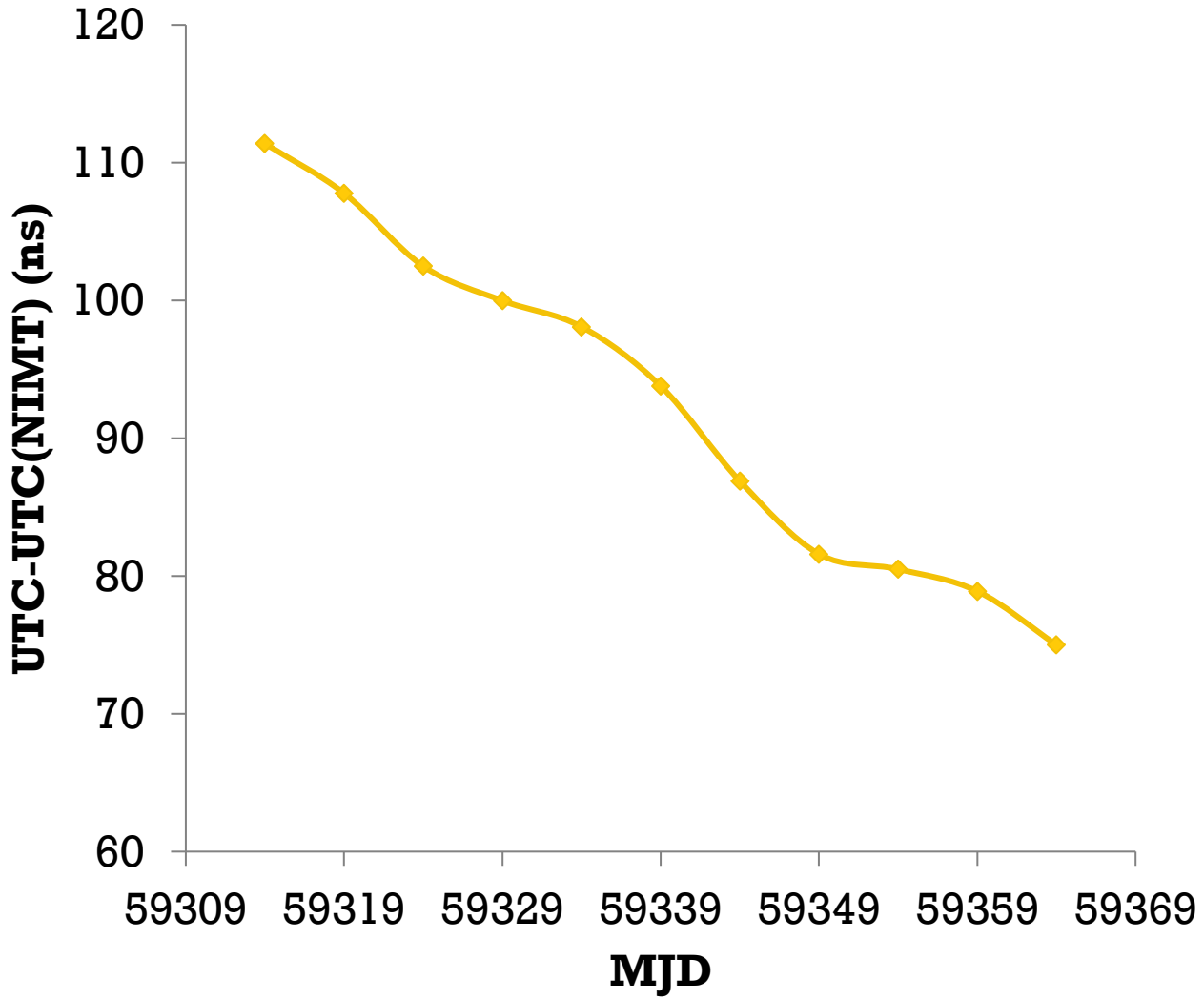


Research methodology

Calibrated receiver measurement settings

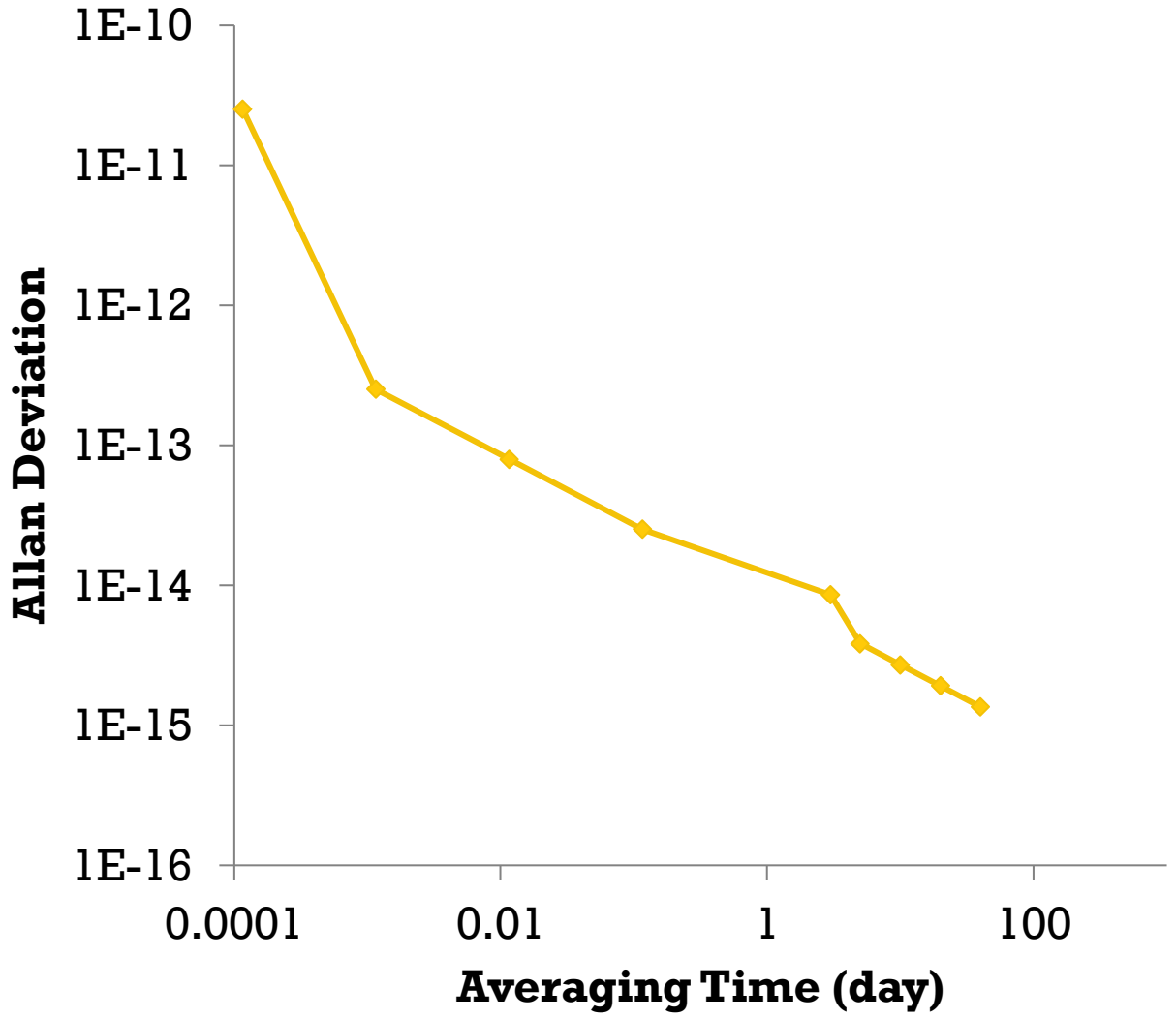


Results
UTC time link



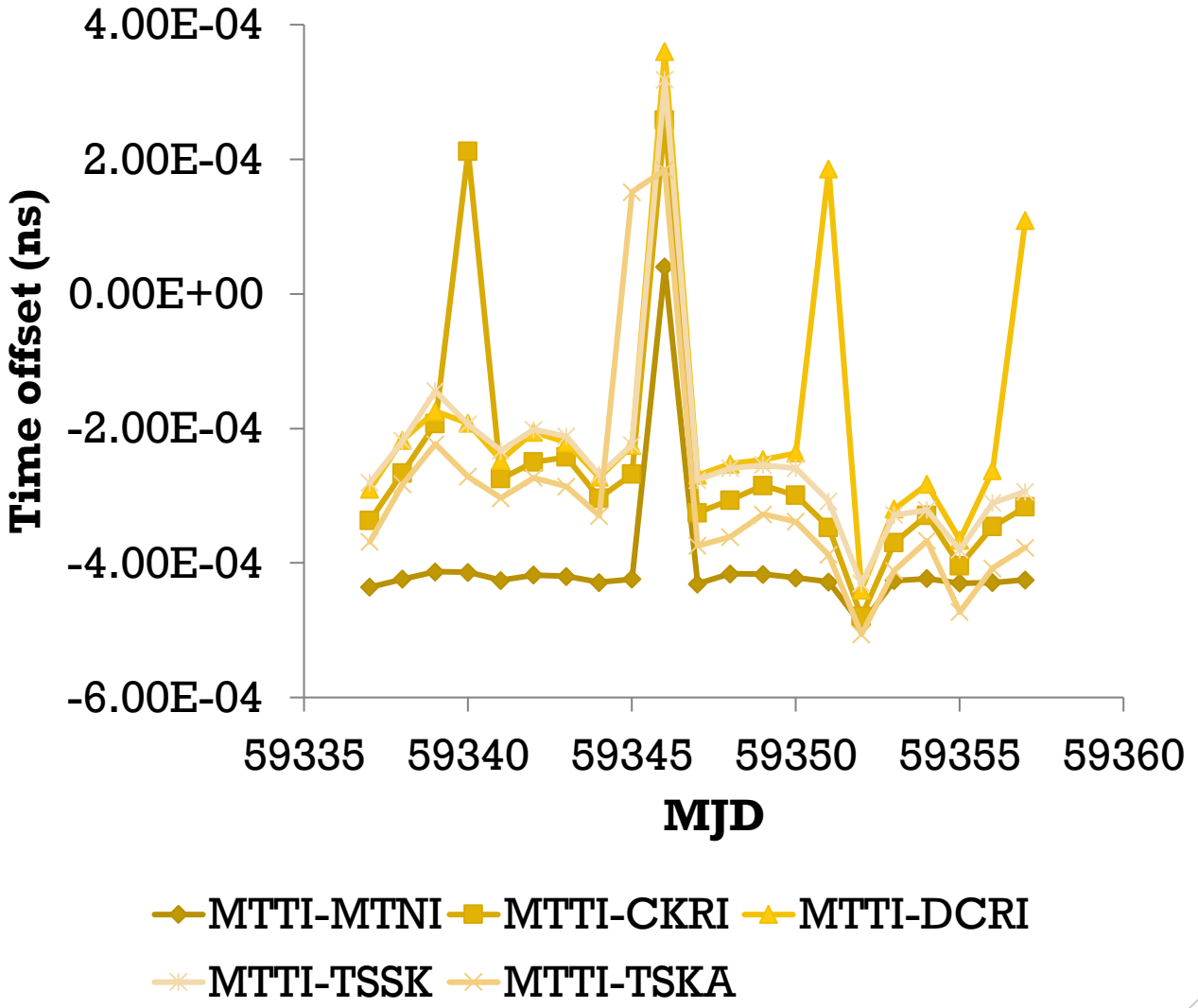
UTC realisations of UTC maintained by NIMT

Results
UTC time link



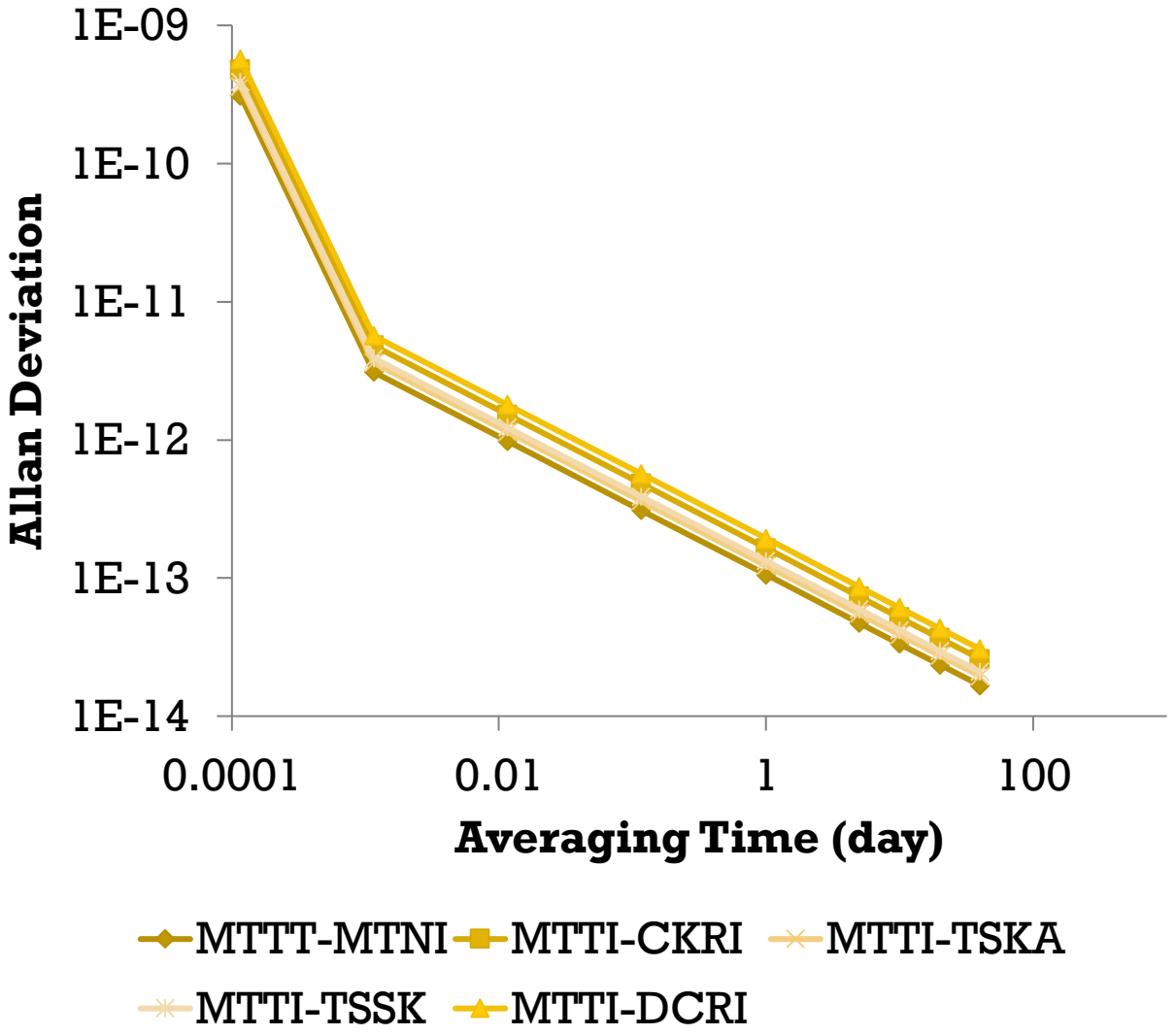
Computed stabilities of UTC realisation at NIMT

Results time comparisons



Time differences of UTC(NIMT) with respect to GNSS receiver internal clocks

Results time comparisons



Time stability of the estimated time differences

Conclusions

- This work determines the GNSS ground station receiver's clock characteristics in terms of fractional frequency offsets and its frequency stabilities in order to provide international time link to the internationally recognised time scale of UTC though UTC time scale maintained at the national time laboratory of NIMT; UTC(NIMT)
- The applied time transfer method is the GNSS common-view for time comparisons between the reference oscillators operated at NIMT and calibrated oscillators at the four GNSS stations used as active control points for geodesy and surveying as well as time distributing nodes at the timing accuracy and stability of picoseconds in the near future
- It demonstrates a precision of approximately 0.3 picoseconds on the clock difference with UTC(NIMT) and relative frequency stability of better than 0.1 picoseconds per day computed from three weeks GNSS observations

Thank you