A proposal to avoid a leap second

*Kozo Takahashi[1]

1.None

The method is shown to avoid the leap second, which needs no special operation for almost persons.
1. Decrease of rotational angular velocity: The maximum rotational angular velocity of the earth at the origin of the earth, is expressed by the following formula, because the centrifugal force caused by the angular velocity ωo should be less than gravity.
(In the following, **: power)
r xωo**2 = g
where Radius of the earth r = 6378100 m
Standard gravitational acceleration g = 9.80665 m/s**2
Substituting these into the above,
ωo = 1.2400x10**-3 rad/sec = 107 rad/day
At this value the force balances with the gravity.
The present earth has
ωp = 7.292x10**-5 rad/sec
Where ωo decreases exponentially,
log (ωp / ωo) = - k t (1)
Substituting followings into the above,
ωo / ωp = 1.240x10**-3/7.292x10**-5
= 16.98
log (ωo / ωp) = 2.833
and the earth's age
t = 4.55 bil. years = 1.436x10**17 secs
We get
k = 1.973x10**-17/sec = 6.226x10**-10/year
= 0.623/bil.year
In past 15 years, the leap second has been substituted five times. Where the present period is T0 , the period T after three years is expressed as follows:
T - T0 = 1 sec
T - T0 = 2π(1/ω - 1/ωo)=2π (ωo - ω)/(ωxωo)
Substituting the following into the above,
ω= ωoxe**(-kt)
We get
2π / ω{1-e**(-kt)} = 1sec
i.e. ω/2π = 1-e**(-kt) = kt
Substituting ω= ωp = 7.292x10**-5 rad/sec = 2301 rad/year
and t = 3 years,
we get
k p = 3.869x10**-6/year
Substituting the above into (1), the present half-period of the earth is calculated as follows:
log 0.5 = 0.6931 = 3.869x10**-6xTp
Tp = 0.6931/3.869x10**-6 = 1.791x10**5 years
= 180 thousands years
This value contradicts with the earth's age of 4.55 bil. years, that is caused by the inappropriate

definition of the second.

The present second is defined as the 9192631770 times of one period T0 of radiant wave from Cs, whose frequency is 9.192631770 GHz. The leap second becomes unnecessary for more than hundred years, where the one second is made longer than present one, as follows: where we make the present radiant frequency f = 9.192631770 GHz from Cs, (1+1sec/3 years = 1+ 1.0563 x10**-8) times, and 9.192631673 GHz, because three years are about eighth power of ten (3 years = 0.9467x10**8 sec). Then the leap second becomes unnecessary, where the last three digits of the effect numbers of ten are changed to 9192631673, then

9192631770/9192631673 = 1+1.056x10**-8

and one second becomes longer 1.056x10**-8, namely present one second becomes loner about one second for three years.

2. Effects of the change of time unit

The basic unit, speed of light, is unchanged, where the unit of meter is changed to become shorter by 0.76x10**-8 m, caused by the second longer by 1.056x10**-8 sec.

Keywords: leap scond, avoid leap seconds

Activities of the Asia-Oceania VLBI Group for Geodesy and Astrometry (AOV)

*Ryoji Kawabata[1], Kojin Wada[1], Yoshihiro Fukuzaki[1], Masayoshi Ishimoto[1], Takahiro Wakasugi[1]

1.GSI of Japan

The Asia-Oceania VLBI Group for Geodesy and Astrometry (AOV) was established in 2014 as a subgroup of the International VLBI Service for Geodesy and Astrometry (IVS) in order to foster regional collaboration of VLBI. In 2015 six regional sessions were carried out within the AOV. Moreover, on November 19-20 2015, AOV held the first Asia-Oceania VLBI Meeting hosted by the University of Tasmania in Hobart, Australia. This is the first meeting of the AOV since its establishment. AOV members shared information on their recent activities and discussed future plan of the AOV. We talk on the recent activities of the AOV.

Keywords: VLBI

Heat flux flow in the outer core and Earth's rotational motion

*Chuichi Kakuta[1]

1.none

Heat flux flow in the outer core transfers heat energy from the Earth's central part into the mantle. It contributes to motion of the compressible outer core and zonal thermal wind in the outer core. These motions relate with the Eartth's rotational motion.

Keywords: boundary of the outer core, heat flux flow, variation of Earth rotation

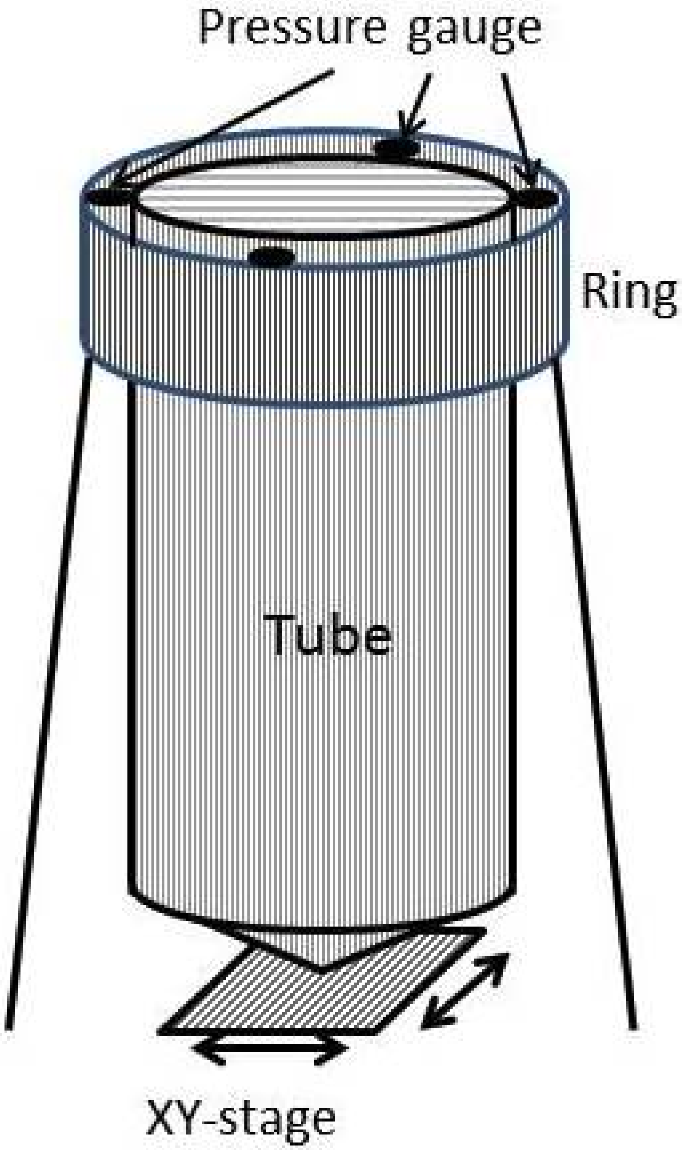
A method for attitude control of telescopes making use of the reverse pendulum

*Hideo Hanada[1,2], Seiitsu Tsuruta[1], Kazuyoshi Asari[1], Hiroshi Araki[1,2], Ken-ichi Funazaki[3], Atsushi Satoh[3], Hideo Taniguchi[3]

1.RISE, National Astronomical Observatory, 2.SOKENDAI, 3.Iwate Univ.

National Astronomical Observatory Mizusawa has developed a telescope with the focal length of 1m and diameter of 0.1m to be set on the Moon for observation of lunar rotation. It is essential to make a much small and light one to meet the requirement from smaller rockets which is a new trend in lunar and planetary explorations in Japan. We propose a new method to control the attitude of the tube by making it to be a reverse pendulum.
A tube supported by a single point at the bottom looks unstable, but it is possible to control the attitude with high sensitivity because it tends to fall down even if it slightly deviates from the vertical. We put a tube with a conical bottom on a XY stage, and surround the top of it by a ring putting 4 pressure gauges between them (Fig. 1). If the tube deviates from the vertical direction, a force acts on the pressure gauges. Then we move the bottom of the tube horizontally until the force becomes zero, and the tube is kept to be vertical. This attitude control does not restrict the optical system of the telescope because any optical element as the horizontal reference plane like a mercury pool is not necessary, nor nothing comes in the field of view.
When a reverse pendulum with the mass m (kg) deviates from the vertical direction by angle θ, the force P acting horizontally is represented as $P = mg\sin\theta$. If we suppose m = 1 kg, θ= 1 arc second (4.8x10 - 6 rad), P becomes 10 - 5 N (about 50 μN). We can detect the force of 0.005mN which is about 1/10,000 of the force in the case of 1 arc second if we use the most sensitive pressure gauge. This means that we can control the attitude of a tube with the sensitivity of 0.1 milli-arc second.
On the other hand, it has the dynamic range of 20,000 times as large as the resolution, thus the most sensitive sensor has the range of 20 μN. Therefore, we must keep the tube within 20 arc seconds of the vertical direction in some other way.
As to the XY stage, it needs to have a sensitivity of 5x10 -10 m (0.5 nm) in order to control the verticality within 1 milli-arc second. It is not impossible if we utilize a certain reduction mechanism or an inchworm.
This method can open the new way in the future mission with a small and light telescope for observation of rotation on the Moon or on the planet.

Keywords: reverse pendulum, attitude control, telescope


Pressure gauge
Ring
Tube
XY-stage

On a wide-band bandwidth synthesis III

*Tetsuro Kondo[1], Kazuhiro Takefuji[1]

1.National Institute of Information and Communications Technology

1. Introduction

An algorithm for wideband bandwidth synthesis (WBWS) exceeding a band width of 10 GHz has been developed. The algorithm has been verified by processing actual wideband VLBI observation data. We have succeeded in a wideband bandwidth synthesis, and then the correctness of the algorithm has been confirmed. The baseline length (about 50km) is too short to investigate an ionospheric effect on a WBWS, therefore the verification of ionospheric correction has been carried out by using VLBI data simulating an ionospheric effect, and its effectiveness has been confirmed.

2. Processing algorithm

The processing algorithm is as follows.

1) Reference scan: define one scan observing a strong source as a reference for an inter-band delay correction and an inner-band phase correction.

2) Inter-band delay correction data: process each frequency band data by a conventional method and get a delay residual of each frequency band. These delay residuals are inter-band delay correction data.

3) Inner-band phase correction data: process each frequency band data by a conventional method and get a cross spectrum of each frequency band. These phase spectra are inner-band phase correction data.

4) WBWS process: combine multiple frequency bands by correcting inter-band delay using "inter-band delay correction data" and by correcting inner-band phase by using "inner-band phase correction data", and get delay residual and a wideband cross spectrum.

5) Ionospheric delay correction: Delta TEC (total electron content) is estimated from a wideband cross spectrum obtained by step 4). Delta TEC obtained this way is used for an ionospheric correction of correlated data of each frequency band, then step 4) is repeated to get a final result.

3. Results

WBWS software is applied to true wide-band VLBI observation data obtained by an experiment conducted on Kashima-Ishioka baseline (about 50km length) in Jan. 16, 2015. We could a good result for a wideband bandwidth synthesis. As for the ionospheric correction, the baseline length is too short to investigate the effectiveness of a correction. We, therefore, evaluated it by using data simulating an ionospheric effect on VLBI data, and we could confirm its effectiveness.

4. Summary

We have been developing an algorithm of wideband bandwidth synthesis and have established a practical algorithm. As for the verification of the ionospheric correction described here, it is not enough. We are therefore planning to verify it by using longer baseline data such as an intercontinental experiment. Lastly, the data used for WBWS are those obtained by a test experiment with GSI’s Ishioka station. We would like to express our appreciation to GSI VLBI staff members for their kind support and cooperation for the experiment.

Keywords: VLBI, wideband bandwidth synthesis, ionospheric correction

VLBI application for Frequency Transfer and Development of GALA-V System (VII)

*Mamoru Sekido[1], Kazuhiro Takefuji[1], Hideki Ujihara[1], Tetsuro Kondo[1], Yuka Miyauchi[1], Masanori Tsutsumi[1], Eiji Kawai[1], Shingo Hasegawa[1], Hiroshi Takiguchi[1], Ryuichi Ichikawa[2], Yuko Hanado[1], Yasuhiro Koyama[3], Ken-ichi Watabe[4], Tomonari Suzuyama[4], Jun-ichi Komuro[5], Kenjiro Terada[6], Kunitaka Namba[6], Rumi Takahashi[6], Yoshihiro Okamoto[6], Tetsuro Aoki[6], Takatoshi Ikeda[7]

1.National Institute of Information and Communications Technology, Space Time Standards Group, 2.Technology Policy Planning and Coordination, Global ICT Strategy Bureau Technology Policy Division, The Ministry of Internal Affairs and Communications, 3.National Institute of Information and Communications Technology, International Relations Office, 4.AIST, National Metrology Institute of Japan, Time Standards Group, 5.NICT, Outcome Promotion Department, Development support Section, 6.NICT, Outcome Promotion Department, Information System Section, 7.NICT, Network Architecture Laboratory

1. Introduction
NICT is conducting a development of the new broadband VLBI system, named GALA-V, for distant frequency comparison. By means of VLBI observations with small diameter VLBI station installed at each of atomic frequency standards to be compared, the frequency of the standard signals are compared. We have developed original broadband feed for Cassegrain type Kashima 34m antenna and enabled observation of celestial radio source in 3-14 GHz frequency range simultaneously. This broadband observation does not only improve the signal to noise ratio of VLBI observation, but also drastically improves delay measurement precision. Our GALA-V system is designed to be compatible with the VGOS (VLBI Global Observing System), which is promoted by the IVS as the next generation geodetic VLBI system, so that GALA-V and VGOS joint observation will be possible. Such collaboration with VGOS stations will be useful for GALA-V to improve the precision of frequency comparison.

2. Super broadband VLBI observation with Ishioka 13m VGOS Geodetic Station and Kashima 34m station
We have made super broadband VLBI experiment between Ishioka 13m VGOS station of GSI and NICT Kashima 34m station with broadband feed (NINJA) in 2015. Then cross correlation data of super broad bandwidth (8 GHz) were synthesized, and precise group delay observable as arrival time difference of radio signal from celestial radio source to the two VLBI stations was determined at sub-pico second (0.1 mm in light velocity) precision by one second of integration time. Although the delay measurement is in great precision, error of geodetic position determination is limited by atmospheric delay estimation error, unless many scans of observable in different direction of the sky are gathered in short time interval via fast slew antennas as required in the VGOS specification. Result of our geodetic VLBI experiment with broadband system between Ishioka 13 m and Kashima 34m stations was following to this expectation. Precision of geodetic position determination is related to measure of frequency comparison precision. Thus we need to investigate strategy to enable quick scan switching observation with the GALA-V.

3. VLBI Frequency Comparison between NMIJ and NICT.
Small diameter antenna systems of GALA-V have been installed at NICT Koganei, where Japan Standard Time (JST) is maintained, and NMIJ, where atomic time standards are developed. This NICT-NMIJ is an excellent test bed to evaluate VLBI system for frequency comparison. By using broadband observation system mentioned above, even small diameter antenna can work as a VLBI station for frequency transfer. Some experiments results with this test bed will be reported in this presentation.

4. Summary
Development of a broadband VLBI system, which is compatible with the VGOS, is being conducted in the GALA-V frequency comparison project. Broadband VLBI experiment conducted between Ishioka 13m VGOS station of GSI and NICT Kashima 34m station has demonstrated sub-pico second delay measurement in one second of integration. This is the highest precision of group delay measurement of microwave technique. NICT and NMIJ are jointly working to evaluate the VLBI application for distant frequency comparison. After verification of this technique, we will plan moving small station to foreign country to for intercontinental frequency comparison.

Acknowledgements
We wish to express our gratitude to staff of Geospatial Information Authority of Japan (GSI) for supporting our development.

Keywords: Very Long Baseline Interferometry(VLBI), VGOS(VLBI Global Observing System), Distant Frequency Comparison

Effect of adjacent frequency signal on geodetic GNSS observations

*Hiromichi Tsuji[1], Yuki Hatanaka[1], Yudai Sato[1], Tomoaki Furuya[1], Akira Suzuki[1], Hiroki Muramatsu[1], Takaaki Inukai[1], Kano Mikihara[1], Naofumi Takamatsu[1], Tomokazu Nakakuki[1], Satoshi Fujiwara[1], Tetsuro Imakiire[1], Mikio Tobita[1], Hiroshi Yarai[1]

1.GSI of Japan

We found a possible radio interference of 1.5 GHz LTE signals from cell-phone base stations to nearby geodetic GNSS receivers installed at 14 GEONET stations of the Geospatial Information Authority of Japan as of February 2016. At these stations, the SN ratio of observed L1 and L2 frequency GPS signals dropped suddenly on the same days when the nearby cell-phone base stations began the transmission of 1.5GHz LTE signals. The height components of GEONET final solutions (F3) of these stations are contaminated with fake periodic variations of up to 5 cm amplitudes and from 2 week to 3 month periods. There are no corresponding horizontal periodic variations. All the 14 stations are equipped with the same type of modern geodetic GNSS receivers and choke ring antennas for multi-GNSS. We suspect that the relatively high power of 1.5GHz LTE signal adjacent to L1 GPS frequency (1.57542 GHz) from the nearby cell-phone base station saturates the antenna and receiver amplifiers, and lowers the received L1 and L2 GPS signals by the receiver. However, the mechanism of the fake height variations of relatively long periods is not easy to identify. Test observations at 2 GNSS stations with notch filters provided by the receiver manufacturer to remove the 1.5 GHz LTE signal show moderate recovery of SN ratio and almost no indication of periodic height variations. The insertion of attenuator of about 5 to 10 dB has the similar effect. As interim measures, we plan to deploy optimal level attenuators to the remaining stations affected by the possible adjacent frequency channel interference.

Keywords: GNSS, adjacent frequency channel interference

Comparison of computational methods of associated Legendre functions

*Takeshi Enomoto[1]

1.Disaster Prevention Research Institute, Kyoto University

Spherical harmonics composed of trigonometric and associated Legendre functions are used in geophysics and in other disciplines in science that deal with phenomena on the spherical surface. In meteorology, spherical harmonics are used to expand the prognostic variables of the atmosphere to compute the dynamical process in an atmospheric general circulation model or to analyze the energy spectrum. Recent increase in computing power allows us to use a large truncation wave number to achieve a horizontally high resolution. However, the values of associated Legendre functions of high order and degree cannot be computed accurately with the traditionally-used three-point recurrence in double precision. Alternatively, underflows can be avoided with the four-point recurrence in double precision or the three-point recurrence in extended floating arithmetic. Comparison of the two methods shows that the former and the latter have advantages in accuracy and speed, respectively. In addition, a method is shown to improve accuracy of the Fourier expansion of Legendre polynomials used along with the four-point recurrence.

Keywords: Sphere, Numerical method, Spectral method

