Status of Broadband VLBI Observation System (Gala-V) Development

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Abstract: The Gala-V is a broadband VLBI system composed of two small diameter antenna and large diameter one. for precise time and frequency transfer over intercontinental distances. The prototype of the broadband feed for the Gala-V has been newly designed for the 34m radio telescope. First light observation has been successfully made as simultaneous observation of 6.7GHz and 12.3GHz Methanol maser line spectrum from W3OH in January 2014. Pair of small diameter antenna MARBLE1 (1.6m diameter) and MARBLE2 (1.5m diameter) are ready for broadband observation with single linear polarization. The MARBLE1 antenna has been moved to National Metrology Institute of Japan (NMIJ) at Tsukuba in March 2014. Since both the NMIJ and NICT are keeping laboratory UTC(x), thus time comparison between NICT and NMIJ is good test bed for evaluation of the time comparison techniques. Three sessions of 24 hours geodetic VLBI experiments were conducted in April - May 2014, and their station coordinates are determined within 2 mm errors in average.

1. Introduction

Counting microwave frequency emitted from Cs Atoms is used for standard unit of length of time at present. More accurate clock based on counting optical emission from particular atoms are investigated and will become atomic time standard in the next generation(e.g.[1]). For establishing re-definition of second, precise frequency comparison between laboratories over intercontinental distances is required. For the purpose of distant frequency comparison, we are developing transportable broadband VLBI system (Gala-V). The data acquisition of the system is made by acquiring signal of 4 bands of 1 GHz width each in the frequency range of 3-14 GHz. Fixed frequency array is designed in the Gala-V at present, and the frequency array is selected based on (1) RFI survey and (2) minimum redundancy array for high delay resolution [2]. Although the frequency array is tentatively fixed in our project whereas flexible choice of the band is specification of VGOS[3], compatibility with the VGOS observing system is always in mind. Following section describes the progress of broadband system development and time and frequency transfer project since the last issue of TDC News[2].

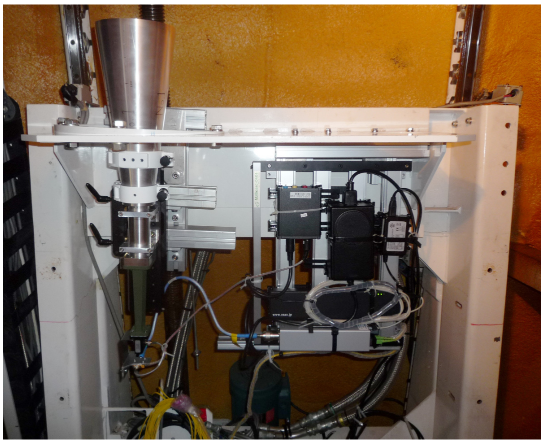

Figure 1. Prototype of Iguana Feed install at Kashima 34m antenna. SEFD is 1000 – 2000 Jy in 6–14 GHz frequency range.

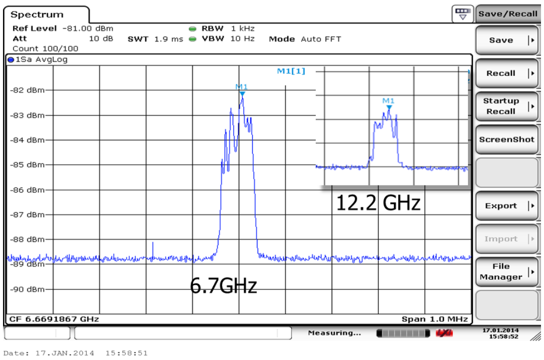

Figure 2. Frequency Spectra 6.7GHz and 12.3 GHz of Methanol maser source W3OH observed with Iguana prototype Feed of Kashima 34m antenna.

2. Broadband system Development

Known broadband feeds such as eleven feed[4] and QRFH[5] have wide beam size, thus we had to develop new broadband feed for our Cassegrain type 34 m antenna, whose viewing angle from the focal point to the sub reflector is 34 degrees wide. The first prototype of the broadband feed (Named 'Iguana Feed') developed by NICT, whose frequency range is 6-14GHz, was installed in Dec. 2013(Fig.1). The first light observation was successfully made in Jan. 2014, where two emission

Figure 3. MARBLE1 station installed at the top of 3-7 building of NMIJ at Tsukuba.

line of methanol maser at 6.7 GHz and 13.3 GHz was simultaneously observed on the radio source W3OH(Fig.2). Current antenna efficiency is above 30 % in 6-14 GHz frequency range, and system equivalent flux density is 1000 - 2000 Jy. Though this feed will be used by the end of 2013 for evaluation, upgrade of the feed design is under the plan to enable 3-14 GHz observation with better efficiency.

3. Moving MARBLE1 to Tsukuba (NMIJ)

The Gala-V system is composed of pair of small antennas and Kashima 34m telescope. Two small antenna (MARBLE1 and 2) have prime focus parabolic antenna with 1.6 m and 1.5 m diameter dishes, respectively. Quad Ridge Horn Antenna (QRHA)[6] is used for the feed, and broadband single linear polarization signal is ready. MARBLE2 station is installed at the top of the second building of NICT headquarters at Koganei. MARBLE1 station was moved from Kashima to Tsukuba (NMIJ) by the end of May 2014(Fig.3). Both NICT and National Metrology Institute of Japan (NMIJ) have been keeping their own time scale by atomic time standards, and their UTC(x) are regularly compared with UTC determined by the BIPM (Bureau International des Poids et Measure). Therefore time comparison between NICT (Koganei) and NMIJ (Tsukuba) is a good test-bed for development of frequency comparison technique. After installation of MARBLE1 to NMIJ(Tsukuba), 24 hours geodetic VLBI experiments were conducted three times with X-band. Table xx shows the estimated station coordinates with station coordinates of 34m antenna is fixed.

Table 1. Station coordinates determined by five VLBI experiments (22-13 Apr., 14-15 May, 30-31 May, 26-27 Jun., and 1-3 Aug.). Station Coordinates and velocities are estimated with Kashima 34m station coordinate is fixed. Coordinates Epoch is MJD=56808.0.

Station	XYZ [mm]		$\sigma_{\rm err}$
MARBLE1	X	-3962276706.9	2
	Y	3308884002.6	2
	Z	3733538092.9	2
MARBLE2	X	-3942062034.9	2
	Y	3368277053.9	2
	Z	3702003875.0	2
KASHIM34 (Fixed)	X	-3997650058.0	
	Y	3276690071.0	
	Z	3724278461.0	

4. Three station experiments and frequency Comparison

By using the geodetic VLBI data in April and May, clock difference between NICT and NMIJ was examined. Clock difference estimated by using VLBI, GPS, and difference of UTC(x) published from BIMP[1] are displayed in Fig. 4. Vertical position of the plots are adjusted by adding arbitrary offsets to the data of VLBI and GPS. These plots indicating that VLBI and GPS show similar performance of clock comparison and both shows good agreement with the final comparison data of UTC(x) reported from BIPM. Since baseline of small diameter antenna pair does not have enough sensitivity, VLBI data of AB baseline was formed by taking difference of observable of OA,OB baseline, where A:MARBLE1, B:MARBLE2, O:KASHIM34. The converting from two baseline data of OA,OB to single baseline AB data is given by

$$\tau_{\rm AB}(t_{\rm prt}) = \tau_{\rm OB}(t_{\rm prt} - \tau_{\rm AB}(t_{\rm prt})) - \tau_{\rm OA}(t_{\rm prt} - \tau_{\rm AB}(t_{\rm prt})), \quad (1)$$

where $t_{\rm prt}$ is Epoch of data to be analyzed. Although this equation is neglecting the source structure effects, there are no significant problem at

[1] `http://www.bipm.org/jsp/en/TimeFtp.jsp?TypePub=publication`

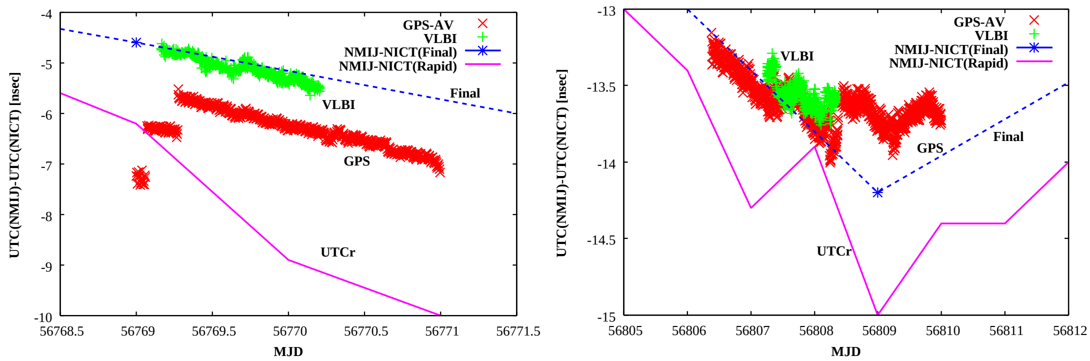

Figure 4. Clock comparison between UTC(NMIJ)- UTC(NICT) via VLBI('+') and GPS('×'). Rapid UTC comparison UTCr and final UTC(x) comparison data published from BIPM are over plotted with solid and dashed lines, respectively. Left panel is data during 22-24 Apr. and right panel is from 29th May to 2nd Jun.

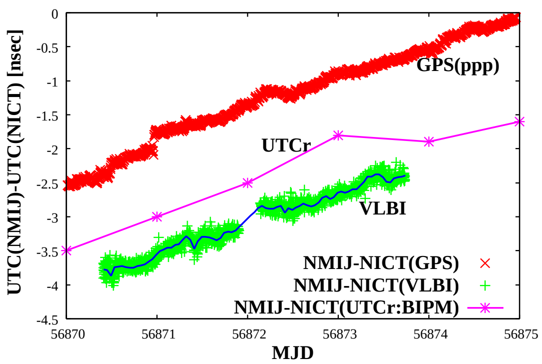

Figure 5. Clock comparison via VLBI('+') and GPS('×') performed during 1 – 3rd Aug. Vertical position of the GPS and VLBI plots are adjusted by arbitrary offset.

present because of relatively short baseline.

Continuous VLBI experiment for frequency comparison was conducted during 1st - 3rd of August. The clock data estimated by VLBI observation, GPS, and UTCr data provided from BIPM were displayed in Fig.5. As the same with the results of Apr. - May, it is confirming that the VLBI analysis gives the consistent results with others. The scattering of the VLBI data is slightly larger than GPS in this experiment. Since the VLBI data is not always obtained in uniform interval, then statistics such as Allan variance is not applicable. Other statistical evaluation such as sigma-z[7] have to be considered.

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