Broadband VLBI at 6GHz to 14GHz frequency range between Kashima 34 m and Ishioka 13 m

K. Takefuji, T. Kondo, H. Hideki and M. Sekido

Abstract First results from the Japanese broad band VLBI between Kashima 34 meter and Ishioka 13 meter are shown. We have been developing a broad-band system for Kashima 34 meter antenna. broadband feed for 6.5 GHz to 15 GHz and broadband receivers were installed to 34 meter and high-speed direct samplers K6/OCTAD-G was also installed to the observation room since 2014. From the session a coherent phase connection over six frequencies were performed. Then quite fine delay resolution function were obtained. An error of delay resolution function by the super bandwidth synthesis is estimated 0.1 ps. Thus, we report more details e.g. the delay variation behavior from the broadband VLBI.

Keywords Broad-band, Super bandwidth synthesis

1 Introduction

To establish next generation geodetic VLBI, called VGOS (VLBI Global Observing System) which is based on the so-called broadband delay which uses four 1 GHz bandwidth in the range from 2.5 GHz to 14 GHz, we have been developing a broad-band system for Kashima 34 meter radio telescope which is the third largest radio telescope with cassegrain optics in Japan. There are several antennas which meet the requirement VGOS specification, e.g Westford and GGAO in United States, Yebes, Santa Maria in Spain and Portgal, Ishioka in Japan, Wettzel in Germany, Badary and Zelenchukskaya in Russia. However, current exist VGOS antenna installed (or will install) Eleven feed or QRFH feed to realize to receive 2 GHz to 14 GHz frequency range. Since these feeds have wide angle, sub-reflector of antenna needs to close to the feed. Thus, an optics of the ring focus is required to gain a high efficiency. Therefore, it is very challenging to develop a feed which has sharp beam width and broad band sensitivity for cassegrain optics. We started to develop the feed since 2011, proto-type feed (IGUANA-H) was installed to 34 meter. To demonstrate broad-band VLBI, feasible VLBI sessions with Kashima 34 m and new VGOS-type Ishioka 13 m were carried out from end of 2014 to January 2015.

K. Takefuji, T. Kondo, H. Hideki and M. Sekido
893-1 Hirai, Kashima, Ibaraki, Japan

2 Development broadband system for Kashima 34 meter

Currently we have installed two type of broadband feed (IGUANA-H and NINJA). Figure 1 shows the two type of feed. Left smaller feed is IGUANA-H, covering 6.5 GHz to 15 GHz frequency range and Right bigger feed is NINJA feed convering 3.2 GHz to 14.4 GHz frequency range. Since December 2013 IGUANA-H feed has already installed and evaluated by VLBI. Second brand new NINJA feed is recently deployed on July 2015. As regards beginning frequency of VGOS specification is 2.5GHz, but NINJA feed has cut-off frequency at 3.2 GHz to prevent highly strong RFI. Since strong RFI from mobile stations is emitted around 2GHz, Broad-band LNA will be easily saturated by receiving such strong signals. Our broad-band system with ambient receiver system having the system temperature is below 200 Kelvin

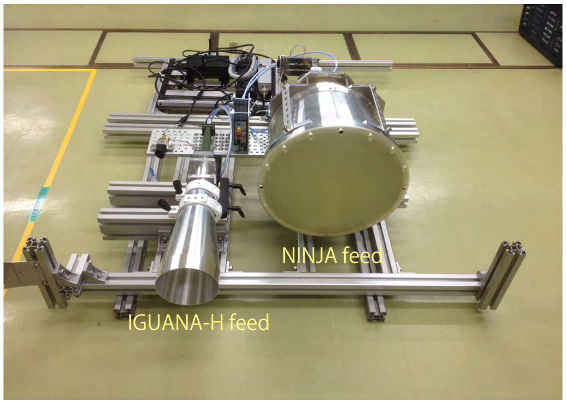

Fig. 1 Iguana-H feed and NINJA feed mounted to the trolley bed

Fig. 3 Appearance of K6/Galas, a direct sampling (16 GHz speed) system including DBBC signal processing

until 14 GHz. The effciency of IGUANA-H feed is over 40 % from 6GHz to 13 GHz frequncy range. Over 13 GHz range efficieny is reduced and has 30 % at 15 GHz (see figure 2). The signal after the LNA is transfered over optical fiber, then high-speed direct sampler called K6/GALAS converts analog stream to digital signals with digital baseband conversion (Takefuji, 2013). There has also conventional analog down-converters, these analog signals are sampled ADS3000+ (figure. 4).

3 Broad band VLBI between Kashima 34 meter and Ishioka 13 meter

Full VGOS radio telescope is built by The Geospatial Information Authority of Japan in Ishioka, Ibaraki,

Fig. 4 Appearance of K5/ADS3000+, A maximum sampling speed is 4 GHz speed, having DBBC signal processing for conventional geodetic VLBI

Japan, where locates 50km north-west side from Kashima. The feasible broad-band VLBI sessions with Kashima 34 m (IGUANA-H feed) and new VGOS-type Ishioka 13 m (Eleven feed) were carried out on January and July 2015. We carried out intensive sessions for 6 to 14GHz (6-bands, 2048Msps, 1bit) in four hour. The backend was made up two parts. One is direct sampling system K6/GALAS covered with 6GHz, 7GHz, 8GHz and 9GHz. The another was analog frequency converter for 10GHz and 13GHz. Two bands were sampled ADS3000+ after analog down-converter. Both systems were set up for both antennas. We carried out intensive sessions for 6 to 14GHz (6-bands, 2048Msps, 1bit). Unfortunatly there had no internet connection. Then, recorded data were transferred from Ishioka to Kashima by car. Fringes from every six frequencies could be immediately detected after transferred by software correlater GICO3 [(Kimura, 2007)].

4 Super bandwidth synthesis from Kashima-Ishioka session

A coherent phase connection with six frequencies bands were performed. The bandwidth synthesis will be processed following the procedures,

1. Choose single scan as a template: At first we choice single scan which has higher SNR as a template. The template scan does not change whole observa-

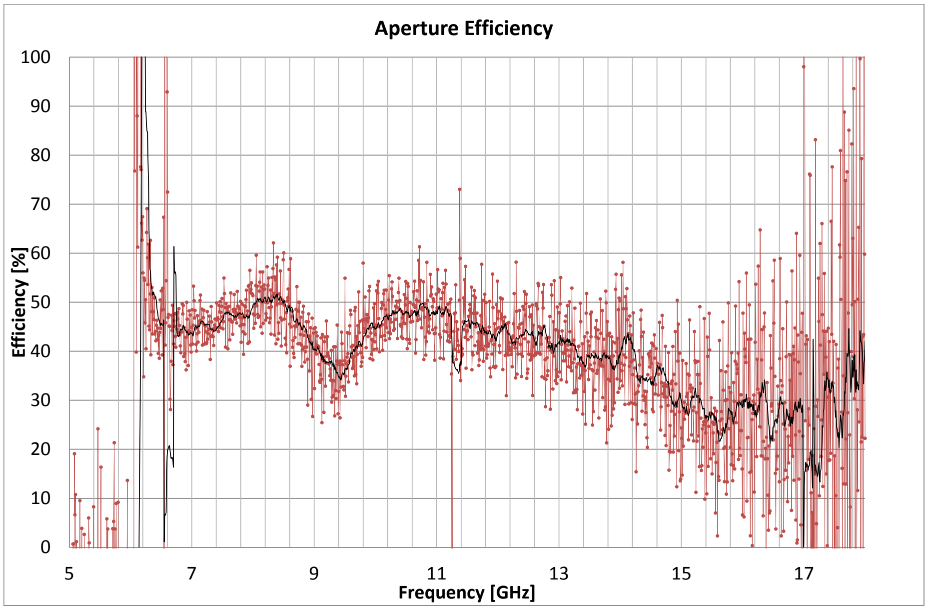

Fig. 2 Aperture efficiency of Kashima 34 meter deployed with IGUANA-H feed

tions. The apriori information (e.g. station position, clock delay and rate) of every frequency bands were necessary to uniform in correlation.

2. Inter-band delay correction: Among frequency bands, a few nano second delay differences were unavoidably included through analog systems. The differences will be normalized by using 1st band (or any frequency bands)
3. Intra-band delay correction: Since a phase curvature on 1 GHz bandwidth is usually waved, the curvature is fitted to use as template.
4. Ionospheric delay correction: After inter and inter delay correction, the ionospheric delay still included. whole bandwidth will be re-analyzed to measure ionospheric delay $\propto 1/f^2$.

An delay resolution function by the super bandwidth synthesis after previous procedures was shown in figure.5. This is the first achievement in the world and its theoretical delay precision reaches $2.7x10^{-14}$ seconds after 60 s integration. Figure.6 shows the delay observable of 1 second integration every over 700 seconds. Different color of plot (red, green, and blue) indicates delay data bandwidth of 1 GHz, 2 GHz and 4 GHz of #1 to #4 band respectively. This Figure indicates the scattering become smaller as increasing the bandwidth with keeping systematic behavior unchanged. The root-mean-square (RMS) of delay observable at 1 second integration are calculated 3.08 ps, 2.01 ps and 0.96 ps in 1 GHz, 2 GHz and 4 GHz bandwidth respectively. It shows the delay precision improved as the bandwidth becomes wider. However, figure. 7 shows a power spectrum of figure.6. The plot bends around 20 sec, it indicates the while noise component continues only 20 sec. When we observe longer than 20sec, flicker noise will be dominated. Thus, the delay fluctuation might be limited mainly caused by atmospheric delay in this case.

5 Conclusions

We developed broad-band and sharp width feed (IGUANA-H and NINJA). We carried out broad-band VLBI experiment from 6 GHz to 14 GHz frequency range between Kashima 34m and Ishioka 13m. The

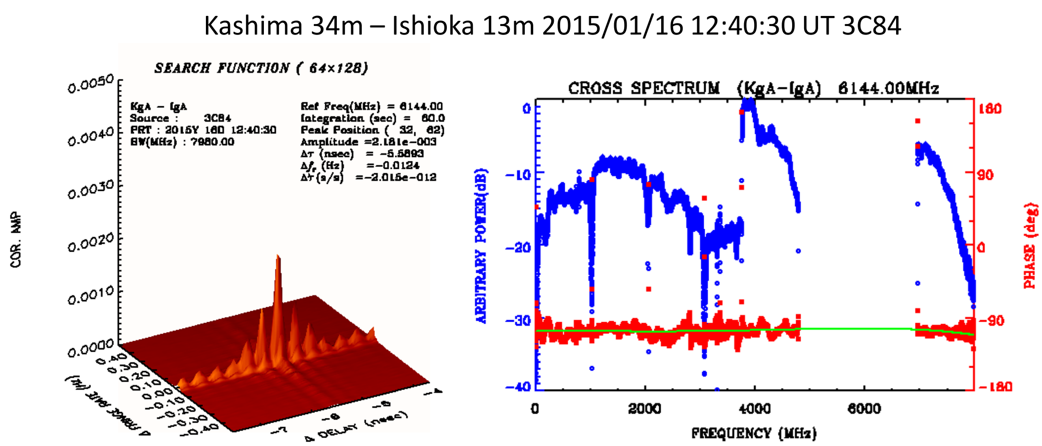

Fig. 5 Super bandwidth synthesis over 8GHz bandwidth between Kashima 34 meter and Ishioka 13 meter

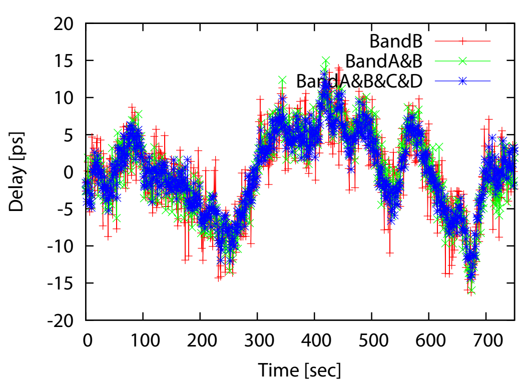

Fig. 6 Delay comparison with 1GHz, 2GHz, 4GHz bandwidth in 700 sec scan.

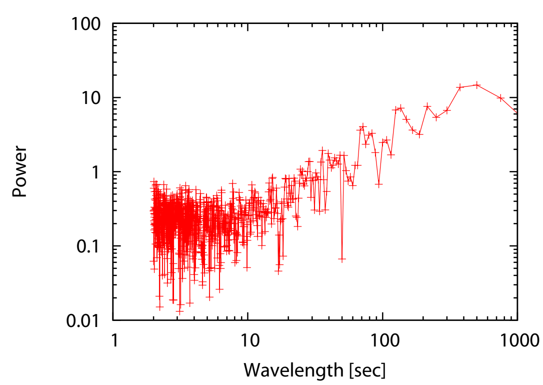

Fig. 7 A power spectrum of figure.6.

six frequency bands over 8GHz were synthesized with correcting inter and intra delay. A delay precision becomes improved as a bandwidth becomes wider, however improvement will be limited caused by atmospheric delay. The limitation in this case was about 20 second.

Acknowledgements

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References

M. Kimura. Development of the software correlator for the VERA system II. *IVS NICT-TDC News (2007). No.28, pp.22-25, 2007*. Web document http://www2.nict.go.jp/aeri/sts/stmg/ivstdc/news_28/pdf/tdcnews_28.pdf, 2007.

K. Takefuji and H. Ujihara Technology Development Center at NICT. International VLBI Service for Geodesy and Astrometry, 2012 Annual Report, edited by K. D. Baver, D. Behrend and K. L. Armstrong, NASA/TP-2013-217511, 342345, 2013.