Broadband VLBI Experiment on the Onsala – Kashima Baseline

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Abstract

We have conducted a joint observation between the **Kashima 34 m** and one of the **Onsala 13.2 m** twin telescopes (**ONSA13NE**). Japanese data acquisition system (DAS) K6/GALAS and the European DBBC3 in OCT-mode were used at Kashima and Onsala, respectively. We have made broadband test observation with four 1 GHz width channels located in 3-11GHz range by using these two heterogenous DASs. After the first success of 1GHz width single channel VLBI experiment on 20th Feb. 2018, full-spec VLBI experiments of **eight 1GHz-width channels in dual linear polarization (total date rate:16.384 Gbps)** have been performed. This is a report on fringe detection, and some results of19 hours radio source survey observation on 27 March.

1. Experiments

Broadband VLBI experiments were mad between Onsala Twin Telescope equipped with DBBC3 and Kashima 34m antenna with NINJA Feed (Fig.1). European DBBC3 in OCT-mode and Japanese K6/GALAS have similar function to extract 1GHz width continuous frequency channel by digital filter. These DASs have been used to perform the first full spec (4band x 1GHz x 2pol.) VLBI observation. Record of experiment is listed in Table 1. Four band of fringe detection and bandwidth synthesis was successful for each polarization combination in the experiment on 15th March (Fig.2).

Table.1 , Observation modes of Broadband Experiments on KASHIM34-ONSA13NE

Date,EXP-code	Observation Mode, Freq.	Duration	Remarks
20th Feb., OK18051	2048Msps-2bit-1band x 2Pol (8192Mbps) RF=9GHz	1 hour	Fringe test → Detected
6th Mar., OK18065	2048Msps-1bit-4band x 2Pol (16384Mbps) RF=3.0GHz,5.4GHz,9.0GHz,10.2GHz (Zero Redundancy)	1hour	Fringe test-> Failed
15th Mar., OK18074	The same with above	1 hours	Fringe test → Successful detection for 4 bands
27th Mar., OK18086	The same with above	19 hours	203 radio source 300sec each, Fringe of band-B(5.4GHz) was not detected.

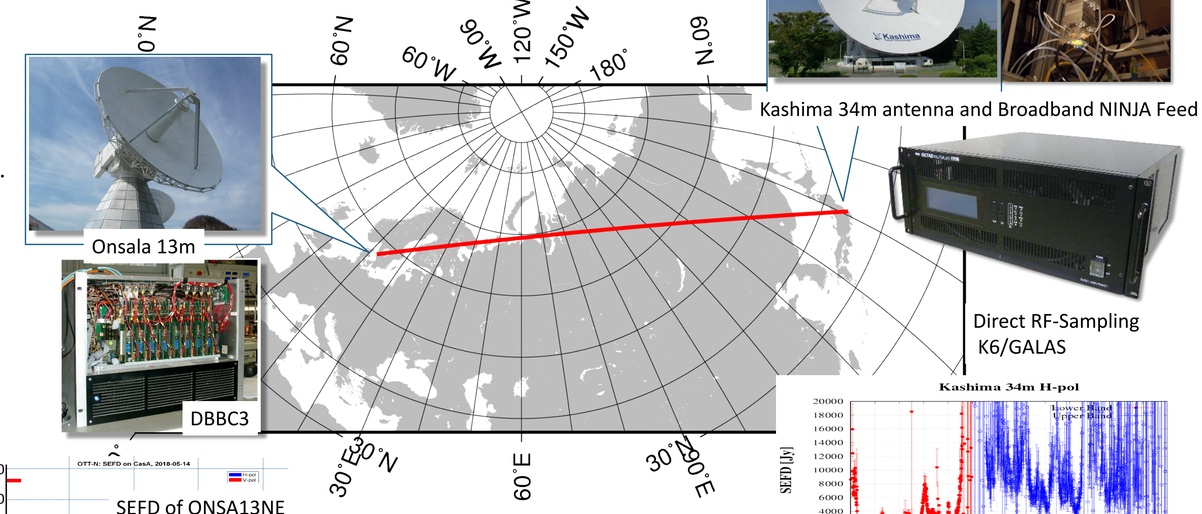
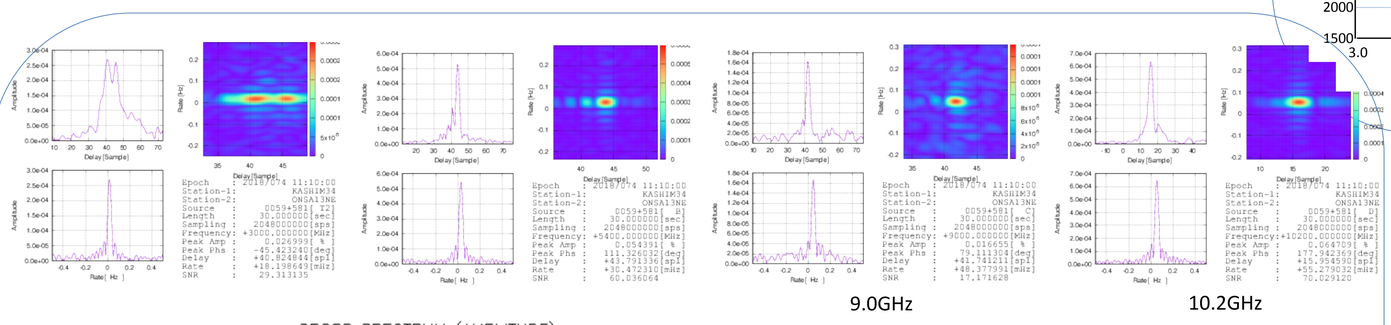


Figure1. Configuration of Broadband VLBI between KASHIM34 with K6/GALAS and ONSA13NE with DBBC3. Frequency characteristic of SEFDs for each antennas are displayed.



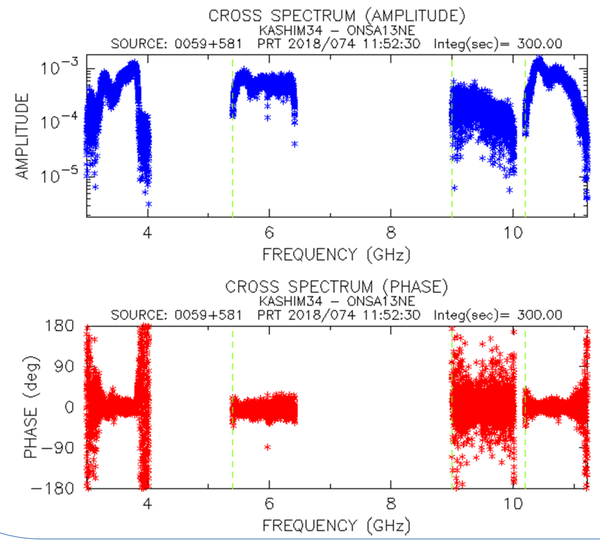


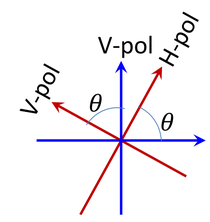
Figure2. Correlation processing have been made at NICT with GICO3 software correlator developed by NICT. Fringes were detected for all four bands and for each polarization. Bandwidth synthesis of four bands was successfully applied for each polarization. However still synthesizing dual linear polarization is subject of development.

2. Broadband Radio Source Survey on 27 Mar.

After the success of the fringe test, a long (19 hours) run of broadband VLBI observation has made on 27th Mar.(OK18086). The purposes of the session were twofold: (1) a radio source survey to check correlation amplitude with broadband antenna, and (2) Obtaining sample data for development of bandwidth synthesis of dual linear polarization data. Totally 203 radio sources selected from source catalog of 'sked' program maintained by GSFC. All duration of scan length was 300 sec. Total recording length of 60,900 sec. with data rate of16364Mbps (2048Msps-1bit-4band-2pol) generates 124TB of data. All the data was e-transferred to Kashima by using 'tsunami/UDP' protocol. It took more than 20 days, however, we learned jive5ab/m5copy by using UDT protocol (H. Verkouter) is faster and more stable, later on. Correlation processing was made by GICO3 software correlator developed by NICT. Because synthesis software for dual linear polarization data is still under development, evaluation of correlation amplitude is made by $\rho_{total} = \sqrt{\rho_{HH} \cdot \rho_{VV} + \rho_{VH} \cdot \rho_{HV}}$, where ρ_{XY} represent correlation amplitude of polarization combination X,Y ($X, Y = V \text{ or } H$).

Assuming that radio source is completely unpolarized, source flux is expressed by scalar value S for any polarization. When difference of parallactic angle was θ, correlation amplitude of polarization pair XX is expressed by $\rho_{XX} = \frac{S \cos\theta}{\sqrt{SEFD_{1,X} \cdot SEFD_{2,X}}} = \rho^*_{XX} \cos\theta$, where ρ^*_{XX} is correlation amplitude with polarization aligned.

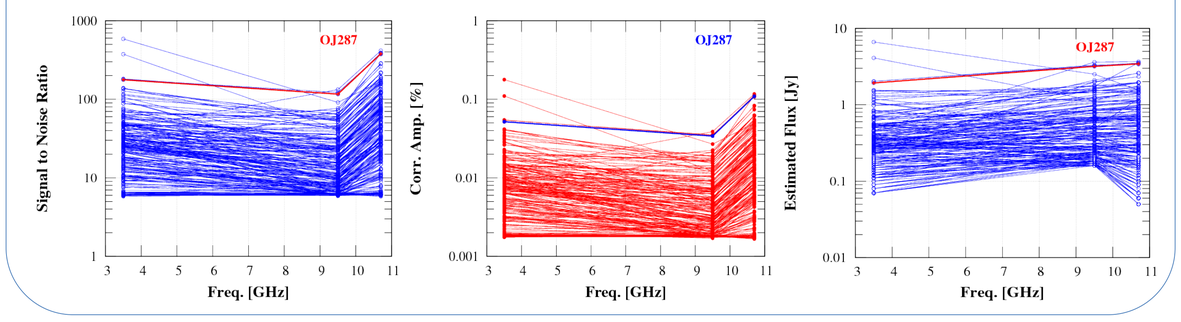
Similarly, $\rho_{XY} = \frac{S \sin\theta}{\sqrt{SEFD_{1,X} \cdot SEFD_{2,Y}}} = \rho^*_{XY} \sin\theta$.



Then, $\rho_{total} = \sqrt{\rho_{HH} \cdot \rho_{VV} + \rho_{VH} \cdot \rho_{HV}} = \frac{S}{\sqrt[4]{SEFD_{1,V} \cdot SEFD_{2,V} \cdot SEFD_{1,H} \cdot SEFD_{2,H}}}$ is an appropriate expression to represent source flux regardless to the parallactic angle.

Unfortunately, fringes of band-B (5.4GHz) was not detected unknown reason, though fringes of rest of three bands are successfully detected for almost all sources. Fig. 3 shows the frequency dependency of SNR, correlation amplitude, and estimated flux. Source flux is computed by scaling with ρ_{total} by using flux of OJ287 (1.68Jy and 2.95 Jy for 2.3GHz and 8.4GHz, c.f.: source flux catalog of 'sked' program by NASA/GSFC).

Figure3. Frequency dependency of SNR, correlation amplitude, and estimated radio source flux of 200 radio sources are indicated as the result of broadband VLBI experiment between KASHIM34-ONSA13NE on 27 Mar.



3. Baseline Analysis

Although the experiment ok18086(27 Mar. 2018) was not scheduled with intention for geodetic VLBI observation, we have supplementary tried baseline analysis with this 19 hours of VLBI data. Because fringes of band-B data were not detected, then broadband group delays have not been available. Then analysis was made for each single band delay data of each polarization pair (VV,HH,VH,HH). Therefore ionospheric delay is not calibrated. Deviation of estimated station position from a priori value (below)

Station Name	X [m]	Y [m]	Z [m]
KASHIM34	-3997650.146	3276689.97	3724278.447
ONSA13NE	3370889.19	711570.78	5349691.1

are listed in Table 2 and plotted In Fig. 4. Smaller scatter of higher frequency data is attributed by uncalibrated ionospheric delay.

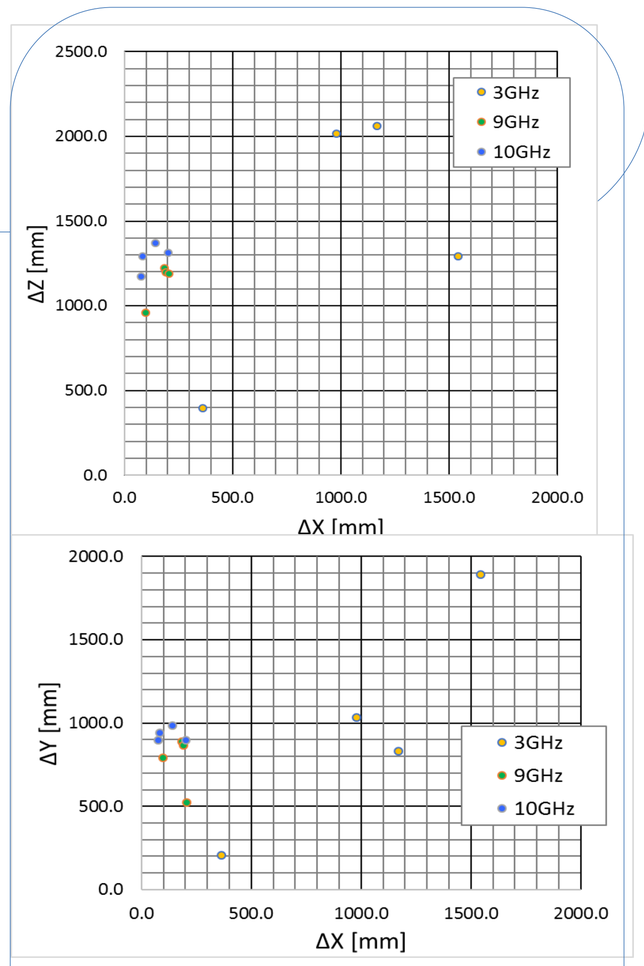


Figure 4. Station position deviation from a priori for ONSA13NE estimated by using single band delay with KASHIM34 fixed in ITRF2014 are plotted for each band and polarization combination. Scatter of higher frequency data is smaller because ionospheric delay is not calibrated.

Table 2. Station coordinates of ONSA13NE estimated by using CALC11/Solve (ver. 2014.2.21) with single band delay data of ok18086 (27 Mar. 2018) experiment, where position of KASHIM34 in ITRF2014 is fixed. Ionospheric delay is not calibrated.

Freq[GHz]	Polarization	EXP DB Code	Epoch	X [m]: Value & 1 σ		Y [m]: Value & 1 σ		Z [m]: Value & 1 σ		ΔX [mm]	σX	ΔY [mm]	σY	ΔZ [mm]	σZ
10.7	HV	$18MAR27KR Ver 2	2018/03/27-19:01:29	3370889.332	0.03573	711571.7671	0.03455	5349692.472	0.07157	142.5	35.7	987.0	34.6	1372.4	71.6
	VH	$18MAR27KQ Ver 2	2018/03/27-19:01:29	3370889.392	0.02544	711571.6759	0.02266	5349692.412	0.04779	202.4	25.4	895.9	22.7	1312.3	47.8
	HH	$18MAR27KP Ver 2	2018/03/27-19:01:29	3370889.274	0.04146	711571.7218	0.04132	5349692.394	0.09226	84.0	41.5	941.7	41.3	1294.2	92.3
	VV	$18MAR27KO Ver 2	2018/03/27-19:01:29	3370889.266	0.05008	711571.6782	0.0345	5349692.273	0.09242	76.0	50.1	898.2	34.5	1173.2	92.4
9.5	HV	$18MAR27XR Ver 2	2018/03/27-19:01:29	3370889.374	0.05271	711571.6675	0.05168	5349692.323	0.10385	184.5	52.7	887.5	51.7	1223.1	103.9
	VH	$18MAR27XQ Ver 2	2018/03/27-19:01:29	3370889.38	0.0292	711571.6485	0.02631	5349692.299	0.05519	189.8	29.2	868.5	26.3	1198.7	55.2
	HH	$18MAR27XP Ver 2	2018/03/27-19:01:29	3370889.289	0.04137	711571.5708	0.0428	5349692.058	0.09449	98.7	41.4	790.8	42.8	958.0	94.5
	VV	$18MAR27XO Ver 2	2018/03/27-19:01:29	3370889.397	0.11546	711571.3054	0.05913	5349692.289	0.1715	206.9	115.5	525.4	59.1	1188.8	171.5
3.5	HV	$18MAR27SR Ver 2	2018/03/27-19:01:29	3370890.169	0.12858	711571.8139	0.11155	5349693.118	0.26201	978.8	128.6	1033.9	111.6	2018.2	262.0
	VH	$18MAR27SQ Ver 2	2018/03/27-19:01:29	3370890.358	0.18528	711571.6094	0.14037	5349693.159	0.28967	1168.2	185.3	829.4	140.4	2059.5	289.7
	HH	$18MAR27SP Ver 2	2018/03/27-19:01:29	3370889.553	0.14722	711570.988	0.15332	5349691.494	0.36192	362.8	147.2	208.0	153.3	393.7	361.9
	VV	$18MAR27SO Ver 2	2018/03/27-19:01:29	3370890.733	0.58845	711572.6708	0.6108	5349692.391	1.42225	1543.3	588.5	1890.8	610.8	1291.1	1422.3

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