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Figure 1. Members of the NICT VLBI group.

Preface

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1. The 10th IVS-TDC Symposium

As one of the Technical Development Centers (TDC) of the IVS (International VLBI Service for Geodesy and Astrometry), Kashima Space Research Center (KSRC) of National Institute of Information and Communications (NICT) hosted the 10th IVS-TDC Symposium at the KSRC. The symposium was held on February 23, 2011, just 16 days before the 2011 Tohoku Mega-Earthquake (see the next section).

In this annual symposium we focused on the most recent R&D related to VLBI technology. In addition, since the symposium was close to the end of the fiscal year 2010 which marked also the end of the 5 year mid-term plan of NICT, we summarized our activities and presented the final outputs. In total, 22 oral and 6 poster papers were presented by researchers from Japan Aerospace Exploration Agency (JAXA), Geospatial Information Authority of Japan (the former Geographical Survey Institute, GSI), National Astronomical Observatory of Japan (NAOJ), Gifu University, Hitotsubashi University, Ibaraki University, Kagoshima University, Yamaguchi University, Yokohama National University and NICT. In addition, three private companies exhibited their products which are related to VLBI and GNSS technologies such as RF and IF samplers for analog-digital conversion and the most recent GNSS receivers.

This volume contains the proceedings of the symposium and it includes 13 papers which cover various VLBI study fields, i.e. results of geodetic experiments using the compact VLBI system, rapid UT1-UTC determination using e-VLBI technique, a proposal of radio-astronomical VLBI experiments, correlation processing of GNSS and communication satellite signals, VLBI2010 issues, precise time and frequency transfer using VLBI and other techniques. The slides of these presentations are available on the web at `http://www2.nict.go.jp/w/w114/stmp/ivstdc/sympo110223/tdcsympo10.html(inJapanese)`.

2. The 2011 Tohoku Megaquake

At first, we would like thank whole VLBI community all over the world for their concerns about the devastating tragedy due to the M_w 9.0 megaquake that occurred on March 11th, 2011. We suffered from strong ground motion and a 5.2-m-high Tsunami attacked the Kashima port as shown in Figure 2. In addition, we were facing serious restrictions due to the Fukushima nuclear accident. Fortunately, we have no staff casualties in KSRC/NICT. Our 34-m antenna has some minor damage due to the strong motion which exceeded 650 gal as recorded around Kashima region. The other facilities at KSRC/NICT (e.g. main building, guest room building, and outreach building) are also partly damaged. Thus, these building are currently under repair. We expect that the 34-m antenna will be recovered by the end of this fiscal year. Coseismic crustal deformations measured by our GPS station nearby the 34-m antenna showed movements of up to 749 mm in the horizontal (eastward) and -245 mm in the vertical (see Figure 3). Moreover, postseismic deformations following the main shock reached values of over 270 mm in the horizontal and about 100 mm in the vertical component as recorded until the end of July.

3. The 3rd NICT 5 year mid-term plan

NICT has started the 3rd 5 year mid-term plan on April 1st, 2011. NICT has changed the logo prior to the launch of the mid-term plan (see Figure 4). In the 3rd mid-term plan, the Space-Time Standards Laboratory (former Space-Time Standards Group) are going to provide the nation with a reliable and precise space-time reference/time and frequency standards through the R&D of the Japan Standard Time generation and improving its distribution services as well as the R&D of the next generation space-time standards application technology. It will also promote the R&D of optical frequency standards and the next generation space-time measuring technology, thereby contributing to the redefinition of the second and to the implementation of comprehensive space-time standards. We, Space-Time Measurement Group which is one of the four groups of the Laboratory, conduct R&D on space and time measurement technologies using radio and optical waves, i.e. VLBI, GNSS, TWSTFT, and optical fiber link. Especially, we perform the R&D of the compact VLBI system including the VLBI2010 concept in order to apply time and frequency transfer of the next-generation frequency standards.

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[1] "Koho Kashima (Kashima public relations [`http://city.kashima.ibaraki.jp/20kouhou/data/20110401/0401_all_ver2.eps(inJapanese)`])", No. 393, April 1st, 2011.

Figure 1. Photos taken during the Symposium.

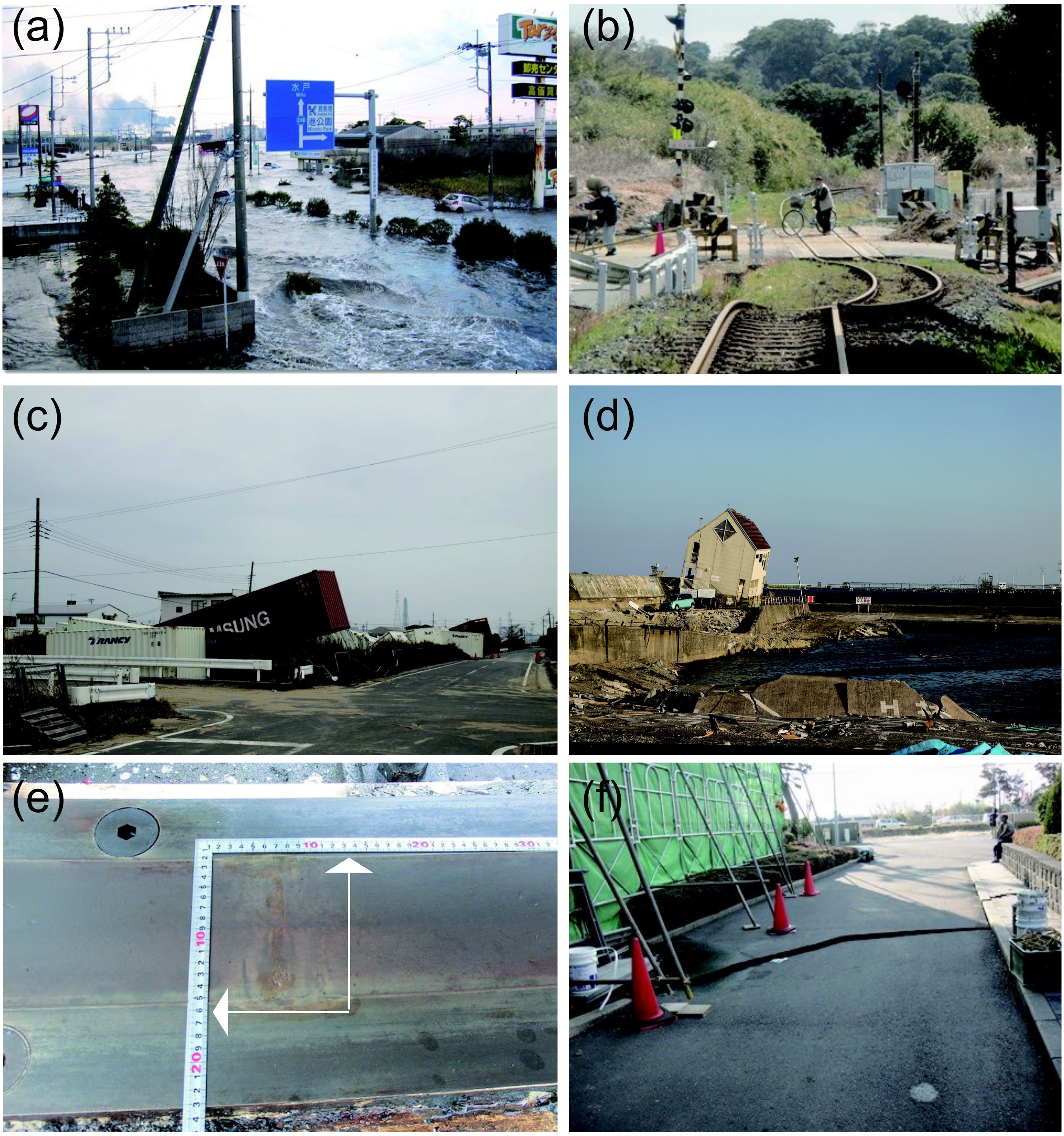

Figure 2. Earthquake damage in Kashima city. (a) Tsunami struck the Kashima port and surrounding area.[1], (b) train rail bent by powerful ground motion, (c) cargo containers thrown around by the tsunami in Kashima, (d) Kashima port hit by Tsunami, (e) ripple mark of 34-m antenna azimuth rail caused by strong motion, (f) broken road in front of the KSRC/NICT main building (photo (b) and (f) were taken by Dr. Kondo)).

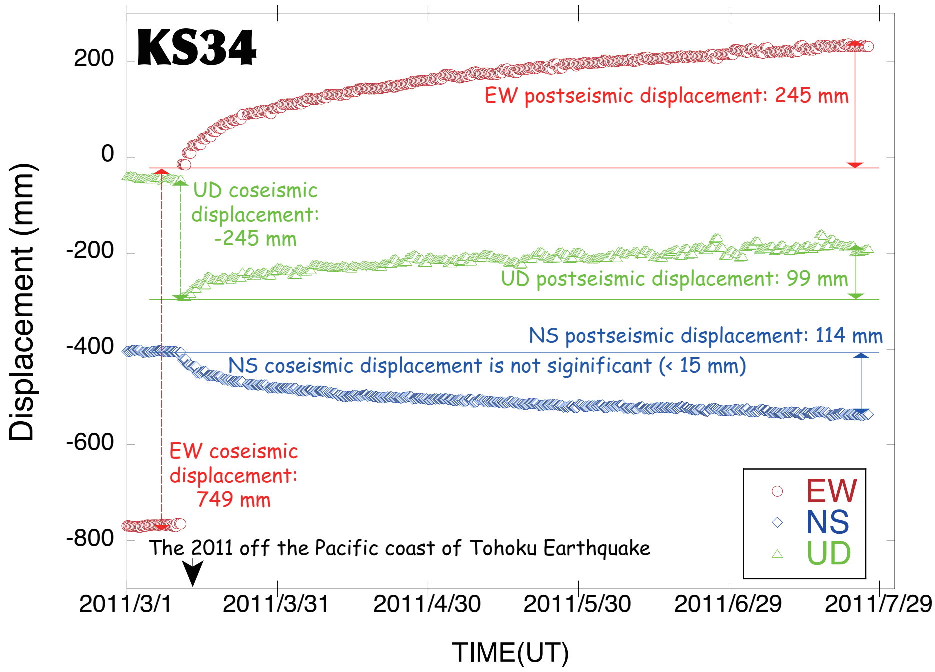

Figure 3. Crustal deformation associated with the 2011 Tohoku Earthquake. These displacements have been obtained by the GPS station on top of the Kashima 34-m antenna building.

Figure 4. Kashima 34-m antenna with the new NICT logo.

Software ”c5++” for Combined Space-Geodetic Analysis

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1. Introduction

Space-geodetic products, such as terrestrial reference frame, earth rotation parameters, etc., can today be derived from multiple geodetic techniques. A new software package called ”c5++” is being developed to enable combined analysis at the observation level (Fig.1).

This policy is a contrast to the current standard way in the international geodetic scheme that is based upon solution combination.
This new software is an update from the ”concerto” software (Otsubo, 2005) that has been developed and used primarily for satellite laser ranging and also for other satellite-based techniques. The existing version 4 is written in Java, but the new version 5 is being written in C++. Although it makes use of common C++ libraries, such as STL, Boost, NetCDF and OpenMP, the important parts are all developed by ourselves. Its subset for VLBI analysis has been already proven to be useful for rapid UT1 determination (Hobiger, 2010).

It is essential to adopt latest physical models for highly precise geodetic analyses. The model collection ”IERS Conventions” was updated in December 2010 (Petit and Luzum, 2010), from the previous 2003 version to the new 2010 version. We experimentally adopt the station displacement models from the new IERS Conventions models in our software.

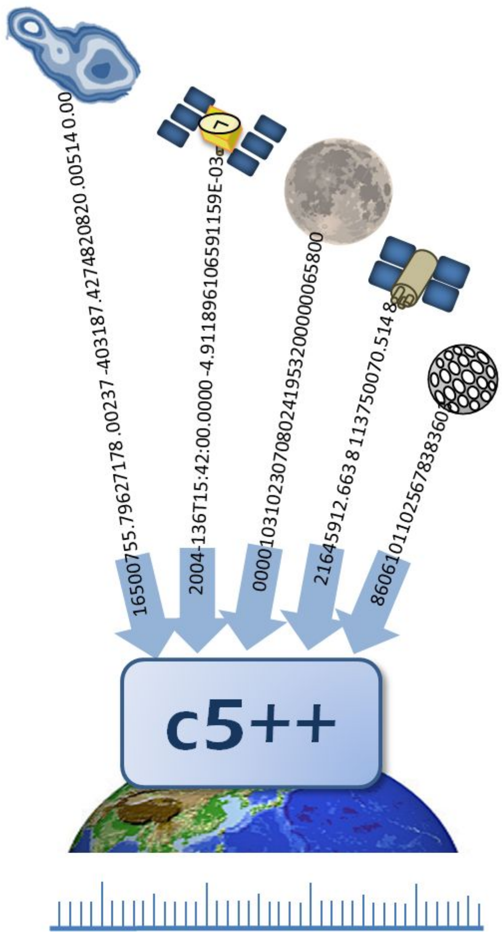

Figure 1. Concept of observation-level combination analysis of space geodetic data.

2. IERS Conventions 2010 Models

Let us quickly look at the displacement models of IERS Conventions 2010 in comparison with the former Conventions 2003.

2.1 Ocean loading

Although the input data set remains the same, that is so-called ”BLQ” format that contains the amplitude and the phase for 11 tides and for three components, the new IERS Conventions 2010 model extends the constituent tides from 11 to 342, by spline interpolation of the tidal admittances.

The Fortran subroutines provided by IERS are converted to C++ by ourselves, and the validity of our computation is confirmed with its sample output. Fig.2 shows the variation of ocean loading displacement at Kashima, of the new model (top) and the difference between the two models (bottom).

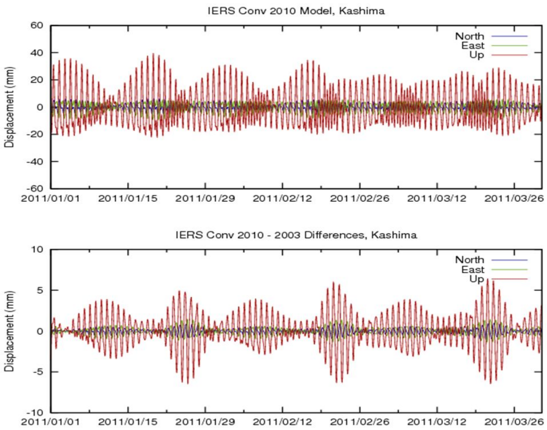

Figure 2. Modeled ocean loading displacement based on NAO99.b ocean tide model. Top: IERS Conventions 2010 model. Bottom: Difference between IERS Conventions 2010’s 342-tide model and IERS Conventions 2003’s 11-tide model.

The two models both show a similar variation up to 50 mm in the vertical component, but the difference between the two models exceeds 5 mm in this case of Kashima, which strongly suggests the 11 tides does not precisely model at the 1 mm level. It should be noted here that ocean loading displacement around Japan is larger than the world average.

2.2 Other displacement models

S1-S2 atmospheric pressure loading is newly included in the new Conventions. This effect is modeled as sinusoidal functions at the period of 1 day and 0.5 days, and the coefficients can be provided by a web-based service at the University of Luxembourg. This effect is implemented and it turns out to be approximately 1 mm variation around Japan. In the computation of rotational deformation due to polar motion, the mean pole model is updated from a linear model to a cubic model. The deviation in the 2000-2010 period amounts to 2 mm at certain middle latitude areas. Note that this difference is the global scale and it could affect the terrestrial reference frame.

Ocean pole tide loading is also newly included in the new Conventions. The IERS provides a coefficient table at a 0.5 x 0.5 degree resolution. Using this table, we evaluate the displacement and find that this effect is typically below 1 mm around Japan.

3. Future studies

The “c5++” software development project is still on-going. We continue implementing the latest physical models such as Earth rotation, tidal gravity variation, tropospheric delay and so on. We are also completing the main part of this software so that it can handle actual space-geodetic observations of VLBI, SLR, etc.

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A GNSS-R system based on software-defined-radio

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Abstract: Multipath signals (e.g. ground reflections) for GNSS are phenomena which need to be avoided by all means to maintain a high positioning accuracy. On the other side, the remote sensing community has an increasing interest in analyzing such reflections as they provide valuable information about the physical characteristics of the reflection area. This technology is called GNSS-Reflectometry (GNSS-R) and operates, similar to a passive radar, with two antennas in order to monitor direct and reflected signals (see e.g. Gleason et al.(2005)). No commercial GNSS-R are available and most of the existing solution focus on hardware processors with a post-processing chain realized in software. This paper presents the GNSS-R system developed by NICT which utilized software defined radio methods to deal with most of the processing stages in software rather than utilizing ASIC or FPGA based hardware solutions.

1. GNSS-R system

In order to receive the direct and reflected signals, two GNSS antennas are necessary whereas it has to be considered that ground reflections change their polarization direction from right- to left-hand. This requires the down-looking antenna to be sensitive to LHCP signals. Figure 1 depicts the antenna pole developed by NICT which mounts both L1 GPS antennas. RF cables leading to the antennas are inside the pole. Since the both antennas are active patch antennas they can be powered by the same RF line using a bias-tee and a standard power supply. In order to test the system a place high enough to receive meaningful reflections but also close enough for debugging the system via a fast internet connection was searched. Such a place has been found by a 55 m high telecommunication tower inside NICT's headquarter in Koganei, Tokyo (figure 2) . As the tower also hosts an air-conditioned container, the power supply, RF front-ends and the processing PC could be placed there. A fast internet connection allows to remotely control the system and download data for post-processing purposes.

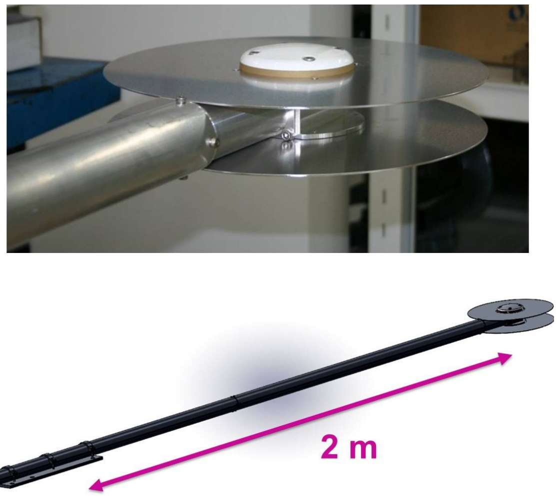

Figure 1. GNSS-R system: RHCP and LHCP antennas separated by two aluminum disks and mounted on a 2 m pole.

2. Hardware front-end and data flow

In order to capture the direct and reflected GNSS signals a cheap, robust and easy to interface front-end was required which also enabled direct sampling in the RF without external down-conversion stages. The USRP2[1] fulfills all these requirements and outputs the sampled data as UDP packets over gigabit Ethernet. Moreover, two USRP2s can be connected by a so-called MIMO cable which allows to transmit data from the second device through this cable and then further on to the PC. Additionally, the MIMO cable synchronizes the two devices to operate at the same local oscillator frequency and start sampling at the same epoch. The USRP2 supports sampling rates of up to 25 Msps in single precision floating point precision for I and Q channels. The maximum sampling rate reduces to 12.5 Msps, when two USRP2s are connected via MIMO, sharing a single Ethernet connection to the PC. Figure 3 shows how the hard-ware front-end is connected to the antennas and depicts the complete signal flow from the antenna to the PC.

3. GNSS-R processing

Processing of the sampled RHCP and LHCP signals requires sophisticated methods as well as a computing platform which is capable of ensuring to run the GNSS-R system in real-time. Based

[1] http://www.ettus.com

Figure 2. Putting the GNSS-R system on a 55m high telecommunications tower in NICT's headquarter.

on the experience gained with graphics processing units (GPUs) for implementing a software GPS receiver (Hobiger et al., 2010) the choice was made to use this parallel platform again for the challenging task to process large amount of data in real-time. Thereby, the GNSS-R system can be split in three modules which are described in the following three subsections.

3.1 Data capture module

The first of the three modules runs entirely the CPU and is dedicated to listen to the Ethernet port, decoding the sampled data streams of RHCP and LHCP, respectively. It outputs these samplings together with a time tag information in a huge circular buffer which is realized in global shared memory which is accessible to different CPU processes. Depending on the sampling rate and the PC RAM, data between a few seconds up to almost one minute can be kept in that circular buffer. As the sampling rate determines the size of this buffer the PC for the initial field tests has been equipped with 16 GB of RAM to allow for higher sampling rates without overwriting unprocessed data in the memory.

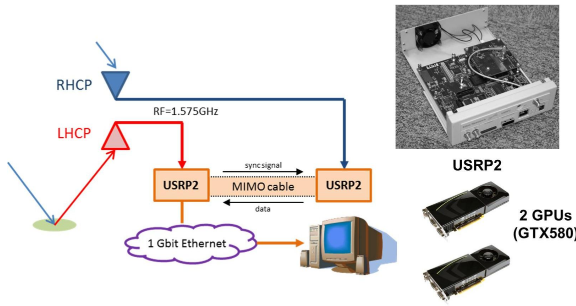

Figure 3. USRP2 hardware front-end and the signal flow to the processing PC.

3.2 Local offset determination

Both samplers are not connected to external frequency references their local oscillators (LO) but the MIMO cable forces them to operate at the same LO frequency which is one of the crucial criteria for a working GNSS-R system. Nevertheless, in order to get meaningful results which are not biased by this LO offset it is important to monitor this effect. Thus, the RHCP data stream is copied continuously from the circular buffer to one of the two GPU cards. Similar to a GPS receiver, all visible satellites are tracked and based on (code) phase variations over a given period of time (usually 32ms) the Doppler frequency of each PRN is determined. Any measured Doppler frequency $\hat{f}_{d,i}$ w.r.t. satellite i turns out to be

$$\hat{f}_{d,i} = f^*_{d,i} + f_{LO}$$

where $f^*_{d,i}$ is the true Doppler frequency and f_{LO} represents the LO offset. As $f^*_{d,i}$ can be computed accurately from station position and orbit information, one could determine the LO offset already from tracking a single PRN. In order to make the determination of this parameter more robust all PRNs in view are monitored and together with signal strength (or correlation amplitude) ρ_i. This allows to determine the local oscillator offset by

$$f_{LO} = \frac{\sum \rho_i(\hat{f}_{d,i} - f^*_{d,i})}{\sum \rho_i}$$

as a weighted mean over all tracked Doppler differences. This information is copied back from the GPU and written in shared memory as well. Figure 4 shows an example for the LO offset tracked for more than 44 hours. Beside short-scale variations the LO offsets varies by almost 6000 Hz which equals roughly the range of possible GPS Doppler values. Thus, if the LO offset is not know well in advance, the obtained Delay-Doppler maps (see next section) would be assigned to a wrong frequency range and can't be aligned in time.

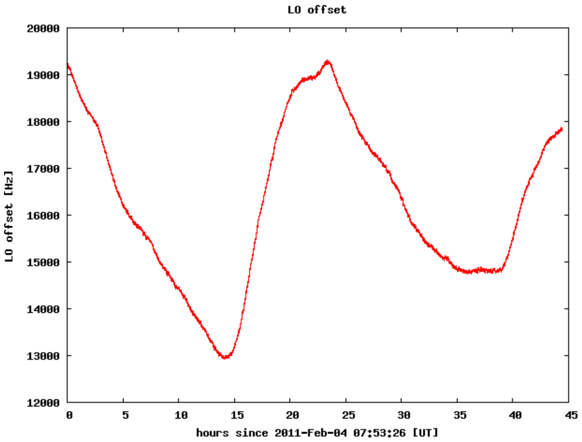

Figure 4. Tracking of the USRP2 LO offset over a period of almost 45 hours.

3.3 Delay-Doppler map generation

The third module of the GNSS-R system runs on the second GPU and makes use of RHCP and LHCP data as well as the LO offset for the corresponding sampling period. It used the latter information for proper mix-down of the signals, before it computes Delay-Doppler maps (DDMs) between each incoming signal and replica codes for RHCP and LHCP data for a user defined integration period. These DDMs are stored in NetCDF format on disk and can be downloaded for post-processing. An example for RHCP and LHCP delay DDMs is shown in figure 5.

3.4 Post-processing

Delay-Doppler maps are continuously calculated and stored on a disk inside the PC on top of the tower. These data-sets can be transferred to another PC in the research laboratory and used for post-processing the results. First, one can compute the excess delay between RHCP and LCHP and based on the observing geometry extract the height (and location) of the reflection point w.r.t. the antenna. This feature can be used to map the surface around the GNSS-R system, but as the surrounding of the tower was quite complex and of urban nature, reflections were originating from a variety of locations which made it difficult to distinguish ground traces from other signals. Moreover, most of the reflections were coming from soil of a nearby university agricultural test field and thus of weak nature. If the system would be placed on an ocean site it is expected to monitor sea surface heights with cm accuracy, but the system in the urban area reached only a few meter of accuracy in the first tests. Beside the geometrical information, one can also extract the radiometric information based on signal amplitudes and the shape of the DDM. If the system would be put on a higher altitude (e.g. in an airplane) the reflection pattern would allow to determine geophysical properties of the scattering/reflecting surface. But as the tower height was 55 meter, only signal amplitudes were investigated in the first field tests as described in the next section.

4. First results

Comparing the DDM amplitudes of the direct (RHCP) and reflected (LHCP) signals and mapping these attenuation coefficients around the site allows to obtain spatial information about the physical properties of the neighboring scattering surfaces. Based on data from a 12h test and the assumption of a single height reflecting surface all attenuation coefficients were mapped around the

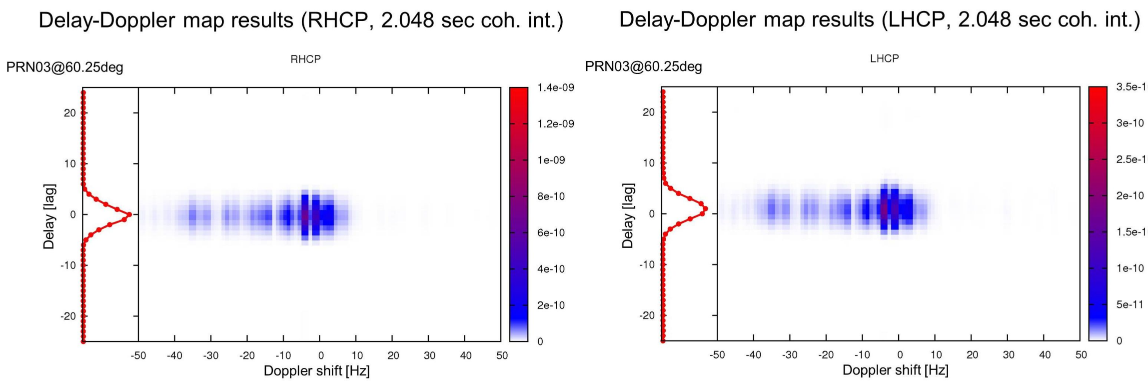

Figure 5. Example for RHCP and LHCP Delay-Doppler maps. The delay (i.e. the excess path between the direct and reflected signal) can be seen as a vertical shift of the pattern. Also note that the amplitudes are differing between RHCP and LHCP data. The skewness of both maps is assumed to be caused by applying a slightly biased LO offset at that epoch.

tower (figure 6). Reflection from nearby rooms ap-

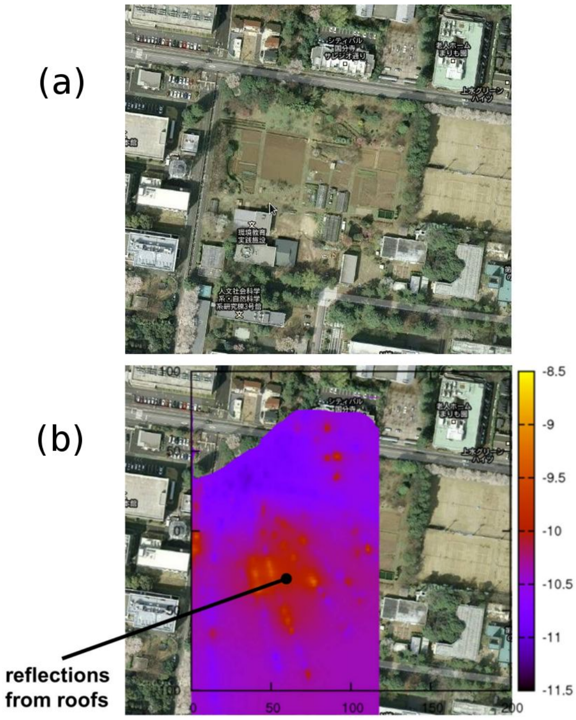

Figure 6. a: Google satellite image around the tower where the GNSS-R has been put for initial tests. b: Mapping the signal ratio LHCP/RHCP (in dB) around this area. Reflections from roofs and other nearby building appear at clearly in the image, although the location of these reflectors is slightly shifted due to the assumption of a single planar reflecting surface instead of a proper digital terrain and building model.

pear as strong signals in the image as well as concrete roads are also indicated by areas of stronger reflectivity. The map considered only the Eastward part of the area, as the Western surface area is not visible to the mounted GNSS-R system.

5. Outlook

Since the system concept of the software defined GNSS-R radio could be confirmed, longer test runs are currently under way. This will help to remove minor bugs in the processing chain and test improved algorithms. Moreover it is anticipated that a denser map of ground reflections can be obtained as well as that time-dependent variations become visible. Thus, e.g. rain or snow dependent changes of reflectivity should become clearly visible in such time-series. Tests runs over longer periods should also be able to reveal soil moisture changes in the nearby fields. The current limitation of the maximum sampling rate (i.e. 12.5 Msps) can be overcome by using unsigned short integer I/Q data streams instead of the single precision floating point representation. Therefor it has to be studied how much the processing overhead due to data conversation and extension of the sampling rate to 25 Msps would cause and if real-time processing can be still ensured. In the close future it is anticipated that the system is being located at a coastal site for sea level measurement or sea state monitoring. Since the reflections from water appear as much stronger signals the accuracy of the system is expected to reach cm-level, which would make it a cheap and valuable tool for a variety of oceanic and geodetic applications. Moreover, the developed system can be mounted on a vessel or inside an airplane in order measure sea state parameters either close to the surface or from several kilometers above. The latter application would also reveal the full potential of the information contained in the Delay-Doppler maps, as the reflection pattern can be assigned to e.g. sea surface roughness which allows to deduce wind parameters or other geophysical signal.

6. Acknowledgments

This work was supported by a NICT Incentive Fund for the year 2010.

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Development of Weak Radiation Power Measurement Technique

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Abstract: Measurement system for very week radiation from Ultra Wide Band(UWB) devices or ZigBee Bluetooth has been developed, which covers from 0.8GHz to nearly 30GHz with three heterodyne receivers of 32MHz or 512MHz I/Q IF output for 8bit samplers, K5/VSSP32 or ADS3000+, to be processed in PCs. Receivers are equipped two Dicke switches operated by the PC, one for dummy load in room temperature and another for a noise diode for gain calibration in signal integration time. This measurement system is aimed for radiation level of -90dBm/MHz.

1. Introduction

Low power wireless communication or sensor devices with ultra wide band have been shipped to the market. Their impulsive signal in time domain is wide spread in frequency domain, and their spurious emission has same characteristic. Also, PLC modem or LED right radiates wide band noise, which power lines may be antennas. Millimeter car radars may be harmful if it was operated near a radio telescope which is extreme sensitive.

Therefore the authors have been developed a system to measure such weak wideband irradiation of -90dB/MHz with techniques in radio astronomy, which is a wideband sampler, Dicke switch and signal integration in several seconds or hours, days in PCs. Table 1 shows regulations on UWB, our system aimed to measure such weak power level. Frequency coverage of this system is totally 0.8GHz to near 30GHz achieved by 3 receivers.

Frequency $[MHz]$	Averaged Power $[dBm/MHz]$	Peak Power $[dBm/MHz]$
< 1600	-90	-84
$1600 - 2700$	-85	-79
> 2700	-70	-64
$10600 - 10700$	-85	-79
$11700 - 12750$	-85	-79

Table 1. Regulations on UWB emmitions.

2. Outlines of SIRIUS system

This system was named SIRIUS(System to Investigate Radio Intensity Using Statistics)[1], which schematic diagram is shown in Fig.1. The system is basically a kind of Dicke radiometer with I/Q IF output for image rejection. These techniques are commonly used in radio astronomy,

This system is composed by 3 receivers, they are named low-band, mid-band, and high-band system. The last one has most wide frequency coverage instead of highest noise figure. Specifications of the system is shown in Table 2, and the block diagram of the system is shown in Fig 2. Antennas are selectable from double-ridged horns or others for measurement frequency, distance to test device and required gain. Two low Noise Amplifiers in RF are placed in the Amp Head Box(AHB), and mixers and IF amplifiers are placed in the IF Converter Box(ICB) with monitoring ports. AHB has a dummy load with temperature sensor and noise diode to calibration. K5/VSSP32 and ADS3000+ high speed samplers, which were developed in NICT for VLBI, acquire IF output and PCs process the signals. Two VSSP32s can be plugged in one PC with new sampler driver for 64bit Linux.

In a case of measurement for UWB, Mid-band or high-band system set to detect UWB impulses, others for noise from UWB system. Overlap of frequency coverage is enable to make an array. ICB delivers 1PPS to all K5/VSSP32 and controls Dicke switches in AHB.

3. Experimental Result

Noise temperature of LNA limits sensitivity of the system in short time scale and gain fluctuation affects S/N in long term. These characteristics are measured and result of low-band system is shown in Fig. 4. Noise temperature of AHB in high-band system is shown in Table 3.

Sensitivity for -90dBm/MHz is equal to increase of antenna temperature +0.94K when 10dBi horn placed with 7m distance to UWB device at Freq=3GHz. Thus, the low-band system can detects increasing of 0.1K in 5sec integration time, for an example.

Image rejection software is developed and tested, which converts IF I/Q output sampled via A/D to USB/LSB signal spectrum. The result of image

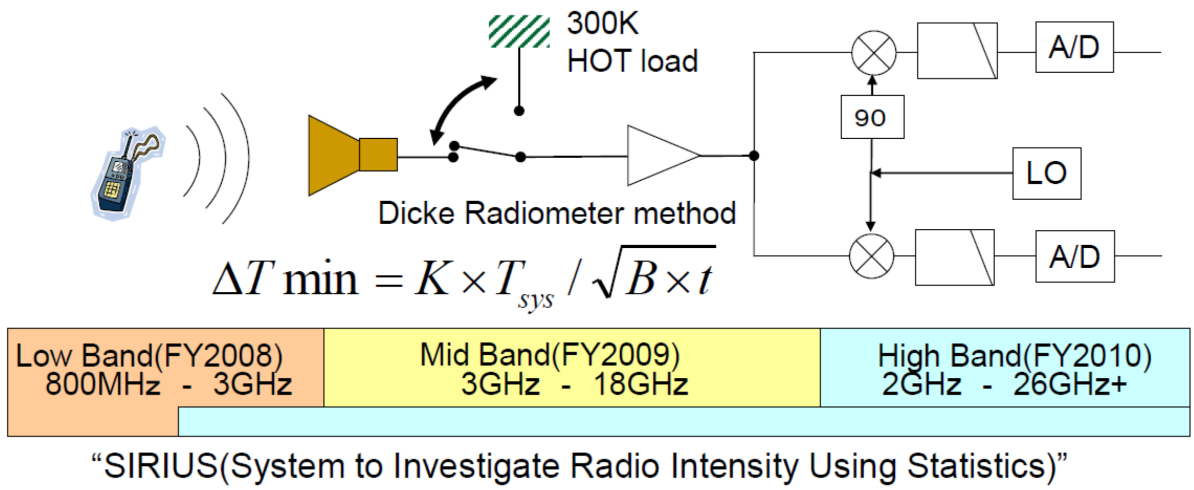

Figure 1. Schematic image of SIRIUS system

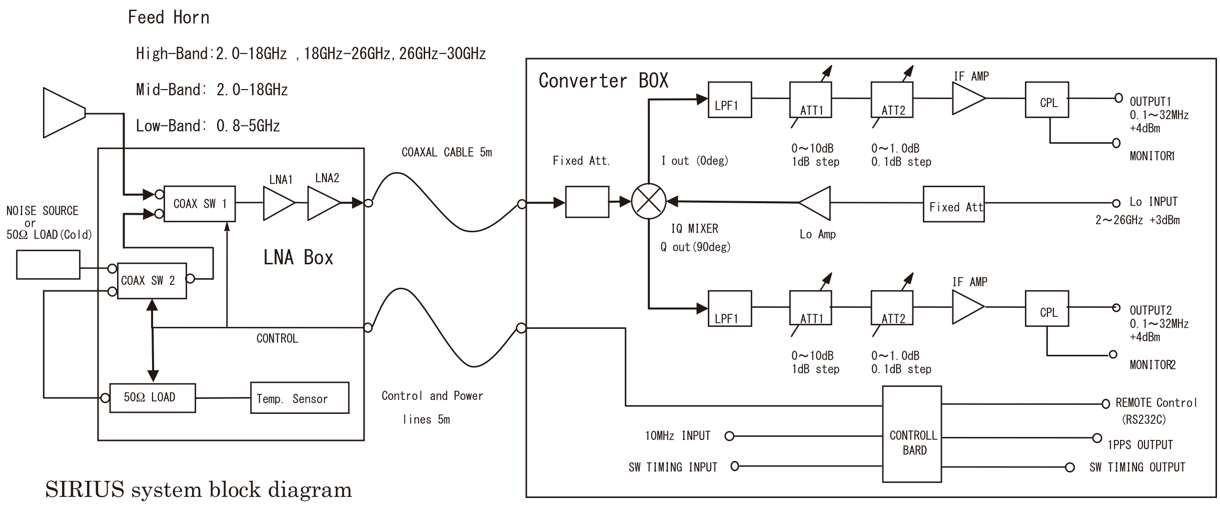

Figure 2. Block Diagram of SIRIUS system

rejection test shown in Fig 5., which used CW at 2352MHz and LO at 2350MHz. Image rejection ratio is nearly -8dB without phase and amplitude calibration.

4. Conclusion

A weak radiation measurement system was developed with software signal integration and image rejection. This system has tenth wider RBW to 512MHz at maximum spec than RBW limitation in spectrum analyzer, and enables accurate and efficient measurement of impulsive signal and spurious noise from wide band wireless applications.

Acknowledgments: This research is supported by the fund from the Ministry of Internal Affairs and Communications.

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	Low-Band	Mid-Band	High-Band
Rf Input Freqency	$0.8 \sim 3GHz$	$3 \sim 18GHz$	$2 \sim 26GHz$
IF I/Q Output Freqency	0.1-32MHz for VSSP32		$0.1 \sim 32MHz$ for VSSP32 $0.1 \sim 512MHz$ for ADS3000+
IF Level IF Flatness	$-500mV \sim +500mV$, Attenuator Range:0dB to 60dB,1dB steps $< 1.0dB$ over $0.1MHz \sim 32MHz$		
Port1:Antenna	$Directivitygain > 4dBi@3m$		
Port2:Calibrator Port3:Calibrator	Internal dummy load with termometer External noise diode cold load, or another antenna.		
LNA Total Gain Nf(LNA) NF(LNA with Coax Switch)	 $> 27dB$ $< 1.0dB$ $< 2.0dB$	 $> 27dB$ $< 2.2dB$ $< 3.7dB$	 $> 27dB$ $< 5dB$ $< 10dB$
LO supply	Internal SG	External SG	
Thermometer	0.1K resolution,aquired via RS232C		

Table 2. Specifications of the system.

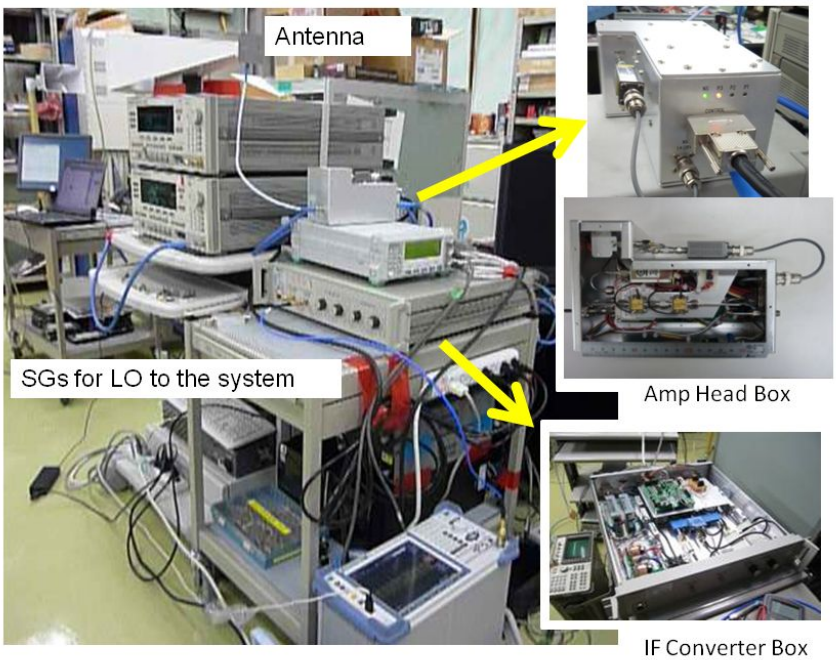

Figure 3. Components of SIRIUS system

Power\Bandwidth	No filter	8GHz HPF via Waveguide	22GHz BPF
Port1 Power[dB]	0.95	-4.57	-11.06
Port2 Power[dB]	6.8	1.88	-5.26
Poer3 Power[dB]	1.82	-3.16	-9.59
Port2 ND input temperature[K]	928	504	477
AHB Noise Temperature[K]	2940	2060	1630

Table 3. Measured system noise of AHB in high-band system.

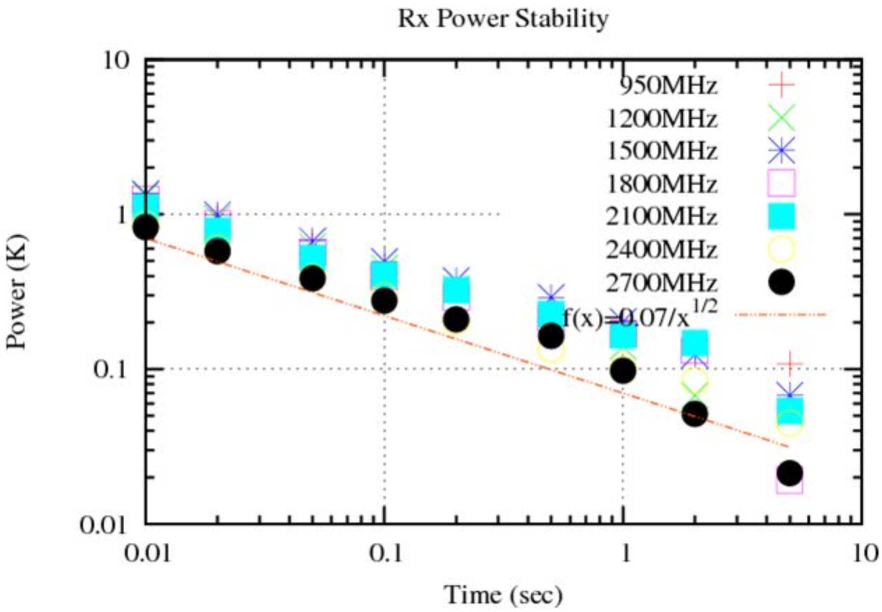

Figure 4. Stability of measured power

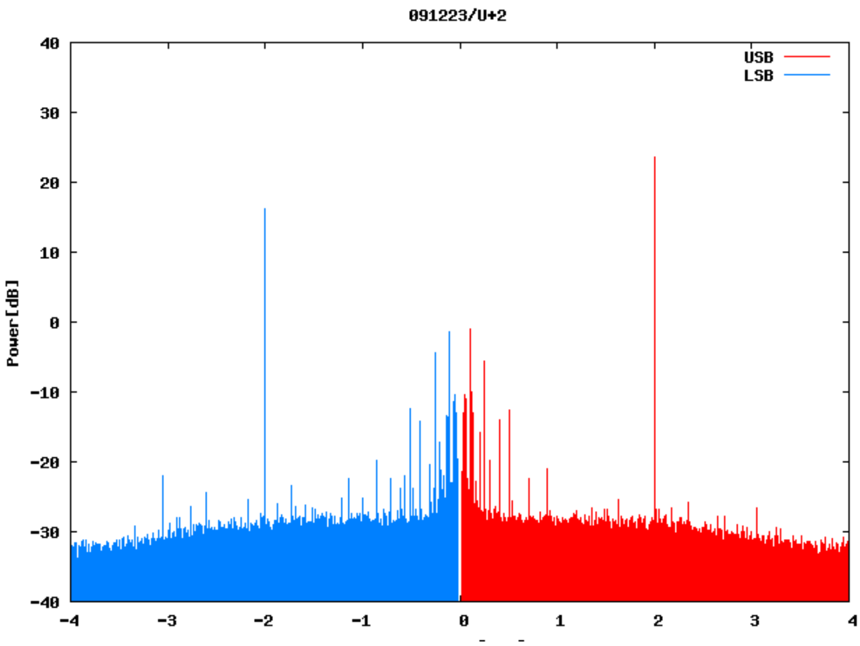

Figure 5. Image rejection test

Estimation of Wifi instruments with DoREMI system (Distribution of Radio Emission Measurement Interferometer)

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Abstract: To detect position and power of radio source on the ground, *Distribution of Radio Emission Measurement Interferometer* project (called DoREMI) has been carried out since 2008. The DoREMI system was applied VLBI technology to receiver and data reduction.

In this report we will report of wifi (during wifi router and laptop-PC transmission) position estimation with DoREMI system.

1. Introduction

Millions of radio instruments (ex handy, wireless-LAN, etc) are developed in the recent years and spread to use everywhere. A frequency band is also used narror radio broadcast signal (mainly voice sound) to much wider signals such as spread spectrum signal, UWB (Ultra Wide Band) which emits GHz-band signal. However, available bandwidth is limited and has to be considered efficient use. By applying VLBI (Very Long Baseline Interferometer) techniques, we measure these radio signals from the ground as a radio map. The system called *Distribution of Radio Emission Measurement Interferometer* (DoREMI).

2. DoREMI system

In the DoREMI (DoREMI: an abbreviation) project, several instruments for broad-band have been designed and developped shown in Fig.1. A target bandwidth is 100MHz to 3GHz to detect not only wireless LAN, handy but also another wideband sources like UWB. The bandwidth is divided low-band (100MHz–1GHz) and high-band (1–2GHz and 2–3GHz separated in receiver). Due to radio sources on the ground do not decided its positions, antenna must have horizontal omni-directional pattern. In low-band, commercial dis-corn antenna is chosen. In high-band, two type of antennas has been newly developped. One is tear-drop antenna which is used for UWB system at 10GHz band. however more lower bandwidth is needed to detect, antenna size was three times bigger than original design. The other antenna has a shape of rotated parabolic curve, and spiral antenna was fixed at focus point.

Each bands are recorded in Nyquist rate up to 2GHz sampling with the ADS3000+ (broad-band mode). Moreover DBBC (Digital baseband conversion) is also possible (narrow band mode) to extract narrow bandwidth from broad band.

3. Wireless LAN experiment

A wireless LAN (WLAN) in Japan has two bands 2.4GHz and 5GHz. Currently 2.4GHz band is used mainly. Each WLAN band is narrowly divided to channel. As for 2.4GHz band, the band has 14 channels, however maximum 4 channels can be used at the same time.

To detect wireless LAN with DoREMI system. Tear-drop antenna of High-band was set in front of building (Fig.2). A laptop PC was set in center of antennas, an WLAN router also was set in near building. They were transmitting large files during experiments to emit 2.4GHz radio waves. Then, Their signals were sampled with ADS3000+ ($64Msps$). The ADS3000+ was sampled 4 analog streams to 8 ditital channnels ($64Msps \times 4bit$) with DBBC (Digital BaseBand Conversion).

Fig.3 shows detected spectra in DoREMI-High with four tear-drop antenna. 2nd channel in 14 channels of 2.4GHz WLAN were seen clearly.

Fig.5 shows times series of sampled wireless LAN. Between laptop and router data transmits with small bins (about 1ms) of packet. About 1 msec peorids, strong pulses can be seen. These pulses generate just end of each bin. So, They were assumed ack signal which means like OK or Miss after data transmission. Next correlation is performed. Detected strong power (position :Cor-1) and (position : Cor-2) are correlated.

In VLBI correlation, 1sec or more integration time takes to performed, but this could not be applied to this case. In VLBI each antenna received almost same power from quasars or pulsars and so on. But in this case, each antenna received different power which depends on length to wireless instruments. one strong wireless LAN used to dominate strong correlation.

As a result, short-time correlation was performed. Fig.4 shows correlation result from 4 receiver. In these figure, several peaks can be seen. There are some possibility of another wireless node exists, multi-pathes and deformed band character due to short-time correlation. But they could not obviously resolved up to now.

Next, Parabolic curve estimation was performed

Developpments in DoREMI Project

ADS3000+	DoREMI-Low	DoREMI-High 1	DoREMI-High 2	Recorder
Up to 4Gsps 4 x VSI-H output 16ch DBBC inside	100-1000MHz Discorn antenna and RX	1 - 3 GHz omni reverse parabolic reflector antenna and RX	1 - 3 GHz Tear-drop antenna and RX	Up to 2Gbps @unit via VSI -H and 10GbE

Figure 1. The Developpments in DoREMI Project. Broad band antenna, receiver and sampler have been developped from antenna to recorder. The antenna needs omni-directional antenna pattern for detecting radio sources on the ground.

with these six correlation result. Fig.6 shows parabolic curve estimation result. Left figure shows Cor-1 result which radio wave from laptop-PC dominates. and right figure is Cor-2 which radio wave from wifi router respectively.

Parabolic curves are made by position of two antenna and delay from correlation result. In correlation results, there are some peaks. Therefore, possible curves are remained. A intersection point made by parabolic curves will point out the position of radio instruments. The intersection point of left figure has 3.3m difference to original laptop-PC position. Right one has 6.5m difference to wifi router position. These differences would cause by especially differences of received wifi power of each antenna and short integration time.

4. Summery

We have measured wifi instruments position with DoREMI system (High-band). The position of wifi could be desided in 6.5m (wifi router) and 3.3m (laptop-PC) with parabolic curve intersection estimation. However, we have to perform short integration time due to wifi character. Therefore we will improve corretion algorithm especially peak search.

Developments of the ADS3000+ system cooperative efforts between NICT, JAXA/ISAS, and COSMO RESEARCH Corp[1]. The authors would like to thank for cooperation of the Kashima VLBI team. This research is supported by the fund from Ministry of Internal Affairs and Communications.

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[1] http://www.cosmoresearch.co.jp

Figure 2. High band of DoREMI was set in front of building in Kashima space center (left). Circle shows tear-drop antenna and square shows wireless LAN nodes.

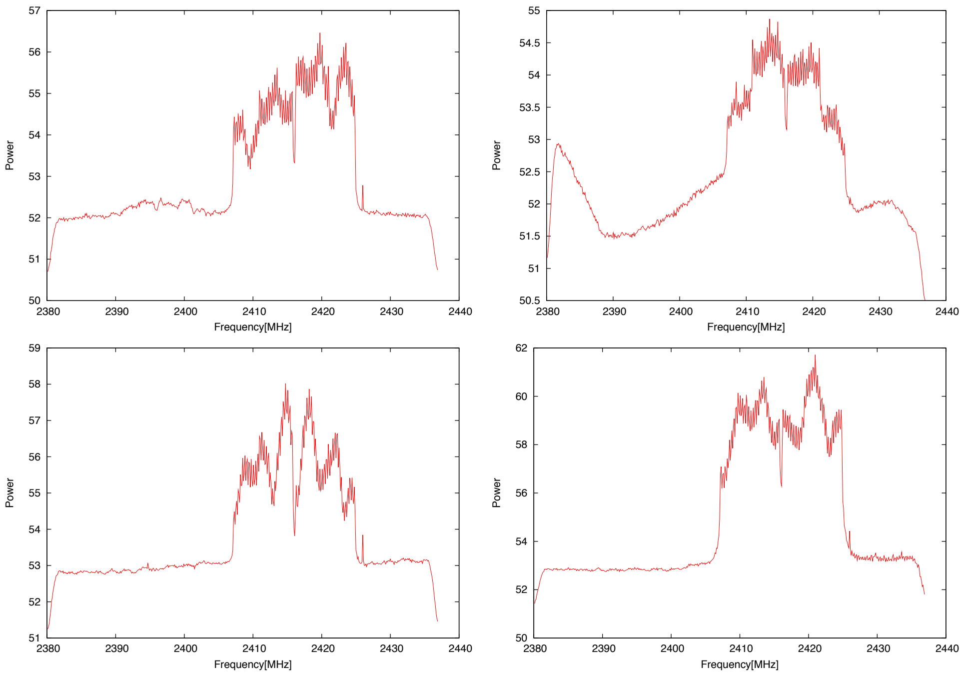

Figure 3. Sampled 2.4GHz band wireless LAN specta with tear-drop antenna.

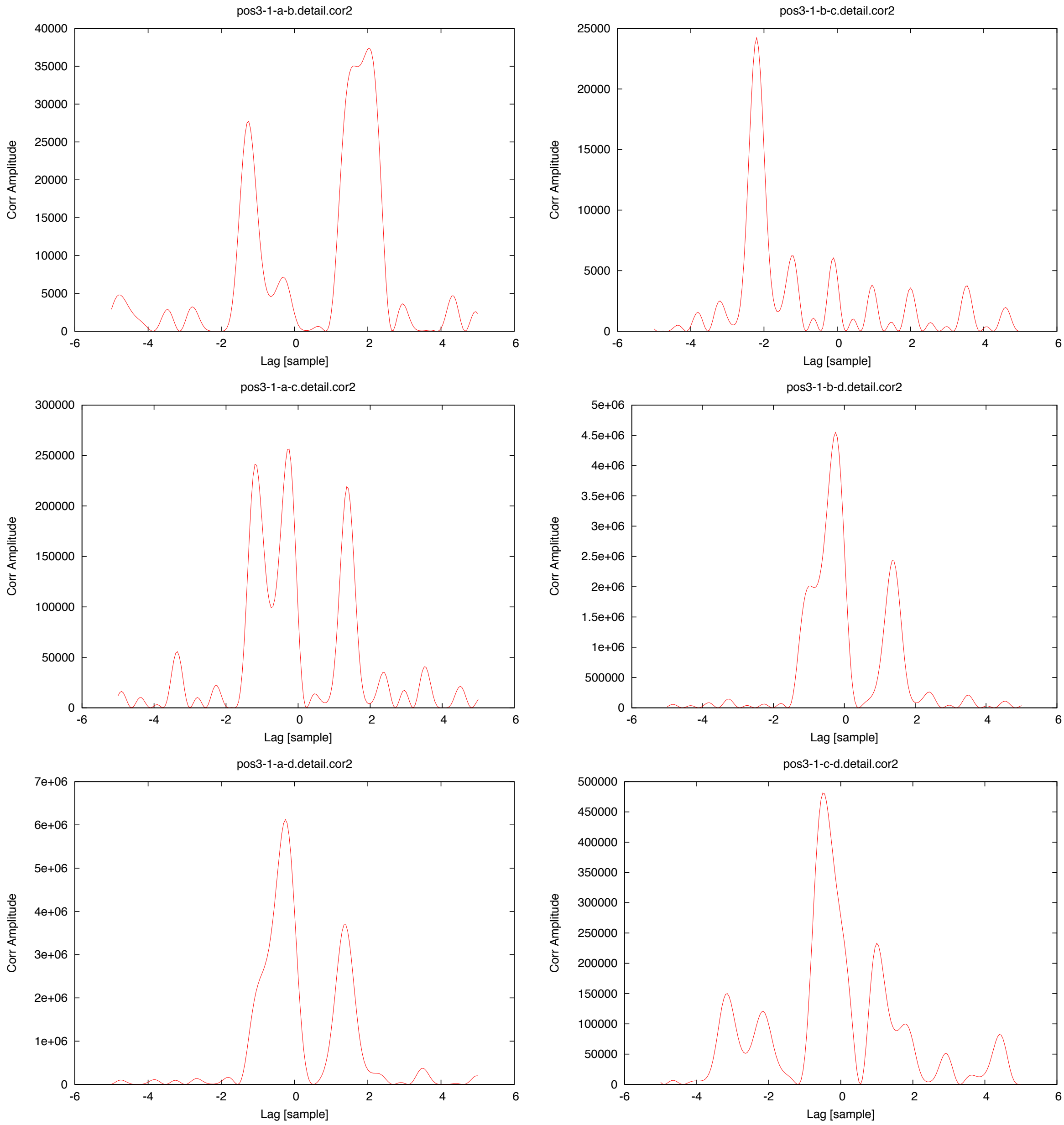

Figure 4. Correlation result of wireless LAN experiment with DoREMI-High (Cor 1 in time series)

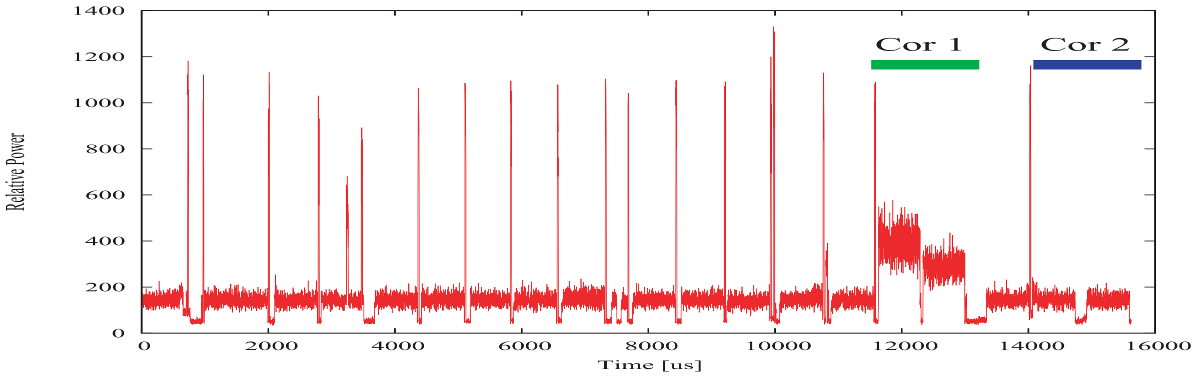

Figure 5. Time series of sampled wireless LAN with DoREMI antenna A.

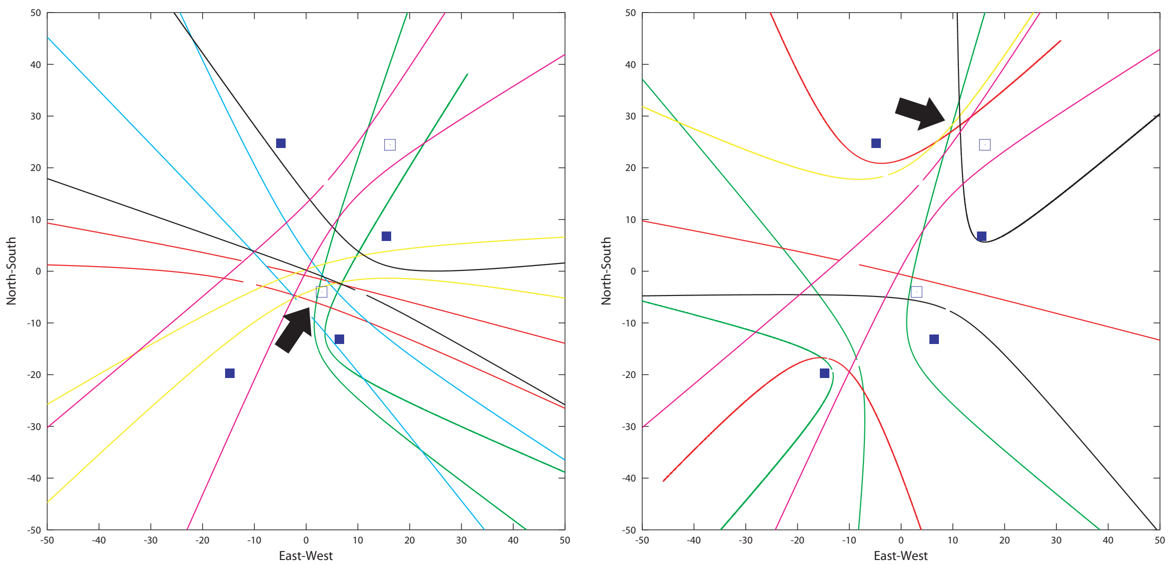

Figure 6. A overlay by parabolic curves from correlation result in Fig.4. Left shows cor-1 result of time series in Fig.5. Right shows cor-2 result.

8Gsps High-Speed Sampling RF Direct A-D Converter ADX-831

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Abstract: The RF Direct A-D Converter ADX-831 can directly sample S-band and X-band RF analog signal without the IF down converters. The ADX-831 supports two sampling modes, 8Gsps × 3bit × 1input and 4Gsps × 3bit × 2input. The Sampling data has been transferred from three 10-Gigabit Ethernet port(Max24Gbps) [Figure 1, 2].
In November 2010, the ADX-831 is obtained first fringe between RF direct sampling and IF sampling. Next we will test the ADX-831 both stations. The ADX-831 can provide the low-cost, compact, and stable VLBI observation systems. We are currently making every effort to further increase speed and resolution.

1. RF Direct A-D Converter

In activities including radio astronomy observation, high-frequency signals received are converted from analog to digital data, transferred, stored and analytically calculated. Due to the difficulty associated with converting high-frequency signals, A-D conversion is undertaken after converting to a lower frequency utilizing IF down converters.
This RF Direct A-D converter is distinguished by its ability to directly convert high-frequency signal analog to digital data thereby realizing the A-D conversion of frequencies as high as X-band at broad conversion bandwidths (4GHz).[Figure3] This compact converter also complies with the 2U EIA Standard rack mount size.

⟨*KeyFeatures*⟩

- 1 mm position accuracy on global scales,
- 2 Sampling mode 8Gsps × 3bit × 1input and 4Gsps × 3bit × 2input
- 3port 10Gigabit Ethernet output interface (Maxim 24Gbps)
- VDIF(VLBI Data Interchange Formata) output format

Figure 1. ADX-831

- Compact (2-Unit height (EIA Standard))

2. Removable Storage Device

As the name suggests, this removable storage device (storage cartridge) is a high-speed, large-volume data recording medium that can be readily inserted and removed.[Figure4] With a two cartridge mount, the recording capacity for each cartridge is a maximum 36 terabytes for an aggregate recording capacity of 72 terabytes.
Extremely high recording and playback speed (4.6Gbps)
10Gigabit Ethernet input-output interface
Robust configuration to ensure durability and shock resistance during cartridge transportation

⟨*KeyFeatures*⟩

- Able to increase / decrease storage capacity from 36TB to 12TB per cartridge
- Stable recording and playback over long periods
- Data can be played while recording
- Each cartridge comes with its own purpose-built carry case
- 5U device height (EIA standard)

Table 1. Specifications

Specification Classification	*item*	*Specification*
Sampling	number of analog input	2
	analog input frequency	0.1–12 GHz
	bandwidth	4 GHz
	sampling frequency	8 Gsps
	resolution	3 bit
	analog input connector	SMA
data output port	number of optical port	3
	data-transport protocol	VDIF/UDP/IP (10 Giga Ethernet)
	optical interface	10 GBASE-SR or 10 GBASE-LR
control port	number of ethernet port	1
	ethernet speed	100BASE–TX/10BASE-T
environment	power requirements	$AC100 - 240V \pm 10\%50/60Hz$
	size	$480(W) \times 88(H) \times 440(D)/EIA$ 19 $inch(2U)$

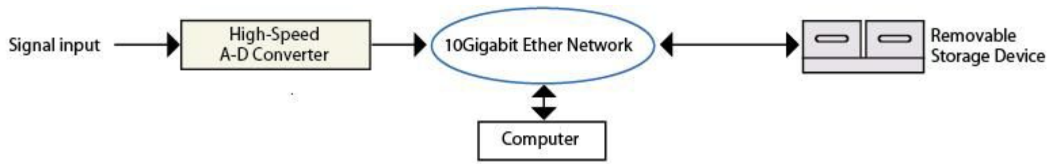

Figure 2. Application system example

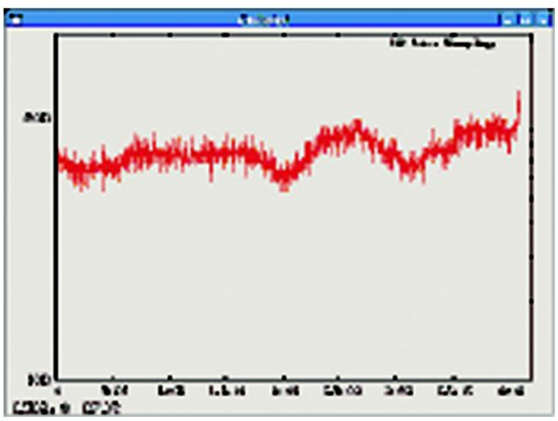

Figure 3. 16ms Integration of 4K point FFT Power-spectrum

Figure 4. Removable Storage (with 2 storage-cartridges)

Development of a cooled low noise receiver at 22 GHz to be installed on Yamaguchi 32-m radio telescope

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1. Introduction

The 6.7 GHz and 8 GHz receivers have been installed on Yamaguchi 32-m radio telescope. The methanol maser at 6.7 GHz, active galactic nucleus(AGN), and radio recombination line at 8 GHz have been observed using the Yamaguchi 32-m radio telescope. We are developing a cooled low-noise receiver at 22 GHz, which is an important observational frequency of the East-Asian VLBI Network. We plan to observe the water maser and ammonia molecular line emissions with this receiver.

2. The 22 GHz Receiver system

The 22 GHz receiver is composed of a polarizer, two Low Noise Amplifiers(LNA) for receiving dual polarization simultaneously, Mixers and two amplifiers as shown in figure 1. A local frequency signal of 14 GHz is injected into the mixer so that to convert the observed 22 GHz signal into 8 GHz band. After the 1st frequency conversion, we plan to use the 8 GHz observational system, which has been already developed and used for many observations. The noise temperature of the LNA is below 30 K. The polarizer is also cooled with the LNA and then a system noise temperature of 70 K is expected.

2.1 Performance of LNA and Polarizer

The gain of the LNA at 22 GHz band is 37 ± 4 dB as shown in figure 3. The feature of the LNA is wide band from 20.5 GHz to 23 GHz as shown in figure 4. The return loss and the insertion loss of the Polarizer are 20 dB and 0.1 dB, respectively, for this wide frequency range.

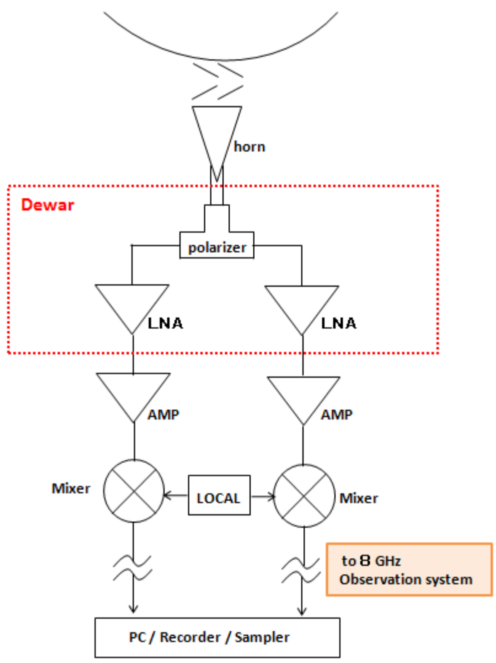

Figure 1. 22 GHz observation system

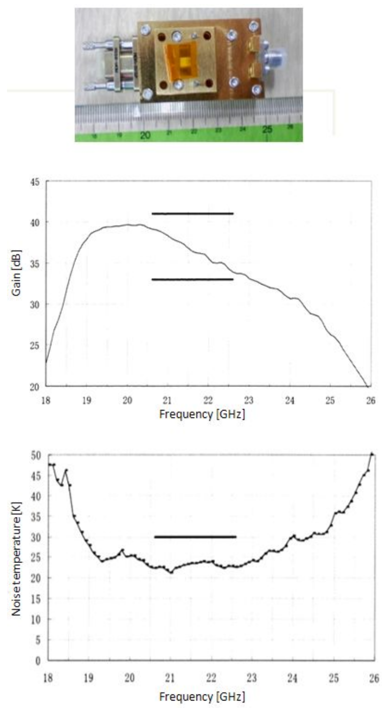

Figure 2. Photo of the low noise amplifier(upper), measured gain(middle) and noise temperature(bottom) of LNA. The line from 20.5 GHz to 23 GHz is effective frequency range

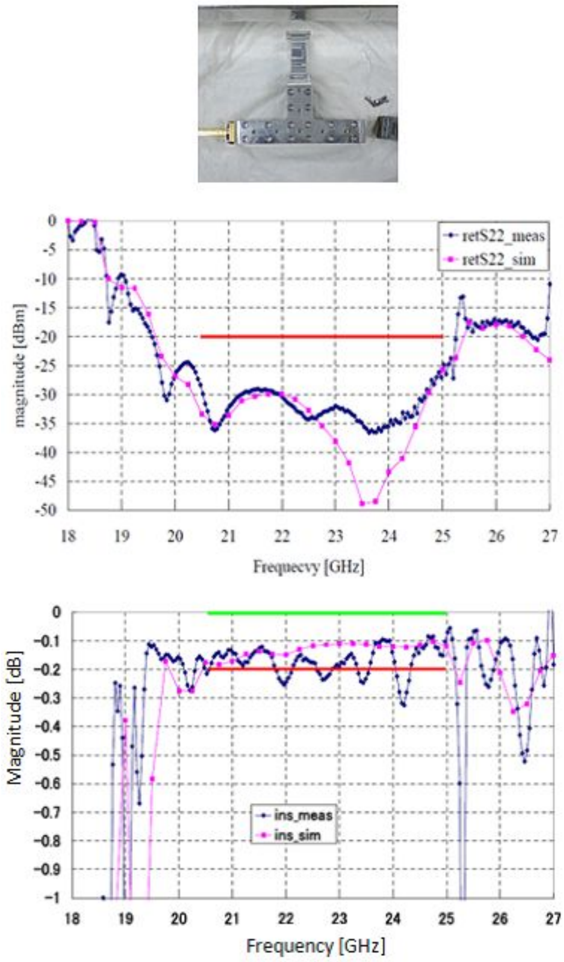

Figure 3. Photo of the polarizer(upper), measured return loss(middle) and insertion loss(bottom) of the polarizer[1]*. The thick line is measured value and the thin line is simulation result. The horizontal lines from 20.5 GHz to 25 GHz is effective frequency range.*

3. Cooling dewar

We plan to cool both polarizer and LNA together in the cooling dewar shown in figure 4

First, the horn is connected with the upper part of the dewar. The polarizer is connected under the horn, and a received signal is separated into left and right circular polarization. The LNA is set up at both ends of the Polarizer. Freezer and vacuum gage are installed under the dewar, and the 10 K stage among dewar is cooled by a cold head. The LNA and the polarizer are connected with the 10 K stage by the thermal conduction mesh, and they are cooled by the thermal conduction. Vacuum and cold test were conducted without setting up among dewar. As a result, the pressure of 0.08 Pa (Cool), and the temperature of 9.1 K in the dewar was achieved.

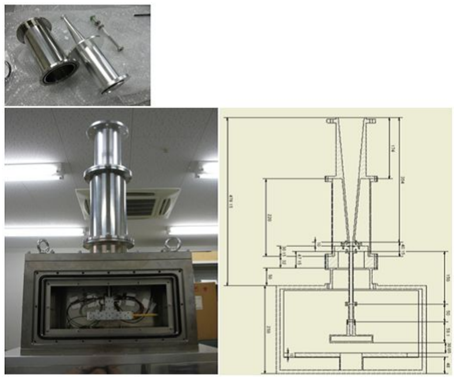

Figure 4. The horn and waveguide(upper), detail of dewar(left) and drawing sheet of dewar(right)

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Present Status of Ibaraki station (Takahagi and Hitachi 32-m Radio Telescopes)

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Figure 1. Takahagi (front) and Hitachi (back) Antenna.

Takahagi and Hitachi 32-m antennas were used for satellite communications at 4 and 6 GHz by KDDI, and decommissioned in March 2007. These antennas were transferred from KDDI to NAOJ in January 2009, and now belongs to the Ibaraki station, which is a branch of Mizusawa VLBI Observatory of NAOJ.

We, NAOJ and Ibaraki University, with the help of other institutes such as ISAS/JAXA, NiCT, GSI, and universities (Hokkaido Univ., Univ. Tsukuba, Gifu Univ., Osaka Prefecture Univ., Yamaguchi Univ., and Kagoshima Univ.) have decided to use these antennas for VLBI network. We will use these antennas not only for VLBI observations but also for single dish and 2-element interferometric observations. We plan to install 3 receivers for 6.7 GHz (C Band), 8 GHz (X band), and 22 GHz (K band) observations. The aperture efficiency is expected to be ~70% at C and X band, and ~30% at K band.

For Hitachi antenna, the antenna control system was installed in November 2009. Soon after that, we successfully detected 6.7 GHz methanol maser emission from several maser sources such as G9.62 and W3OH with a room-temperature receiver and a spectrum analyzer. The C-band cooled receiver system was installed in February 2010. In August 2010, we replaced the receiver by the wide-band cooled receiver covering 6.5-8.8 GHz (C and X band), whose system noise temperature was measured to be ~20 K, including atmosphere. We achieved so-called “first fringe” in June 2010 between Hitachi and Mizusawa, and between Hitachi and Iriki, using K4 terminal. We also succeeded first scientific VLBI imaging observations at 6.7 GHz in August 2010, with 6 antennas (VERA×4, Shanghai, and Hitachi) participated. Between Shanghai and Hitachi, both polarizations (LHCP and RHCP) are successfully correlated. In November 2010, we succeeded first 8 GHz VLBI observations among VERA×4 and Hitachi. The pointing accuracy is ~0.5 arcmin, which is measured by the observations of strong radio continuum sources such as 3C273.

The spectrometer system using K5/VSSP32 was installed in February 2010 for single dish observations.

For Takahagi antenna, the antenna control system was installed in July 2010, and we successfully detected 6.7 GHz methanol maser emission from several maser sources with a room-temperature receiver and a spectrum analyzer. The wide-band (C and X band) cooled receiver system was installed in December 2010, whose system noise temperature was measured to be ~20 K, including atmosphere. VLBI observations are not carried out yet.

The room-temperature K-band receiver was installed on Takahagi in November 2010 and on Hitachi in February–March 2011. The system noise temperature including atmosphere toward zenith was ~250 K. We succeccfully detected H_2O maser emission from several sources such as Ori-KL and W49N.

We are now preparing optical fiber connection (i.e., “e-VLBI”) between Ibaraki and Kashima stations. Kashima station is already connected to Mitaka correlation center, and thus data taken by Ibaraki station can be transferred to Mitaka via Kashima. We also plan to construct two-element array using Hitachi and Takahagi antennas.

Table 1. Antenna performances

	Hitachi	Takahagi
max. speed	0.3 deg/s	0.1 deg/s
Az range	±200°	±175°
Az operation range	2–358°	11–349°
El range	0–92°	0–92°
El operation range	5–88°	5–88°
Construction	1983 Oct.	1992 Sep.
Constructor	Mitsubishi	Mitsubishi

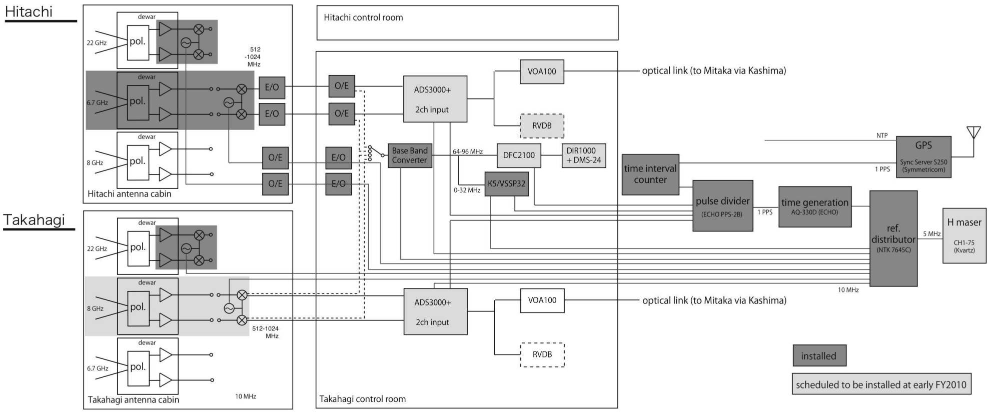

Figure 2. System block diagram.

Table 2. Antenna location (before the earthquakes occurred on March11, 2011)

	Hitachi	Takahagi
X (km)	-3961.787684	-3961.880535
Y (km)	$+3243.598963$	$+3243.373951$
Z (km)	$+3790.598229$	$+3790.687986$
Longitude (E)	$140^\circ\ 41'\ 31''.5286$	$140^\circ\ 41'\ 40''.9119$
Latitude (N)	$36^\circ\ 41'\ 50''.8574$	$36^\circ\ 41'\ 54''.5625$
Height (m)	80.093	77.05
Ellipsoidal height (m)	120.313	117.27
Geoid height (m)	40.22	40.22
Distance between 2 antennas: 259.438 (m)		

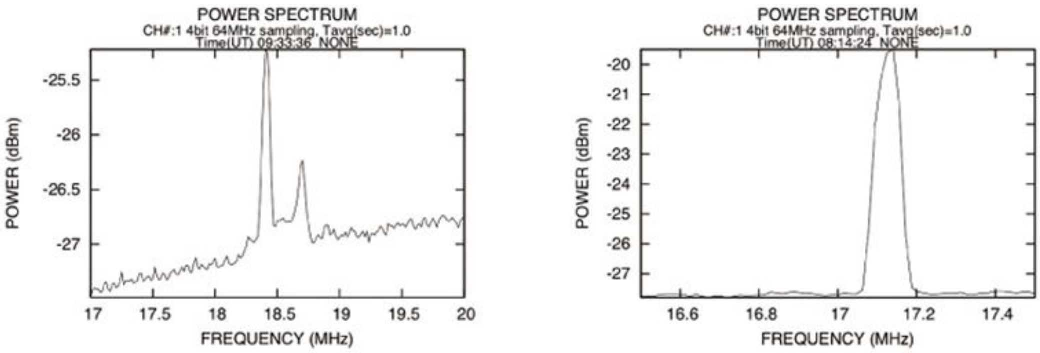

Figure 3. Observed spectra by the single dish mode. (left) H_2O maser emission from W3OH observed by Hitachi antenna on March 4, 2011. (right) CH_3OH maser emission from W3OH observed by Takahagi antenna on March 4, 2011.

Geodetic VLBI Observations by Compact Antennas

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1. Introduction

: The Geospatial Information Authority of Japan (hereafter GSI) has carried out experiments of geodetic VLBI observations by using compact antennas with diameter of about 1.5 m, in collaboration with the National Institute of Information and Communications Technology (hereafter NICT). The main purpose of this research is to prove that compact antenna system can calibrate the distance of the reference baseline for the calibration of GPS ranging. The reference baseline is so long that it can be calibrated only by GPS itself. Since the precision of the VLBI measurement principally does not depend on the baseline length, VLBI observation by compact antennas can measure the length of the reference baseline with enough precision. For the calibration of reference baseline precisions of the measurement of the baseline length less than 2 mm is needed. We have developed the compact antenna systems in order to achieve our goal.

2. Application of the Compact Antenna Systems

Since the reflector and elevation motor of the compact antenna can be removed from the basement, the compact antenna can be replaced by the GPS antenna. Then we can measure the position of the basement of the compact antenna by GPS. Moreover the cross point of the azimuth axis and elevation axis can be seen directly. Hence we can measure the length between the antenna and other reference points by setting a target at the cross point. These features enable us to measure the distance between the position of the antenna and reference points whose positions are determined by other geodetic techniques. Compact antenna could realize collocations for the large antennas whose cross points cannot be seen.

3. Developments of the Compact Antenna Systems

In 2007 we designed and produced a prototype compact antenna with diameter 1.65 m diameter, named MARBLE 1. This antenna was installed in the NICT Kashima Space Research Center. In 2008 we produced second prototype antenna of 1.5 m diameter, named MARBLE 2, and installed it in GSI. Then we carried out some fringe tests by using these antennas and large VLBI antennas, Kashima 34 m and Tsukuba 32 m.

After the success of the fringe tests, we carried out geodetic VLBI observation during 24 hours, in order to measure the distance between the antennas. In this observation we found sub-ambiguities in many scans, so we improved the series of observed frequencies. Then we had 8 geodetic VLBI observations after the first observation. Detailed results of these geodetic VLBI experiments are described below.

3.1 Geodetic VLBI Observation by the Compact Antenna Systems

To evaluate the precision of those prototypes, we carried out 8 geodetic VLBI experiments of 24 hours using the two prototypes and the Tsukuba VLBI station (Tsukuba 32 m) or the Kashima 34 m antenna. Table 1 shows details of the experiments.

We could obtain reliable baseline lengths between the two prototypes in the five experiments among the eight experiments. In the three experiments among eight experiments, we could not obtain reliable base length due to the breakdown of a standard signal distributor and the sub-

Table 1. Lists of the VLBI experiments

Code	Strat Time (UTC)		End Time (UTC)	Stations	
M10223	8/11 5:00	–	8/12 5:00	KASHIM34	MARBLE2
M10244	9/ 1 5:00	–	9/ 2 5:00	KASHIM34	MARBLE2
M10259	9/16 5:00	–	9/17 5:00	KASHIM34	MARBLE2
M10266	9/23 5:00	–	9/24 5:00	TSUKUB32	MARBLE2
M10281	10/ 8 7:00	–	10/ 9 7:00	TSUKUB32	MARBLE2
M10282	10/ 9 8:35	–	10/10 7:25	TSUKUB32	MARBLE2
M10316	11/12 5:00	–	11/13 5:00	TSUKUB32	MARBLE2
M10356	12/22 7:00	–	12/23 7:00	TSUKUB32	MARBLE2

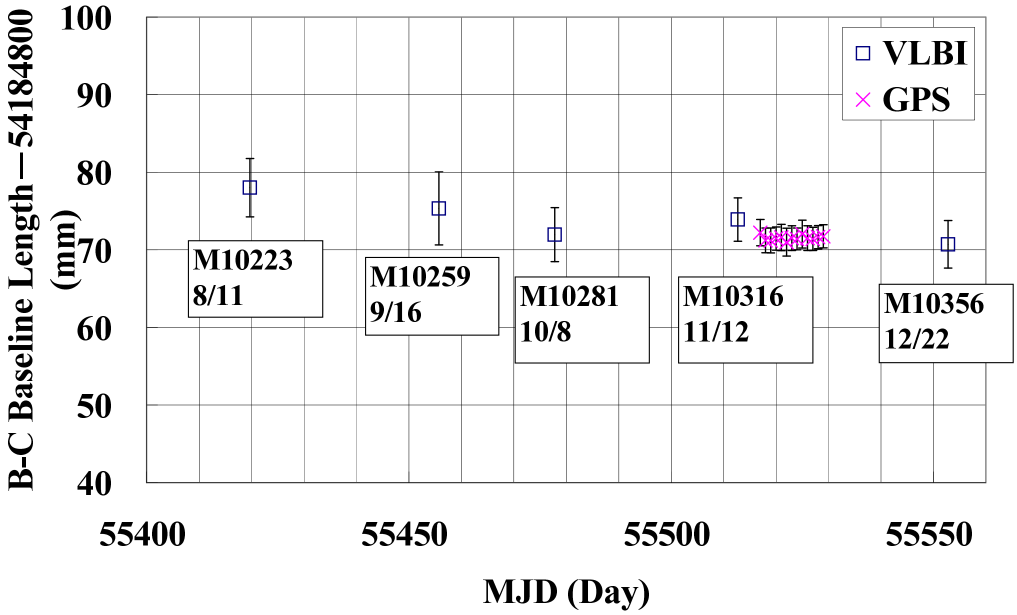

Figure 1. Estimated baseline lengths by the VLBI experiments and GPS measurements.

ambiguities. Figure 1 shows the results of the former experiments. The figure also shows the results of the GPS measurements for the comparison. The baseline analysis was performed by using the geodetic VLBI analysis software packages CALC/SOLVE, developed at NASA's Goddard Space Flight Center. In the baseline analysis, we didn't apply the collection of ionosphere delay. The root mean square (RMS) of the measured baseline lengths of VLBI is 2.6 mm, which is slightly worse than that of our goal. The lengths of the measurement baseline by the VLBI experiments are almost corresponding to measurements by GPS.

4. Summary and Future Plans

We have developed the compact antenna system in order to obtain enough precision of VLBI measurement for the calibration of the reference baseline. We have succeeded in the VLBI observations and obtained geodetic results. We will continue to carry out VLBI observations and improve the antenna systems, in order to obtain enough precision of the baseline measurement.

Ultra-rapid dUT1 measurement with high-speed network

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Abstract: The Tsukuba 32-m VLBI station of the Geospatial Information Authority of Japan has performed an ultra-rapid dUT1 measurement in collaboration with the NICT Kashima, Onsala and Wettzell VLBI stations since 2007. The motivation of the measurement is to obtain dUT1 results as soon as possible after the observing sessions. We have shortened the latency of dUT1 measurement by carrying out real-time data transfer, automatic data conversion, and correlation processing during the session, and we succeeded in obtaining the dUT1 result 3 min 45 sec after the end of the session in 2007[1]. We have implemented the ultra-rapid dUT1 measurement on IVS 24-hour sessions since 2010 and succeeded in obtaining dUT1 results for every 35 scans during the observing sessions on 24-hour sessions. The system is also introduced the developed system in ultra-rapid dUT1 measurement during IVS intensive session. On Jan. 29th, 2011, we started to submit the dUT1 results obtained from intensive session into the IVS data center officially.

1. Introduction

At the Tsukuba 32-m station, 24-hour and 1-hour international sessions known as "Intensive2 (INT2) sessions" are held once a week and on weekends (Saturday and Sundays), respectively. In these sessions scheduled by the International VLBI Service for Geodesy and Astrometry (IVS), Earth orientation parameters (EOP) such as the earth's polar motion and dUT1 can be determined. EOP results obtained by VLBI can be updated on a daily basis as new VLBI data become available and can be used individually or combined with contributed analysis results that have been obtained using data collected by other techniques, such as the Global Navigation Satellite System (GNSS) and Satellite Laser Ranging (SLR). The dUT1 is proportional to the true rotation angle of Earth with respect to the International Celestial Reference Frame (ICRF), whose axis directions are fixed relative to the distance matter in the universe. Therefore, dUT1 can be determined only by astronomical observation of extragalactic objects. VLBI is the only space-geodetic technique by which the dUT1 can be monitored. Single-baseline "Intensive sessions" are continuously carried out with the aim of observing dUT1 with minimum latency. In the early years of the sessions, the data were recorded on magnetic media and transmitted to the correlator by shipment. In the session after 2004, data transfer was carried out over broadband networks by using FTP, and this improved the latency. Currently, the minimum latency in the intensive sessions is approximately 3 hours. This reduction of the latency has resulted in an improvement in the prediction accuracy of the dUT1 from IERS solutions. The goal of the ultra-rapid dUT1 measurement is to obtain dUT1 results within the shortest possible time by adopting high-speed network. The developed technique in the experiment has been introduced in the intensive sessions and contributed to an improvement in the accuracy of dUT1 prediction value. In this paper, the technique details and results of ultra-rapid dUT1 measurement are described.

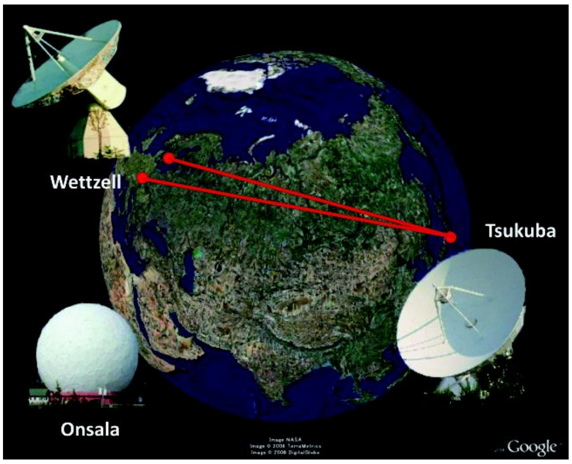

Figure 1. VLBI network for ultra-rapid dUT1 measurement

2. Ultra-rapid dUT1 measurement

The key factor in enabling the ultra-rapid dUT1 measurement is to process the observed data as

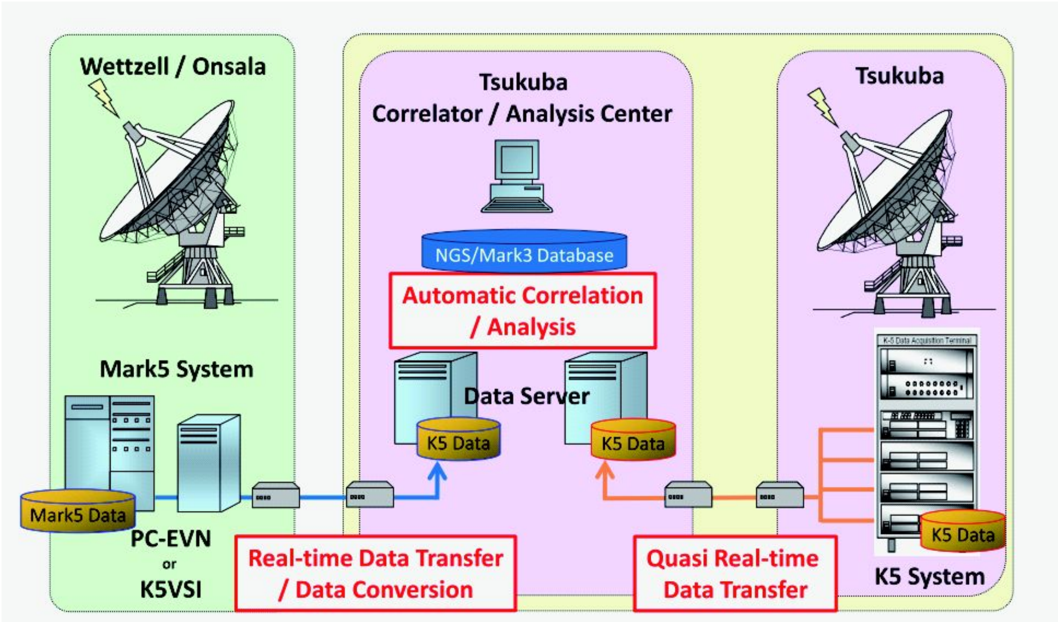

Figure 2. Data transfer and processing system for the ultra-rapid dUT1 measurement.

fast as possible. We have developed some new programs, whose functions include real-time data transfer and automatic data conversion, as well as an automatic correlation and analysis. The technical details of the ultra-rapid dUT1 measurement are described in this chapter.

2.1 VLBI stations participating in the experiments.

The VLBI stations involved in the ultra-rapid dUT1 measurement are Tsukuba station of Geospatial Information Authority of Japan (GSI), the Onsala station of the Onsala Space Observatory (OSO) in Sweden, and the Wettzell station of Forschungseinrichtung Satellitengeodäsie (FESG) in Germany. The locations of the VLBI stations are shown in Figure.1. The current network speed is 1 Gbps for all stations. The Mark5 system developed by the Haystack Observatory is used in the Onsala and Wettzell stations. In Tsukuba station, the K5/VSSP32 system developed by NICT is used for the observation

2.2 Data-transfer and processing systems

The data captured by Mark5 in Onsala station is fed to a VSI board and transferred to the Tsukuba correlator with EVN-PC. And then, Tsukuba correlator converts the Mark5 data to K5/VSSP format. In Wettzell, they introduce a real-time data transfer system developed by NICT. The system adopts VLBI Data interface Format (VDIF) and Simple UDP (SUDP) protocol in the data transfer process. As the VSIF format data is converted to K5/VSSP format at the same time of recording on the transfer server in Tsukuba correlator, it is not necessary to convert the data after data transfer. It enables us to reduce the latency of VLBI session. The converted data is put on the data server in Tsukuba correlator in real time and correlated automatically at the same time as the data transfer is completed. The correlation process jobs are shared by a cluster of computers in parallel. The data-format conversion and the correlation processing are performed by a software package developed by NICT. By using the data processing system, correlation and bandwidth synthesis are completed in a few minutes after the end of the observing session. The data transfer and processing system is shown in Figure.2

2.3 Automated analysis program

After the bandwidth synthesis of all scans is completed, the data is analyzed by automated analysis software[4]. We adopt mainly OCCAM developed by Vienna university if technology and C5++ developed by NICT[2]. The software can be run by only entering an argument on the command line, so it enables us to make an unmanned analysis program.

2.4 Type of ultra-rapid dUT1 experiment

Since 2007, we have performed several types of ultra-rapid dUT1 experiment. The first type is 1-hour experiments. From 2007 to 2009, we have implemented the 1-hour experiments with Onsala station several times a year and improved the system more stability[3]. In 2008, we started to introduce the system to IVS regular 1-hour session "INT2" with Wettzell station. The second type is 24-hour experiment. Since 2009, Tsukuba station has carried out the experiments with Onsala station on IVS 24-hour sessions, such as R1 or RDV, in which Tsukuba and Onsala stations participate. It enables us to obtain continuous dUT1 value in 24 hours. In the case of 24-hour sessions, the number of scan is more than 100. Therefore, we can obtain a lot of dUT1 value during the session. As the data analysis program is set to perform analysis once every 35 scans now, more than 50 dUT1 value are estimated on the 24-hour or additional dUT1 experiments. However, the error of dUT1 value is larger than regular IVS intensive session, because IVS 24-hour session is not optimized to estimate dUT1 value. The third type of experiment is implemented to obtain continuous dUT1 value with higher accuracy than the results of IVS 25-hour session. The experiment has been implemented in about 10 hours after 24-hour experiment which is optimized for dUT1 measurement.

3. Results of the ultra-rapid dUT1 measurement

The dUT1 results of 24-hour session "R1461" and 10-hour additional session "UR0348" are shown on Figure.3 and Figure 4. We succeeded in obtaining the dUT1 results during the VLBI observation, and the uncertainly of dUT1 determination on the additional experiments were about 9 micro sec which is better than one of 24-hour experiments (17.3 micro sec). We use C5++ software on the INT2 analysis and compared with the C5++ analysis results with one of the calc/solve (Figure.5). Although the difference of the results is more than 10 micro sec on a few sessions, it seems that the result of C5++ is consistent with one of the calc/solve.

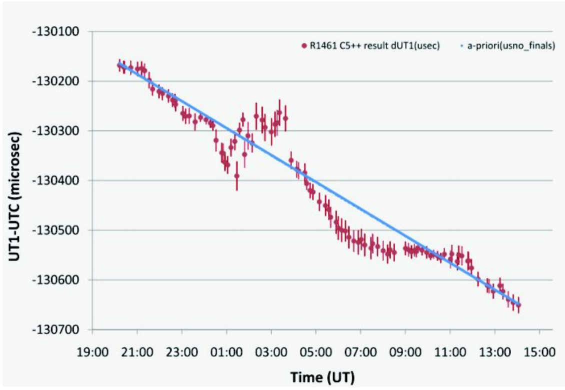

Figure 3. dUT1 results of "R1461" session

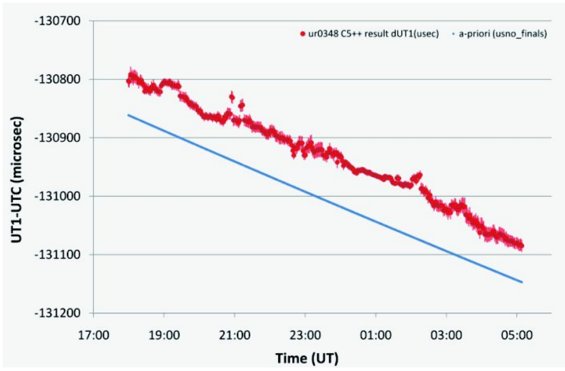

Figure 4. Averaged repeatability of station position during June 2009 for 1214 GEONET stations.

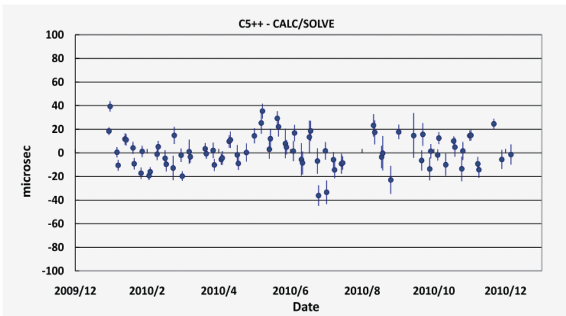

Figure 5. Comparison of the results of c5++ and calc/solve.

4. Issue of the ultra-rapid dUT1 measurement

On some experiment, we failed in obtaining dUT1 results during the observing session. The cause is delay of data conversion for Onsala Mark5 data. The data conversion process is done on several servers, and the access to the Mark5 data is via network file system (NFS). In the case of NFS, the network speed would be down if the data is accessed by several clients. Therefore, it is not appropriate system for distributed processing, and it might be cause of the delay of the data conversion. We plan to introduce another file system "Lustre File System" designed and developed by

Oracle Corporation, which is a parallel distributed file system, generally used for large cluster computing. We expect that the new file system solve the delay of the data conversion.

5. Future Plan

The next goal to work toward is achievement of ultra-rapid EOP measurement on several baselines. Although we can obtain dUT1 within a few minutes after the observing session, we can't obtain polar motion because the baseline of our experiment is on only east-west direction. Therefore, we plan to implement an experiment which includes east-west and north-south baselines. We have been implementing some fringe observations with Warkworth station in New Zealand since Dec. 2010. When we succeed in VLBI observation on Tsukuba-Warkworth baseline, we will be able to perform the ultra-rapid EOP measurement.

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Inter-comparison Study of Time and Frequency Transfer between VLBI and Other Techniques

(GPS, ETS8(TCE), TW(DPN) and DMTD)

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Abstract: We carried out the intercomparison experiments between VLBI and other techniques to show the capability of VLBI time and frequency transfer by using the current geodetic VLBI technique and facilities as the summary of the experiments that we carried out since 2007. The results from the two different types of experiments show that the VLBI is more stable than GPS but is slightly noisier than two new two-way techniques (TW(DPN), ETS8(TCE)), and VLBI can measure the correct time difference as same as ETS8(TCE).

1. Introduction

As one of the new time and frequency transfer (hereafter T&F transfer) technique to compare the next highly stable frequency standards, we proposed the geodetic VLBI technique [1]. Since 2007, to evaluate the capability of geodetic VLBI for precise T&F transfer, we carried out intercomparison experiments between VLBI and GPS Carrier Phase (hereafter GPS) on the Kashima 11m and Koganei 11m baseline several times. These intercomparisons showed that the geodetic VLBI technique has the potential for precise frequency transfer [2], [3]. Also, these results showed that the geodetic VLBI can measure the correct time difference [4].

Space-Time Standards Group of National Institute of Information and Communications Technology (NICT) which we belong to, is conducting research and developments for precise T&F transfer techniques other than VLBI such as using GPS and two-way satellite time and frequency transfer (TWSTFT) at NICT Koganei Headquaters. In 2010, we carried out the intercomparison experiment between VLBI and other techniques to show the capability of VLBI time and frequency transfer by using the current geodetic VLBI technique and facilities as the summary of the experiments.

In this paper, we describe the two intercomparison experiments from a viewpoint of the VLBI mainly. Therefore, we leave the details of the result of other techniques to different papers.

2. Two new TWSTFT techniques developed by NICT

NICT developed the two new TWSTFT techniques. One is the method using a pair of Pseudo Random Noises (dual PRN, DPN) (hereafter TW(DPN)). The other one is the method using Time Comparison Equipment (TCE) on the Engineering Test Satellite VIII (ETS8) (hereafter ETS8(TCE)). To carry out the intercomparison experiment, we installed the TW(DPN) antenna and the ETS8(TCE) ground station at Kashima Space Technology Center (KSTC, former Kashima Space Research Center) next to the VLBI antenna (Kashima 11m). In this section, we describe the brief overview of two techniques. Please see the reference papers for more details.

2.1 TW(DPN)

TW(DPN) was developed to improve the measurement precision and decrease operational cost of TWSTFT. The precision can be improved by increasing the chip rate of the PRN. However, this method of enhancing the precision is not feasible because the rental costs of the commercial communication satellites used for signal transfer are high.

TW(DPN) is composed of a waveform generator and an A/D converter. By using this method, we can improve the delay measurement precision by one order of magnitude, even though the occupied bandwidth is only 400kHz, which is less than one-sixth the currently used bandwidth. Since the transponder cost is proportional to the occupied bandwidth, we can reduce the operational cost of the TWSTFT [5].

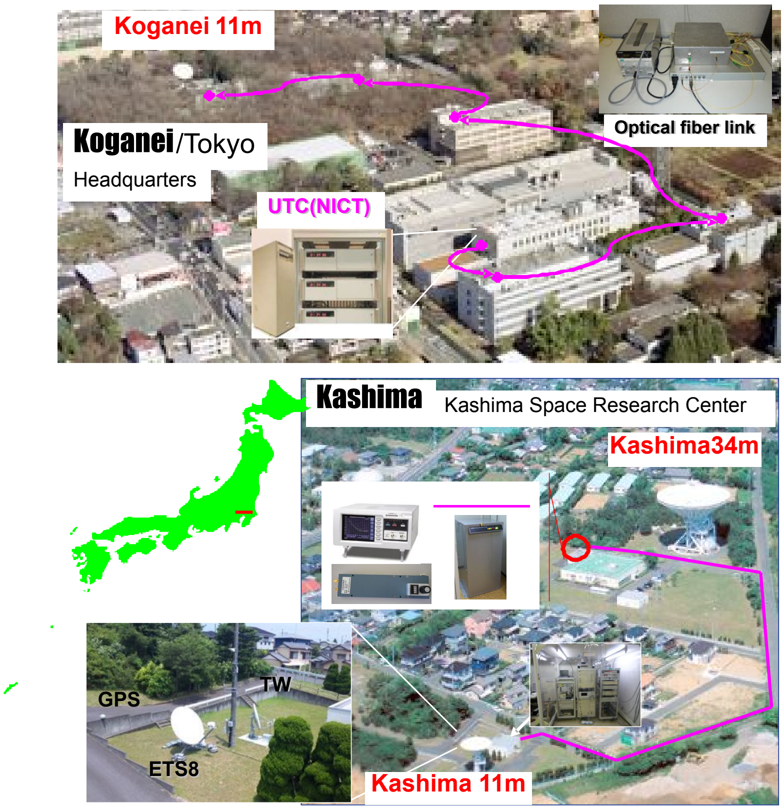

Figure 1. The layout map of KSTC and Koganei Headquaters.

Table 1. The setting parameters of experiments

	K5/VSSP32	K5/VSI (ADS1000)
Band	S/X	S/X
Input Freq. Width	16MHz/ch	512MHz/ch
Sampling Rate	32Mbps, 1bit	1024Mbps/ch, 1bit
Number of Channels	16ch	2ch
Effective Bandwidth of X-band	364.8MHz	147.8MHz

2.2 ETS8(TCE)

ETS8 is a Japanese Geostationary Satellite, which launched in 2006. ETS8 has missions for mobile communication experiments and for precision timing experiments using Cesium atomic clocks in space.

At the time of T&F transfer, TCE transmit and receive signals to and from the ground. As the two-way uplink and downlink transmission pathways are approximately equivalent, the effects of transmission delay in the atmosphere or those due to the motion of the satellite will be cancelled out, enabling highly precise time transfer, with anticipated precision on the order of several nanoseconds in code-phase operation and approximately less than 100 picoseconds in carrier-phase operation [6], [7], [8].

3. Intercomparison experiments

3.1 Outline of the experiments

Figure 1 is the layout map of KSTC and Koganei Headquaters. The baseline length of Kashima 11m - Koganei 11m is about 109 km. In 2010, we carried out intercomparison experiments two times (August and October). At August experiment, to evaluate long term stability of these techniques, we acquired the over 100 hours data. At October experiment, we compared the precision of these techniques by stretching the Coaxial Phase

Shifter (hereafter trombone) which was inserted in the path of the reference signal from Hydrogen maser to the Kashima 11m antenna [4]. The reference signal which is provided from hydrogen maser is transmitted by coaxial cable (the distance is about 300m) in KSTC. In 2009, we installed the RF distribution system using optical fibers at Koganei Headquaters to transmit the reference signal to VLBI back end which is coherent with UTC(NICT). To cancel the length fluctuation of optical fibers, we adopted the feedback system using the round-trip signal. Hence, this transfer stability reached the 10^{-16} level over 1000 seconds. Therefore, the reference signal (10MHz/1PPS) at Koganei station is coherent with UTC(NICT) [9].

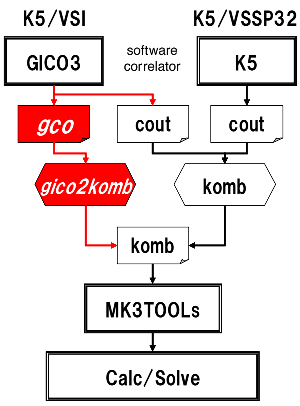

Figure 2. The flowchart from the two K5 sampling systems to the baseline analysis software.

Table 2. The baseline length calculated from the data that was sampled with each system of K5/VSSP32 and K5/VSI.

Exp. date	System	Baseline Length	1σ
August	VSSP	109099639.00	0.53
	VSI	109099639.00	0.57
October	VSSP	109099635.43	0.58
	VSI	109099635.58	0.66

Unit: mm

3.2 Geodetic VLBI using K5/VSI system

NICT are currently developing the two types of sampling system named as K5/VSSP32 (hereafter VSSP) and K5/VSI such as ADS1000 and ADS3000+ (hereafter VSI) [10]. Also, we are developing the software correlator and data conversion utilities [13] corresponding to each system. VSSP and K5 software correlator are one of the sets, and that is mainly used for the geodetic VLBI experiments in Japanese stations [11]. VSI and GICO3 software correlator are another sets. That is mainly used for astronomical purpose. The processing speed of the GICO3 worthy of special mention is about 10 times faster than that of the DiFX at 2k FFT points [12]. In order to use VSI system in the geodetic VLBI experiment, we developed the data conversion programs and carried out the experiments. Figure 2 show the flowchart that indicate from K5 sampling system to the baseline analysis software. The gray background indicate the new programs which were developed in this time.

The setting parameters of both experiments are shown in Table 1. At first, we supposed VSSP was main. Therefore, the effective bandwidth (X-band) of VSI was narrower than VSSP in spite of a wideband sampler. In addition, because the schedule was optimized for VSSP, the scan length was longer, and the number of observation was less, than the schedule that was optimized for VSI. As the result, the estimated delay precision of VSI was 70% with reference to VSSP.

Table 2 shows the baseline length calculated from the two types of K5 system. In the two time experiments, these results show the good agreement. Thus it is concluded that using the K5/VSI and GICO3 software correlator for the geodetic VLBI experiment is not a problem. However, the results of the clock offsets from VSSP have daily variations which were influenced from the problem of phase calibration system. Therefore, the results of VSSP shown afterward were corrected using VSI data.

3.3 Comparison of Time Series

To evaluate long term stability of these techniques, we acquired the over 100 hours data at August experiment. Figure 3 show the time series of time difference calculated from these techniques at Kashima-Koganei baseline. The common trend of these time series was already removed up to 2nd order. Table 3 show the data property (integration time, etc) of each techniques. Also, Table 4 show the root-mean-square of time series variation calculated from with reference to ETS8. The result of ETS8(TCE) is extremely stable than other techniques. TW(DPN) is also stable, but it has clear daily variation. The cause of the daily variation does not yet clear, but we think that it is caused by interference from spread signal and/or sunlight.

The results of the VLBI agree with GPS, but these results vary than other results. Figure 4 show the difference of the atmospheric delay calculated from VLBI and GPS between Kashima and Koganei. Time delay and atmospheric delay

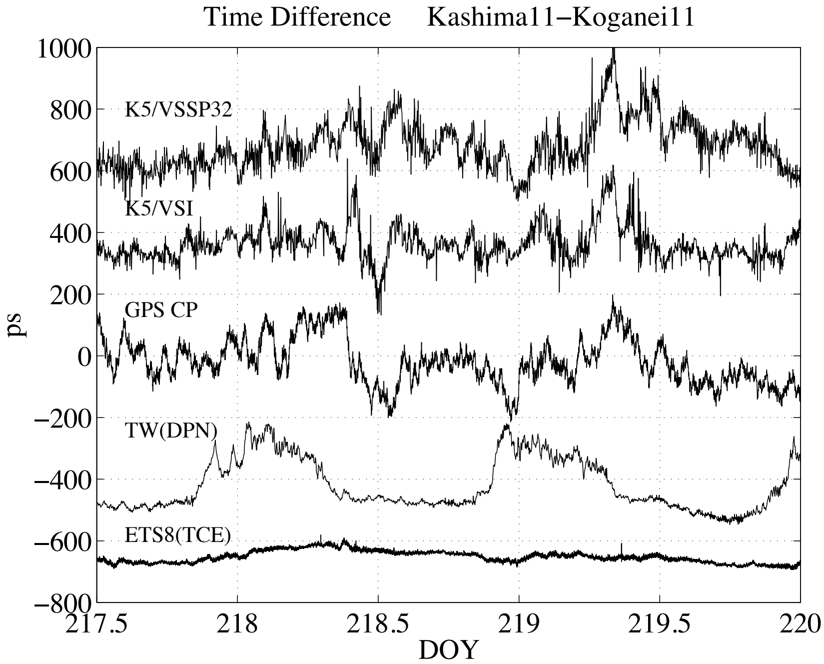

Figure 3. Time difference obtained from these techniques.

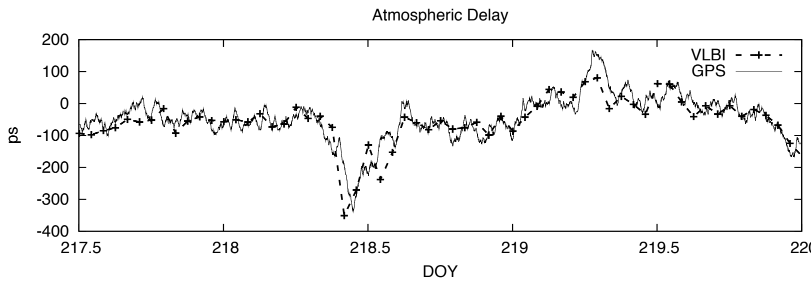

Figure 4. The difference of the atmospheric delay calculated from VLBI and GPS between KSTC and Koganei Headquarters

variations agree well. As already described, the influence of atmospheric delay was removed from TW(DPN) and ETS8(TCE) because both techniques are TWSTFT. Usually in the analysis of VLBI and GPS, the atmospheric delay and time delay are estimated at the same time. These results suggested the estimation of atmospheric delay in the analysis of VLBI and GPS is not enough. To obtain the more precise result, it is necessary to use the more precise model and/or another method such as KARAT [14].

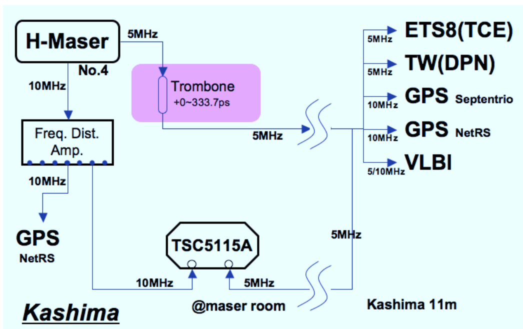

Figure 5. The reference signal setup diagram at Kashima station.

3.4 Comparison of T&F transfer precision

At October experiment, we compared the precision of these techniques by stretching the trombone

Table 3. The data property of each techniques

	VLBI/VSSP	VLBI/VSI	GPS CP	TW(DPN)	ETS8(TCE)
Integration Time	Scan Duration		1	120	1
Data Interval	100 (averaged value)		30	120	1
Analysis Software	Calc/Solve		NRCan PPP	NICT	
remarks	wide-band data	multi-channel data	–		

Unit: second

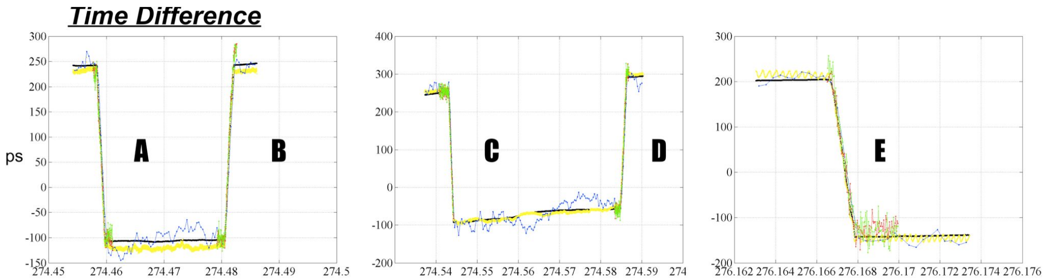

Figure 6. Time difference of October experiment. The large steps (A to E) were artificial delay change parts by trombone. Black lines are DMTD. Gray thin lines are VLBI (VSSP and VSI) and ETS8(TCE). Variety lines are GPS.

which was inserted in the path of the reference signal from Hydrogen maser to the Kashima 11m antenna. Figure 5 show the reference signal setup diagram at Kashima station. This experiment is almost same strategy in the case of [4]. In this time, we stretched the trombone more slowly and more constantly. In addition, we expanded scan time of VLBI according to the time of stretching trombone. Also, as the reference of correct change of time difference, we introduced the new DMTD equipment (TSC511A, Phase Noise and Allan Deviation Test Set).

Figure 6 show the time difference of each techniques. The large steps (A to E) were artificial delay change parts by trombone. Black lines are DMTD. Gray thin lines are VLBI (VSSP and VSI) and ETS8(TCE). Variety lines are GPS. Also, we show the summary of the amount of the steps obtained from these techniques at the artificial delay change parts in Table 5. These results show that each technique agree very well. The differences of each technique except GPS are only a few picoseconds on the average. Anyway, the result of our experiment clearly show that the geodetic VLBI technique can measure the correct time difference as same as ETS8(TCE) and DMTD.

Table 4. The root-mean-square of time series variation calculated from with reference to ETS8.

	August	October
TW(DPN)	95 (20)	-
GPS CP	75	56
VLBI(VSI)	60	36

Unit: ps

Table 5. Results of the time steps obtained from each technique (see Figure 6)

	A	B	C	D	E	Average
DMTD	347	346	346	347	348	347
GPS CP	352	340	385	353	345	355
ETS8	348	340	343	349	347	345
VSSP	-	349	342	350	340	345
VSI	347	340	-	351	348	346

Unit: ps

4. Summary and Outlook

We carried out the intercomparison experiments between VLBI and other techniques (GPS CP, TW(DPN), ETS8(TCE), and DMTD) to show the capability of VLBI time and frequency transfer by using the current geodetic VLBI technique and facilities as the summary of the experiments that we carried out since 2007.

The results from the August experiments show that the VLBI is more stable than GPS but is slightly noisier than two new two-way techniques (TW(DPN), ETS8(TCE)). Also, these results show that the estimation of atmospheric delay in the analysis of VLBI and GPS is not enough.

At October experiment, we produced artificial delay changes by stretching the trombone which was inserted in the path of the reference signal from Hydrogen maser to Kashima 11m antenna. At the artificial changes, the results of VLBI, ETS8 and DMTD hardly had a difference. Consequently, the geodetic VLBI technique can measure the correct time difference as same as ETS8(TCE) and DMTD.

Currently the T&F transfer experiment using ETS8 in NICT was finished. And the project shifted to the next phase of the R&D of T&F transfer using Quasi-Zenith Satellite System (QZSS). Also, the VLBI project shifted to the next phase which is the R&D of the new facilities and strategy suitable for T&F transfer. In the near future, we are planning to carry out the following list.

- apply KARAT for the VLBI and GPS analysis
- using MARBLE [16] and ADS3000+ [15] for T&F transfer
- international experiment

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A First Black Hole Imager at Andes

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The massive black hole in Sagittarius A^* (SgrA^*) at the Galactic center has the largest apparent Schwarzschild radius of $6-10\mu as$. Relativistic phenomena around the black hole should be observed in very near future.[1],[2],[3],[4],[5]

We plan to construct a sub-mm VLBI system at Andes only dedicated to the detection of the event horizon of SgrA^* black hole. Using two of fixed large spherical dishes and a mobile small station, we sample sufficient u-v coverage, aim to detect the event horizon of SgrA^* from visibility analysis (and to image the figure with other telescopes). Because we are in a big monetary crisis and the catastrophic earthquake of the Tohoku area that only happens once a century and once a thousand year, a cost down around 107 US dollars-level is required to realize the project.

We dare to abandon general capability and expansivity of the system and dedicate to observe SgrA^* in order to detect the event horizon of SgrA^*.

For the two large dishes, we plan to use ground-fixed spherical dishes like Waseda's.[6] The large dishes give us sensitivity. Spherical reflector has no focus itself, but devising the shape of sub-reflector, we can make a focus. By shifting the sub reflector, tracking observations for a few hours is possible. Because the main reflector is fixed on the ground, we are free from the worry about the deformation due to the self weight. Unlike parabola, panels of spherical dish have a common curvature, we can achieve cost down by mass production of the panels.

We plan to locate the fixed stations at the Huancayo observatory, IGP in Peru and the Chacaltaya Cosmic-ray Observatory in Bolivia. The NICT in Japan has been developed geodetic VLBI mobile stations for 20 years.[7] We also use a mobile VLBI station to sample various baseline vectors (u-v coverage). The Caravan station moves around Andes, and changes observing site position.

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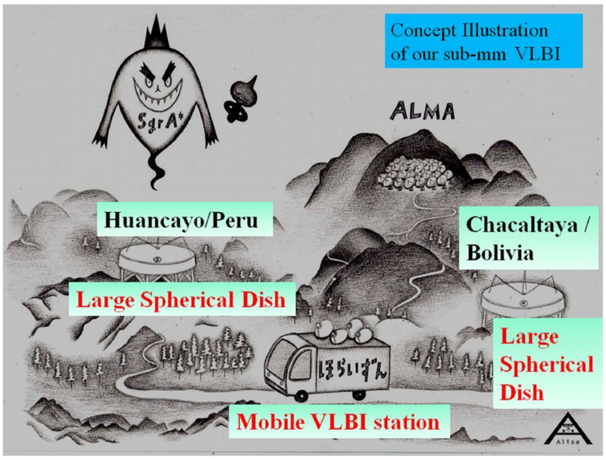

Figure 1.

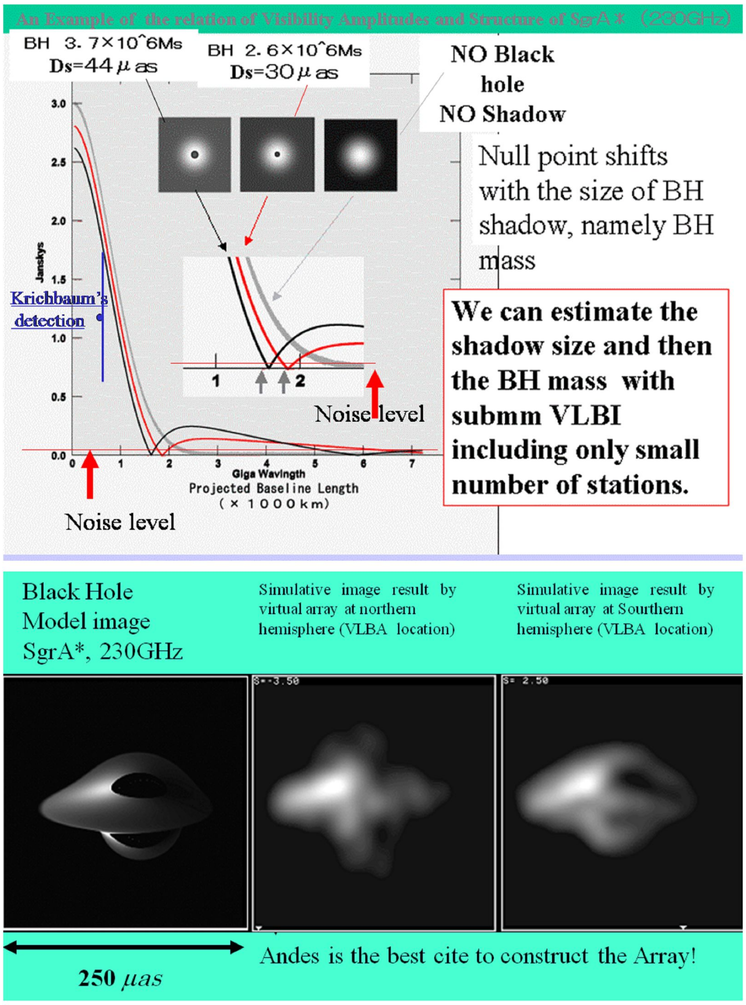

Figure 2.

VLBI2010 and GGOS

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1. What is VLBI2010?

VLBI2010 is the next-generation VLBI system promoted by the International VLBI Service for Geodesy and Astrometry (IVS). The IVS set the following three goals[1]:

- 1 mm position accuracy on global scales,
- continuous measurements for time series of station positions and Earth orientation parameters,
- turnaround time to initial geodetic results of less than 24 hours.

The following systems are suggested to realize above three goals.

- smaller (< 12 m) fast-slewing automated antennas,
- broadband delay with $2 - 14$ GHz,
- realtime data transfer using e-VLBI > 10 Gbps.

Several advanced countries have already constructed the new VLBI stations with such an observation system.

2. Current Situation of VLBI2010

The VLBI2010 Project Executive Group (V2PEG) was organized in the IVS to provide strategic leadership to the VLBI2010 project and guide the transition from the VLBI2010 development phase to the VLBI2010 implementation phase. The V2PEG conducted the IVS Network Station Survey to gather information about VLBI2010 plans, trigger VLBI2010 discussion at network station level and get input on what the V2PEG can do to best support individual VLBI2010 projects. The results of the survey are summarized in this section.

VLBI2010 is characterized by continuous observations (24 hours / 7 days a week), 30-s slew-track cycles, and broadband frequency coverage ($2 - 14$ GHz). These characteristics are necessary to meet the VLBI2010 (and GGOS) performance goals of 1-mm position error and 0.1-mm/yr site velocity error which have been identified as long term goals of the Global Geodetic Observing System (GGOS) of the International Association of Geodesy (IAG). They demand a new class of radio telescope that is fast moving ($12°$/s for Az, $6°$/s for El, acceleration $3°/s^2$ for Az/El) and has a suitable geometry to accommodate wideband feeds. In 2012 the first VLBI2010 prototype, the Twin Telescope Wettzell, will become operational.

The survey showed that up to 20 new radio telescopes at 17 sites with full VLBI2010 compliance could become operational by 2017. This number is based exclusively on the present IVS network station survey and does not reflect the possibility of new institutions joining in.

In addition 13 other radio telescopes (some of them co-located with the above new telescopes) will be operated with partial VLBI2010 compliance, the most common shortfall being limitations of radio telescope slew speed.

By 2014/2015 a sufficient number of VLBI2010 compatible radio telescopes will be available for initial VLBI2010 operations.

The V2PEG will provide support for the planning, preparation, and justification of VLBI2010 proposals and for the technical specification of new VLBI2010 stations. The group will accommodate as best as it can requests for in-person meetings with representatives of funding agencies[2].

3. The GSI's activity for VLBI2010

Japan is located in area of plate boundaries of four plates and it causes a large number of tectonic earthquakes. Besides, there are a lot of active faults and volcanoes in Japan. It is necessary for such a country to monitor the phenomena of the Earth like a plate motion precisely.

The Geospatial Information Authority of Japan (GSI) established the VLBI2010 Exploratory Committee in the Geodetic Department and has considered policy dealing with the VLBI2010 since January, 2010. In March, 2010, the committee compiled the interim report. Following is a summary of the report:

- VLBI technology and application is very important as an infrastructure of the Geospatial information.
- When countries in the world transition into VLBI2010 system, if only Japan remains existing system, we will miss opportunities for

the international VLBI observation and cannot maintain the infrastructure of the Geospatial information.

- Therefore we need to progress the construction of VLBI2010 system and complete it by the end of 2015 fiscal year.

- There are following two or more candidate site;
  1. inside of the GSI campus
  2. bedrock outcrop near Tsukuba

- Also we need to consider the ideal future for the four existing stations including Tsukuba 32-m.

According to the interim report, the GSI submitted the budget proposal for the VLBI2010 construction. In 2011 fiscal year, the amount of the budget is 15 million yen for site selection and it was approved. We plan the RFI environment investigation and soil surveying.

4. Promotion Framework for the Earth Observation in Japan

The VLBI2010 is a component of the GGOS promoted by the IAG. GGOS contributes to the emerging Global Earth Observing System of Systems (GEOSS) not only with the accurate reference frame required for many components of GEOSS but also with observations related to the global hydrological cycle, the dynamics of atmosphere and oceans, and natural hazards and disasters[3]. In Japan, Ministry of Education, Culture, Sports, Science and Technology (MEXT) has set up a committee for promotion of the Earth Observation since 2005 and related government ministries and agencies have conducted observation services individually.

5. GGOS and the Global Geodetic Observation Framework in Japan

Japan also ought to be actively involved in GGOS. In Japan, GSI conducts geodetic VLBI and the National Astronomical Observatory of Japan (NAOJ) and some universities implement astronomical VLBI observation and research. While, the Japan Coast Guard is carrying out SLR observation, and GNSS observation is implemented by a lot of organizations. On the other hand, there is no DORIS station in Japan, but one DORIS station at SYOWA base in Antarctica. Currently in Japan, there is no organization or association in order to coordinate these organizations concerned with the Earth Observation. In order to promote GGOS in Japan, cooperation with international organization and contact point for international affairs are necessary.

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Major Results of Medical ICT Experiments using Sapce Technology -WINDS VSAT, Interferometer, VLBI and QZS-

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Abstract: The Japanese WINDS satellite shows the top level bandwidth of Giga bit level. The satellite links are very effective to transfer very heavy contents of the distant e-Medicine and e-Education. We have been supported the construction of Japanese JICA ICT Centre in the University of the South Pacific (USP). The first stage of the contraction of ICT centre has completed by April 2010 and the second stage of the ICT Centre will be completed by the August 2011. The Centre will be the very suitable and challenging counterpart of our medical ICT experiment using Japanese WINDS satellite. To promote our experiment we installed the Japanese side counterpart satellite station at YRP venture building with Ka-band VSAT system and the Interferometer for the measurement of rain fall attenuation of Ka-band satellite receiving signal. In August we visited the hospitals of Suva, capital of Fiji and we comfirmed very strong request of the transfer of DICOM data from the latest high tech medical equipments to advanced countries using satellite links. We are also now promoting the software receiver development of new type of GNSS such as QZS “Michibiki”. We already successfully received MSAS GEO satellite and QZS is also a very challenging quasi-GEO satellite for precise navigation. Another target of our common challenges is successfully performed using the technology of virtual OS for WINDS experiments and space geodetic applications such as VLBI.

Keywords — Telemedicine, WINDS Satellite, USP, Ka-band, VSAT, virtual OS, GNSS, QZS

1. MICT WINDS Experiments using super IP Satellite WINDS

Japanese Super Internet Satellite WINDS shown in Fig. 1 enables global high-speed data transmission for such as the telemedicine, the distance education, etc. WINDS is the latest experimental Super Internet satellite system developed by JAXA and NICT and successfully launched in February 2008. WINDS has a widespread scanning antenna coverage that includes almost all eastern Asia and Pacific area. We already performed the international medical ICT multicast experiment between Thailand and Japan and demonstrate the high performance of the WINDS for our purposes.

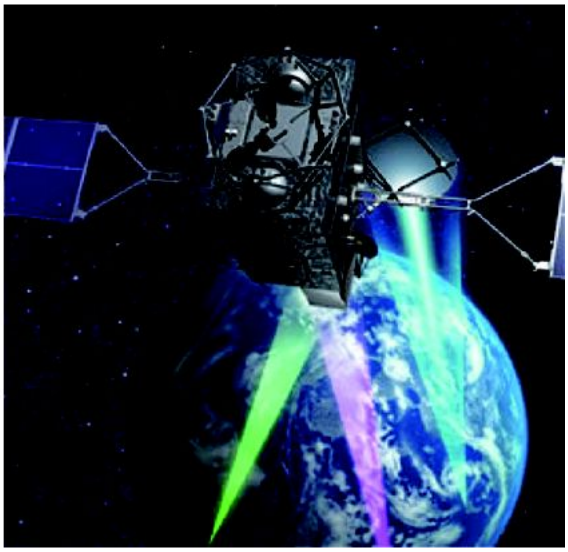


Figure 1. WINDS Satellite and APAA Beam(Ka-band)

On the experiment with Ka-band Active Phased Array Antenna (APAA) of WINDS, we use Ka-band VSAT antenna and Indoor Units (IDUs) for the ground terminals. The IP layer structure of APAA schema is as shown in Fig. 2. We can use any kinds of IP based PCs for experimental host computers. The hosts is connected by Ethernet to IDU. IDU is an almost pure RedHat linux box with the ATM cell converting unit. The IP application datagram/ packets pass through from Host 1 to IDU 1 and are converted ATM cells. The output baseband of physical layer from IDU1 is up-converted to Ka-band and transmitted to the satellite. WINDS satellite has an onboard ATM multiplexer and beam switching function. The downlink signals are received by another Ka-band antenna and down-converted by the receiver and IDU 2.

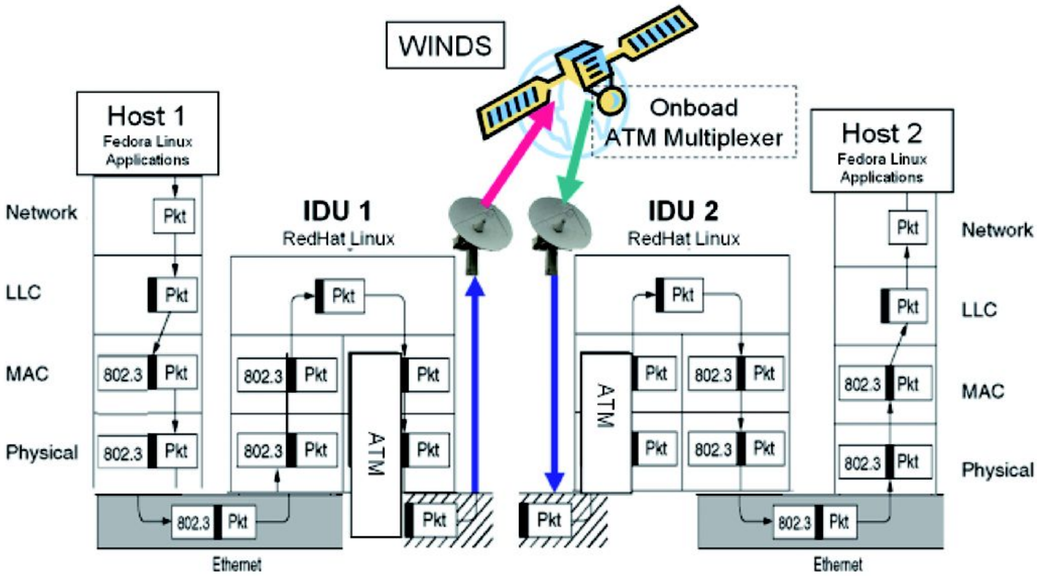


Figure 2. IP Layer structure of APAA mode of Japanese Internet Satellite WINDS

The cells/packets flow to Host 2 via IDU 2 is just inversely same as upload process.

2. YPR Venture Building: Counterpart of WINDS Medical ICT

To perform the international WIND medical experiments YNU installed the counterpart facilities on the YRP Venture Building as shown in Fig. 3(a). Yokosuka Research Park (YRP) is located about 30 km south of Yokohama city (or YNU) as showed in Fig.3(b), which is the Japanese research center of wireless communication developed by Keikyu Trains Group.

On the roof of YRP Venture building we installed Ka-band 1.2m VSAT antenna system and two 67cm interferometer antenna as shown in Fig.4 . The VSAT system has the Ka-band transmitter and receivers suitable for the APAA system of WINDS satellite. The two interferometer antenna are receive-only with low noise receivers and coherent down converter with the local signals from Rubidium atomic standards. To use the VSAT system we need to get the permission of JAXA, but we do not need any permission to use our interferometer, which works every 365days a year and monitors the conditions of WINDS and measure the rainfall attenuation continuously.

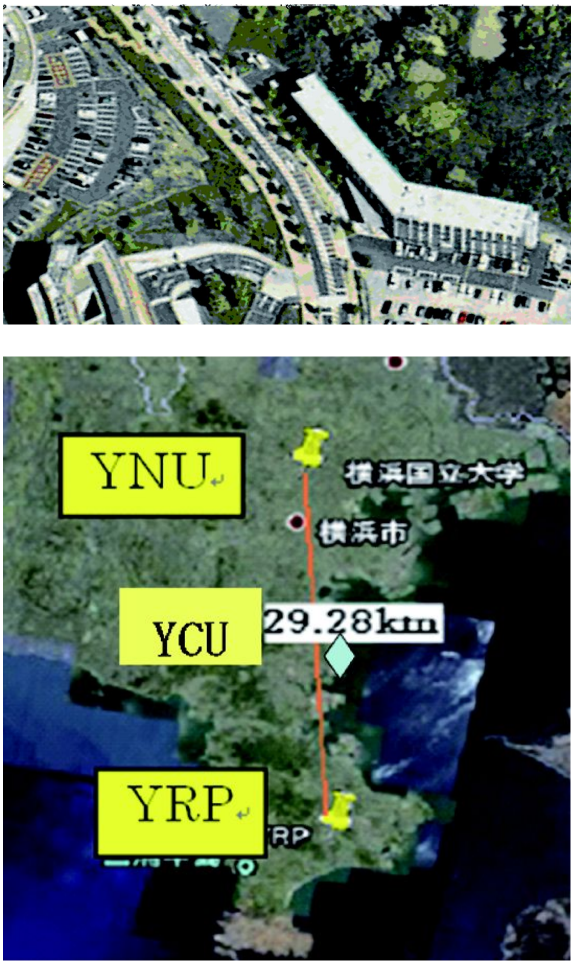
2.1 First phase completion of JICA USP ICT Centre

One of our targets of Medical ICT WINDS experiments is to realize the medical ICT experiments between YNU and USP based on the MOU. The base station of YNU side is the YRP Venture Building above mentioned and the station of USP should be the JICA ICT Centre in USP. In August 2010, the first phase construction completed as shown in Fig.5. This building is the first fourth floor building in USP. The ICT Centre is the super ecological because they do not use air conditioning but they use effectively the trade wind which blows from east almost all year. Suva campus of USP is in the area with rains, wet and bad humidity because of the trade wind from east and their western high mountains. This is very important point because Ka-band or mm-band radio waves should have attenuations by heavy rains. However the recent high-vision video transfer and heavy contents such as medical DICOM contents require the huge bandwidth for the satellite communications. Thus the long-term statistical analysis of Ka-band attenuation measurement in USP will produce valuable data for the global use of Ka-band satellite.

By the fall of 2011, the final phase construction of the Centre will be complete. They will have new auditorium equipped with latest ICT equipments.

2.2 Medical ICT Experiment Plan using WINDS satellite

Our two major targets of Medical ICT experiments are (1) DICOM data transfer[1] and (2) tropical infection disease such as Dengue. The first DICOM one is base on the local needs of the medical equipment provision by JICA as mentioned below.



Location among YNU, YCU and YRP

Figure 3. (a) YRP Venture Building., (b) Ka-band VSAT antenna for WINDS on the roof of YRP Venture Building

The second Dengue one is based on my experiences of the local long stay in the South Pacific area.

2.3 DICOM server experiments using WINDS

Recently DICOM (Digital Imaging and Communications in Medicine) interface becomes the de facto standard for the medical contents transfers among the hospitals using broad band network. We visited the Colonial War Memorial Hospital (CWMH) in Suva, Fiji(See Fig.7) in the August 2010. JICA provided the latest medical equipments to CWMH in April 2010 as shown in Fig.8. And all of them have the DICOM interface for data transfer. If they have a broadband network, DICOM interface will be very useful to get the quick diagnostics or the second opinion from outside medical doctors using their broad band network. Only in

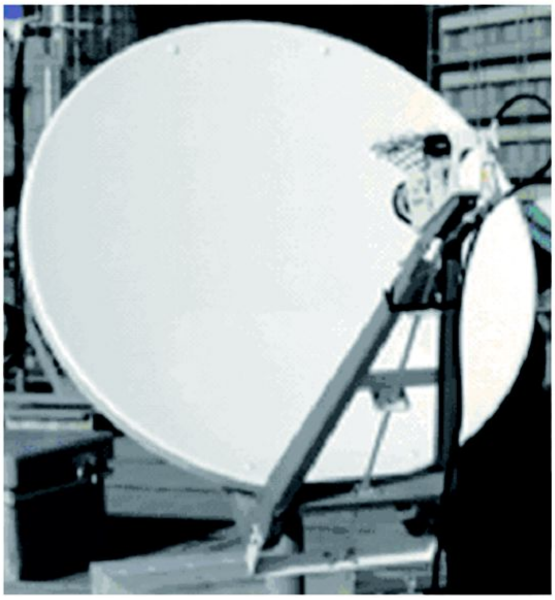


Figure 4. 1.2m Ka-band VSAT antenna for WINDS on the roof of YRP Venture Building

Figure 5. First phase completion of JICA USP ICT Centre

Figure 6. Last phase construction of JICA USP ICT Centre (Auditorium)

Viti Levu Island, they are very lucky because they have the landing point of the latest Tbps Southern Cross marine cable. But other south pacific islands do not have such kind of advantaged network connection. The chances to use the super internet satellite communication are necessary for the major islands to establish how to apply these latest medical equipments effectively and sustainably. The one idea to realize the sustainability is to establish the group medical examination on the reasonable cost performance. For the major islands or communities with big populations weekly base group medical examination system using satellites may be reasonable. For the miner islands or communities with small population monthly base group medical examination system using satellites may be reasonable. Using Japanese WINDS satellite they can test and check the feasibility of the group medical examination system using satellites.

Figure 7. Colonial War Memorial Hospital (CWMH) in Suva, Fiji

Figure 8. Latest medical equipments with DICOM provided by JICA

We have started the DICOM data transfer experiments using WINDS APAA communications and we measured the throughput of DICOM data with the big latency of the satellite.

Figure 9. Typical DICOM images for the interpretation of radiogram (MRI or CT)

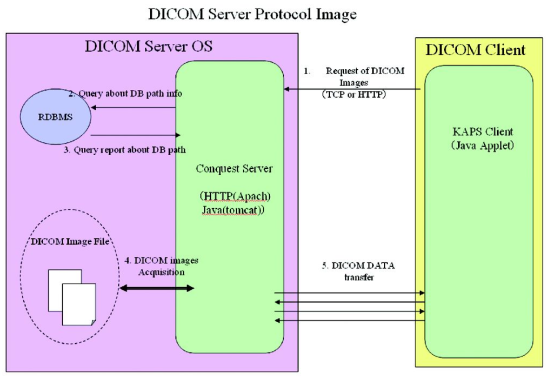


Figure 10. DICOM Server Protocol Image

3. RNA PCR data transfer for Dengue infection deceases.

During Takahashi's stay in the South Pacific I experienced and observed the severe cases of the infection of Dengue via tropical mosquitoes. Dengue is known as one of the typical "abandoned diseases". There are four kinds of Dengue viruses with different RNA structures which produce the different kinds of antibodies, respectively as shown in Table 1. It is well-known that two different antibodies make very strong interferences and severe damage to the human body. Thus the first stage infection is called as Dengue fever and the second phase is called as Dengue hemorrhagic fever with heavy blood issue. To make the precise diagnostics for Dengue patients, we need the analysis of RNA data using PCR equipments. The purpose of our Dengue experiments is to transfer the RNA data by using such as real-time PCR to the professional hospital using satellite communications. The Earth

Table 1. Nucleotide sequences of dengue virus primer

primer	Sequence	gene	product size(bps)
Dls	GGACTGCGTATGGAGTTTTG	E	490
Dlc	ATGGGTTGTGGCCTAATCAT	NSI	
D2s	GTTCCTCTGCAAACACTCCA	E	230
D2c	GTGTTATTTTGATTTCCTTG	E	
D2(TR)s	GCATAGAGGCTAAGCTGACC	E	263
D2(TR)c	AAGGGGACTCACTCCACAAT	E	
D3s	GTGCTTACACAGCCCTATTT	E	320
D3c	TCCATTCTCCCAAGCGCCTG	NS1	
D4s	CCATTATGGCTGTGTTGTTT	NS2a	398
D4c	CTTCATCCTGCTTCACTTCT	NS2b	
Dus	TCAATATGCTGAAACGCGCGAGAAACCG	C	511
Duc	TTGCACCAACAGTCAATGTCTTCAGGTTC	PreM	

D1,2,3,4;dengue type 1,2,3,4s;sense premer, c;complimentary primer,u;universal primer

warming and heat islands are alarmed us the occurring of Dengue infection via mosquitoes in the cities of mid latitude countries in the temperate zone. Thus this issue is not only for tropical people but also for people in the temperate zone.

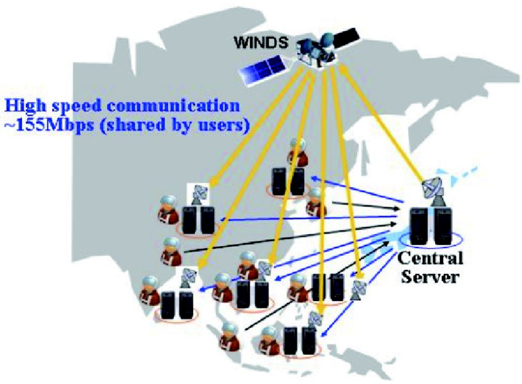


Figure 11. Sentinel Asia project for emergencies & disasters

4. How to promote WINDS satellite link between Japan and South Pacific

As mentioned above we installed Japanese side WINDS stations on YRP Venture Building and we are/have been strongly supporting the designs and the completion of JICA ICT centre in the USP. This fiscal year we have investigated the way how to connect between Japan and very isolated South Pacific islands using WINDS satellites as soon as possible. The present possible one of our solutions is the cooperation with the Sentinel Asia project (See Fig.11).

The major purposes of this JAXA project is the prevention of emergent disasters such as Tsunami, volcano eruptions, heavy storms and etc, using satellite technologies. We are now under the discussion with JAXA and NICT people and we now get the positive possible solutions using JAXA's Ka-band antenna which started the operation from January, 2011 in Suva, Fiji (see Fig.12) and Japanese WINDS VSAT antenna.

Figure 12. JAXA's Ka-band antenna in Suva, Fiji

This idea is already assured technically no problem by the antenna maker and we are now proceeding the local domestic subjects should be solved in both countries.
The reason why we promote the link between Japan and South Pacific as soon as possible is to appeal the importance of satellite communication such as medical ICT in the South Pacific regions on coming PALM 6 summit meeting dated in May 2012. On

PALM summit Japanese Prime Minister is always the chairman and he can gathers the prime ministers of about twenty Pacific countries and he can have initiative in the meeting and we strongly hope our prime minister will show the initiative about the importance of satellites in the Pacific Regions.

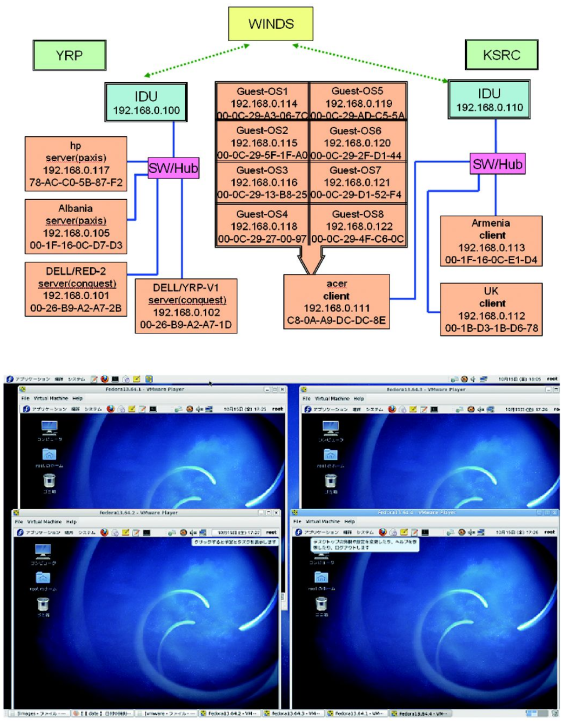


Figure 13. (a) Multi virt-guest OS experiments (upper), (b) Multi virt-guest OS VLBI experiments (lower)

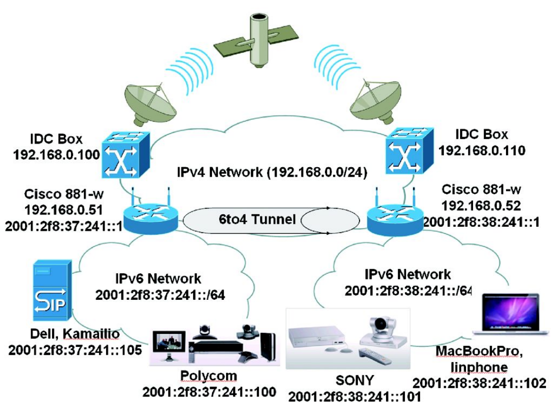


Figure 14. Diagram of High-vision video conference SIP server experiments via WINDS satellite

5. Multi virtual OS/multi cores experiments

One of the hot topics of computer networks is the combination of multi-virtual OS environments and multi-cores processors. Our strong concern is the unusual behaviour of multi-core and multi-virtual sessions over the satellite communications. Because the target is too wide, we mainly concentrate on the application of the medical ICT such as DICOM server experiments and VLBI data reduction. From our multi-OS and multi-core DICOM experiments via WINDS APAA connection, our results shows the very clear linear proportional between the number of multi-OS and the total throughput. Since the NICs of multi-OS are the virtual and shared NIC resource, the bridge function of host OS (VMware player on 64bit linux) shows very good performance, our results mean. As DICOM data transfer with the big latency is much lower than the usual throughput of iperf file transfer. Thus multi-OS DICOM transfer is a very high cost performance solution to improve the throughput via WINDS satellite.

6. SIP server experiments on IPv6/IPsec

We usually use very closed environment system for the video conference using H322 protocol such as terminal of Polycom and/or SONY. It is possible to change the video conference environment binary files by only their terminals. The Session Initiation Protocol (SIP) is a text-based protocol, similar to HTTP and SMTP, for initiating interactive communication sessions between users. Such sessions include voice, video, chat, interactive games, and virtual reality. By using SIP technology instead of H323, we can make very flexible and dynamic connection of video conference.
We succeeded in the SIP server high-vision video conference experiments through WINDS satellite. We even succeeded in the experiment on IPv6/v4 tunnel and IPsec environment. Fig.12 shows the diagram of high-vision conference SIP server experiments via WINDS satellite. Fig.13 shows our successful results of high-vision video conference via WINDS satellite between Polycom and SONY' cameras using SIP technology.

7. WINDS Ka-band Inteferometer on the YRP Venture building

In the early 2010 we installed and setup the Ka-band Inteferometer as well as VSAT antenna on the roof of YRP Venture building (see Fig.14). The main purpose of the interferometer is the measurement of rain fall attenuation of Ka-band receiving signal from the satellite. The observation hardware

Figure 15. Diagram of High-vision video conference SIP server experiments via WINDS satellite

of the interferometer is double super heterodyne-very normal type using the RF and IF local signals from the rubidium atomic standard as sown in Fig.15. We developed XF type real-time correlation software using dynamic bitsets technology of boost library of C++. Untile now the dynamic bitset technology has been used for mathematical purposes such as for the set theory. Our challenge of the dynamic bitset technology to the engineering of the interferometer is very first one. Our actual achievement of about one-year continuous use of the dynamic bitset technology for real-time signal processing show the long term stability of the technology. The dynamic bitset is very intuitively-plausible and thus suitable for the time domain cross-correlation. The intuitively-plausible codes are usually considered as very sustainable and easy maintenance ones.

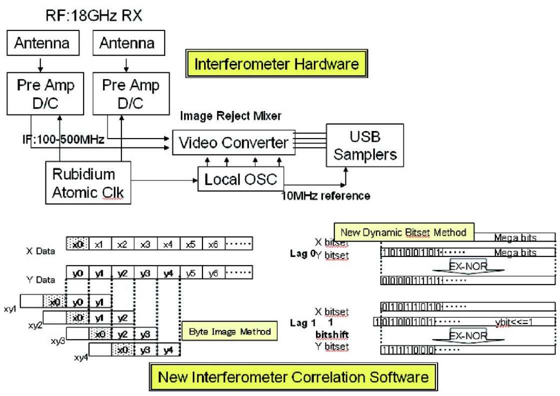


Figure 17. the block diagram of Ka-band interferometer hardware and correlation software

Figure 16. the Ka-band Inteferometer antenna (67cmϕ) on the roof of YRP Venture building

We adopted the fringe stopping method for the data reduction software of Ka-band interferometer as shown in Fig.16. We can get the two kinds of XF type cross-correlation data: the first is the direct converted cross correlation between two antenna data and the second is $\pm 10kHz$ offset cross correlation between two antenna data. By using these data and $10kHz$ rotating we can get the real part and imaginary part of XF correlation data and then we can calculate the phase of correlation and get the precise amplitude of WINDS signals. In generally the level of the weak signal measured by the total power method might be unstable. But using the coherent interferometer method we can improve the S/N and the stability of signal level. Fig. 19 shows one example of the result of the rain fall attenuation of Ka-band signal from WINDS. The results from the interferometer amplitude are coincident well with the Nowcast results from the Meteorological Agency of Japan.

8. The acquisition of first QZS using the software GNNS technology

JAXA succeeded in launching Quasi-zenith Satellite (QZS: "Michibiki") in September 2010. QZS system (QZSS) is the first challenge to improve the GPS positioning accuracy over Japanese islands. QZS's orbital elements are very similar to the usual geostationary satellite and with the adjustments of the inclination and the eccentricity QZS's orbit is very slow and very near to zenith

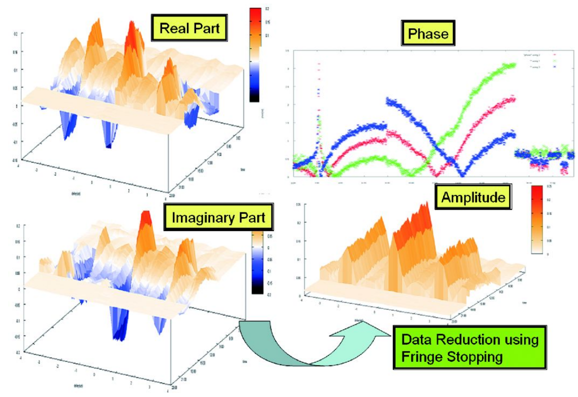


Figure 18. The flow of data reduction of fringe rotation of Ka-band interferometer

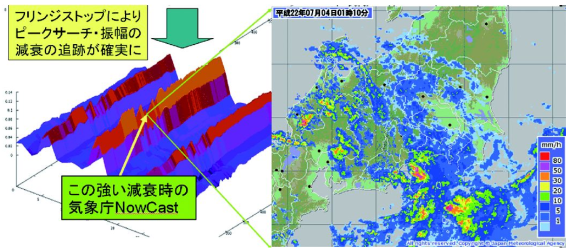


Figure 19. One sample of comparison of the correlation results with Nowcast (Real time Web rain database by Meteorological Agency)

around Japanese islands as shown in Fig.20.

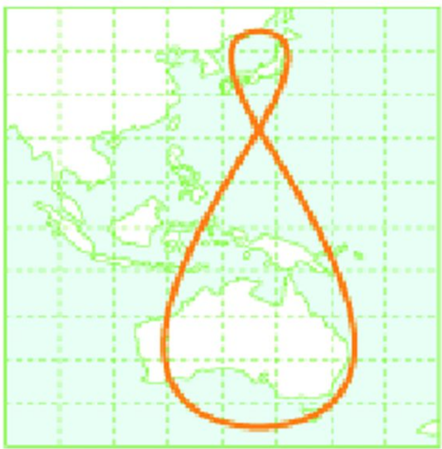


Figure 20. QZS's orbit around Japanese islands and Oceania region

Last fiscal year we already succeeded in the acquisitions of the replica code of the MSAS geostationary satellite. Since the geostationary satellite and QZS are almost same semi-major radius (40,000 km), the signal to noise ratios are about four times smaller than GPS (orbit radius: 20,000 km). Thus we can apply the same system of GNSS and made the modification of the replica acquisitions (see Fig.21).

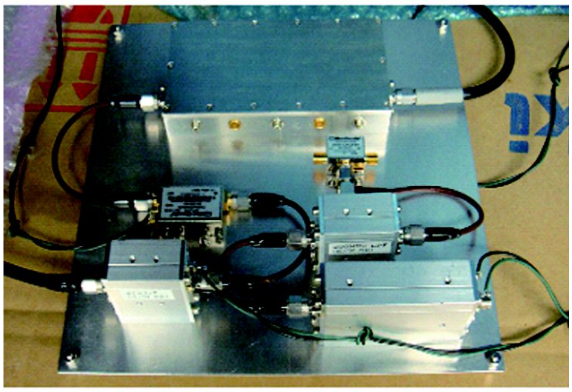


Figure 21. GNSS RX hardware (for QZS and MSAS)

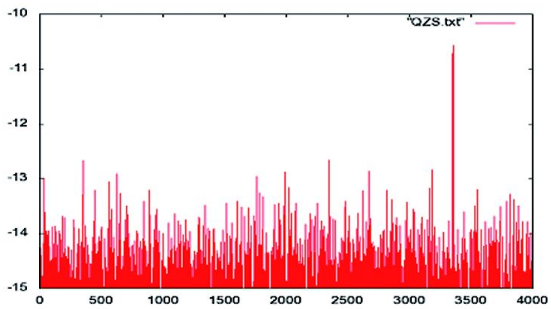


Figure 22. The first acquisition fringe of QZS in December 2010

And we could get the first acquisition fringe of QZS in December 2010 as shown in Fig.22. We are now improving the system more smart using "USRP" and "GNU Radio" software radio technology.

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Success in an X-band VLBI using an RF direct sampling technique

NICT VLBI group has been carrying out a series of test VLBI experiments evaluating the feasibility of a so-called "RF direct sampling" technique with GSI in cooperation with a private company group (TOYO Co., Ltd., ELECS Industry Co., Ltd., Japan Communication Equipment Co., Ltd. (aka "NIT-SUKI"), etc.). In the last experiment carried out on May 12, 2011, RF direct sampling technique was employed at the both ends of the Kashima (11m) - Tsukuba (32m) baseline (Fig.1). ADX-830 developed by the ELECS is a sampler that has an input band width as wide as 30 GHz. RF signals of X-band LNA output are transmitted to an observation room through an optical analog link, and then they are directly sampled by this sampler with a sampling mode of either 2bit-1024Msps or 1bit-2048Msps. Sampled data with a VDIF format are transmitted to a host PC for data storage through 10Gb Ethernet. After observations, Kashima and Tsukuba data are correlated each other by using our software correlator, and fringes were successfully obtained (Fig 2).

(by T. Kondo/NICT Kashima)

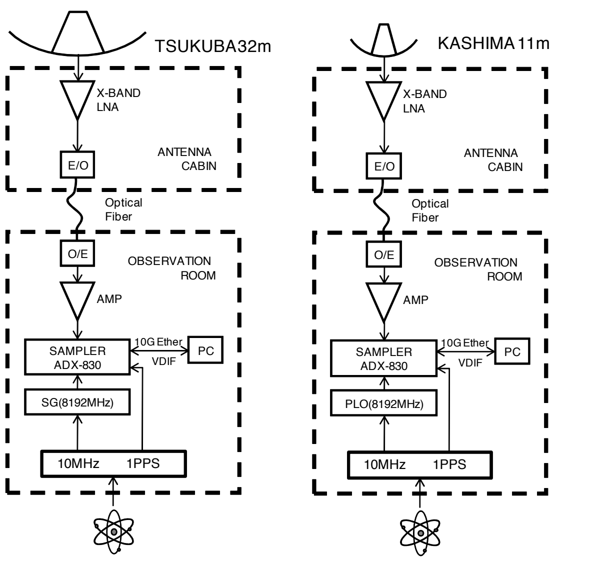

Figure 1. A system block diagram of RF direct sampling VLBI experiment conducted on Kashima-Tsukuba baseline on May 12, 2011.

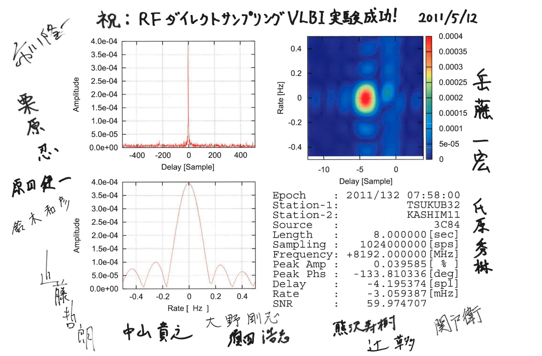

Figure 2. Successful detection of fringes for RF direct sampling VLBI at X-band with signatures of members involved. The sampling mode of ADX-830 is 2bit-1024Msps.

"IVS NICT Technology Development Center News" (IVS NICT-TDC News) published by the National Institute of Information and Communications Technology (NICT) (former the Communications Research Laboratory (CRL)) is the continuation of "IVS CRL Technology Development Center News" (IVS CRL-TDC News). (On April 1, 2004, Communications Research Laboratory (CRL) and Telecommunications Advancement Organization of JAPAN (TAO) were reorganized as "National Institute of Information and Communications Technology (NICT)".)

VLBI Technology Development Center (TDC) at NICT is supposed

1) to develop new observation techniques and new systems for advanced Earth's rotation observations by VLBI and other space techniques,
2) to promote research in Earth rotation using VLBI,
3) to distribute new VLBI technology,
4) to contribute the standardization of VLBI interface, and
5) to deploy the real-time VLBI technique.

The NICT TDC newsletter (IVS NICT-TDC News) is published annually by NICT.

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Summaries of VLBI and related activities at the National Institute of Information and Communications Technology are on the Web. The URL to view the home page of the Space-Time Measurement Group of Space-Time Standards Laboratory is :
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