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New VLBI Observing System 'OCTAVE-Family' to Support VDIF Specifications with 10 GigE for VERA, JVN, and Japanese e-VLBI (OCTAVE)

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Abstract

The new VLBI observing system (OCTAVE-Family) has been designed and developed based on the VSI-H and VDIF specifications at NAOJ (National Astronomical Observatory of Japan). It consists of 1) a high speed 8-Gsps 3-bit ADC (OCTAD) enabling us to acquire not only wide intermediate frequencies but also radio frequencies up to 50 GHz, 2) a converter (OCTAVIA) between one 10 GigE port and four 2 Gbps input and output ports conformable to VSI-H, 3) new recorders (OCTADISK and OCTADISK2) at rates of 4.5 Gbps and above 8 Gbps, and 4) a high speed software correlator system (OCTACOR) using GICO3 which was developed by NICT. These OCTAVE systems are connected via 10 GigE network with VDIF and VSI specifications. These components are used for VERA, JVN (Japanese VLBI network), and KJJVC (Korea-Japan Joint VLBI Correlator).

1. Introduction

NAOJ has been conducting the VLBI Exploration of Radio Astrometry (VERA) project and operating the Optically Connected Array for VLBI Exploration (OCTAVE) [2], [3]. The VERA-terminal includes a gigabit digital filter and a gigabit tape recorder DIR2000 [1]. These systems are currently over 10 years old and are nearing the ends of their expected lifetimes. It will be difficult to maintain these systems over the next decade. Moreover, the VERA project is aiming to observe with higher sensitivity to get more target and calibrator sources. On the other hand, the OCTAVE project which is operated as a sub-array of the JVN has been conducted for eight years with ATM-IP and 10 GbE-IP protocol via Science Information NETwork 3 (SINET3) operated by National Institute of Informatics (NII) and Japan Gigabit Network 2 plus (JGN2plus) operated by National Institute of Information and Communications Technology (NICT). From 2011, NII and NICT have upgraded these network systems to SINET4 and JGN2X. These networks enable us to transmit the data from several Japanese radio telescope stations (Yamaguchi 32-m, Gifu 11-m, Tsukuba 32-m, Kashima 34-m, and Tomakomai 11-m) to Mitaka Correlation Center at up to 8.4 Gbps. Therefore, we have been developing the OCTAVE systems for VERA, OCTAVE, JVN (Japanese VLBI network), and EAVN (East Asian Network). Also, we will upgrade the Raw VLBI Data Buffers (RVDBs) named VDB-2000 for Korea-Japan Joint VLBI Correlator (KJJVC), (e.g., [4]) to OCTAVIA and OCTADISK.

2. Development of OCTAVE-Family

This OCTAVE-Family consists of the following:

- OCTAD (**OCTA**ve A/**D** Converter): High speed RF ($\leq$50 GHz) sampling A/D converter
- OCTAVIA (**OCTA**ve **VSI A**dapter): VSI-H $\Leftrightarrow$ 10 GigE (VDIF) converter
- OCTADISK (**OCTA**ve **DISK** drive): Disk recorder compliant with VDIF specifications
- OCTADISK2 (**OCTA**ve **DISK** drive2): PC recorder using VSREC
- OCTACOR (**OCTA**ve **COR**relator): Gigabit real-time Hardware correlator (VSI-H)
- OCTACOR2 (**OCTA**ve **COR**relator 2): Software correlator system with the GICO3
- VSREC (**V**DIF **S**oftware **REC**order): Sender and Receiver of VDIF packets software

These instruments and software have been developed as a new terminal for VERA, OCTAVE, and JVN. The specifications and photographs are shown in the figures and tables.

2.1. OCTAD

The OCTAD is a high speed A/D converter and is capable of sampling an RF wide-band signal at a sampling rate of 8192 MHz. It was designed and developed for scanning 18 GHz to 26 GHz as a Water-Vapor Radiometer. Direct digital, wide band sampling of the RF signal enables us to eliminate artificial differences between the lower frequency bands that are introduced by the mixers and analog filters in the baseband converter. The InP HBT sampler chips were fabricated by NTT Electronics and were adopted for the development of OCTAD.

2.2. OCTAVIA

The OCTAVIA converts between VSI-H and Ethernet packets based on the VDIF specifications with 10 GigE network. It was originally designed for the OCTAVE-array and data buffer for KJJVC with a capability of converting sustained data rates to 8192 Mbps. In case of e-VLBI usage, it supports variable bit rate transfer control automatically.

2.3. OCTADISK

The OCTADISK was originally designed and developed as the data buffer for KJJVC, with a capability of recording and playing sustained data rates up to 4096 Mbps in 2006. In 2009, we modified it for use as a new recorder for VERA and JVN. The data rate was increased to 4608 Mbps in order to simultaneously observe broadband streams for continuum sources and three narrow bandstreams (one at $\leq$ 0.5 Gbps and two at 2 Gbps) for maser sources.

The OCTADISK2 sends and receives VDIF packets using VSREC for OCTAD, OCTAVIA, and VDIF-compliant system. The VSREC is similar to using KVTP-lib [5]. In addition to functioning like KVTP-lib, OCTADISK2 supports RTCP (Real-time Transport Protocol) to connect and operate OCTAVIAs. It is under development, and a prototype has been released. It can record data streams through 10 GigE ports at a rate above 8192 Mbps. The recorded data are stored in a RAID disk array on the Standard Linux File system which various software correlators, that are compliant with VDIF specifications, can access directly.

2.4. OCTACOR

The OCTACOR is a three-station hardware XF correlator for real-time e-VLBI. This correlator system can process three pairs of 2048 Mbps data streams with a lag length of 256 bits. This correlator was developed starting in 2000, and it obtained its first fringes in 2002.

The OCTACOR2 is a software FX correlator. This correlator system consists of the main correlation software named GICO3 developed by NICT, pre- and post-processing software, and operating software. This correlator can accept various file-formats (K5-VSI [6], Mark 5B, and VDIF). There is no hard upper limit on the number of spectral points, antennas, and output rate. The correlation speed is about 200 Mbps in the case of processing seven-station data recorded at 1024 Mbps (Xeon, 3.47 GHz dual processor).

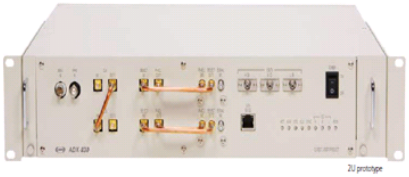

Figure 1. OCTAD.

Figure 2. OCTAVIA.

Figure 3. OCTADISK.

Figure 4. OCTADISK2 (prototype).

3. Configuration of OCTAVE-System

Figure 5 shows a schematic view of a configuration of the OCTAVE-Family and other systems as an example. Because these devices are compliant with VSI-H and VDIF specifications, it is possible to connect them. Actually, in VERA, several JVN sites, and Mitaka Correlation Center, high speed A/D sampler ADS1000 or ADS3000+ [6], OCTAVIA, OCTADISK, Mark 5B and software and hardware correlator (OCTACOR1,2) were installed and have been operating. At KJCC (Korea Japan Correlation Center), we installed four OCTAVIAs and sixteen OCTADISKs (Server version) for a data buffer of KJJVC which is used for storing data from tapes and Mark 5B VERA, JVN, OCTAVE and other arrays (e.g., KVN, CVN, and EVN using Mark 5B).

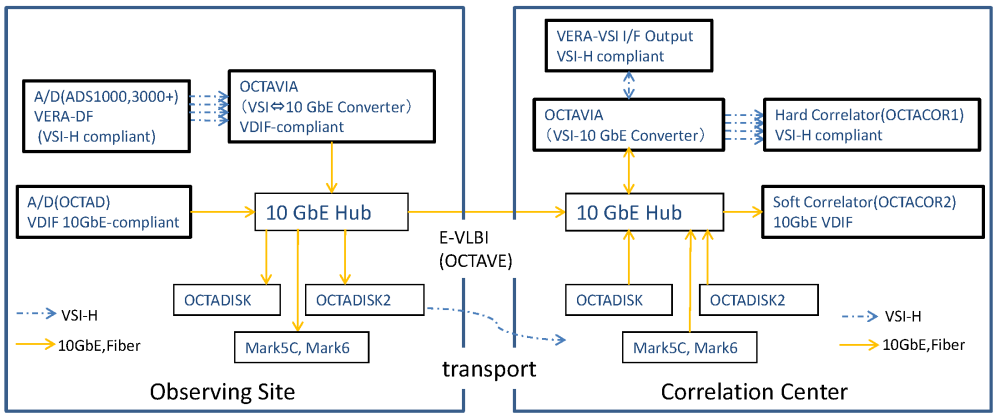

Figure 5. Diagram of OCTAVE-Family.

Table 1. Specifications of OCTAD.

	OCTAD
Sampling Clock	8192 MHz (fixed)
Input Freq	Up to 50 GHz
Quantization Bit Length	3
Output rate	8192 Mbps × 3
Output	SFP+, 10 GigE × 3
Output Format	VDIF

Table 2. Specifications of OCTAVIA.

	OCTAVIA	**OCTAVIA2**
Number of VSI-H ports	4+4 (Input and Output)	4 (Input or Output)
Number of 10 GigE ports	1 (XFP, SC, LR)	1 (SFP+, SR, LR, ER or ZR)
Data rate (VSI-H)	1024 or 2048 Mbps	1024 or 2048 Mbps
Time Code	PDATA, QDATA	PDATA, QDATA
VBR Function	128 steps (variable)	None
Data protocol	VDIF	VDIF
Software Interface	VSI-S	VSI-S
Release	2009 -	2012 -

Table 3. Specifications of OCTADISK.

	OCTADISK	**OCTADISK2**
I/O	10 GigE-LR (XFP)	10 or 40 GigE (SFP+ or T)
Recording rate	4608 Mbps	$\geq$ 8192 Mbps
Playback rate	4608 Mbps	$\geq$ 8192 Mbps
Number of Disk Units	12 + 12	according to need
Total Recording Time	50 hours@2Tbyte HDD, 2 Gbps	arbitrary
Data Format	VDIF	VDIF, K5, or Mark 5/6
Software Interface	VSI-S	Original, (VSI-S)
Release	2009 -	2011 - (Prototype)

Table 4. Specifications of OCTACOR.

	OCTACOR	**OCTACOR2**
Architecture	XF	FX
Station number	3	no limit
IF number	1 or 16	1, 2, 4, 8, 16
Data rate per IF	32, 1024 Msps	32, 64,,, 2048, 4096 Msps
Quantization	1 or 2 bit	1 or 2 bit
FFT size	256	$\leq$ 4M
Integration period	0.1 or 1.0 sec	arbitrary
Correlation speed	Real time	200 Mbps *
Data Input	VSI-H	VDIF, K5, or Mark 5/6
Archive	FITS	CODA, FITS
Release	2002 -	2011 -

* 1 Gbps recording data, seven stations using one PC (Xeon 3.47 GHz Dual Processors)

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