A VSI-compliant 2Gsps DAS for Spacecraft Differential VLBI

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1. Abstract

A VSI-compliant, 2048-Msps(2048 Mega samples per second) data acquisition system (DAS) has been developed. The DAS, named ADS-3000, is upward compatible with ADS-1000, previous-generation 1-Gsps DAS used for wide-bandwidth astronomical observations. This new DAS has two VSI-H output ports and each operates at a clock frequency of 32MHz or 64MHz. Thus maximum output rate reaches 4096 Mbps. In the DAS, 8-bit digitalized data with a 2-Gsps,10-bit A/D converter (Fig.3) are sent to FPGA device (Xilinx XC2VP40) to be processed. This 16-Gbps input data are decimated with the FPGA and VSI-compliant output is selectable from 2Gsps/2bit, 1Gsps/4bit, 512Msps/8bit, 256Msps/8bit, or 128Msps/8bit. FPGA code is easily rewritable by using compact flash cards so that it can be used for multiple applications such as digital baseband converter for multi-channel geodetic VLBI, software demodulator for spacecraft downlink signal in spacecraft VLBI or satellite communications, or spectrometer for broadband astronomical observations. Price per unit is less than ¥3,000,000 (Depends on the number of units needed).

2. Specifications

Dimension: 88.1mm(H) x 482.6mm(W) x 430mm(D)
Power supply voltage: AC100V-230V
PLO phase noise: 100Hz-up to 70dBM/Hz, 1kHz-up to 80dBm/Hz,
10kHz-up to 90dBm/Hz, 100kHz- up to 110dBm/Hz
A/D performance
•A/D input: 0V±250mVp-p(50Ω), Sampling rate 2048MHz (fixed)
•3.3GHz full power input bandwidth(-3dB)
•Gain flatness:±0.2dB(from DC up to 1.5GHz)
•Low input VSWR: 1.2 Max From DC to 2.5GHz
•SFDR = -54dBc; 6.5 Effective Bits at Fs=2 Gsps, Fin=2GHz[-1 dBFS]
•Low bit error rate (10e-12) at 2Gsps

Fig 1:Front view of ADS-3000

Fig 2:Rear view of ADS-3000. FPGA code is easily rewriteable with a compact flush card, or an Ethernet port, which will be equipped after the next upgrade. 2048-MHz PLL-output port and 2048-MHz input port are directly connected in most cases. 2048-MHz reference signal can be distributed to other units by using these ports.

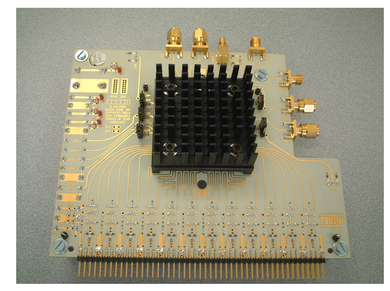

Fig 3: 2Gbps/10bit A/D device (Atmel TS83102G0B)

Total rate	Sampling rate	# of bits	VSI-H clock rate	Output port
1Gbps	128MSps	8	32MHz	VSI1
2Gbps	1024MSps	2	32MHz	VSI1+VSI2
2Gbps	512MSps	4	32MHz	VSI1+VSI2
2Gbps	256MSps	8	32MHz	VSI1+VSI2
2Gbps	256MSps	8	64MHz	VSI1
4Gbps	2048MSps	2	64MHz	VSI1+VSI2
4Gbps	1024MSps	4	64MHz	VSI1+VSI2
4Gbps	512MSps	8	64MHz	VSI1+VSI2

Table 1. Selectable output modes

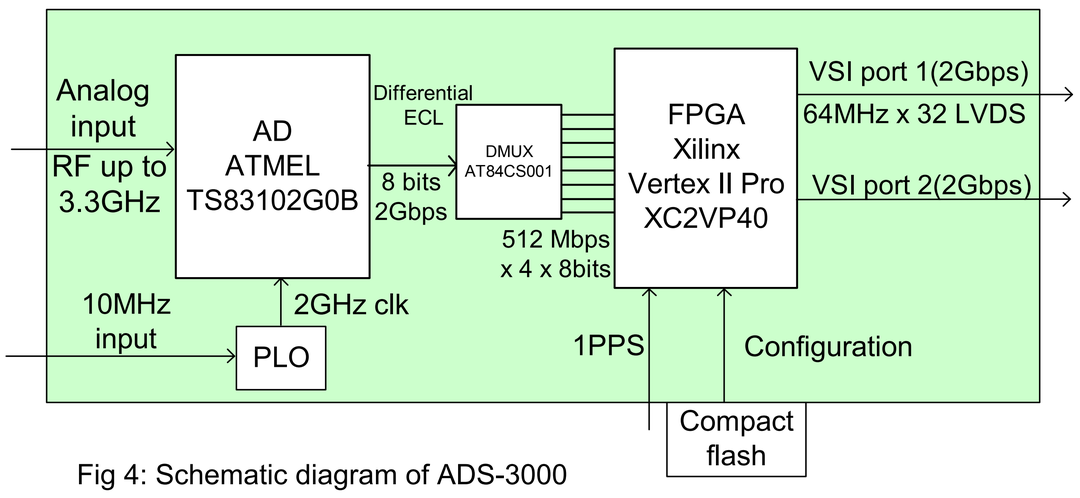

Fig 4: Schematic diagram of ADS-3000

3. Applications

By configuring FPGA, various applications will be possible (see Table 2). Some applications can be realized with free IP-cores distributed by FPGA vendor (Xilinx). Digital baseband converter (DBBC) is one of the most useful applications, which substitutes the conventional multi-channel analog baseband converters. It is also useful in differential VLBI observations for spacecraft navigations. In the observations, target source is switched between spacecraft and phase-reference QSOs in order to cancel out phase variations. To ensure a sufficient number of phase-reference QSOs near the spacecraft, wide-bandwidth IF sampling is effective. On the other hand, DBBC is useful for the observations of spacecrafts because the bandwidth of the spacecraft signals is very narrow. Using the software BBC system, total data size can be reduced and the signal-to-noise ratio of the data can be improved for the narrowband spacecraft signals. Because the phase relationship is preserved through the baseband conversion processes, we can use wideband quasar signals as phase reference for narrowband spacecraft signals.

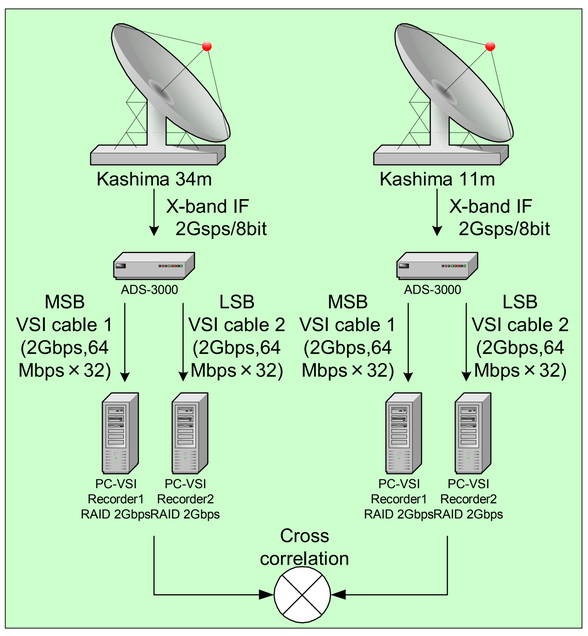

Fig5. Schematic diagram of recording system for the 4-Gbps VLBI experiments

Application	Available IP-core
DC-cut, RFI mitigation	Subtractor, or FIR filter
DBBC	DBBC,FIR filter, DDS
Spectrometer	FFT
Format converter (K5,MarkV,…)	CRC, etc.
Dispersion compensator for pulsar observations	FFT
Wide-band P-cal detector	FFT
Software receiver for satellite communications	FIR filter, DBBC

Table 2. Expected applications

4. Observations

The first-ever 4-Gbps VLBI fringe was successfully detected (Fig.6) in the HAYABUSA spacecraft navigation differential VLBI experiments performed on November 25, 2005. Two-sets of PC-VSI recorders were used at each station (Fig.5). While 4-Gbps (2Gsps/2bit) of wide-bandwidth sampling mode was used for the scans for reference quasars, 512-Mbps/8bit mode was used to capture the high-SNR signals from HAYABUSA spacecraft.

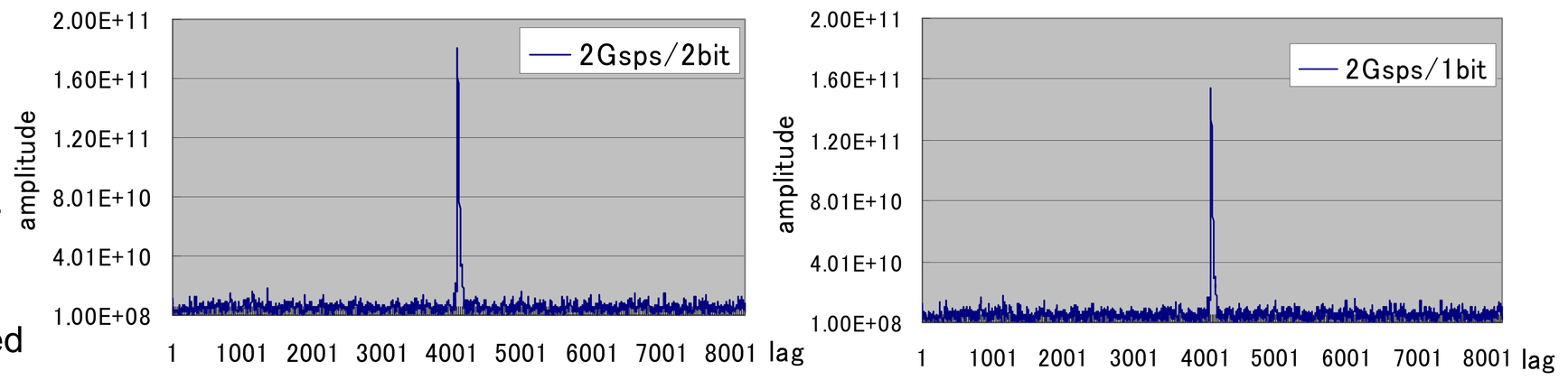

Fig 6: The first-ever 4-Gbps fringes between Kashima 34m – Kashima 11m at X-band observation toward 3C273B on November 25,2005. Integration time is 4s. The over-sampling factor is 2, because the current IF bandwidth at Kashima 11m station is limited to 500MHz. A correlation amplitude with 2-bit correlation was 119% of that with 1-bit correlation (using only the MSB data). This is consistent with the theoretical value of 124%(= 0.935/0.744).