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# Wide-band Data Transmission System Expected in the Next Generation Space VLBI Mission: VSOP-2

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## Abstract

Following the success of the VLBI Space Observatory Programme (VSOP), a next generation space VLBI mission (VSOP-2) is currently being planned. We expect the data rate of more than 1 Gbps to get more sensitivity. Here we will present: 1) How to sample the data (on board), including the radiation test results which show we can have the 10 Gbps sampler LSI which can use in space. 2) Possibility of the bit rate more than 1 Gbps to downlink the VLBI data. We studied the link budget for the wide band data transmission, and discussed the various ideas which can get more than 1 Gbps. 3) What kind of VLBI tracking station and recording system will be expected for the VSOP-2 mission? We will present the idea of using normal radio telescopes as a tracking station, and also review the possibility of recording and processing at the tracking stations and correlators.

## 1. VSOP-2 Mission

The overview of the VSOP-2 mission has been shown by Hirabayashi et al. (2002) [1] in this symposium. Here is the summary of the VSOP-2 mission and the comparison with the VSOP mission [2].

Table 1. Comparison of the VSOP, VSOP-2 and the options.

| | VSOP | VSOP-2 | (options) |
|---|---|---|---|
| Antenna Diameter | 8m | 10m | 10 ? 15 m |
| Apogee Height | 21,500 km | 30,000 km | 40,000 km |
| Period | 6.3 hours | 8.9 hours | 12.2 hours |
| Polarization | LCP | LCP/RCP | |
| Downlink bit rate | 128 Mbps | 1 Gbps | 1 – 4 Gbps |
| Observing Bands (GHz) | 1.6, 5, (22) | 5 or 8, 22, 43 | 5 to 8, 86 |
| Maximum Resolution | 0.3 mas | 0.025 mas | |
| Typical Sensitivity | 140 mJy | 12 mJy (5 GHz, 25m GRT) | |
| Launch | 1997 February | 2009 | |

We studied the mission based on so-called *basic* design. It is also useful to study the possibility of the various extension of the mission, shown in the (options) column. Main target of the data transmission rate in the *basic* design is 1 Gbps, but now we try to find the possibility of the link more than 1 Gbps. We also try to find the possibility of the options.

## 2. On-board Data Sampling

When we design the space VLBI mission, we select the ellipsoidal orbit, which is more severe environment than that in LEO, or geo-stationary orbit. We must consider carefully about the radiation effect of the space environment. We can use space-qualified parts for the units/parts of the spacecraft.

When we design the on-board observing system of the satellite one of the problems is whether we can have a space-qualified high speed sampler to get the digital data adequate to the high bit rate link. If we assume the bit rate of 1 Gbps, and 2 bit sampling mode, the maximum total IF bandwidth will be 256 MHz (cf. HALCA, 32 MHz @ 128 Mbps downlink rate). It is difficult to make a video converter with more than 50 MHz bandwidth. The solutions to sample a 256 MHz bandwidth are to split into 8 - 16 IF channels, or to use the over-sampling technique to get the wider bandwidth sampling, which is used for the VSOP terminal A/D converter [3]. Many IF channels are not good for the satellite to make the smaller and lighter circuit. We need more than three times faster sampling speed than for the normal bandwidth. Because we will make the polarization observation, we will have the two IF channels. This means we need the sampler to work at more than 768 Mbps. This number will be 1536 Mbps in case we can do 2 Gbps downlink. We do not know of a space-qualified sampling LSI with such a high speed in this time.

We tested the sampler LSI and 1:16 demultiplexer LSI (figure 1), which work with 10 Gbps speed maximum, in the simulated space radiation environment [4]. We simulate the total dose environment up to 1000 k rad, which corresponds to a total dose of about 30 years with HALCA orbit. We also made a heavy ion radiation test to simulate the single event phenomena in space (figure 2). We can know that as least those LSI's are possible to use the future space VLBI mission.

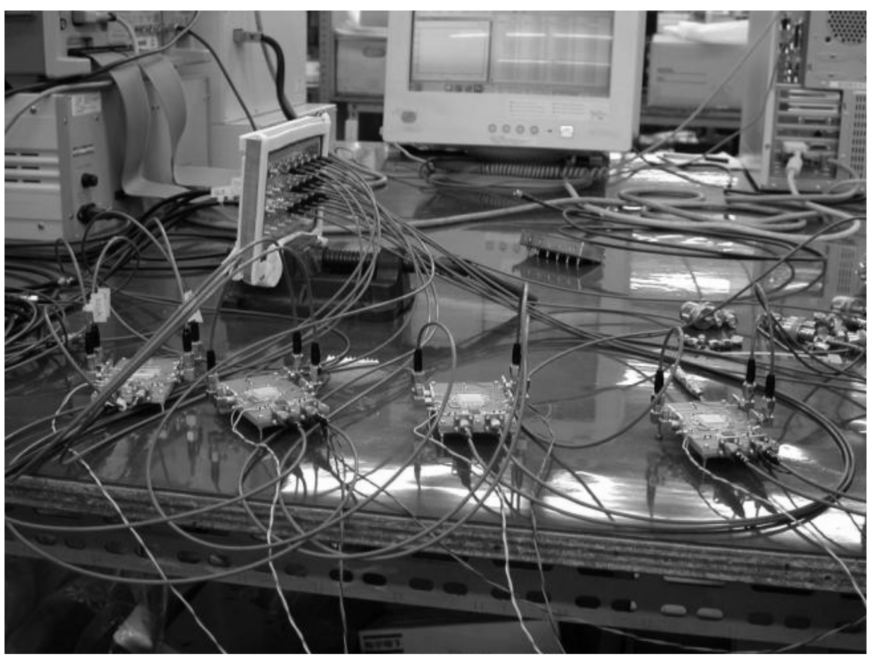

Figure 1. 10 Gbps 1 bit A/D LSI and 1:16 demultiplex LSI, configured for the radiation test

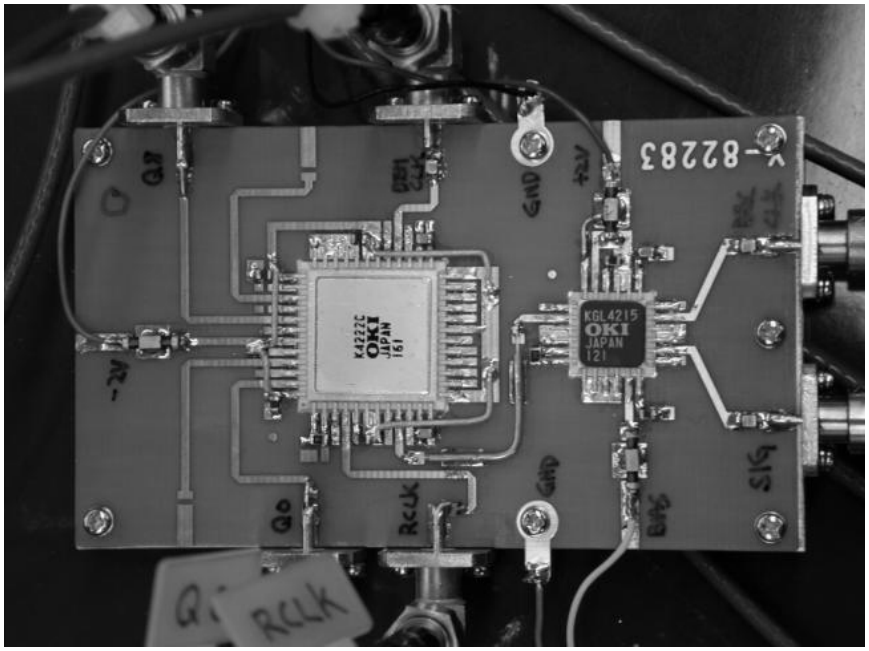

Figure 2. The single-event radiation test configuration. The tested LSI is set in the vacuum chamber, and the heavy ion beam is radiated.

Based on these tests, we think we can design the larger bandwidth IF channels, at least 256 MHz, which have the benefit to make the onboard wideband digital system simpler. Currently, we designed to have two IFs with the total data rate of 1 Gbps, total bandwidth of 128 MHz per IF, which will be sampled with 2-bit mode. If the downlink of the spacecraft allow us to have 2 Gbps, we will make the IF bandwidth twice.

## 3. The High Data Rate Link

One of the technical problems for the VSOP-2 mission is the high speed data link between the spacecraft and ground stations. We realized the bandwidth of 128 Mbps with HALCA. Uplink signal to the VLBI spacecraft is a tone signal locked to the hydrogen maser reference. We also have the round trip frequency offset change information to measure the time offset between the groud tracking station and the spacecraft.

Downlink requires a wideband signal. HALCA was allocated 14.2 GHz $\pm$ 64 MHz for the 128 Mbps downlink. When we make the target of more than 1 Gbps data transmission, it is difficult to use Ku band. This is because we have no uplink frequency allocation for space research use at Ku band, and downlink allocation bandwidth is not enough for the wider bandwidth.

Possible frequency for the $>$ 1 Gbps downlink will be the band of 37 – 38 GHz with selecting current frequency allocation table for the telecommunication and the radio observation. Uplink will be 40 GHz. Though the antenna gain will be larger with the higher frequency, wider bandwidth transmission requires more signal to noise ratio, and the rain attenuation of the signal is estimated to be 15 - 25 dB (based on various conditions) maximum. We need larger transmission power (about 20 W) in onboard transmitter, and the larger ground station antenna (larger than 15 - 20 m class antennas).

Springett and Smith (2001) [5] proposed the idea that we use the radio telescopes for receiving the wideband data. We can separate the functions of the time-keeping and the data transmission of the spacecraft. The time-keeping needs the uplink and the round trip timing measurement functions at the tracking station. This is a narrow band system and 3-5 m antenna is enough to establish the timing link. On the other hand, the data transmission needs only the receiving function. If we replace the VLBI sampler with the demodulator of the downlink signal at the VLBI station, we can use the telescope as the downlink station of the space VLBI spacecraft. We need to add the tone signal for the timing link to the wideband signal transmitted from the spacecraft.

We assume QPSK modulation (same as HALCA modulation) for the 1 Gbps data transmission. If we want to have wider bandwidth, we need to have n-PSK (or n-QAM, n-QASK) modulation, where integer $n > 4$. When we try to get 2 Gbps data transmission, we need to have 6-7 dB more link budget to get enough signal to noise ratio for the demodulation.

Current target data rate of the VSOP-2 mission is 1 - 2 Gbps. We have already had the experimental VLBI system recording and correlating with this bandwidth. We think it is easier to have the wideband recording/correlating functions at the time of VSOP-2 launch. There is the possibility to use the disk and the optical link for the next mission.

## 4. Concluding Remarks

We are investigating the many possibilities to the backend of the VSOP-2 mission. We have many techinical issues to confirm, but we think we do not have the major dificulty to realise the VSOP-2 data transmission, except for the budget cap for the mission.

## 5. Acknowledgements

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