Standard Scientific Interface Connecting Radio Telescopes In Japan and Finland

The first-ever observation

"Radio Telescope star tracking, OK!"
The Finland group responds that they are also ready.
"No interference, radio spectrum is good."
"Data capture, start!"

The first attempt to connect radio telescope observations in Finland and Japan started with the radio astronomers in an atmosphere of tension. Almost instantly, a multiple-thread-network file transfer from Finland started to generate tens of gigabytes of data in Japan. Simultaneously, data processing to find a common radio star signal buried under receiver noise had begun.

Radio telescopes left behind in network connection

The Internet and high-speed networking have brought about great changes in scientific measurements and data transfers between countries. Yet, use of radio telescopes and the data collected in this way had fallen behind in benefiting from these advances. Using large parabolic dishes at widely separated VLBI (Very Long Baseline Interferometric) sites, the high-resolution observation of objects in the sky required continuous 256-Mbps transmission. Modern sensitive observations require speeds of more than 1 Gbps for data. The speeds far exceeded the bandwidth capacity allowed for an individual Internet user.

Data compression cannot be applied to noise data from the sky, and no method existed for storing the huge amount of data. Thus, for a long time only tape media served to exchange the observed data, and this took up time after observations and involved shipping costs.

Another difficulty existed in the telescopes themselves. The development of radio telescopes resulted in the instruments having different digital interfaces from country to country. Astronomers and engineers have been trying to convert the gathered data over different media, but this effort is more difficult when the amount of observation data exceeds several T-bytes.

Versatile Scientific Interface

VLBI observation of radio stars is conducted due not only to a pure astronomical interest in the distant radio galaxies, such observation also plays a role in determining the Earth Orientation Parameter (EOP) and Universal Time (UT) by using these distant objects as reference points. To achieve compatibility between telescopes, international researchers agreed to establish a scientific interface in 2000. The International VLBI Service (IVS), an organization under the auspices of the International Astronomical Union (IAU) and the International Geophysical Union (IGU), defined a standard interface. The MIT Haystack Observatory, the Communications Research Laboratory (CRL), and other institutes drew up the specifications. After researching existing interfaces, none available were found to be adaptable to our objective. Eventually, researchers found and agreed upon a unique interface.

The autumn issue of New Breeze 2001 (pages 26-27) presents the VSI interface in detail. After one year of discussions, the interface was named the VLBI Standard Interface (VSI). The VSI interface of LVDS (Low Voltage Differential Signal) handles Gbps and higher data rates, can determine data epochs, indicates instrument status, and generates test signature vectors to maintain compatibility between systems. Such one-directional continuous data flow is common in radio telescope observation, as well as in other scientific observations.

In Japan, the CRL and the Telecommunications Advancement Organization (TAO) in a joint project have promoted acceptance of the Versatile Scientific Interface since 2001. The CRL completed a Gbps AD sampler adapted to VSI, and the TAO completed a VSI data recording terminal (Fig. 1) designed around PC technology to establish mutual compatibility.

The joint observation of Japan and Finland

Another group that achieved a VSI hardware instrument, the Helsinki University of Technology (HUT), in Finland proposed to us the first VSI-based compatibility test in early 2002. Located near the Nokia Corporation, this skilled group belonging to the university observatory had quickly completed an instrument according to the standard specification.

The 14-m radio telescope of the Metsahovi Radio Observatory and the 34-m radio telescope at the Kashima

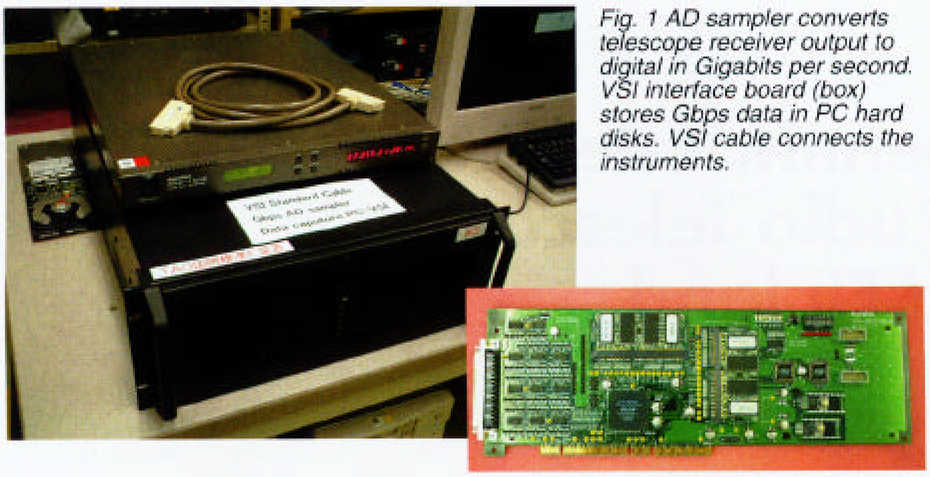

Fig. 1 AD sampler converts telescope receiver output to digital in Gigabits per second. VSI interface board (box) stores Gbps data in PC hard disks. VSI cable connects the instruments.

Space Research Center of the CRL are being used in this observation (Fig. 2). In the initial experiment, we used the CRL Gbps AD sampler at both sites. The Japanese AD sampler and Finnish data capture system started work immediately after the hardware was connected. This was a moment that filled us with admiration for the power of standardization. In former decades, in addition to the difficulty of achieving a scientific target, research groups had to work separately before starting observations.

Via the Internet, we aimed the linked telescopes to achieve the world's first cooperative radio star detection. Usually, the first observation with a new combination of telescopes is highly complicated since the geophysical parameters that are required to process the data are unknown. The projected distance of 6400 km between the two countries against the star increased the difficulties. Furthermore, 22 GHz, the only common frequency between the telescopes, is easily affected by weather. Despite these conditions, we successfully and quickly correlated a part of the Gbps data after the observations.

Figure 3 shows the correlated peak from the radio star W3OH. Radio star generated noise buried in other system noise was successfully found by searching the data from the two telescopes.

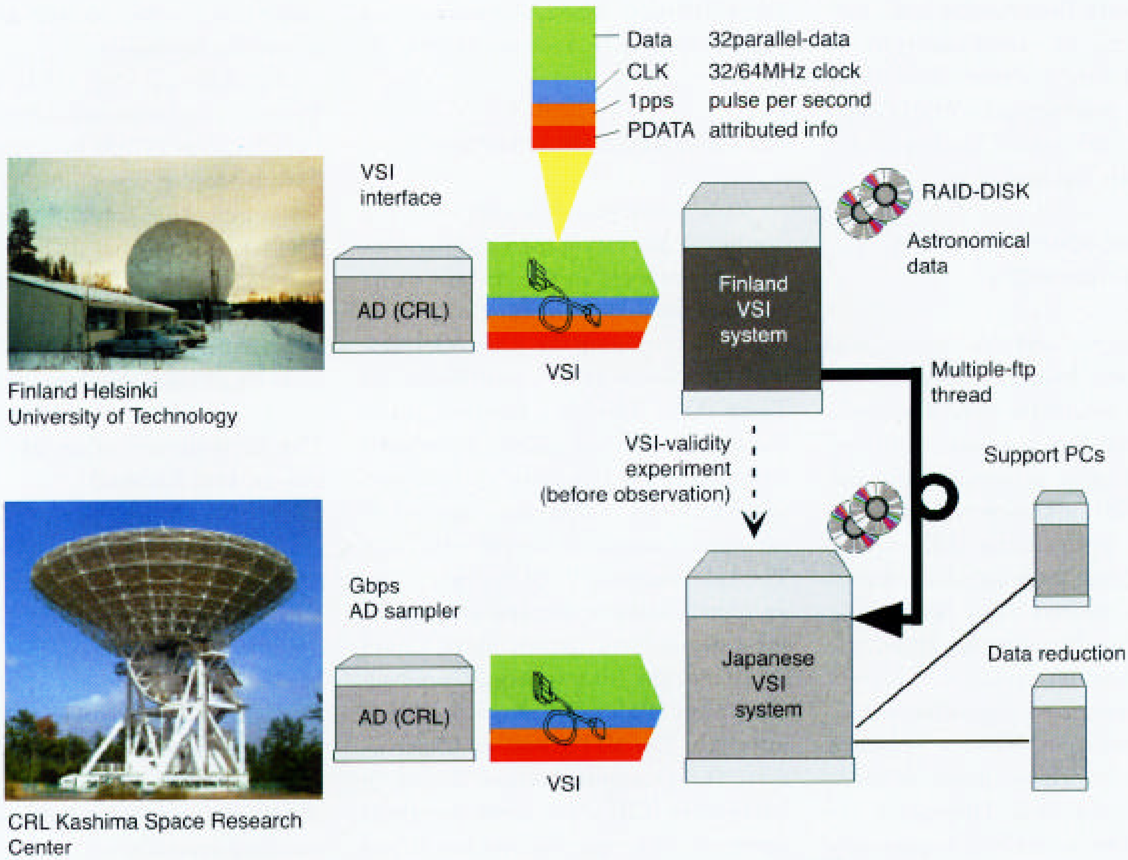

Fig. 2 International observations made use of the standard interface. Reliable data from VSI interface is transferred directly to Japan over the Internet.

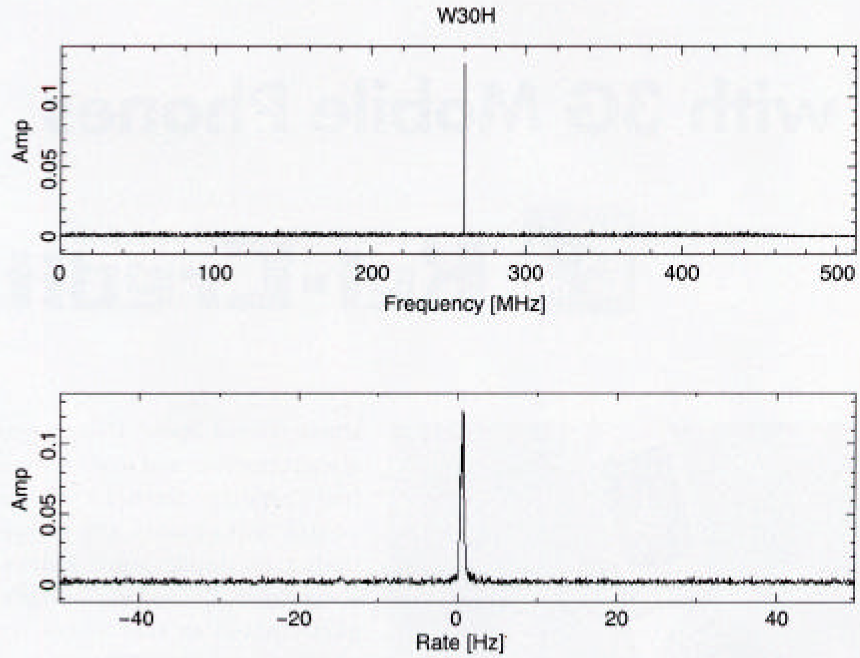

Fig. 3 Resultant data spectrum from W3OH (top), the massive star-forming region in Cassiopeia. Down-converted stellar water masar emission appeared at 260. Doppler residual (lower) appeared around zero. This proved predicted observation parameters were correct. Astronomers will extract information about the physical object by gathering these interferometric outputs.

We introduced high-speed correlation software for the search. However, the key to the experiment's success was the standard interface because it eliminated unknown instrumental parameters and the need for data conversion. Without doubts as to data validity, researchers could concentrate on using the scientific data.

Now, the PC-based VSI data acquisition system is used to store the Gbps data in a RAID system. The system serves as a huge data buffer forwarding the data to destination sites, and it is adapted for network capability without media transport. The world may be surprised by the sudden appearance of this network-based Gbps observation from a new combination of assets shared between continents. The VSI and network environment achieved exactly this.

Global radio telescopes in future

In the near future, we expect researchers will adapt most of the radio telescopes in the world to the VSI interface. Through worldwide telescope compatibility, scientists will see further possibilities in a global radio telescope network. For example, searching for a missing spacecraft in deep space will be enabled by joint apertures. Continuous observation of a sporadic astronomical event, such as a star burst, could be handled by telescopes on the opposite sides of the earth.

The observational assets of ground facilities will be used more efficiently (Fig. 4). On the engineering side, one of the applications being considered is use with small communication dishes. A small communication dish that is inadequate on its own to calibrate a radio star can be supported by large-dish data from the network. In addition, the noise data of astronomical sources can be used for testing instruments used in network communications. The infinite random data of radio telescope reveals instrumental reliability and can even be used for network cryptology.

The observation conducted by Finland and Japan is an initial step toward these possibilities.

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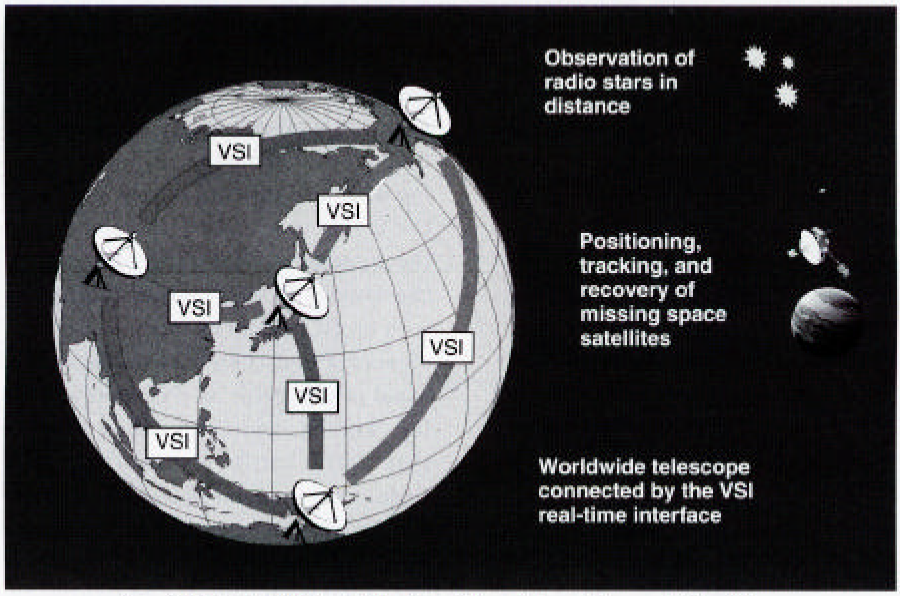

Fig. 4 Expected international collaboration scheme in the future. Telescope resources located around the world will be linked by VSI interface and high-speed network connections.