

## The First Experiment with VLBI-GPS Hybrid System

Younghee Kwak <sup>1</sup>, Tetsuro Kondo <sup>2</sup>, Tadahiro Gotoh <sup>2</sup>, Jun Amagai <sup>2</sup>, Hiroshi Takiguchi <sup>2</sup>, Mamoru Sekido <sup>2</sup>, Ryuichi Ichikawa <sup>2</sup>, Tetsuo Sasao <sup>3</sup>, Jungho Cho <sup>4</sup>, Tuhwan Kim <sup>5</sup>

<sup>1)</sup> *Ajou University / Korea Astronomy and Space Science Institute*

<sup>2)</sup> *Kashima Space Research Center, NICT*

<sup>3)</sup> *Yaeyama Star Club*

<sup>4)</sup> *Korea Astronomy and Space Science Institute*

<sup>5)</sup> *Ajou University*

Contact author: Younghee Kwak, e-mail: [bgirl02@kasi.re.kr](mailto:bgirl02@kasi.re.kr)

### Abstract

In this paper, we introduce our GPS-VLBI hybrid system and show the results of the first experiment which is now under way. In this hybrid system, GPS signals are captured by a normal GPS antenna, down-converted to IF signals, and then sampled by the VLBI sampler VSSP32 developed by NICT. The sampled GPS data are recorded and correlated in the same way as VLBI observation data. The correlator outputs are the group delay and the delay rate. Since the whole system uses the same frequency standard, many sources of systematic errors are common between the VLBI system and the GPS system. In this hybrid system, the GPS antenna can be regarded as an additional VLBI antenna having multiple beams towards GPS satellites. Therefore, we expect that this approach will provide enough data to improve zenith delay estimates and geodetic results.

## 1. Motivation

Combination of space geodetic techniques has been one of the fundamental issues in the IERS. Especially, the effective combination of the VLBI and GPS techniques is expected to solve the largest difficulties in current VLBI geodesy: the wet delays and clock offsets [4][5]. There have been several suggestions along this line [1][4][5][6][7][8]. In this study, we observationally tested the feasibility of the newly proposed observation-level combination technique, GPS-VLBI (GV) hybrid system [4][5] (Figure 1).

## 2. Concept

In the GPS-VLBI hybrid system, VLBI antennas observe quasars just like in a usual geodetic VLBI session. The GPS L1 and L2 signals are received by commercial GPS antennas, down-converted to video-band signals, and then sampled by VLBI samplers. The sampled GPS data are recorded as ordinary VLBI data by VLBI recorders and correlated by a VLBI correlator [4][5]. Observed group delay and delay rate from quasars and GPS satellites are analyzed following the usual VLBI analysis scheme. Thus we can expect to minimize various systematic errors between the two techniques.

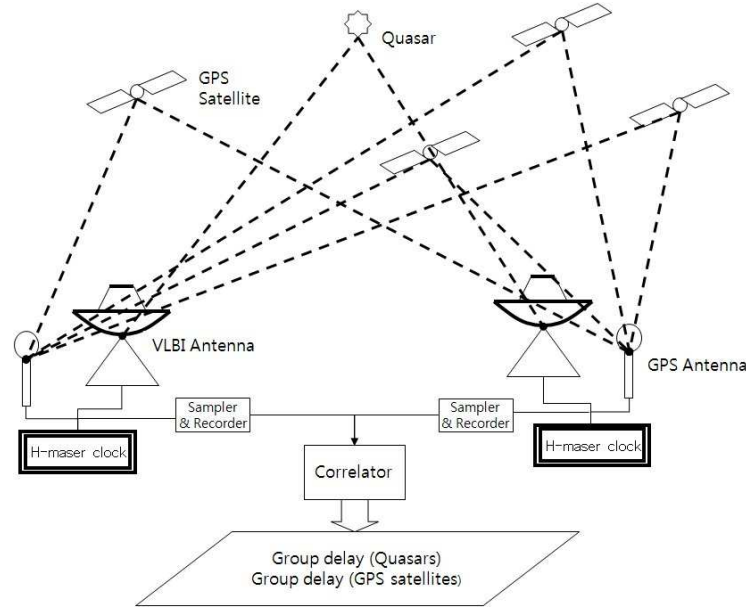


Figure 1. Concept of the GPS-VLBI Hybrid system.

### 3. Test Experiment of the GPS Part of the GV Hybrid System

Before the GPS-VLBI hybrid observation, we conducted a test experiment to verify that VLBI type observations of GPS satellites can be realized.

#### 3.1. Settings

The test experiment was held at 06:19:00-06:20:00 (UTC) on September 9th in 2009 between Kashima and Koganei, Japan. The baseline length was about 110 km. The signal of each GPS satellite was received together in 32 MHz bandwidth covering 20.46 MHz GPS bandwidth. There were eight satellites above 15 degree cut-off elevation angle.

We used commercial GPS antennas, specially developed GPS down converters (see below), VSSP32 [3], and a software correlator [2] developed by NICT.

#### 3.2. New GPS Down Converter

In a conventional GPS observation, the whole procedure from receiving signals to generating GPS data is accomplished in a normal GPS receiver. In order to record GPS signals with a VLBI system, we need to convert the GPS L1 (1575.42 MHz) and L2 (1227.6 MHz) signals to input signals for the VLBI sampler. One of the authors, J. Amagai, designed a special GPS converter system for this purpose. The outputs of the converter system are 75.42 MHz and 77.6 MHz signals for L1 and L2, respectively, with 32 MHz bandwidth each.

### 3.3. Results

As correlation results for 1 minute integration time, we simultaneously obtained clear fringes (Figures 2, 3) from all eight satellites above 15 degree cut-off elevation angle. If we approximate the GPS signals by white noise for simplicity, 87.5% and 12.5% of resultant signal-to-noise ratios (SNR) for L1 and L2 signals, respectively, already reach the typical VLBI group delay precision of 0.1 nsec.

### 4. Future Work and Perspectives

These results show that VLBI type observation of GPS satellites is readily realized in the GPS-VLBI hybrid system. Based on this test experiment, we successfully performed a 24-hour GPS-VLBI hybrid observation last December. The data are now in the correlation stage. After correlation, we will develop an analysis model for GPS satellites.

We expect the GPS-VLBI hybrid system to contribute to the following aspects:

- Better estimation of wet delays by using a large amount of GPS data,
- Better estimation of clock offsets by using identical H-maser clocks for both GPS and VLBI observations,
- Observation-level combination of space geodetic techniques,
- Direct connection of GPS satellite orbits to the International Celestial Reference Frame [1][4],
- Better UT1 determination using GPS [4][5],
- Connection of the origin of VLBI Terrestrial Reference Frame (TRF) with the Earth center of mass position [1].

### References

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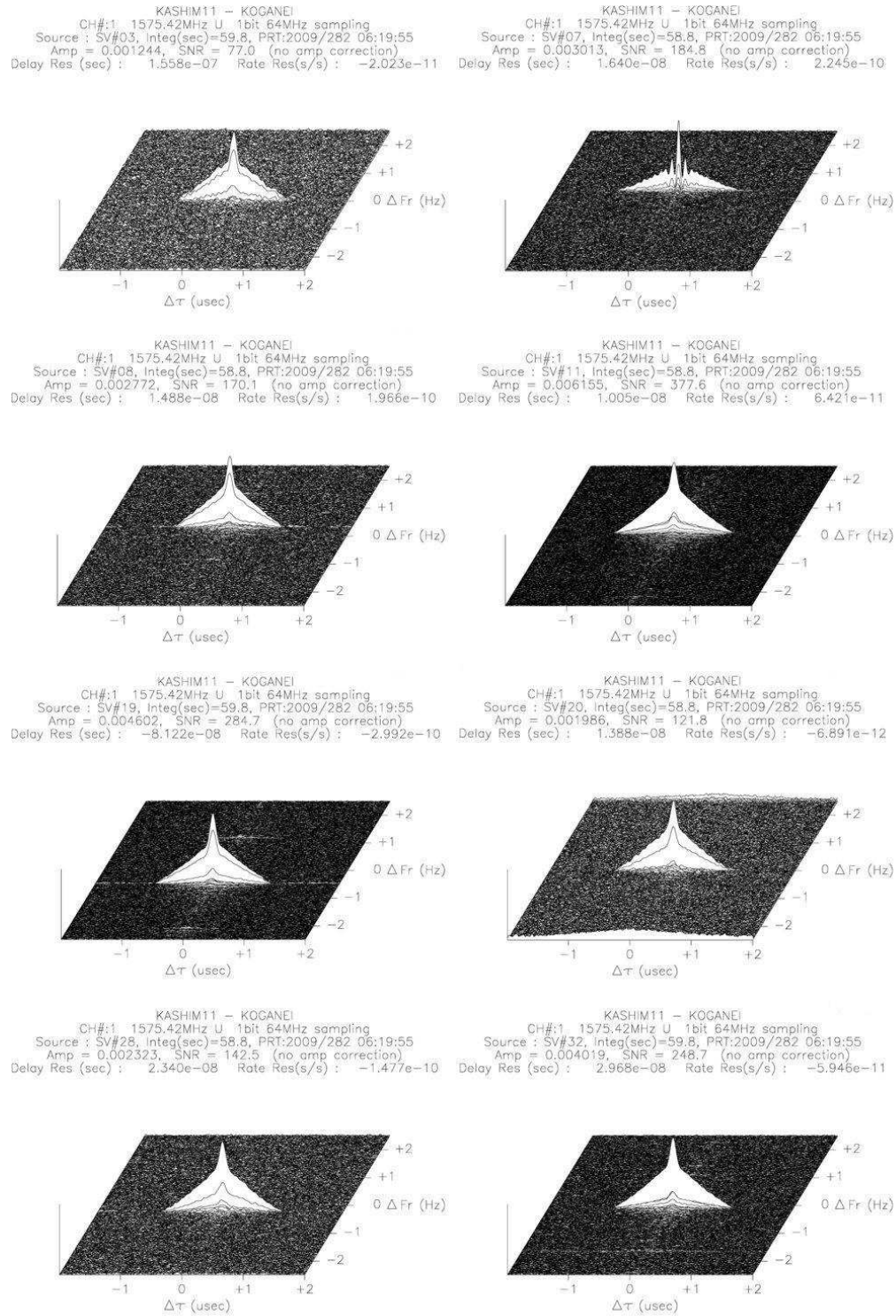


Figure 2. Fringe peaks for GPS L1 signal.

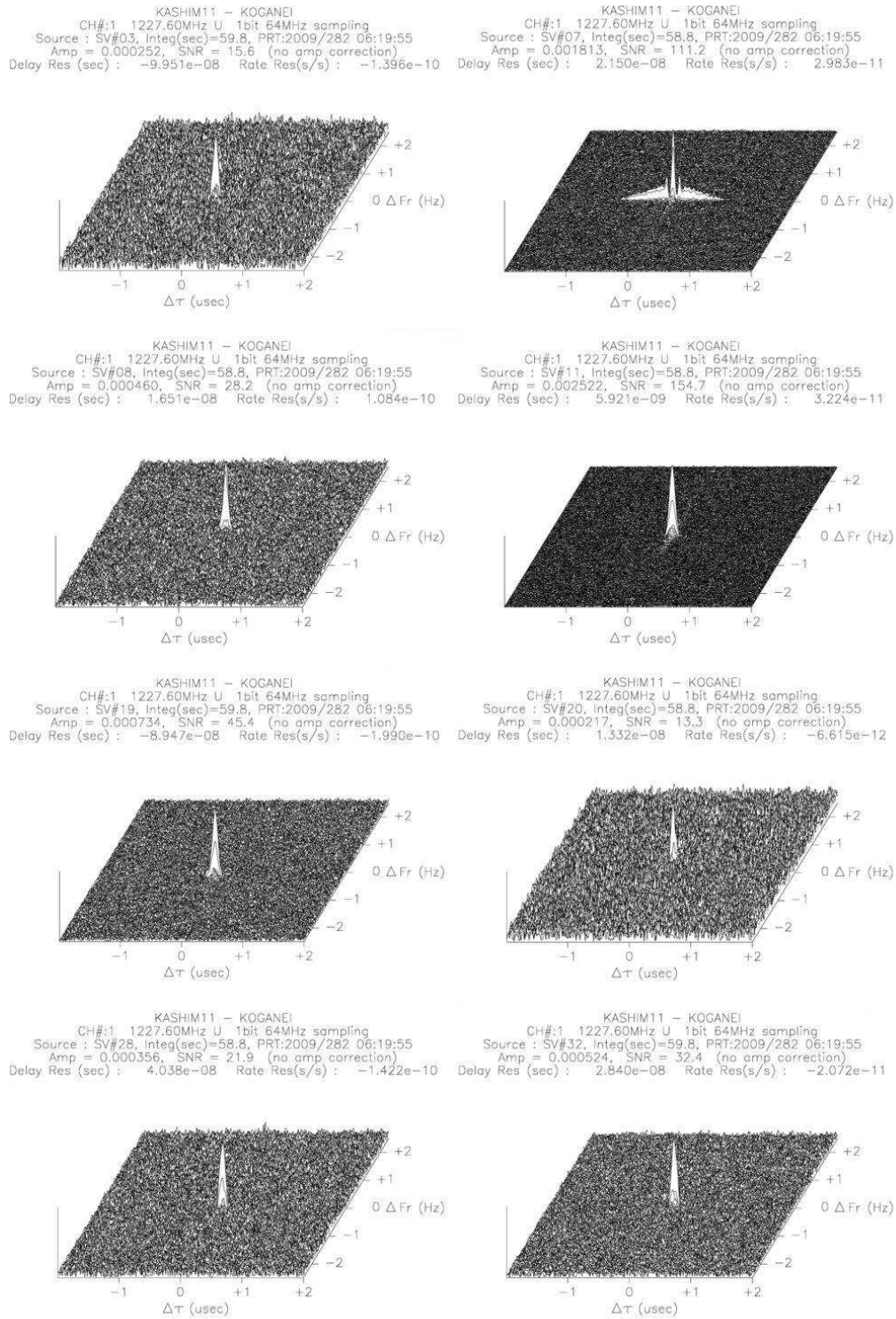


Figure 3. Fringe peaks for GPS L2 signal.