Vol. 31 No. 132 *Journal of the Radio Research Laboratories* *March 1984*
Printed in Tokyo, Japan *pp. 31–37*

Short Note

THE FIRST US-JAPAN VLBI TEST OBSERVATION BY USE OF K-3 SYSTEM AT THE RADIO RESEARCH LABORATORIES

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(Received on January 12, 1984)

ABSTRACT

A precision Very Long Baseline Interferometer, called K-3 system, has been developed since 1979 according to the five-year plan(1) in the Radio Research Laboratories. The system is designed to be compatible with the MARK-III system of the U.S.A. for the purpose of US-Japan joint experiment. The K-3 system, consisting of hardware and software, was almost completed at the end of September, 1983, and various tests for the system integration have been made as the final phase. In order to check the overall system performance of K-3 and its compatibility with Mark-III system, the first VLBI test observation for the trans-Pacific baseline was performed on November 4, 1983, by thorough co-operation of NASA. The purpose of this short note is to give the brief description of the characteristics of K-3 system as developed and the outline of the first US-Japan VLBI test observation.

1. Main characteristics of K-3 system.(2),(3)

The K-3 system is set up at Kashima Branch of the Radio Research Laboratories. The antenna of 26 meters in diameter has an altitude-azimuth driving mount, and the reference point for VLBI observation is the position of intersection of these two axes. Its SAO-C7 coordinate is 140°39′45″.6 in longitude, 35°57′15″.1 in latitude and 77.08 meters in geoid height. The automatic program tracking of radio source can be made simultaneously for S-band and X-band at the maximum slew rate of 1 degree per second. The receiving system noise temperature of 124.6 K at zenith and the antenna efficiency of 53.4% for S-band and those of 94.0 K and 51.4% for X-band were measured.

The IF channels consist of eight low-frequency channels (90–230 MHz) and eight high-frequency channels (200–520 MHz), which are followed by 14 video converters. The local oscillator for the video converters is a 10 kHz-step frequency synthesizer phase-locked to the reference signal from a hydrogen maser. The bandwidth of 28 video outputs can be selected out of 4, 2, 1, 0.5, 0.25 and 0.125 MHz. The formatter can accept up to 28 channels, which is completely compatible with MARK-III system. The data recorder (Honeywell M-96) is

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Fig. 1 (a) 26-meter Antenna

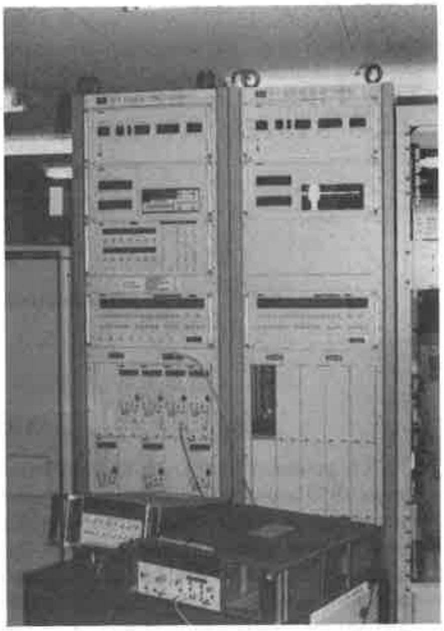

Fig. 1 (b) K-3 Data Acquisition Terminal.

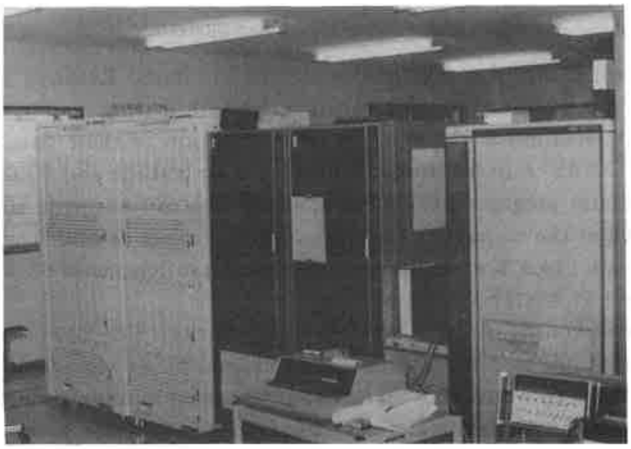

Fig. 1 (c) K-3 Correlation Processor.

used for recording and reading 28-channel digital data, which has the read module and I/O module for reproducing 33.3 kbpi data on 28 tracks at the maximum speed of 270 ips. All the sequences of the operation of the data recorder are controlled by a microprocessor according to the instructions from a host computer, and the physical position of a tape mounted on the recorder is controlled by monitoring a footage counter.

The variation of the cable delay of 62 meters between S/X band receivers at the antenna site and the data acquisition terminal can be calibrated by a delay calibrator with a resolution of about 0.5 picoseconds and a stability of better than 5 picoseconds. Two hydrogen masers are installed, which has the short-term stability of about 5 parts in 10^{15} for the averaging time from 500 to 1000 seconds and the long-term stability for one day of better than one part in 10^{14}. The water vapor radiometer is a temperature-stabilized Dicke-type using two frequencies at 20 and 26.5 GHz. The error of sky noise measurement is about 1 K or better.

The correlation processing is conducted by the use of two Hp-1000 computers of model 45 F and 10 L, and K-3 correlation processor. The processor has 4 correlation units, each of which can make cross-correlation for 8 pairs of data streams. The maximum integration period is 8.38 seconds at the data rate of 4 Mbps and the maximum processing speed of 8 Mbps. The fringe rotator has a capability of three-level compensation with phase resolution of 0.02 micro-radian and phase rate resolution of 0.93 MHz at the fringe rate of 15 kHz and 1.83 MHz at 31 kHz.

The K-3 software is composed of three major groups and three active buses. In the first group, there are a scheduling program, KASER, and an automatic operation one, KAOS. The second group includes a setting-up utility, KASET, a correlation software, KROSS, and a bandwidth synthesis software, KOMB. In the third group, a priori model software, KAPRI, and a least-square-determination software, KLEAR, are included. In addition to these three groups, there is a data-base system, KASTL, as a common resources for the overall K-3 software. In establishing these softwares, the attentions are paid on the compatibility with those of MARK III, such as scheduling of observation, logging file, high density data format and others.

Many tests for system integration have been made so far. A compatibility test of the automatic system operation software between the K-3 KAOS and the MARK III Field system program was made in March, 1983. The cross correlation processing test for the K-3 correlation processor with KROSS program was performed in August, 1983, using a raw data tape obtained for Westford-HARS baseline in the U.S.A. The test for bandwidth synthesis software, KOMB, showed that the values obtained by K-3 system in the determinations of the delay time and the rate of delay time were coincident with those processed by MARK III within 0.001 ns and 0.11 ps per second, respectively. As a result of test observation between the antenna of 26-meter at RRL-Kashima station and that of 5-meter at GSI-Tsukuba station receiving S-band signal from the radio source of 3C273, the overall coherent loss of 53% for the K-3 system was confirmed, which is very close to the estimated value in consideration of various losses in the system[(4)].

The photographs showing the antenna, the K-3 data acquisition terminal and the K-3 correlator are given in Figs. 1 (a), (b) and (c), respectively.

2. The first US-Japan test observation

The purpose of the test observation is to detect fringe in order to check the over-all system performance of the K-3 system and the compatibility with the MARK-III system. The observation was made for about two and half hours from 20 h 00 m to 22 h 34 m UTC on November 4, 1983, by three antennas, that is, 26-meter antenna at Kashima station of RRL with K-3 system, 12-meter antenna at Mojave Base station of NASA with MARK-III system and 40-meter antenna at Owens Valley Radio Observatory of Calif. Inst. of Tech. with MARK-III system.

Taking into consideration of the purpose of the test, the signals from three radio sources, 3C273B, 3C345 and 4C39.25, were alternately received six times throughout the time of observation. Each reception was made simultaneously at X-band frequency from 8211 to 8571 MHz and at S-band frequency from 2218 to 2303 MHz for 12 minutes. The sampled digital data from 8 video signals for X-band and those from 6 video signals for S-band were recorded on 14 tracks of the tape. Then, each station obtained three fully-recorded tapes during the whole period of the observation.

The data processing was made by K-3 correlation processor at the RRL and also by MARK-III at Haystack observatory, independently, and both detected the fringe successfully. Fig. 2 shows the examples of correlation detection at X-band and S-band for a single channel and also the bandwidth synthesis obtained by K-3 software process. Table 1 shows the correlation amplitude which is thought to be very reasonable value.

Thus, it is confirmed by data processing that the K-3 system has the expected performances and good compatibility with the MARK-III system. Though an analysis for the determination of some parameters is now being made, the preliminary result shows that the measurement precision or the internal error in the test observation is better than 20 cm for X, Y and Z components and also for the distance, and better than 1 ns for clock synchronization. The detailed report including some of the analysis will be published in near future.

In succession to the first test, we will make more precise experiments of 24 or 28-hour observation using 13 radio sources in January and February, 1984, in close co-operation of NASA.

Table 1 Measured correlation amplitude.

Baseline \ Radio source		4C39.25	3C273B	3C345
X-band	OVRO-KAS	0.50×10^{-3}	1.13×10^{-3}	0.99×10^{-3}
	OVRO-MBS	1.65×10^{-3}	1.17×10^{-3}	5.0×10^{-3}
	KAS-MBS	0.30×10^{-3}	0.79×10^{-3}	0.46×10^{-3}
S-band	OVRO-KAS	1.71×10^{-3}	2.29×10^{-3}	3.31×10^{-3}
	OVRO-MBS	2.6×10^{-3}	1.8×10^{-3}	5.6×10^{-3}
	KAS-MBS	0.76×10^{-3}	1.13×10^{-3}	1.44×10^{-3}

In closing, we wish to express our great appreciation to many VLBI researchers of NASA Headquarters, GSFC, JPL and Haystack observatory in the U.S.A. for their kind suggestions and encouragements given to us in developing of K-3 system. We would also like to express our sincere thanks to many staffs of GSFC, Mojave station and Owens Valley Radio Observatory for their kind co-operations in performing the first US-Japan test observation. Finally, we express our gratitude to many members of the RRL who have provided continuous encouragements and co-operations to the project of K-3 system development.

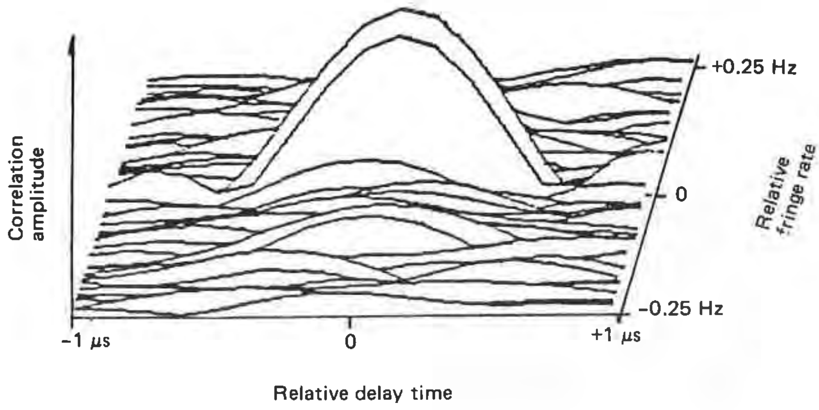

Fig. 2 (a) Correlation pattern of a single channel at S-band signal from 3C273B for Kashima-Mojave baseline.

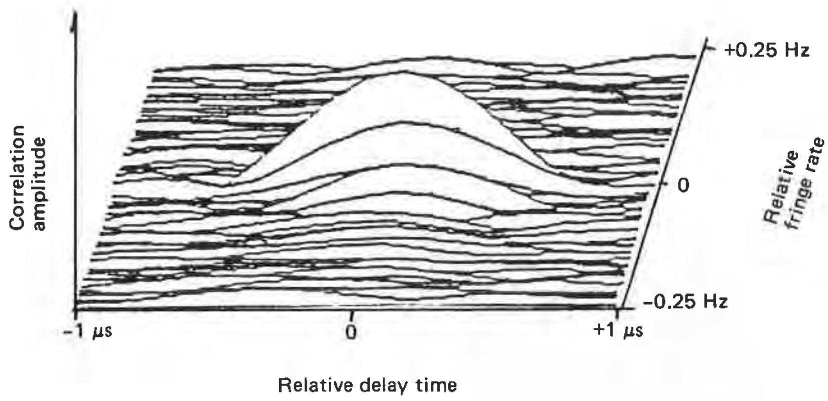

Fig. 2 (b) Correlation pattern of a single channel at X-band signal from 3C273B for Kashima-OVRO baseline.

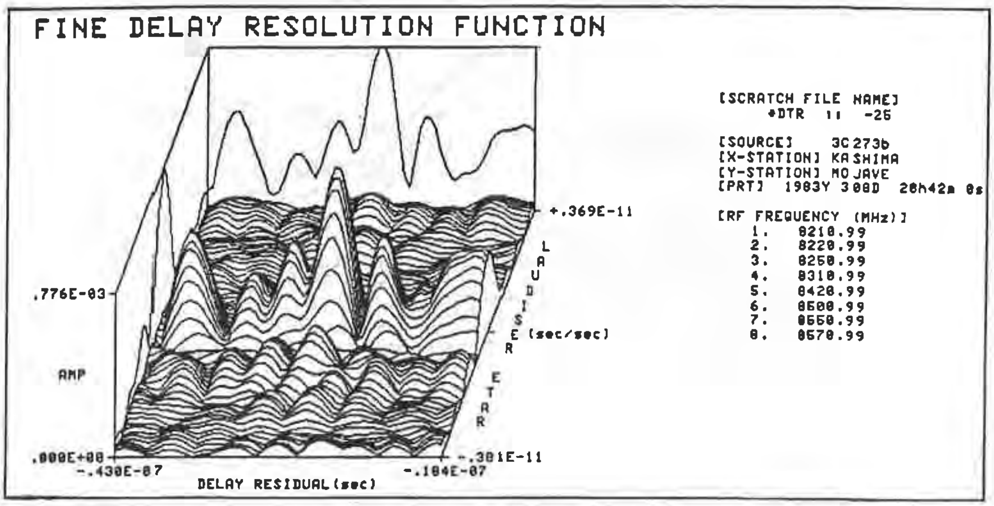

Fig. 2 (c) Correlation pattern of bandwidth synthesis of 8-channels at X-band signal from 3C273B for Kashima-Mojave baseline.

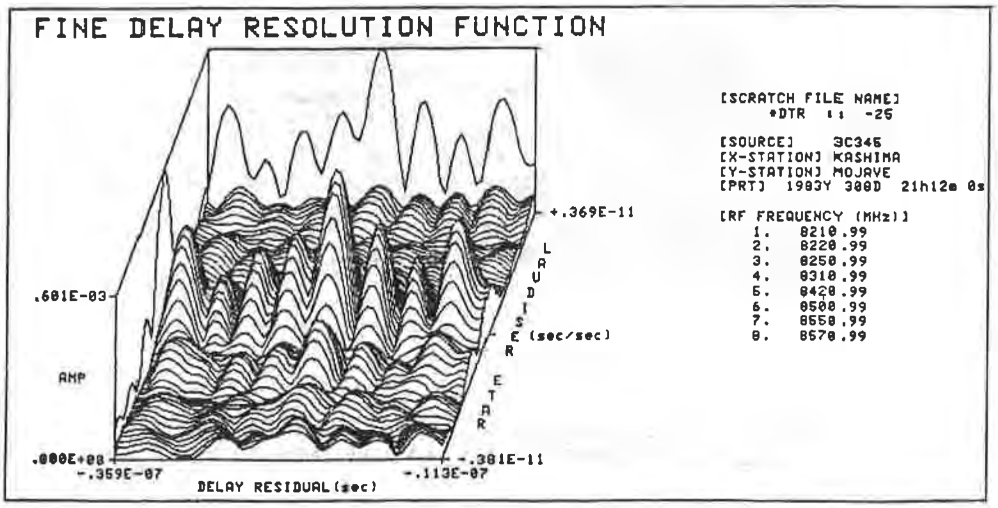

Fig. 2 (d) Correlation pattern of bandwidth synthesis of 8-channels at X-band signal from 3C345 for Kashima-Mojave baseline.

References

(1) Saburi, Y., Yoshimura, K., Kato, S., Tsukamoto, K., Yamashita, F., Kawajiri, N., and Kawano, N.; "Development of VLBI system and future plan in the Radio Research Laboratories", NOAA Tech. Report Nos. 95 NGS 24, pp. 307–314, 1982.

(2) Kawaguchi, N., Sugimoto, Y., Kuroiwa, H., Kondo, T., Hama, S., and Amagai, J.; "The K-3 Hardware system being developed in Japan and its capability", ibid., pp. 163–176, 1982.

(3) Takahashi, F., Yoshino, T., Murakami, H., Koike, K., Kunimori, H., and Kondo, T.; "K-3 VLBI software development for international experiments", ibid., pp. 177-183, 1982.

(4) Kawaguchi, N.; "Coherence loss and delay observation error in very-long-baseline interferometry", Jour. RRL, **30**, 129, pp. 59–87, 1983.