PHASE COHERENT VLBI USING A SATELLITE LINK

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ABSTRACT

Results will be presented from experiments using the Hermes (formerly CTS) communications satellite to provide a local oscillator and data link between two antennas. The techniques used to compensate for the satellite motion and translation oscillator will be described. Plans for a series of three station experiments to measure UT and polar motion using the ANIK-B satellite to synchronize the local oscillators will be discussed.

INTRODUCTION

In November 1976, our group used the Hermes geosynchronous communications satellite (formerly known as CTS) as a data link for the first successful realtime VLBI experiment.[1] Following this and other experiments, we began work to use the satellite link to obtain full phase coherence for the local oscillator signals as well as to provide a realtime data link. The ability to obtain direct phase data from the interferometer rather than group-delay or fringe-rate data should provide a substantial improvement in accuracy, particularly in the measurement of absolute positions, universal time (UT), and polar motion. It should also permit the use of crystal oscillator or rubidium-vapor frequency standards at the telescope sites in place of the more expensive hydrogen masers.

The primary effect which must be cancelled in the phase link is that due to the motion of the satellite. A geosynchronous satellite may exhibit a link delay change of more than 600 μsec within a 24-hour period because of its non-zero orbital inclination. This is equivalent to more than 10^6 turns at an 18-cm observing frequency. A two-way link must be used to cancel this delay change. A second effect is that of the satellite translation oscillator. A block diagram of the CTS satellite is shown in figure 1. Incoming signals in the 14-GHz uplink band are translated to the 12-GHz downlink band by the crystal controlled oscillator on the satellite. In the Hermes satellite, the same oscillator also generates an 11.7-GHz beacon signal which can be received at each end of the link and used to cancel the effect of the translation oscillator.

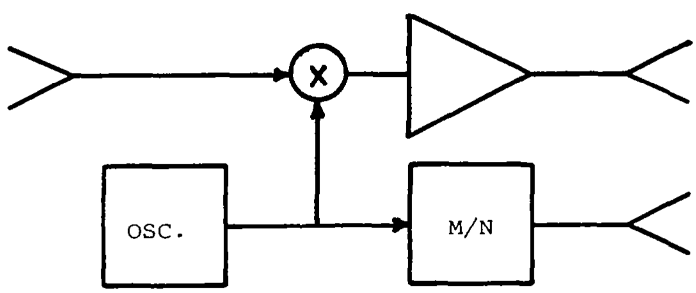

Figure 1. Hermes satellite.

PHASE LINK EXPERIMENT

The basic technique used for the phase link is shown in figure 2. Rather than generating an actual coherent local oscillator signal, the phase link is used in a separate experiment simultaneously with the VLBI to monitor the phase relationship between the frequency standards at the two sites. To cancel the effects of satellite motion, a dual link is used. The results from the remote site are sent over the data link to be subtracted from the local results giving an output independent of the length of the phase link path. The actual system used is shown in figure 3. It differs from the basic system in three ways. First, the beacon signal is received at each site and used to cancel the satellite translation oscillator as previously mentioned. (The translation oscillator frequency is 5/27 of the beacon frequency.) Second, the pilot signal at the remote end is 14.09-GHz while the pilot signal at the

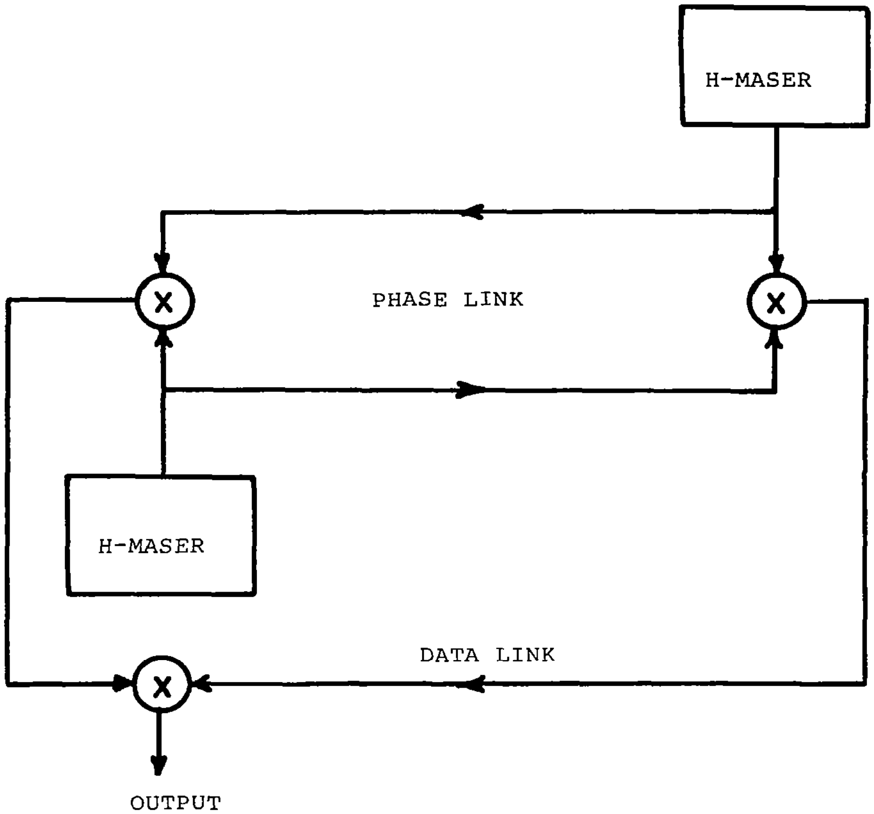

Figure 2. Basic phase measurement link.

local site is 14.23-GHz due to satellite frequency band assignments. Third, the final outputs from the local and remote sites are separately recorded by the computer for later processing.

The computer post-processing interpolates over data gaps due to loss of data sync, antenna peaking, etc., multiplies the remote phase by 14.09/14.23 to correct for the different pilot frequencies, and computes the difference between the local and remote phase values. An arbitrary phase zero is established at the beginning of each run and the phase is tracked for the duration of good data. The constant frequency offset of the two hydrogen masers is subtracted from all results.

EXPERIMENTAL RESULTS

This link was operated successfully in May 1978 and November 1978 between the Algonquin Radio Observatory, Lake Traverse, Ontario, and the Owens Valley Radio Observatory of California Institute of Technology, Big Pine, California. The May experiment yielded only short runs of data due to difficulties with the digital data link. The results of the November experiment are shown in figures 4 and 5. These results show the measured difference in phase between the two masers, with the

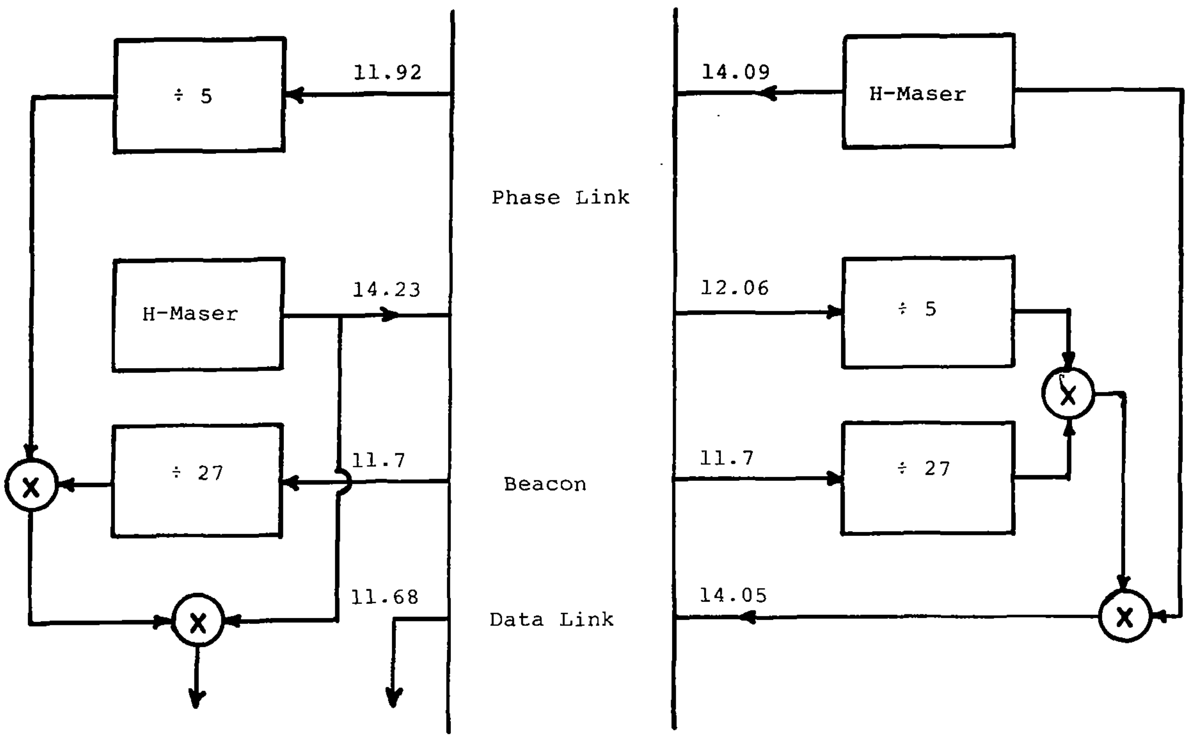

Figure 3. Hermes phase link.

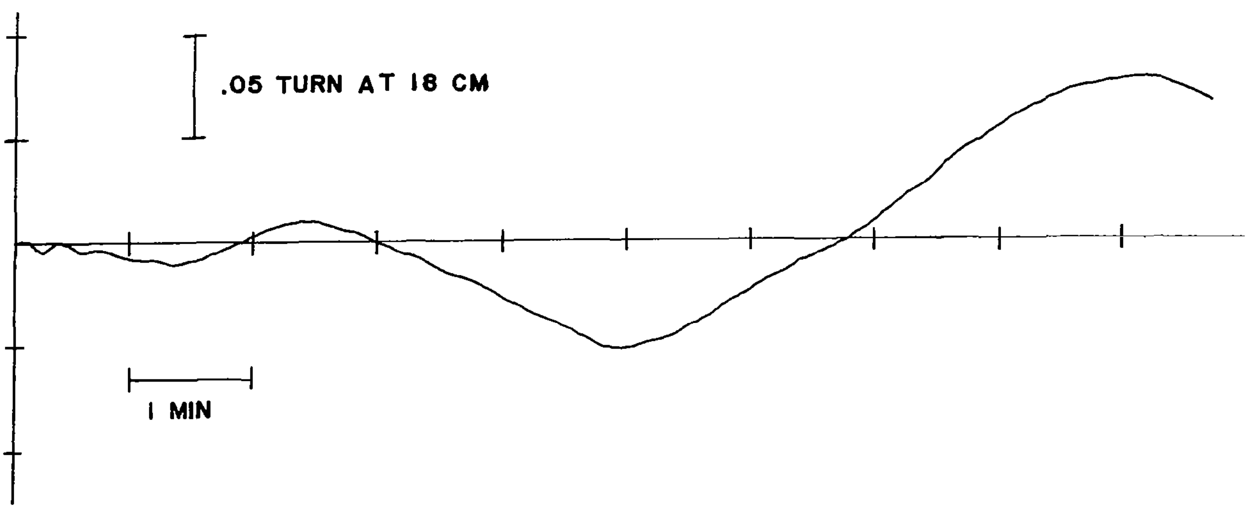

Figure 4. Hermes phase link results.

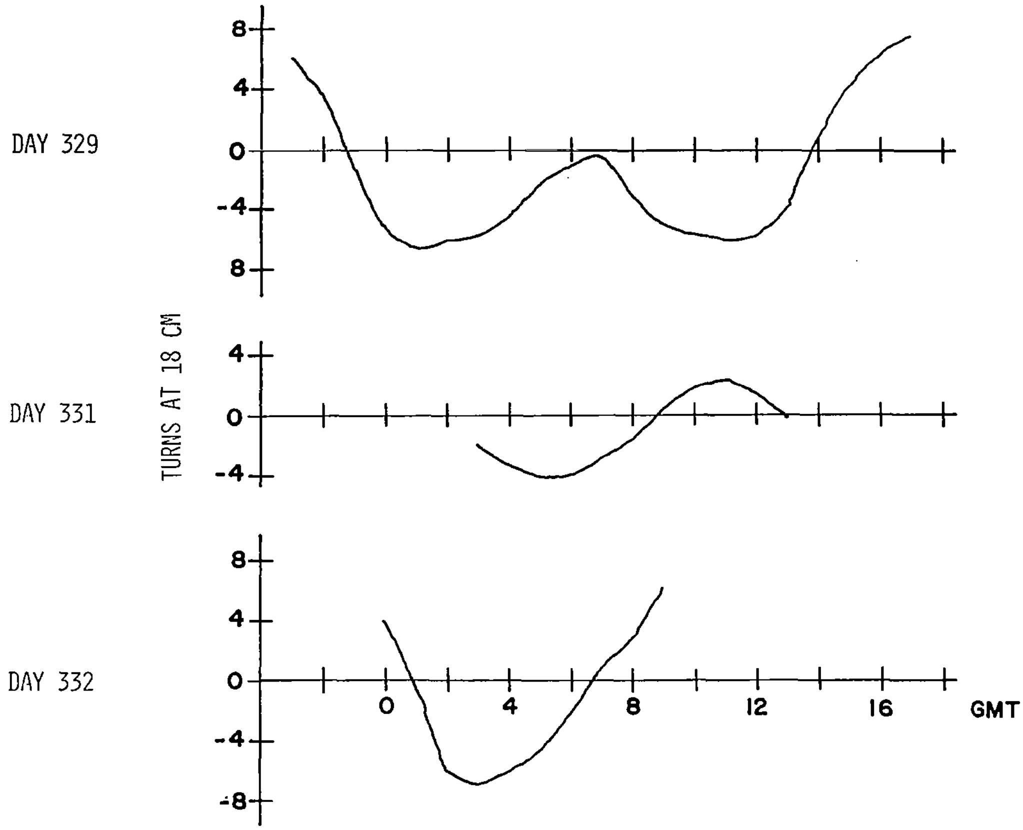

Figure 5. Hermes phase link results - Nov. 1978.

frequency offset removed, normalized to the 18-cm wavelength of the VLBI experiment. The short term data in figure 4 has been smoothed with a 300-second filter.

The short term data show that the signal-to-noise of the link is sufficient, so only a good crystal oscillator, or at most a rubidium frequency standard, would be needed at each site. The long term data show no evidence of a 24-hour period indicating that the 10^6 turns due to the satellite motion have been totally cancelled. The result obtained of ±6 turns over 18 hours (±3.5 nsec) is still not as good as we had hoped. We believe most of the observed phase change is probably in the cables and electronics used in the link. Figure 6 shows a comparison of the present phase link data with the laboratory performance of hydrogen masers and rubidium standards. We expect that with calibration and monitoring of the instrumental phase delays, the link performance will exceed that of the hydrogen maser for times greater than 1 day.

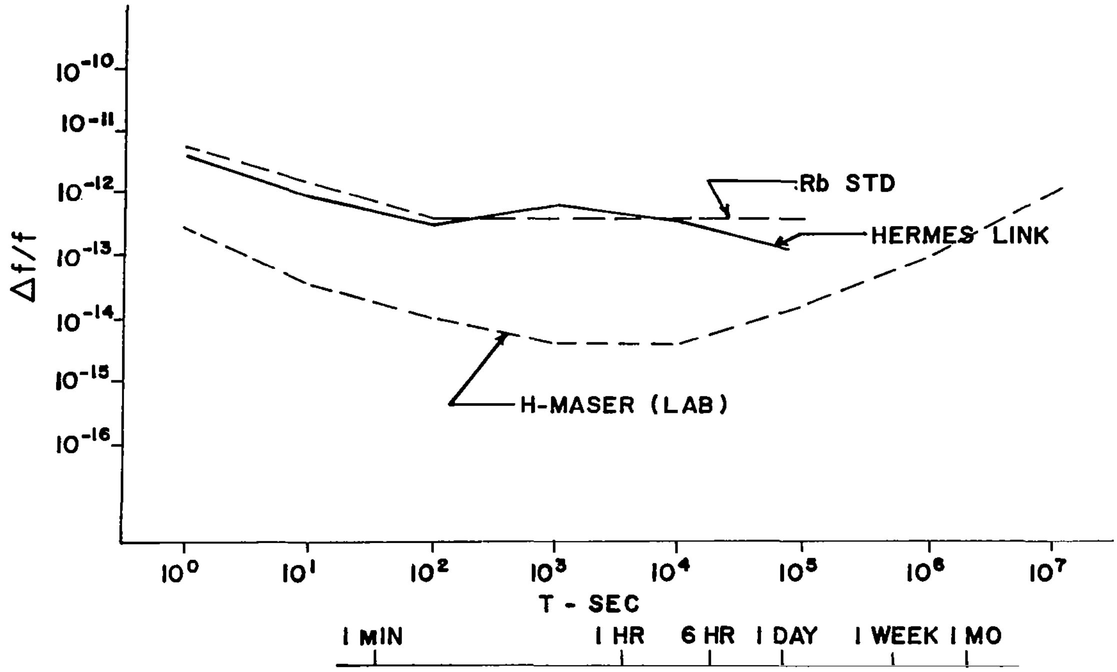

Figure 6. Comparison of phase stability.

FUTURE PLANS

This was our last opportunity to use the Hermes satellite; however, our efforts will continue with a program to use the ANIK-B satellite in a series of three station experiments to measure UT and polar motion. A detailed description of this system is given in another paper.[(2)]

REFERENCES

(1) J. L. Yen, K. I. Kellermann, Benno Rayhrer, G. W. Broten, D. N. Fort, S. H. Knowles, W. B. Waltman, and J. W. Swenson, Jr., Science, 198, 21 October 1977.

(2) W. H. Cannon, W. T. Petrachenko, J. L. Yen, J. A. Galt, W. B. Waltman, S. H. Knowles, J. Popelar, "Plans for Phase Coherent Long Baseline Interferometry for Geophysical Applications Using the ANIK-B Communications Satellite," Symposium on "Radio Interferometry: Techniques for Geodesy," MIT, June 19-21, 1979.