Variations in Propagation Delay Times For Line Ten (TV) Based Time Transfers

M. C. Chiu and B. W. Shaw

The Johns Hopkins Univsersity, Applied Physics Laboratory
Johns Hopkins Road
Laurel, MD 20707
(301)953-7100 X2571

ABSTRACT

Variation in the propagation delay for a 30 km TV (Line Ten) radio link has been evaluated for a series of 30 independent measurements. Time marks from TV Channel 5 WTTG in Washington, DC were simultaneously measured at JHU/APL and at the USNO against each stations' local cesium standard clocks. Differences in the stations' cesium clocks were determined by portable cesium clock transfers. Thirty independent timing determinations were made between May 1980 and August 1981. The RMS deviation in the propagation delay calculated from the timing determinations was 11 ns.

The variations seen in the propagation delays are believed to be caused by environmental factors and by errors in the portable clock timing measurements. In correlating the propagation delay variations with local weather conditions, only a moderate dependence on air temperature and absolute humidity was found.

Advantages and Disadvantages of TV Based Time Transfers

The TV Line Ten System provides a submicrosecond method for obtaining the timing of a local time standard relative to the U.S. Naval Observatory (USNO) timing. Time transfers based on TV Line Ten measurements can be an attractive alternative to time transfers using portable cesium clocks. TV Line Ten measurements take only minutes to perform and can be done with little advance preparation. These features are useful both for routine time transfers and in particular for varification and recovery of local clock operation following a power outage or other operational anomaly. In comparison, portable cesium clock transfers, for our location, require an average of three to four hours to complete for transporting the clock from the USNO to our facility at JHU/APL and back again.

The primary drawback in using the TV Line Ten System for time transfers has been in the resolution limitation of 10 ns or more and in the difficulty of accounting for the propagation delay and its variations between the TV transmitter and the receiver at the local time standard. As a consequence, these factors make the accuracy of the time transfer based on Line Ten measurements difficult to assess.

The propagation time of a TV signal from transmitter to receiver is influenced by many environmental conditions along its path, including the terrain and the local climate. These influences can not be incorporated into a calculation of propagation time along a given path with a high degree of accuracy. Compounding the problem, variation in the propagation time can result from localized environmental changes (particularly climatic) at any point along the transmitter-receiver path. Recognizing the difficulties in calculating propagation delays inherent in the TV based time transfer, an experiment was conducted at JHU/APL in which the propagation delay for our pathway was determined using the results of portable cesium clock time transfers.

Calculation of the Propagation Delay

Our TV Line Ten measurements were obtained from WTTG's (Channel 5) transmission originating in Washington, D.C. (See schematic of tuning measurement shown in Figure 1.) The pathway from WTTG's transmitter to our receiver at JHU/APL is approximately 30 km. The terrain along the propagation path varies from city environment to open fields and wooded areas. The propagation between the transmitter and receiver is not line of sight, but rather gently rolling hills.

The propagation delay along this path was calculated using both the results of the TV Line Ten measurements and of the portable clock time transfers. The TV Line Ten measurements were made to coincide with the portable cesium clock time transfers which are carried out between the USNO and JHU/APL on a weekly basis. These portable clock transfers give the timing of our local cesium standards (APL System Nos. 1-3) relative to USNO System No. 1 timing. Immmediately following the measurement of our local standards against the portable cesium clock, the timing of APL System No. 2 was again measured using the TV Line Ten System*. The measurement obtained from the TV Line Ten System is the sum of three elements, 1) the APL System No. 2 timing relative to the USNO System No. 1, 2) the emission timing of WTTG, and 3) the propagation delay between WTTG's transmitter and our TV receiver at JHU/APL. (All cable delays have been taken into account.) The emission timing data of WTTG at the instant of our TV Line Ten measurements was obtained over the phone from the USNO. This emission timing and the timing of APL System No. 2 relative to the USNO System No. 1 obtained from the portable cesium clock transfers, were then subtracted from the TV Line Ten measurements to determine the propagation delay.

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*An ILC Data Device Corporation, Model 5433 Timing System on loan from NASA was used for the measurement.

Twenty independent determinations of the propagation delay were made between May 1980 and January 1981. Ten additional determinations were made between April and August 1981. These propagation delays are shown in Figure 1. The mean value of the first twenty determinations is 88,402 ns with a standard deviation of 16 ns. The mean value of the entire 30 determinations is 88,408 ns with a standard deviation of 11 ns.

Variations in the Propagation Delay

The range of the propagation delay variation shown in Figure 2 is much smaller than expected. The variation seen in Figure 2 represents the fluctuations in the propagation time along the transmitter recovery path plus any errors resulting from the portable cesium clock transfer. In these tests, the primary source of error in a portable clock transfer resulted from the closure time. The closure of a time transfer is designated as the change in timing of the portable cesium clock relative to the USNO System No. 1 between the start and finish of the transfer. To determine the most probable value of the portable clock timing at the instant of measurement against our cesium standards, it was assumed that this timing varies linearly during the course of the transfer. The error in a time transfer resulting from the closure should then be only a fraction of the closure time. The RMS of the closures for the first 20 transfers used in the propagation delay determination was 19.7 ns. The closures for the ten additional determinations were not available but are assumed to have an equal or smaller standard deviation.

Unfortunately, for this data, there is no way to isolate errors in the portable clock transfers from the variations seen in the calculated propagation delay. However, assuming these errors to be relatively small an attempt was made to relate the propagation delay variation to climatic conditions of air temperature and absolute humidity. Local weather conditions recorded at the meteorological obsertatory at Washington National Airport (Ref. 1) were obtained for the dates and approximate times on which the first 20 propagation delay determination measurements were taken. Correlations were made between propagation delay variations and the air temperature and between the delay variations and the dew point temperature (which is a measure of absolute humidity). These correlations using a least squares fit are shown in Figures 3 and 4. The coefficient of determination was .48 for the air temperature dependence and .55 for the dewpoint temperature. Both indicate only a moderate dependence of the propagation delay variations on gross climatic conditions. Localized climatic disturbances along the actual propagation path may have been present which could have altered the propagation time. Time transfer errors in the calculated propagation delay may also have obscured the weather dependence.

Significance of Propagation Delay Results

While the variation in the propagation delay determined for our TV Line Ten based time transfers could not be correlated with gross climatic conditions, again the range of the variation itself is significant. The propagation delay variation over 30 independent determinations, spanning 15 months had a standard deviation of only 11 ns. This indicates that TV Line Ten based time transfers, for our system, also have at best a standard deviation of 11 ns. Depending on the final use of the timing information, this accuracy could be sufficient.

It is difficult to apply the data on propagation delay variations obtained in our experiment, directly to another propagation path. Since the variations can result from a number of factors, a shorter or longer path may depart from proportionality in the propagation delay. Our data does indicate that if several determinations of the propagation delay along a specific path can be made over an extended period of time, the variations in the propagation delay can be bracketed for use in assessing the accuracy of a TV Line Ten based time transfer.

References

1. National Oceanic and Atmospheric Administration, Local Climatological Data, Washington National Airport, Monthly Summary. May 1980 Through January 1981.

Acknowledgements

Data based on measurements initiated by B. H. Shaw who has since retired from JHU/APL. The TV (Line Ten) receiver was loaned to JHU/APL by the Goddard Space Flight Center as a part of a cooperative study for station time synchronization.

FIG. 1

SCHEMATIC OF TIMING MEASUREMENTS

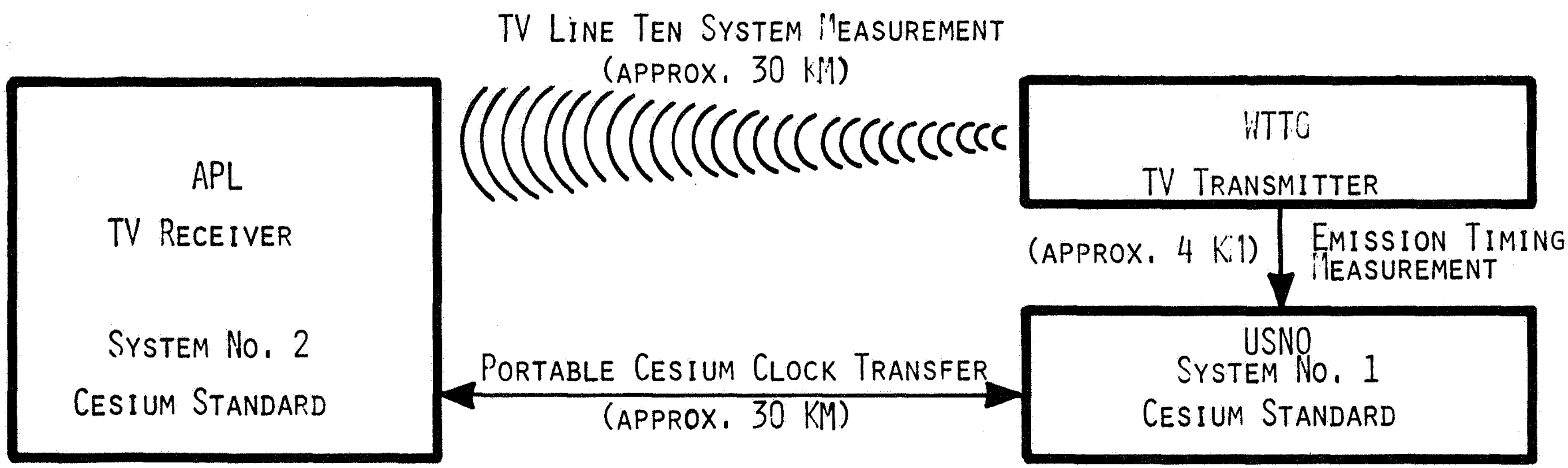

FIG. 2

PROPAGATION DELAY

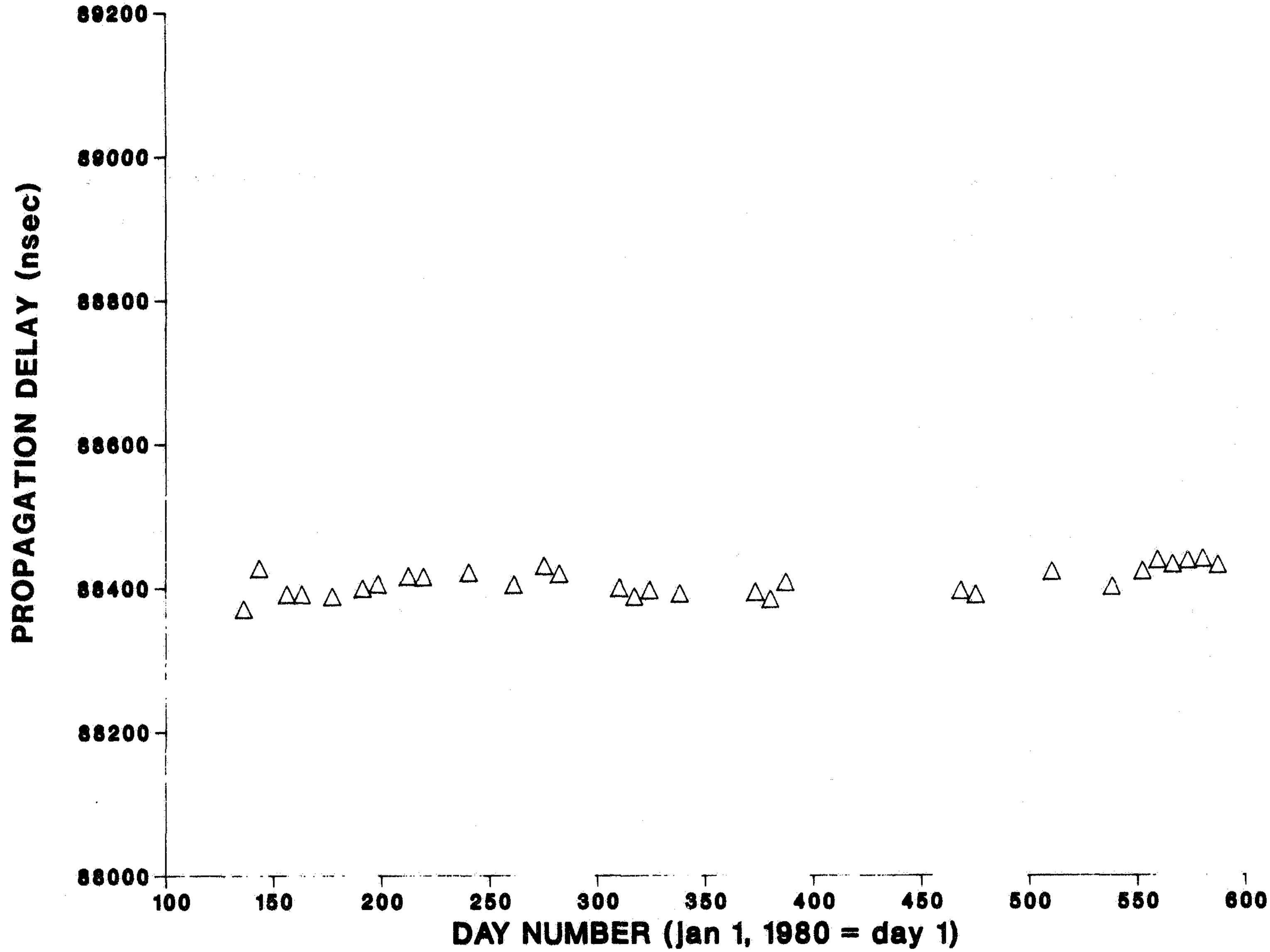

FIG. 3

PROPAGATION VS TEMPERATURE

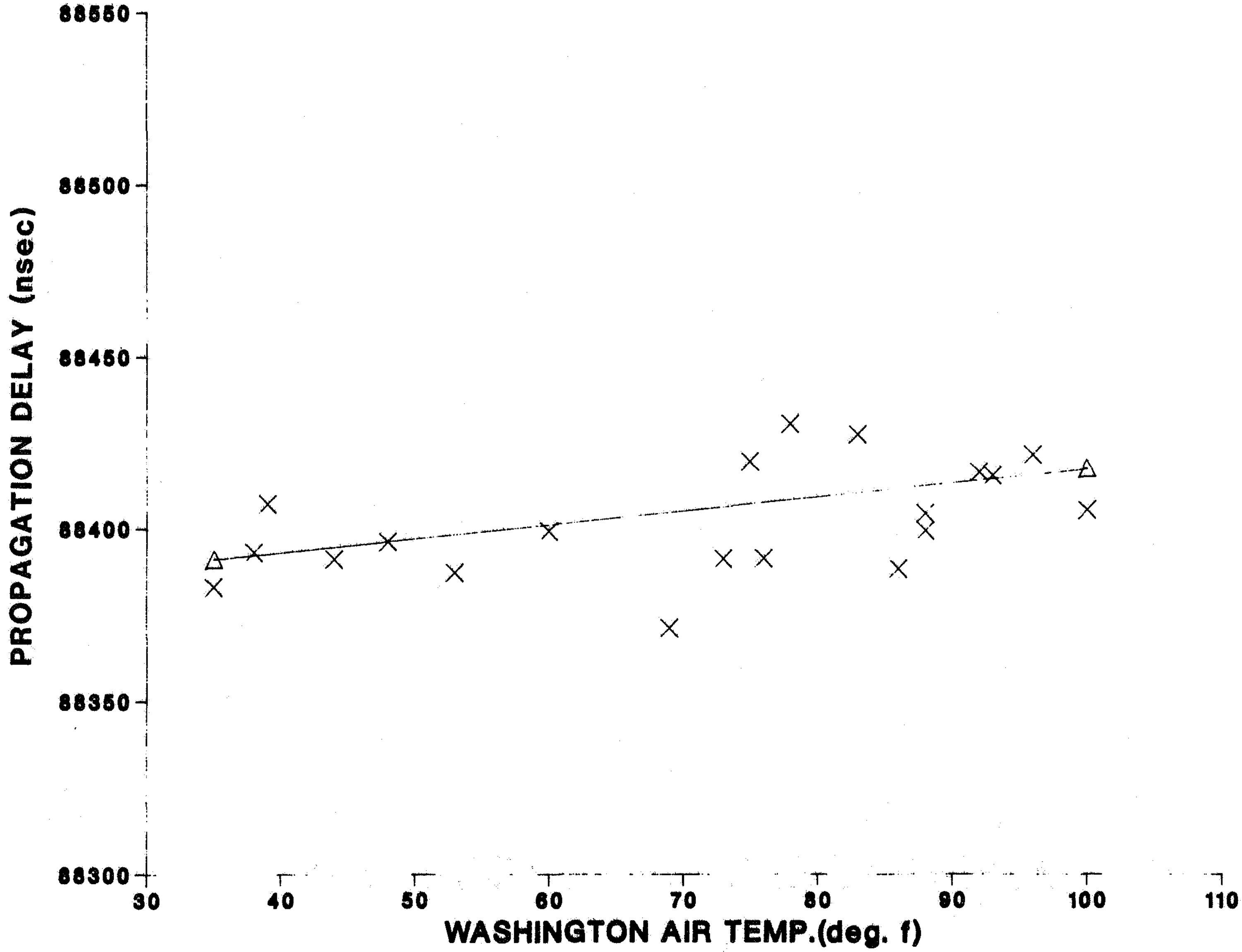

FIG. 4

PROPAGATION VS DEW POINT