A STUDY OF TIME DISSEMINATION VIA SATELLITE IN INDIA

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ABSTRACT

The availability of French-German satellite Symphonie, coupled with the increasing demand on accuracy and coverage by the Indian users, provided an opportunity to carry out time transfer experiments with satellite, thus to enable us to have some gainful experience on the merits and demerits of different possible modes of time transfer via satellite. We report some of these observations and analysis in this paper.

A simultaneous two-way clock synchronization experiment between three Earth stations, New Delhi (DES), Ahmedabad (AES) and Madras (MES) was performed and improvements over the technique earlier attempted in India, where transmit/receive roles of the two stations were alternated at regular intervals, were studied.

The National Physical Laboratory, New Delhi (NPL) has been disseminating standard time and frequency signals, under the call sign "ATA," at three carrier frequencies, 5, 10 and 15 MHz. To study the improvements over the existing HF broadcast, a similar time format as used in HF "ATA" transmissions was disseminated via satellite Symphonie and was studied at DES, AES, MES and the mobile terminal TRACT located at Calcutta. The Time signals via these two modes (HF and satellite) were critically monitored at AES and analysed.

This time format was later modified to include the additional information about time of the day in year, month, day, hour, minute and second as well as DUT1 in BCD code and was disseminated via the satellite from DES. These signals were decoded, displayed and studied at DES, AES, MES and with TRACT at Calcutta, thus covering a very large cross-section of India.

Some preliminary work on time transfer via TV using direct satellite broadcast, is also reported. These studies, which yielded encouraging results, will be useful when different TV stations are linked via Indian satellite INSAT.

INTRODUCTION

In this paper we report a study of time dissemination over India, using French-German satellite Symphonie which was parked over equator at 49° East Longitude and was made available to India for two years, from June 1977 to June 1979, for doing telecommunication experiments. Three satellite Earth stations at Delhi (DES), Ahmedabad (AES), Madras (MES) and the Transportable Remote Area Communication Terminal (TRACT), stationed at Calcutta during the period of the experiments, participated in the experiments. In view of the vastness of the country and the Indian Space Programme, where an experimental satellite Ariane Passenger Payload Experiment (APPLE) and an Indian National Satellite (INSAT) are to be launched in 1980 and 1981 respectively, the aim of these experiments was to make preliminary studies on various time dissemination techniques via satellite which will provide helpful inputs and generate the desired expertise for the ultimate use of these by the Indian satellites APPLE and INSAT. These experimental studies were carried out during January - June 1979 period.

The experiments described in this paper include: simultaneous two-way clock synchronization between Delhi and Ahmedabad, Delhi and Madras and nearly simultaneous[1] three-way alternate transmit/receive clock synchronization experiments between Delhi, Ahmedabad and Madras; time dissemination, both in standard high frequency broadcast format (ATA) and time of the day coded format, and its studies and evaluation at Delhi, Ahmedabad, Madras and TRACT (Calcutta); and time dissemination using direct television broadcast via satellite.

SIMULTANEOUS TWO-WAY CLOCK SYNCHRONIZATION BETWEEN DELHI AND AHMEDABAD/MADRAS AND A NEAR SIMULTANEOUS[1] THREE-WAY CLOCK SYNCHRONIZATION BETWEEN DELHI/AHMEDABAD/MADRAS.

A block diagram of the experimental setup is shown in Figure 1. An experiment on clock synchronization where the transmit/receive roles of the two participating stations were alternated at regular intervals was reported from this group in the tenth PTTI meeting[1] last year. This limitation arose because out of the two C-band transponders aboard Symphonie, only one was made available for Indian Telecommunication Experiments. This, however, introduced uncertainties due to the satellite motion as extrapolations were needed to account for the satellite drift. A typical Symphonie range curve over the duration of 24 hours is shown in Figure 2. The straight line represents the range from satellite to AES and the dotted line represents the range from satellite to DES.

In view of these limitations, the interface units and modulator/demodulator systems at the Earth stations were modified to accommodate simultaneous two-way transmission within the available bandwidth of ±10 MHz of the 70 MHz intermediate frequency. Bandpass filters centered at 70 MHz and 61 MHz with bandwidths of ±1.1 MHz were used for the simultaneous two-way transmissions.

At Ahmedabad (AES), 1 PPS was modulated on the 70 MHz intermediate frequency. This 70 MHz was converted to 61 MHz using a 70 to 61 MHz frequency translator. This 61 MHz was up-converted to 6 GHz and transmitted to satellite. At Delhi (DES) the signal was received at 4 GHz, down-converted to 61 MHz and again converted to 70 MHz, using a 61 to 70 MHz frequency translator. It was demodulated to extract 1 PPS. At DES the 1 PPS transmission was done at 70 MHz modulation, as normal, up-converted to 6 GHz and transmitted to satellite. At AES, this signal was received at 4 GHz, down-converted to 70 MHz and then demodulated after passing through 70 MHz ±1.1 MHz bandpass filter to eliminate the reflected signal at 61 MHz.

There were, however, some inherent limitations in this mode of clock synchronization. Only a limited bandwidth (±1.1 MHz) was available for each way of transmission and thus some advantage gained in simultaneous mode of transmission was lost due to sacrifice in the risetime. Also the 1 PPS amplitude was reduced to 0.5 volt as the 1 volt peak amplitude signal, which was used with the earlier system with full bandwidth of ±10 MHz, caused a deterioration of SNR in the received signal due to excessive frequency deviation. The frequency translators and bandpass filters used at the Earth stations introduced fixed delays in the transmission path.

The data for simultaneous two-way mode of transmission between DES and AES for 28, 29 and 30 March is plotted in Figure 3. Simultaneous two-way clock synchronization experiments were also conducted between Delhi and Madras (MES) Earth stations with similar results. The precision obtained, even with the above limitations, was 4-5 times better than the earlier quoted results[1]. A relative drift of the two cesium clocks at DES and AES is quite noticeable in this figure.

In absence of proper portable clock time comparisons between the three Earth station clocks, a three-way check on clock settings was obtained between DES, AES and MES by alternately one station transmitting and the other two receiving, as shown in Figure 4, and exchanging the data over the radio network or hot telephone lines among the three Earth stations. Discrepancies of submicrosecond nature were observed in these clock settings of the three stations. These were due to satellite motion not being accounted for properly and different propagation delays encountered at three Earth stations, even though the instrumentation at all ends was based on the same design. The lack of communication due to occasional break-downs of radio network and hotline channels between DES, AES and MES as well as limited experimentation time were the other limitations. As the system was not designed for simultaneous two-way transmissions, changing from one system to the other also presented some technical inconveniences.

As a practical use of this technique on 30th June 1979 a recently procured atomic cesium clock for the STARS project at Kavalur, near Madras, was brought to MES and synchronized to submicrosecond precision in the near simultaneous three-way alternate transmit/receive mode between DES, AES and MES.

DISSEMINATION OF HIGH FREQUENCY TYPE TIME FORMAT (ATA) VIA SATELLITE SYMPHONIE

The National Physical Laboratory, New Delhi has been transmitting standard time and frequency signals[2] at 5, 10 and 15 MHz under the call sign 'ATA.' The time format transmitted is shown in Figure 5. The accuracy limitations of high frequency broadcast are quite well known. One-way time transmission technique via satellite provides not only wide coverage but also a more accurate time synchronization means, due to a stable path, as compared to ionospheric propagation. In view of these and in accordance with the national plan to, ultimately, disseminate time via Indian Satellite INSAT, a time format similar to ATA (HF) was disseminated via satellite Symphonie and experimental studies were made at Delhi, Ahmedabad, Madras and with the mobile terminal at Calcutta. The major part of the studies were, however, concentrated between DES and AES. A block diagram for the experimental setup of ATA format dissemination via satellite is shown in Figure 6. At AES, ATA (HF) data via ionosphere was, side by side, recorded for the sake of comparison with the satellite data.

The ATA format data via ionosphere and satellite, as received at AES, are plotted in Figures 7 and 8 along with the standard deviation from the best line fit. In Figure 9 is shown comparison of ATA format via satellites with 1 KHz bursts; ATA format with 1 MHz bursts where 1 KHz signal of Figure 5 was changed to 1 MHz signal; and 1 PPS transmissions from a cesium standard. These signals were transmitted from DES and monitored at AES. The corresponding standard deviations are also shown in the figures. It is clear from these that the precision achieved by using 1 KHz signal is of the same order as that with 1 MHz or 1 PPS implying a great saving on bandwidth without sacrifice in the precision.

DISSEMINATION OF TIME OF THE DAY CODED FORMAT

The ATA format was later modified to include time of the day information in year, month, day, hour, minute and second and DUT1 information in BCD code. A slow code was used and is shown in Figure 10. The block diagram of the experimental setup is shown in Figure 11. The encoding scheme is shown in Figure 12 and the decoding scheme in Figure 13. Initially, rectangular pulses were tried but these got differentiated by the interface units and the information about time was lost. Later, sinewave pulses were transmitted and rectangular pulses were generated from the received signal.

The time via satellite along with DUT1 information was displayed and studied at Delhi, Ahmedabad, Madras and with the mobile terminal at Calcutta.

As in the previous case with ATA format, no corrections were applied for the propagation delays, neither the satellite orbit elements were disseminated along with the timing information. These will, however, be incorporated in the future satellite controlled clocks to be operated via Indian satellites APPLE and INSAT.

DISSEMINATION OF TIME VIA DIRECT TELEVISION BROADCAST BY SATELLITE

Time synchronization via television, using both passive and active techniques, is a common practice in many countries. A line 10 sync separator circuit was developed for using with land television systems. The availability of satellite Symphonie provided an opportunity to try this technique using the direct TV broadcast between Delhi and Ahmedabad. The scheme of pulses in vertical blanking interval of Indian TV format is shown in Figure 14.

The block diagram of experimental setup is shown in Figure 15. The circuit diagram for a TV line -10 pulse identifier is shown in Figure 16. The TV signals were transmitted from Delhi to Ahemedabad via satellite. The TV sync separator identified line 10 of the odd field with an ambiguity of 40 milliseconds. As the propagation delay between DES and AES via satellite and between DES to satellite and back to DES were of the same order of 250 milliseconds, the time interval counter at DES was started with the local cesium clock 1 PPS and stopped with the reflected TV sync separated pulses from the satellite and the time interval counter at AES was started with local cesium clock 1 PPS and stopped with the same DES transmitted TV sync separated pulses received at AES. If C_{11} is the time interval counter reading at DES, C_{12} is the corresponding time interval counter reading at AES, T_1 is the propagation delay from DES to satellite and back to DES and T_2 is the propagation delay from DES to AES via satellite; all C_{11}, C_{12}, T_1 and T_2 correspond to the same TV sync pulse, then:

Clock off set (τ) between DES and AES is

$$= (C_{11} - T_1) - (C_{12} - T_2)$$

$$= (C_{11} - C_{12}) - (T_1 - T_2)$$

The procedure adopted for the measurements was as follows: The DES and AES clocks were first synchronized to as close a value as possible, to within a fraction of a microsecond, by using nearly simultaneous technique(1). This was done to check TV synchronization results and to gain confidence in the TV measurements via satellite. In the beginning and at the end of TV measurements, the propagation delays of 1 PPS transmitted from DES were noted at DES for the reflected pulses via satellite (T_1) and at AES for the same transmitted pulses via satellite (T_2). From these measurements the ($T_1 - T_2$) data, corresponding to the respective TV line 10 measurement time, was deduced by using Lagrangian Extrapolation. The ($C_{11} - C_{12}$) and ($T_1 - T_2$) data of TV readings and the propagation delays at DES and AES for 27th and 28th April are plotted in Figure 17 along with the mean difference of the two sets of readings and the standard deviations. From this data it is clear that TV direct broadcast via satellite is capable of giving submicrosecond precision.

The propagation delay for the TV signals were taken care of by experimentally measuring ($T_1 - T_2$) rather than theoretically calculating it where a knowledge of satellite orbital elements is necessary. However, in routine calibrations, as in other cases, a knowledge of satellite orbital elements will be required for the clock synchronization purposes.

Due to limitation on satellite time, the experiments on active TV technique and time display via direct TV broadcast could not be carried out. The National Physical Laboratory, New Delhi is developing such a technique for use with land-line connected TV systems and will try these when next Indian satellite APPLE becomes available in 1980.

CONCLUSION

As the errors involved in time dissemination experiments via satellite are quite well known and are amply discussed in literature and in the earlier paper(1) presented at 10th PTTI meeting, we have not gone into these details. The standard deviations from the best line fit are calculated and shown in the respective figures.

A major limitation in these experiments has been that only one satellite transponder was available and simultaneous two-way transmission using full video bandwidth was not possible. Thus, a parallel experimental check on the precision of the measurements, in which satellite motion could be tracked simultaneously, was not possible thus necessitating extrapolations for the satellite motion.

Another limitation from practical use point of view was that satellite orbital elements were not disseminated along with the timing information. The reasons were two fold: firstly, the emphasis of these experiments was more on to develop and try out various possible time dissemination schemes via satellite and to study their merits and demerits rather than to push the limits of accuracy and precision of any single measurement; and secondly, that the satellite orbital elements were not readily available in advance and could be had only post facto.

The future Indian plans on time dissemination via satellite include some more experimentation in this direction when the next Indian satellite APPLE becomes available in 1980 with an effort to disseminate, simultaneously, satellite orbital information as well. The ultimate aim is to use Indian National Satellite INSAT, to be launched in 1981, for a general and wider time dissemination.

Towards the end of this series of experiments, a simultaneous two-way clock synchronization experiment using both the satellite transponders was performed between the National Physical Laboratory, New Delhi (NPL) and Physikalisch - Technische Bundesanstalt, Braunschweig, West Germany (PTB) in May and June 1979. These experiments were done using the facilities at Delhi Earth Station in India and Raistings Earth Station in West Germany. The results, which are under preparation, will be reported somewhere else.

ACKNOWLEDGEMENTS

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2. V. R. Singh, G. M. Saxena and B. S. Mathur, "Development of an atomic rubidium vapour frequency standard at NPL of India using indigenous sources," Proc. Ninth PTTI Meeting, pp. 437-461, March 1978.

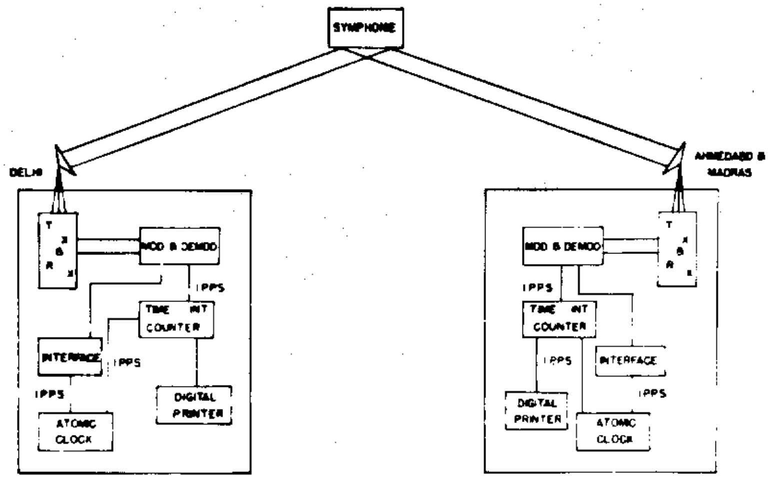

Figure 1. Block Diagram of Simultaneous Two Way Clock Synchronization Experiment

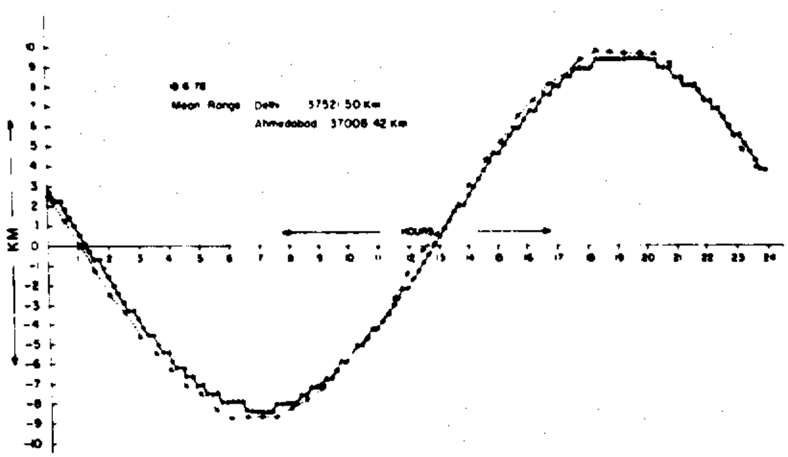

Figure 2. Variation of Satellite Range

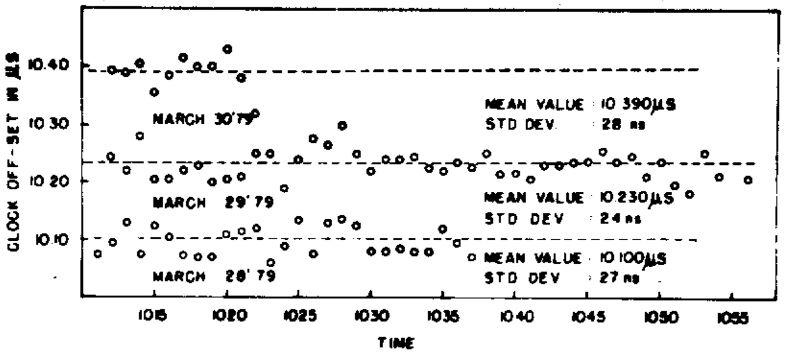

Figure 3. Simultaneous Two Way Time Comparison Between Delhi and Ahmedabad

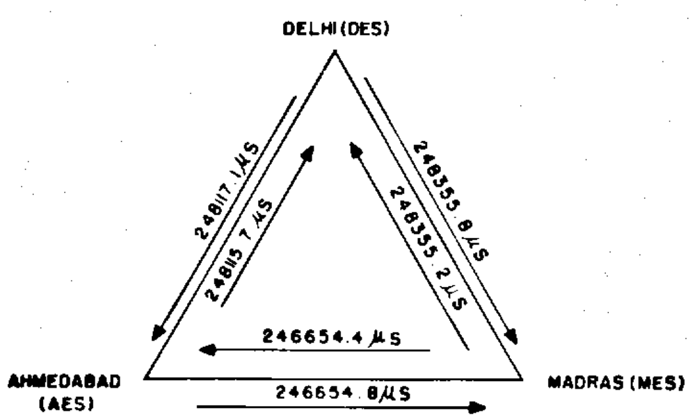

Figure 4. Three Way Time Comparison Between DES-AES-MES

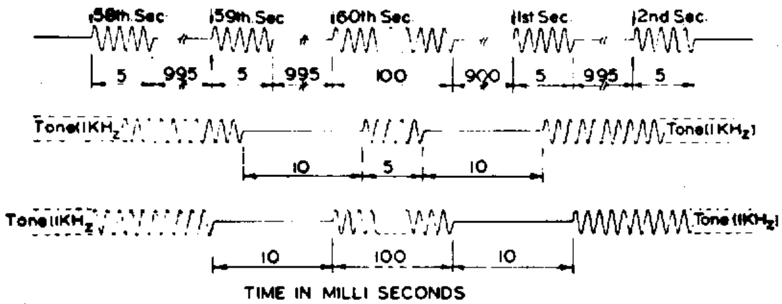

Figure 5. Time Format of ATA Signal

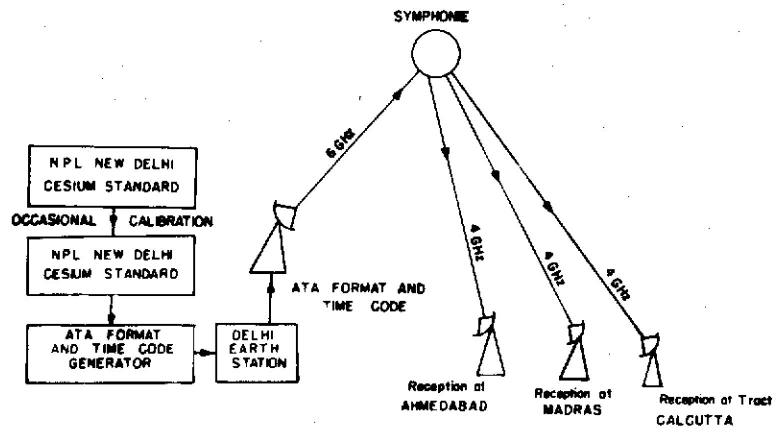

Figure 6. Block Diagram of Experimental Set–Up

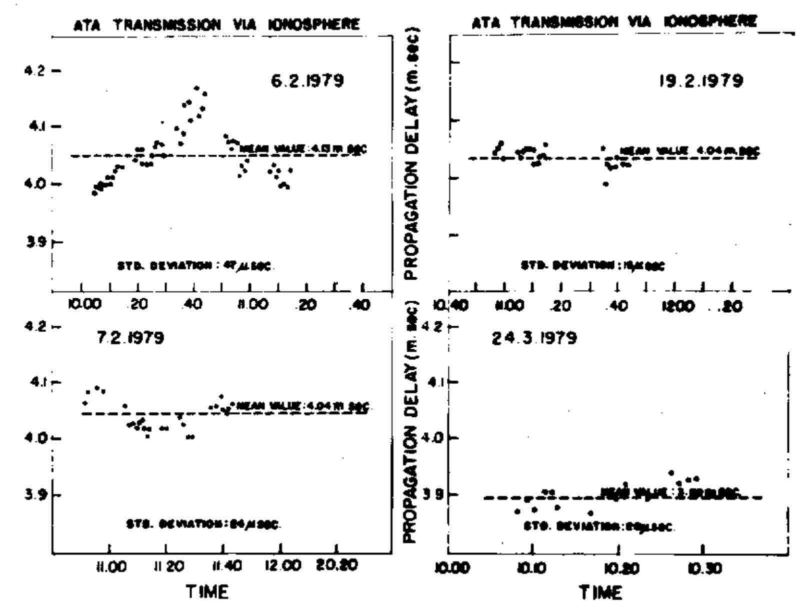

Figure 7

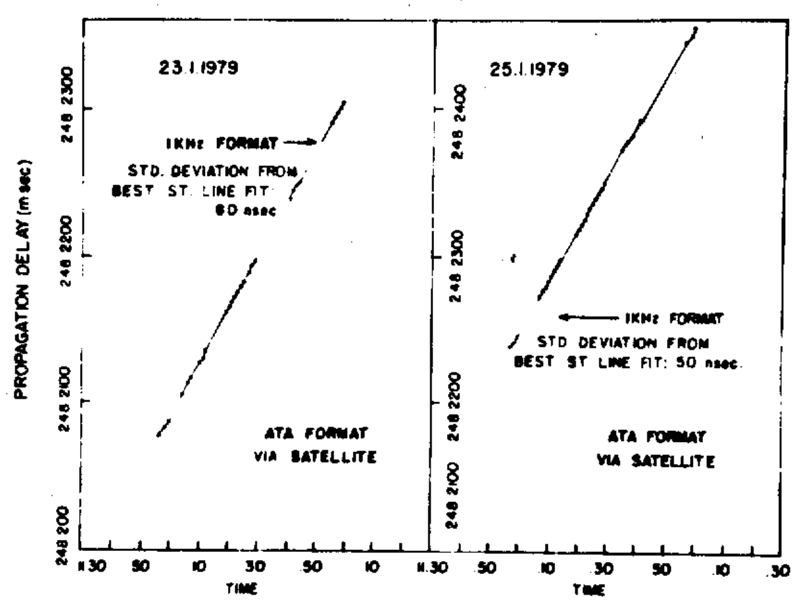

Figure 8

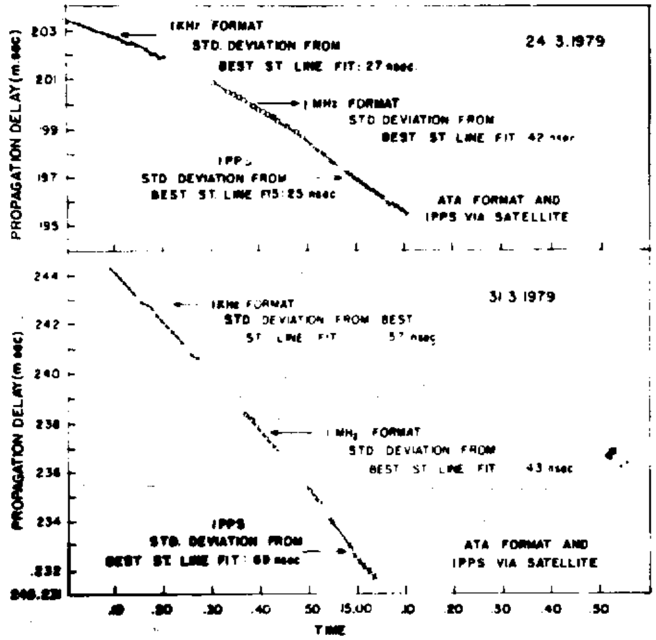

Figure 9. A Comparison of ATA Format Data Via Satellite with 1 kHz and 1 MHz Pulses and 1 PPS from a Cesium Standard as Recorded at AES

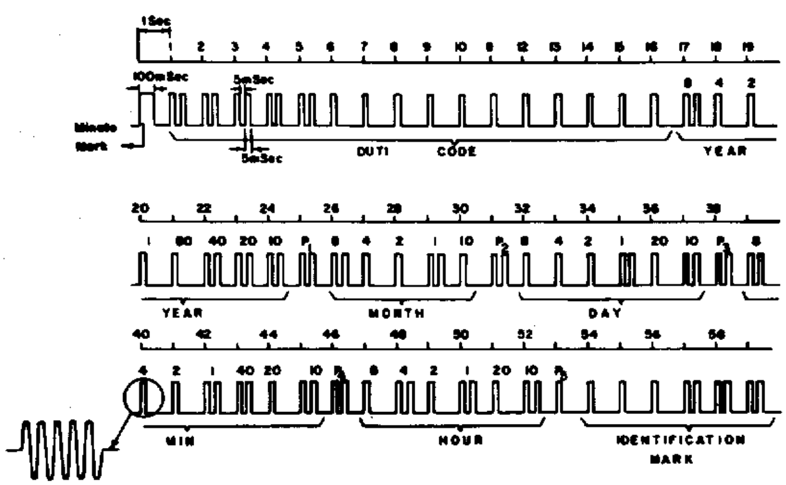

Figure 10. Code for Time of the Day Dissemination

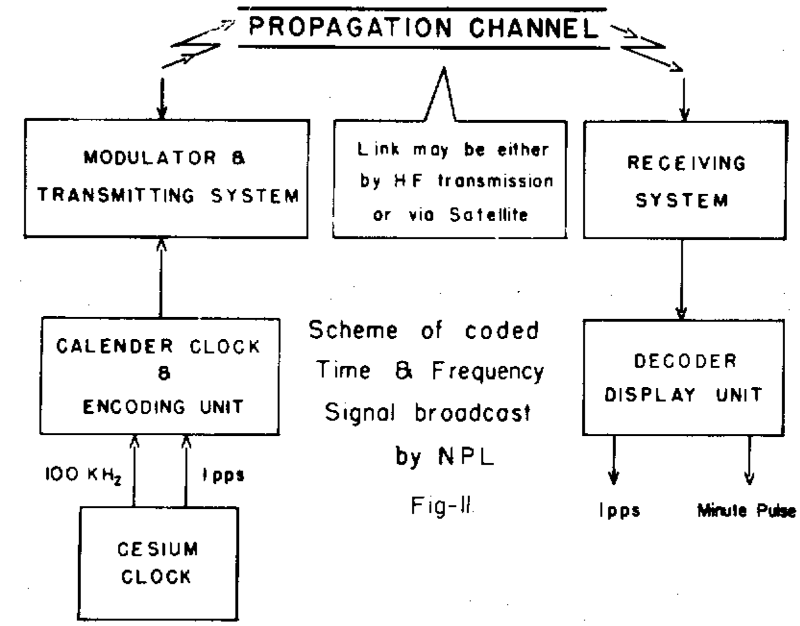

Figure 11. Block Diagram of the Experimental Set Up for Coded Time Signal Broadcast

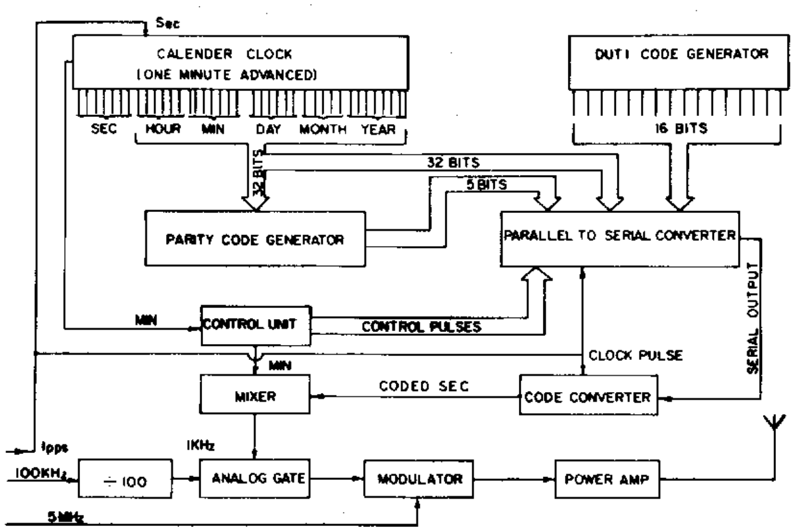

Figure 12. The Encoding Scheme for Time Signal Broadcast

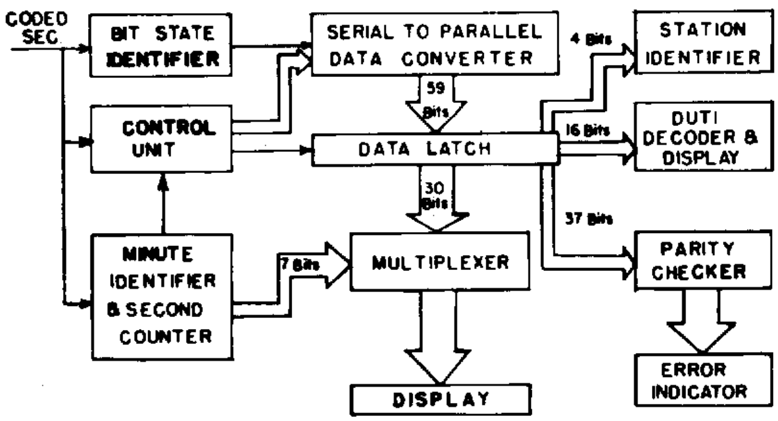

Figure 13. The Decoding Scheme for Time
Signal Broadcast

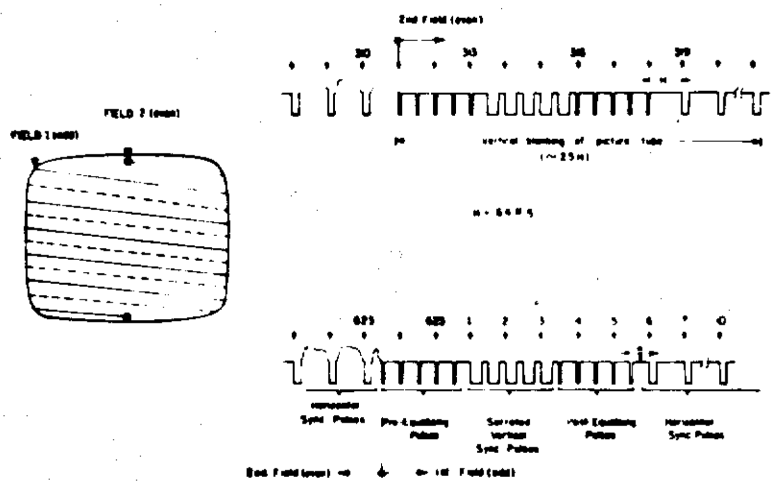

Figure 14. Pulses in Vertical Blanking Interval
of TV Format in India

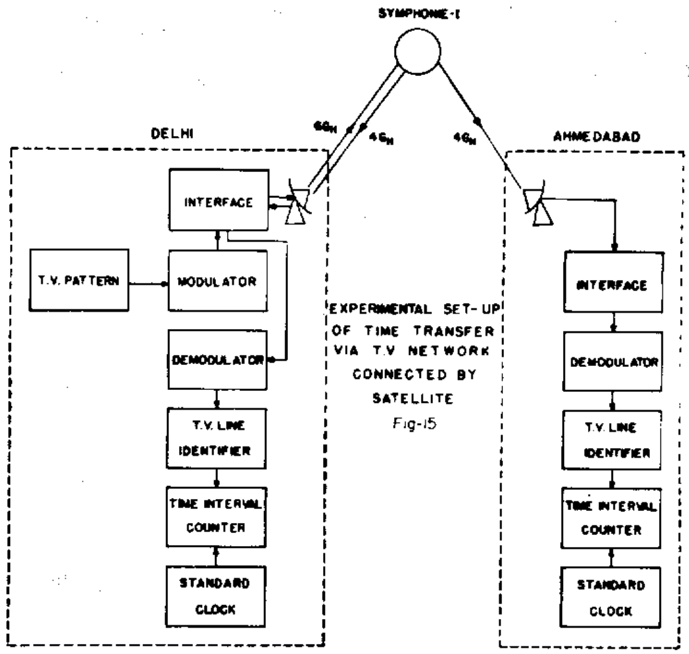

Figure 15. Block Diagram of Experimental Set Up for Time Dissemination Via Direct TV Broadcast by Satellite

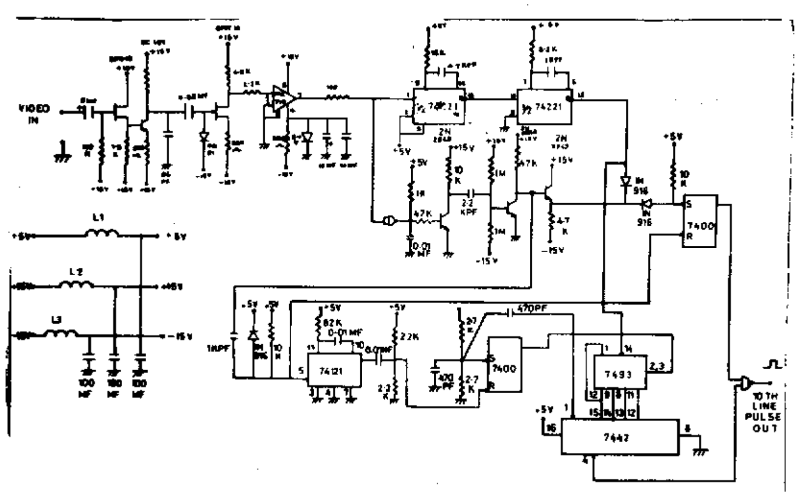

Figure 16. Circuit Diagram for a TV Line-10 Pulse Identifier

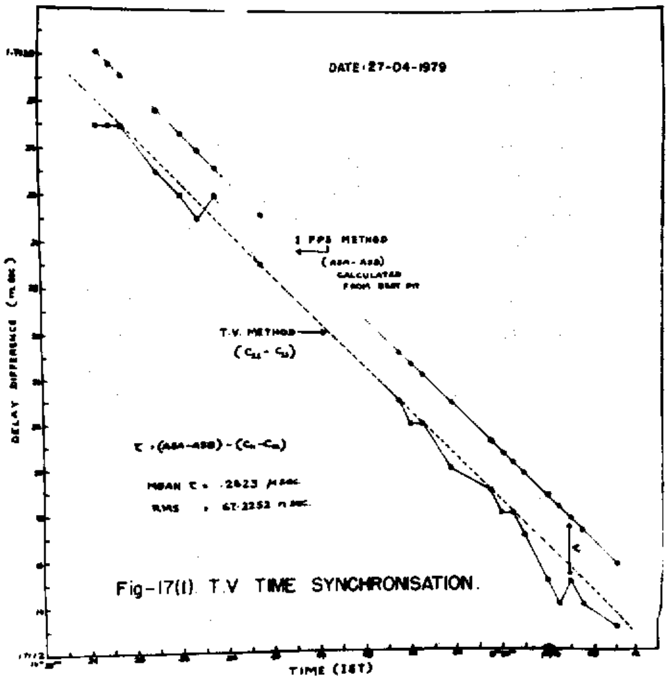

Fig-17(1). T.V TIME SYNCHRONISATION.

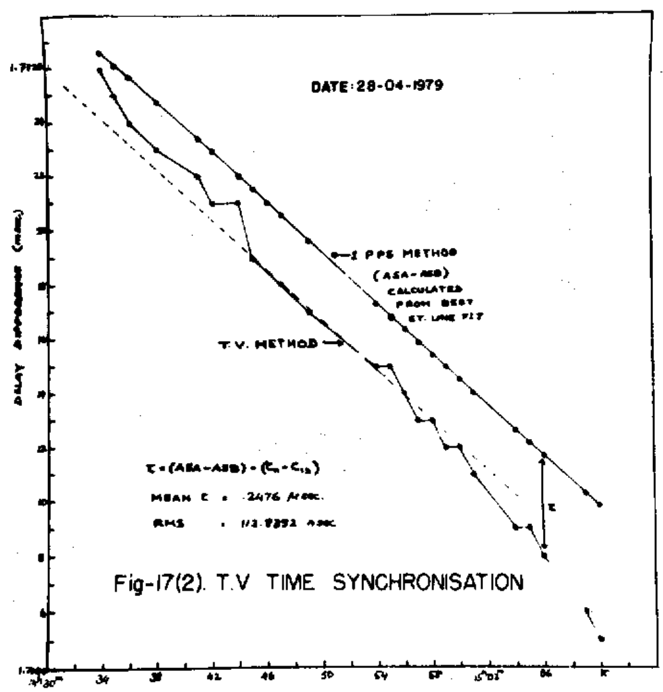

Fig-17(2). T.V TIME SYNCHRONISATION

Figure 17. Data Plot for Time Synchronization Via Direct TV Broadcast by Satellite