TIME SYNCHRONIZATION EXPERIMENTS WITH APPLE

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ABSTRACT

Several Time Transfer/Synchronization techniques viz transmissions of 1PPS, TV Passive, TV Active, transmission of INSAT Time Code etc. were tried out on the Indian Experimental Satellite APPLE. The availability of the APPLE Satellite for a long time gave us the opportunity to try out various new techniques which could not be tried out earlier on Symphonie and to firm up the specifications of the hardware required to be developed for various catagory of users when INSAT becomes available on an operational basis for the dissemination of Standard Time and Frequency.

The drift of APPLE Satellite in its orbit was found to be about 150 meters/sec. Because of such large change in the range of the satellite it was not possible to achieve expected accuracies in the time transfer. Due to the availability of only one transponder on board, most of the experiments were conducted in quasi-simultaneous mode. The use of 2nd order range extrapolation technique to correct for the satellite range helped us to get better time transfer accuracies than was possible with linear extrapolation. Using the techniques of 1PPS, ranging to the APPLE was carried out and orbit computation was attempted and used in a TV passive technique. In this paper results of various experiments conducted on APPLE are presented.

INTRODUCTION

The technique of Standard Time and Frequency (STF) dissemination via satellite is well established. Dissemination of STF via satellite provides many unique advantages over HF propagation technique viz larger coverage, better accuracy, better S/N ratio. A satellite in its orbit is used in two modes, first in which the satellite is the source of Standard Time and Frequency and the second in which satellite is used to transfer time from a Master Station to the User Station. In the first technique the user should know the precise orbital elements of the satellite along with various bias parameters like Onboard Clock accuracy and its drift, propagation path delay, Receiver ground co-ordinates, tropospheric and ionospheric delay, Receiver delay etc. (Satellites like NNSS, GOES, GPS etc. fall in this category). In the second case the various biases that should be known accurately are the propagation path delay from Master Station to the User Station, earth station delay, ionospheric and tropospheric path delay, clock offset of the Master Station with respect to UTC, satellite transponder delay, etc. The advantage of Geostationary satellite for the dissemination of STF is that most of the bias parameters can be determined fairly accurately and they remain unchanged for a long period. In this paper results of various experiments conducted on APPLE Geostationary satellite are presented.

APPLE UTILIZATION PROGRAM

Under APPLE Utilization Program, Space Applications Centre, Ahmedabad and National Physical Laboratory, New Delhi conducted mainly two types of experiments viz:

(a) Time Dissemination experiments relevant to INSAT
(b) Ranging of the Satellite

(a) In India several time dissemination techniques have been tried out on experimental basis using Symphonie [1, 2, 3, 4, 5] and APPLE Geostationary satellites. In Table -1 we have given a list of various techniques tried out on Symphonie and APPLE and accuracies achieved. Out of the various techniques used, three techniques viz TV Passive technique, TV Active technique and Transmission of INSAT Code on RN Channel are found to be more useful on INSAT for the dissemination of STF. These three techniques could be used without affecting the basic usage and with no additional requirement on the Space-craft and with only incremental investments on the ground segment.

The necessary hardware required for the generation of and decoding of the INSAT Format was developed at National Physical Laboratory, New Delhi and tested on APPLE. A narrow band RN Channel in S band has been allotted for this purpose on INSAT-1B. Initially it is planned to use this channel on an experimental basis but it is likely to be made operational as the number of users increase with time.

The Format of Standard Time planned for INSAT-1B is shown in Figure 1. It is a slow code and carries information about the number of days of the year, time of the day in Indian Standard Time, satellite position co-ordinates and DUT1. Distribution of bit information is elaborated in Figure 2, one complete Format of information consists of 59 bits between two consecutive minute marks, the first 29 bits carry information about days, hours and minutes, the remaining 30 bits carry information about satellite co-ordinates.

(b) In the satellite ranging experiment a station transmits 1PPS (one pulse per second) and receives back the same via satellite and measures the time interval between the transmitted and received pulse. If T is the time interval between the transmitted and received pulse, the range to the satellite is given by $\frac{cT}{2}$ where c is the velocity of electromagnetic waves in free space. The overall accuracy of the range measurements depends on several bias parameters. We have comapred in Table-2 the ranging data obtained from Clock synchronization technique with the C -Band tone ranging technique carried out simultaneously. The C -Band tone ranging technique is a conventional technique used for satellite tracking by transmitting a burst of low frequency tone and comparing its phase differences with the received tone burst, transmitted back by the satellite. Range values from clock synchronization data were found to be consistently lower by about 6.5 to 7.0 km from tone ranging values. The difference could be attributed to the unknown bias parameters of either earth stations. This comparison indicated the potentiality of using time synchronization technique for tracking geostationary satellite. A Computer Program for orbit determination using these ranging data was developed. In this program by a least square method the square of the difference between the observed range and theoretically calculated range is minimized by iteration and updating of the orbital parameters. This was done mainly for the determination of orbital elements required for the INSAT Format. The main aim of ranging and orbit determination was to study the feasibility of generating orbital elements of the satellite to be transmitted with INSAT format keeping in view the accuracy requirements of various users. With such Orbit improvement it was possible to cater the requirement of Users who needs time to an accuracy of better than 50 microsecond.

CONCLUSION

Though the accuracy achieved via APPLE is not as good as was obtained using Symphonie, it gave us an opportunity to try out some of the new techniques which could not be tried out on Symphonie and also to develop and test necessary hardware to be used on INSAT for the dissemination of STF. The main reason for the poor time transfer accuracy was due to the large drift of the APPLE owing to the instability of its Orbit.

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TABLE -1.

S.No.	TIME DISSEMINATION TECHNIQUE	ACCURACY SYMPHONIE	ACCURACY APPLE	REMARKS
1.	Two way quasi simultaneous[1]	Better than 1 Microsecond	Better than 10 Microsecond	Second order range extrapolation technique tried on
2.	Two way simultaneous[2, 3]	"	-	
3.	ATA transmission via satellite[2, 5]	"	-	
4.	TV Passive technique[2, 4]	"	Better than 30 microsecond	
5.	TV Active technique	-	-	Hardware tested & Methodology Established
6.	Transmission of INSAT Time Code	-	-	"

TABLE -2.

DATE 25-8-82 TIME UT HR	MN	SEC	RANGE IN KMS TONE RANGING TECHNIQUE	RANGE IN KMS CLOCK SYNCHRONISATION	ABSOLUTE DIFFERENCE
09	56	32	38070.365	38063.822	6.543
09	59	31	38074.600	38068.020	6.579
10	02	31	38078.83	38072.123	6.709
10	04	31	38081.72	38074.810	6.910

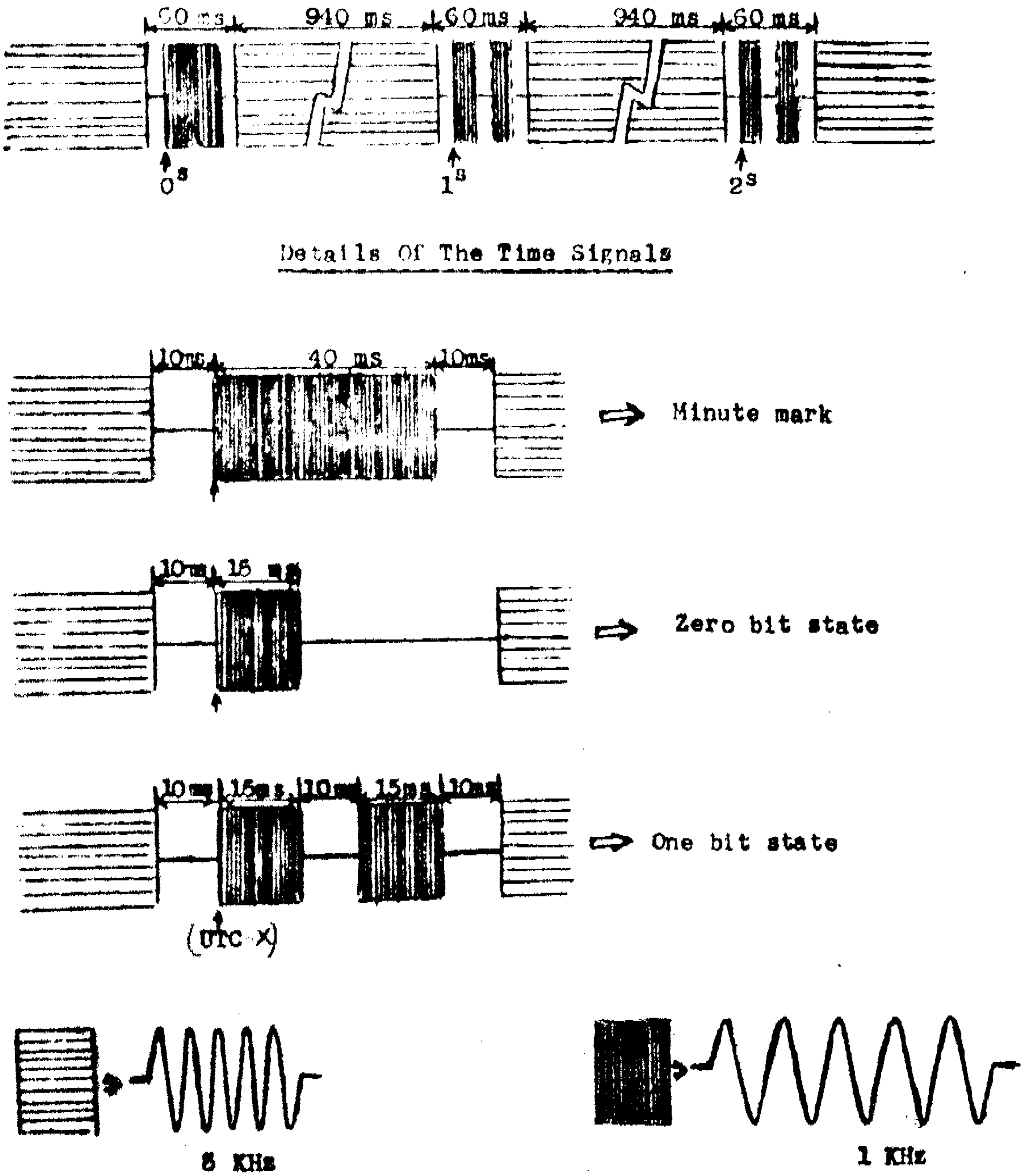
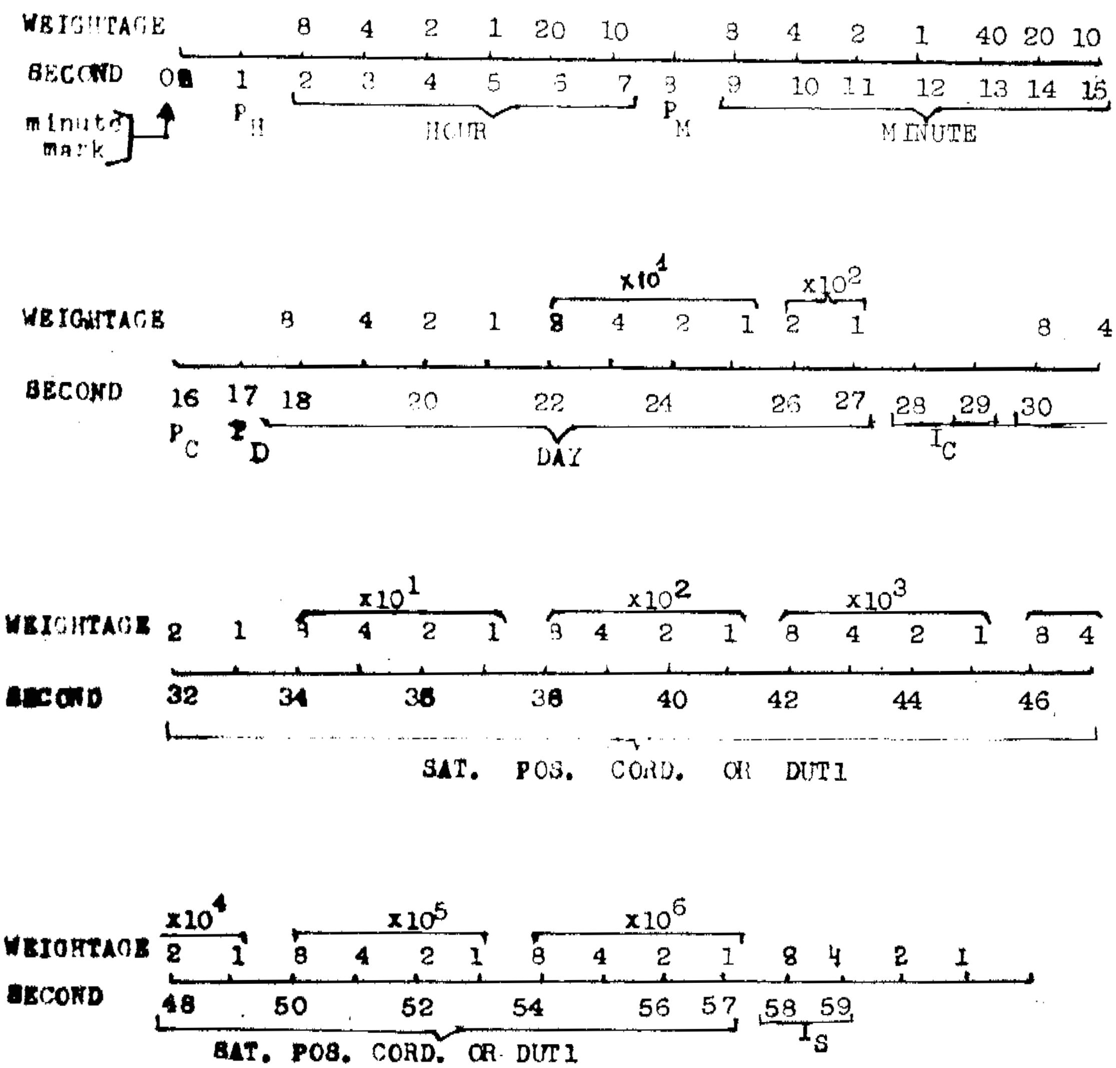


FIG. 1: STF SIGNAL FORMAT VIA INSAT (RN TYPE CHANNEL)



P_H = Hour Parity	I_D = Status Indicator	1 = Normal 0 = Poor
P_M = Minute Parity	I_C = Identification for position cordinates.	00 = X 10 = Z 01 = Y 11 = DUT1
P_C = Combined (Hour and minute) Parity	I_S = Identification for Satellite	11 = INSAT 1A 00 = INSAT 1B

FIG. 2: DISTRIBUTION OF BIT INFORMATION FOR INSAT TIME SIGNAL FORMAT