EVALUATION OF TROPOSPHERIC AND IONOSPHERIC TIME DELAYS USING 3-DIMENSIONAL RAY TRACING AND THEIR COMPARISON WITH GLOBAL POSITIONING SATELLITE SYSTEM FOR TIME DISSEMINATIONS VIA SATELLITES IN L-BAND MICROWAVE FREQUENCY

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1. Introduction: The time and frequency microwave transmissions via satellite undergo a time delay due to group retardation effects through the troposphere and ionsophere and this sharply decreases the accuracy of time signal. In the microwave band, Global Positioning Satellite system (GPS) transmit on two frequencies, one at 1572.42 MHz and the other at 1227.6 MHz from an altitude of 20,183 Km. with a 12 hour orbit. In terms of navigation accuracy, one nano second of time error is equivalent to 0.3 meters of range error so that the precision timing and frequency control are essential for the GPS system.

The major influencing factors in troposphere are humidity and temperature. For the propagation of radiowaves in the ionosphere, electron density is an imporant factor which has local time, seasonal and solar activity variations. The calculations of time delay were done in the past by several authors (Hopfield 1969, Tyagi et al. 1972 , Somayajulu et al. 1972, Millman,1975 Ghosh A.B., 1976, Mitra A.P., 1976, Easton et al 1976, Spilker J.J. 1977, Hogg et al 1981, K. Davies 1982, Bock et al 1985, Ware et al. 1985, Randolph et al. 1986, Ghosh A.B., 1987, Ghosh et al. 1988). In the present paper actual GPS computations using a GPS receiver at 1.57542 GHz in NPL, are compared with the computations usuing 3-dimensional ray tracing program for time disseminations via satellites.

2. System description of GPS receiver

National Physical laboratory procured a GPS receiver in August 1986 and started tracking regular satellite passes since February 1987. The receiving set up tracks the GPS satellite in L-band at 1.57542 GHz. The block diagram for the receiving system is shown in Fig.1. The receiving set up uses an omnidirectional whip antenna and an antenna mount pre-amplifier and down-convertor. The first conversion produces an I.F. of 75.42 MHz which is fed to the indoor unit. The unit makes two further conversions with intermediate frequencies of 10.7 MHz and 700 KHz. The use of triple conversion almost eliminates the problems of false locking. The transmitted PN sequence is a 1023 bit C/A code. When the receiver is in tracking mode, the microprocessor computes the expected Doppler from Aluminac data and sets the carrier synthesiser accordingly. The carrier synthesiser remains within $\pm$ 200 Hz of the carrier centre frequency when the track mode is initiated. The receiver has abuilt in time interval counter with a resolution of 0.1ns. During satellite tracking, each measurement computation involves doing a least square quadratic fit to 15 seconds of pseudo-range data, evaluating the mid point estimate of the fit, computing the slant range to the space vehicle (SV), making a sagnac correlation, computing the S V clock correction and storing time interval values of (Local-SV) and (Local-GPS). At the end of each track time, the system does a least square linear fit on the 15 second data points for Local-SV and Local-GPS. It then stores intercepts and slopes alongwith SV , time at beginning of track, azimuth and elevation of the satellite and at the end of track, the ionospheric delay and standard deviation for the fits. The cesuim clock has an accuracy of few parts in 10^{13} and drift of 10 nsec/day.

3. *Model calculations and comparison with GPS computation*

The total time delay (ΔT) can be summed up as equal to tropospheric time delay (ΔT_t) ionospheric time delay (ΔT_i) and a noise ϵ

$$\Delta T = \Delta T_i + \Delta T_t + \epsilon$$

The contribution of tropospheric and ionospheric time delays to the total time delay (ΔT) can be calculated from the model profiles.

3.1 *Tropospheric models*

It is possible to build tropospheric profiles from 0 to 10 Km for different locations in India (Majumdar et al, 1977, Sarkar et al. 1985).

3.2 *Ionospheric models*

Ionospheric models have been built by NPL for different locations in India (Somayajulu and Ghosh, 1979, Singh et al. 1987). Using these profiles and using a ray tracing program also available in NPL (Ghosh, 1976), one can trace the actual trajectory of the microwave from the ground to satellite in each case for chosen times. Considerale improvement in prediction is possible with the residual error ϵ being the only remaining error. The procedure is as follows.

1) *To build the appropriate tropospheric refractivity and ionospheric electron density profiles over the path*

2) *To trace the ray trajectory for the appropriate path*

3) *To compute ΔT_i & ΔT_t*

4) *To introduce a noise in the profile and to obtain ϵ*

5) *To carry out computations for different locations in the world*

The data presented here is based on GPS measurements taken at NPL during December 1988 when the average susnpot number is 150, although daily sunspot numbers sometimes went upto 190. Calculations of ionospheric time delay using electron density profiles for Delhi for sunspot numbers 150 and 80 during daytime for the month of June, October and December were conducted using 3-dimensional ray tracing program for L-band at 1.57542 GHz. The Global Positioning Satellite system (GPS) receiver has been used to track the satellite signal only above 20^o elevation angle. The GPS time delay computations during the month of December 1988 are plotted as a function of elevation angle in Fig.2. The computations from 3-dimensional ray tracing program of ionospheric time delay for the sunspot number 150 at 1.57542 GHz over Delhi correlates fairly well with the GPS computations. The GPS computations are found to have a spread of 10 n second time delay mainly because of the diurnal and solar activity variations which has its effect on the electron density profile fluctuations. 3-dimensional Ray tracing program also calculates the tropospheric contribution to the total time delay of the L-band signal (Fig.3)

4. *CONCLUSION*

For precise time dissemination of L-band signals using Global Positioning Satellite system, it will be appropriate if the total delay through the troposphere and ionosphere is taken into consideration.

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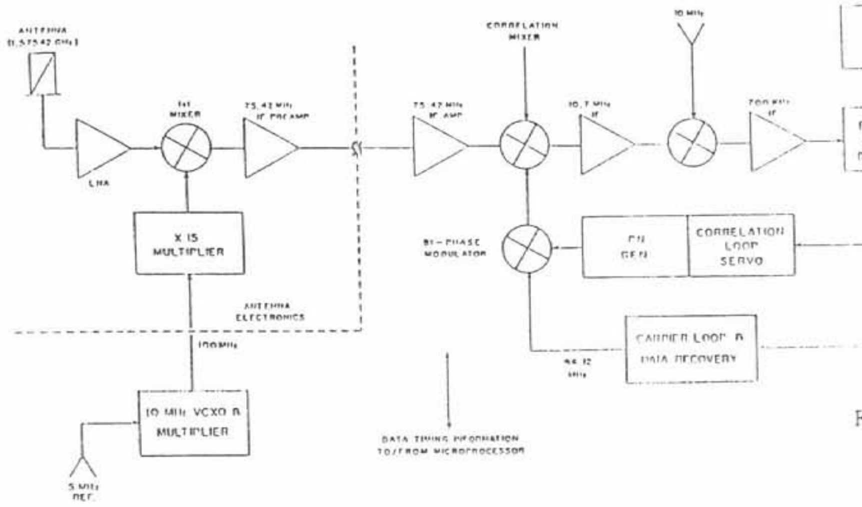

Fig. 1

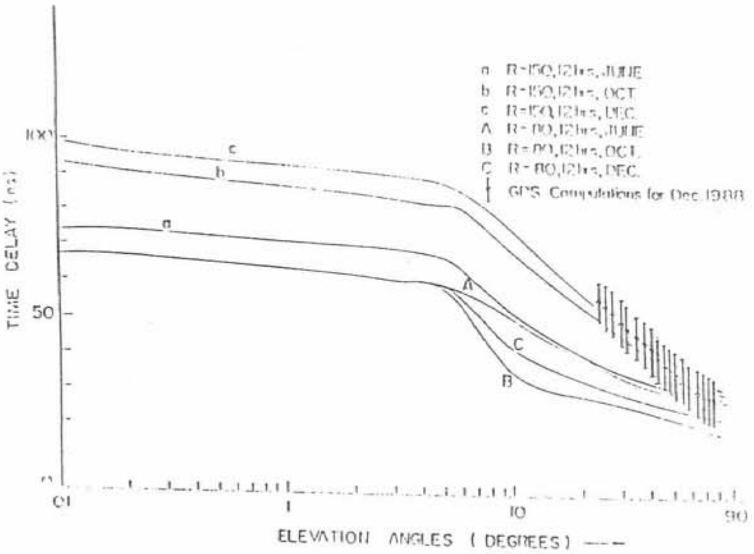

Fig. 2

COMPARISON OF IONOSPHERIC TIME DELAY OVER DELHI (28.6°N, 77.2°E) USING REFERENCE ELECTRON DENSITY PROFILES WITH GLOBAL POSITIONING SATELLITE COMPUTATIONS.

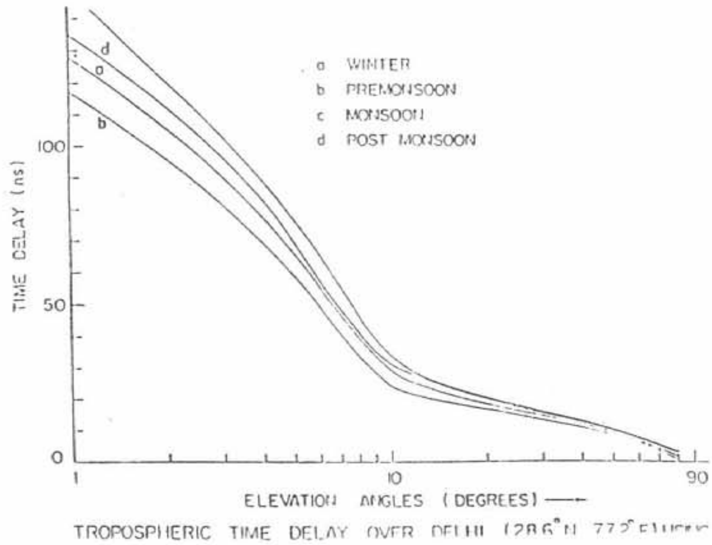

Fig. 3

TROPOSPHERIC TIME DELAY OVER DELHI (28.6°N, 77.2°E) USING