C–9–3 SHORT TERM PHASE SCINTILLATION THROUGH TROPOSPHERE

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1. Introduction

Tropospheric turbulence such as mirages, gusts and precipitation cause root-mean-square phase deviation of a received radio wave, which means the electrical propagation-path length or time delay fluctuations occur in the troposphere. The magnitude of the effects were calculated from the model derived by Muchmore and Wheelon (1955)<1>, who give the one-way phase fluctuations, and some papers reported the measured r.m.s. phase fluctuations and their spectrum<2,3>. In this paper, short term phase fluctuations(milli-seconds order) measured in the VLBI(Very Long Baseline Interferometer) experiment using the ATS-1 satellite at 4180MHz are presented. The results show that about 2 millimeters r.m.s. path length fluctuations or 6 pico-seconds r.m.s. time delay fluctuations in 10 milli-seconds were observed at low elevation angle.

2. Measurement

The VLBI experiment system block diagram is shown in Figure 1. The baseline length between two antennas is 120 Km and the 26-meter antenna at the Kashima Branch of the Radio Research Laboratories and the other 12.8-meter one at the Yokosuka Electrical Communication Laboratory of the NTT (Nippon Telegraph and Telephone Public Corporation) were used.

The noise power from the ATS-1 was received at each antenna at the same time and each received signal was converted to video band (200kHz-2MHz), extreamly clipped and sampled at 4MHz clock into one bit signal. One-bit sampled signals were coded to di-phase signals and recorded on magnetic tapes(VTR).

Each tape was repro-

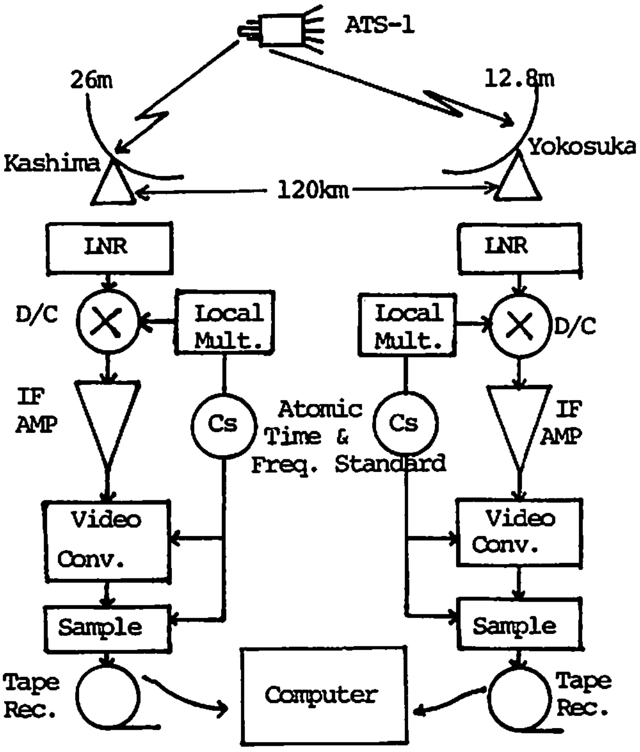

Fig.1 VLBI Experiment Block Diagram

duced to correlate and process the data in the computer. Phase spectrum and differential delay were calculated from the correlation function. Phase of the cross-correlation function at the received frequency include phase fluctuations of instruments, especially local oscillators, and propagation through troposphere.

In the system, the local frequency stability is very important and its phase jitter at the first local frequency 4110 MHz limits the averaging time of the cross-correlation and the accuracy of phase scintillation or time delay fluctuation due to troposphere.

All local frequency and sampling clock were supplied by multiplying or dividing the 5 MHz signal of the cesium atomic frequency standard oscillator and measured frequency stability between the two local oscillators at Kashima and Yokosuka, was less than three parts in ten to the eleven at one second averaging time.

If another phase variation during measurements are small and negligible, the observed or calculated phase fluctuation is expressed as follows;

$$\phi_{obs} = \sqrt{\phi_{trop}^2 + \phi_{local}^2} \tag{1}$$

Phase fluctuation, ϕ_{trop} , in the troposphere depends on the total propagation-path length in turbulent media, that is, the elevation angle of the antenna and it may be formulated as follows <1>;

$$\phi_{trop} = \frac{\pi}{\lambda}\cdot\Delta\varepsilon_r\cdot\sqrt{2 l_o R} \tag{2}$$

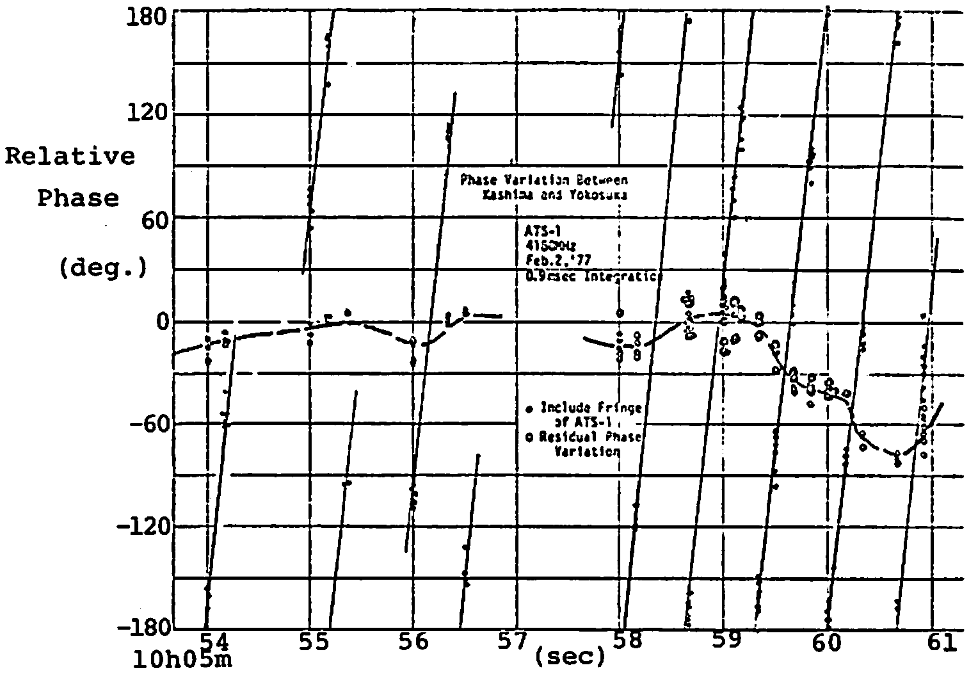

Fig.2 Observed Phase Variation in VLBI Experiment

where, λ: free space wavelength
$\Delta\varepsilon_r$: dielectric constant excursion(r.m.s.)
ℓ_o: scale length of turbulence
R: total propagation-path length in turbulent media

In many case, $\Delta\varepsilon_r$ is in the order of ten to the minus six, ℓ_o is 3--30 meters and if H is the zenith height of turbulent atomosphere and $E\ell$ is the elevation angle, R is denoted as follows;

$$R=H\mathrm{cosec}(E\ell) \qquad (3)$$

Figure 2 shows the typical observed phase variations in 7 seconds and many steep solid lines are total phase variations including the fringe variations due to the satellite drift and the slowly varying broken line is in correspondence to the residual phase fluctuations after subtracting the linear-fitted phase variations due to the satellite drift, which may be equivalent to Equation 1 .

Figure 3 shows the observed phase fluctuations at some different elevation angles. Each observed phase was measured in 0.9 milli-seconds and r.m.s. phase fluctuation was caluculated during about 10 milli-seconds. Figure 4 shows a typical phase fluctuation in 10 milli-seconds. ϕ_{obs} in Figure 3, the broken-line, is calculated the right side of Equation 1 to fit the observed values.

From this, phase jitter due to local frequencies, ϕ_{local}, is about 5 degrees r.m.s., and the pase scintillation through troposhere at 1.7 degree elevation angle may be about 8.7 degrees r.m.s., which means that about 2 milli-meters r.m.s. propagation-path length or 6 pico-seconds time delay fluctations was observed during 10 milli-seconds.

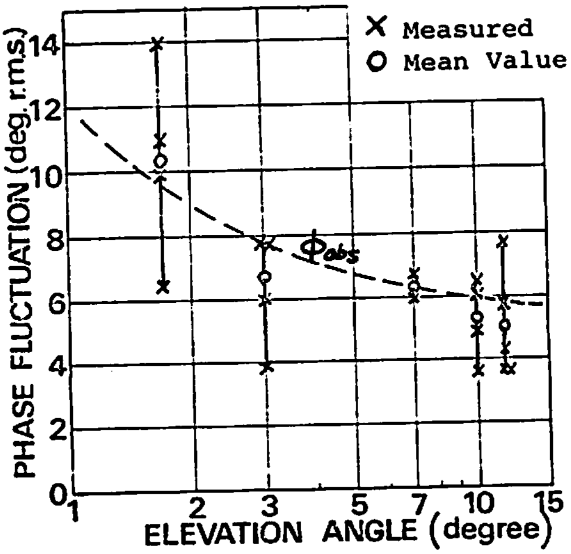

Fig.3 RMS Phase vs Elavation

3. Conclusion

There has not been reported a short term phase fluctuation about less than one second. For the first time, a very short term phase scintillation was observed at 4 GHz at low elevation angle. The amount of the scintillation was not large, i.e. less than 2 milli-meters r.m.s. propagation-path length variation in milli-seconds term due to tropospheric turbulece, and no serious effects are supposed to a mm-wave wideband communication channel. Data measured are not sufficient to calculate the spectrum.

However, this gives a limitation to the accuracy of differential path length or time delay in VLBI experiment and it seems to be important to a geodetic application <4>, precise tracking of a satellite <5> and a large scale phased array on the ground.

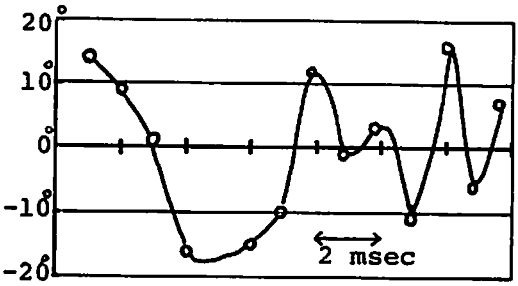

Fig.4 A Typical Scintillation

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Reference

<1> R.B. Muchmore & A.D. Wheelon; "Line-of-Sight Propagation Phenomena - I. Ray Treatment", Proc. IRE pp1437-, Oct. 1955

<2> J.W. Herbstreit & M.C. Thompson; "Measurement of the Phase of Radio Waves Received over Transmission Paths with Electrical Lengths Varying as a Result of Atmospheric Turbulence", ibid pp1391-

<3> M.C. Thompson et al; "Phase and Amplitude Scintillations in the 10 to 40 GHz Band", IEEE Trans Ap-23 No.6, Nov. 1975

<4> I.I. Shapiro et al; "Transcontinental Baseline and the Rotation of the Earth Measured by Radio Interferometry", Science Vol.186, Dec. 1974

<5> J. Ramasastry et al; "Tracking of the ATS-3 Synchronous Satellite by the VLBI Technique", GSFC X-553-72-290, July 1972