差動ラジオメータを用いた大気位相補償実験

Experiments on atmospheric phase correction using a differential radiometer

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Abstract

Experiments to detect the spatial difference of the excess path length(EPL) was performed by using a 2-channel water vapor radiometer at 22GHz at Mizusawa, Japan. To attain a good spatial resolution angle 10m antenna which is usually used for maser radio source observations was used. The detected EPL difference corresponds to atmosphere which has phase stability of 3×10^{-12} in Allan standard deviations when antenna was switched spatially by 5° and 10° in azimuth angle while elevation angle was maintained at 60°.

1. Introduction

A 2-channnel water vapor radiometer was assembled using 10m antenna designed mainly for astronomical observations, which is considered to be good for spatial resolution angle of 1° or better. An outline of our hardware system and some of the results obtained by the system are described.

2. System Description

Our 2-channnel radiometer uses ordinary astronomical observation system for 22GHz band. Some of the auxiliary devises were added for radiometer use. Outline of our system is shown in Fig. 1 and Table 1.

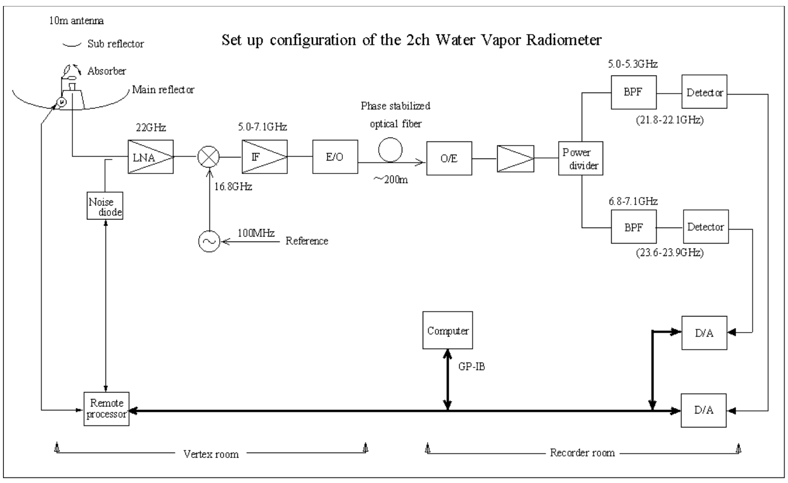

Fig. 1 A block diagram of our radiometer

Antenna diameter:	10m
Antenna drive speed and acceleration:	3° /sec and 3° /sec^2
Frequency of channel 1:	21.95GHz
Frequency of channel 2:	23.75GHz
Receiver noise temperature of channel 1:	150K
Receiver noise temperature of channel 2:	128K
Bandwidth of each channel:	300MHz
Calibration:	radio wave absorber (300K, 77K) and noise diode

Table 1 Some of the specifications of our radiometer

3. Elimination of the continuum component

Continuum components were removed being assumed quadratic form for brightness temperature vs. frequency and the estimated excess pass length and the brightness temperature of the continuum component(Tc) are shown in Fig's.2 and 3.

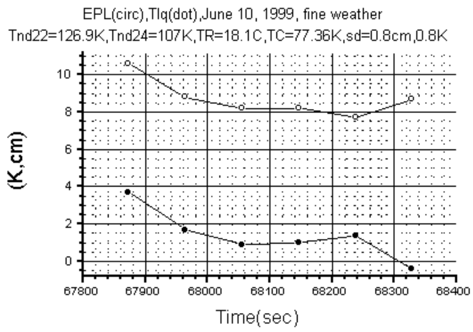

Fig.2 Observed EPL(upper line) and T_C on a good weather condition.

Figure 3 is for the bad weather condition being opacity is 0.3 at 21.95 GHz. Enhancement in Tc is seen after 36000sec. while EPL remains almost constant.

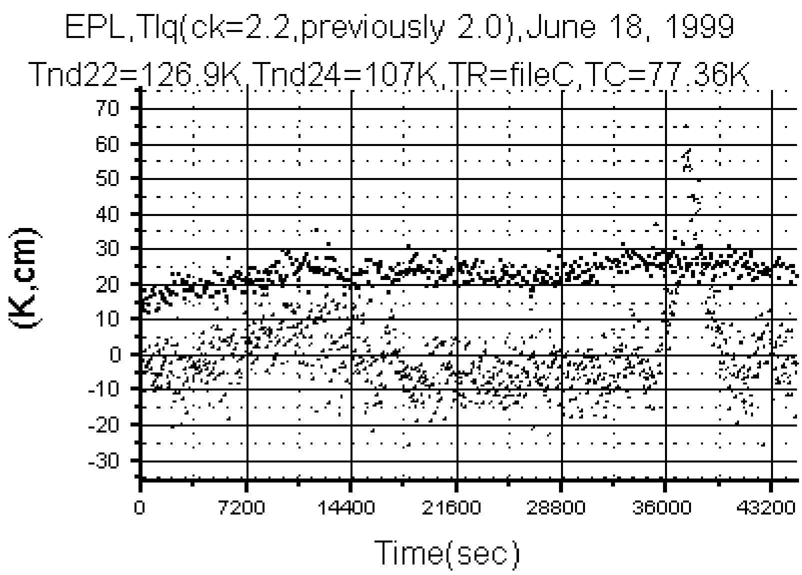

Fig.3 Observed EPL(upper line) and T_C on a bad weather condition.

4. Spatially Differential Radiometer

Atmospheric phase fluctuation characteristics were measured for spatially differential phase by switching antenna pointing angle. Phase stability in Allan standard deviation (ASD) is shown in Fig.4a when antenna pointing was maintained at azimuth angle of 140° and elevation angle of 60° . Only system noise temperature was observed by making noise diode on and off and atmospheric noise temperature was obtained by subtracting the receiver noise temperature, which was assumed to be constant. Typical atmospheric phase fluctuation seems to lasts up to the time scale of 100sec in Fig.4a. The ASD enhancement seen at the time scale of 1300sec. is probably due to receiver noise temperature variation, which is out of the time scale concerned with atmospheric phase fluctuations.

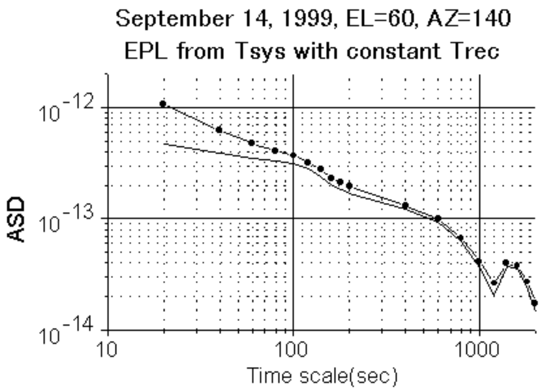

Fig.4a Atmospheric phase stability with no antenna pointing angle switching.

Fig.4b shows the ASD of the spatially differential EPL which were obtained by switching the antenna pointing in azimuth angle of 5° with the elevation angle fixed at 60° . The spatially differential phase shows that the phase fluctuations are white phase noise like which means that the typical atmospheric fluctuations are removed. Spatial separation of 5° corresponds to about 20sec. in temporal separation if the velocity of the frozen flow at the altitude of 1000m is assumed to be 8.6m/sec. This properly applies the case shown in Fig.4b.

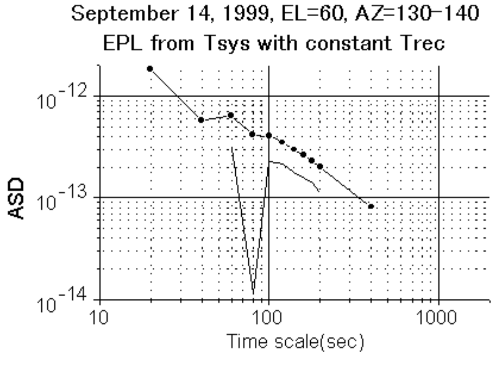

Fig.4b Atmospheric phase fluctuations obtained by spatially differential radiometer with the separation angle of 5° in azimuth angle.

The ASD for the differential phase with separation angle of 10° is shown in Fig.4c. The ASD is larger than the one shown in Fig.4b corresponding to the larger separation angle.

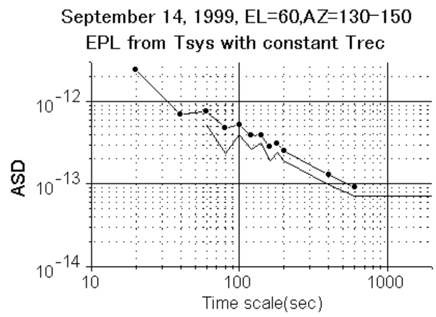

Fig.4c Atmospheric phase fluctuations obtained by spatially differential radiometer with the separation angle of 10° in azimuth angle.

These examinations show that the typical atmospheric phase fluctuations of flicker frequency like noise can be removed by spatially differentiation. Then can we detect the EPL difference by our radiometer? It is required to remove thermal noise by integrating for longer time period because the expected EPL difference would be a few mm if the ASD at one second is assumed to be 5×10^{-13} as expected from Fig.4a. The standard deviations of the observed EPL differences are shown against spatial separation angle in azimuth angle in Fig.5. This figure shows the general tendency of the increasing standard deviations with separation angle but the magnitude of variations are several times larger than the expected one. The observed magnitude of phase variation corresponds to 3×10^{-12} with assumption that constant white phase noise is superposed to atmospheric flicker frequency noise. The magnitude of the standard deviation of differential EPL which was calculated by subtraction with time lag of the same time series of EPL data is almost consistent with the expected value. This evidence shows additional EPL variation is aroused by switching antenna pointing probably due to the effect of ground radiation and gain variation of the low noise amplifier. The 3-channel radiometer may improve the contribution from the ground and some other same kinds of additional radiation.

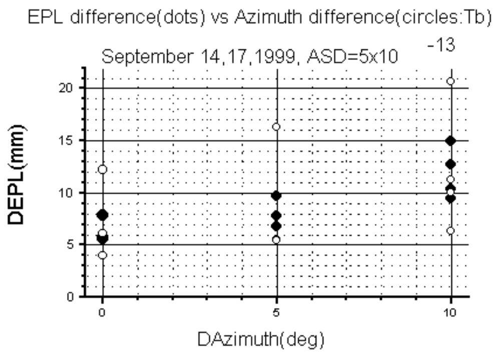

Fig.5 Observed standard deviations of the EPL difference between two directions in the sky. Dots shows the results which eliminated the effect of the continuum component by dual channel radiometry and circles are the one which includes the continuum component.

5.Conclusion

1) The 2-channel water vapor radiometer which has channel separation of 2GHz well works to eliminate the continuum component in the atmospheric radiation.

2) The fundamental function of spatial differential radiometer was confirmed by switching the 10m antenna by 5 and 10 degrees in azimuth angle.

3) System noise was large as much as 5 times compared with the expected one which was calculated from receiver noise, bandwidth, and integration time. Radiation from ground may be included, which could effectively be eliminated by 3-channel radiometer and modification is under way.