Wind Effects on the Nobeyama 45-m Telescope

Kuno, N.,[1] Mikoshiba, H.,[1] Hirota, A.[1,2], Maruyama, K.[3], Kasuga, T.[3], Sunada, K.[1], Mori, A.[1]

[1] ***Nobeyama Radio Observatory, Minamimaki-mura, Minamisaku-gun, Nagano, 384-1305***

[2] ***The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo, 113-0033***

[3] ***Hosei University, 3-7-2 Kajino-cho, Koganei-shi, Tokyo, 184-8584***

kuno@nro.nao.ac.jp

ABSTRACT

We investigated the wind effects on the Nobeyama 45-m telescope. We measured the movement of the sub-reflector and the deformation of the main reflector by wind. We found a tight correlation between the pointing offset and the deformation of the main reflector. It is confirmed that the change of the beam shape is more significant at higher frequency when the wind is so strong.

1. INTRODUCTION

Nobeyama 45-m telescope is one of the largest telescopes in the world for mm wave observations. We can get high angular resolution with the telescope. However, high accuracy pointing is needed to take the advantage. Since homologous design was adopted for the 45-m telescope to minimize elevation-dependent gravitational deformations, the main reflector is deformed even by wind. Although the deformation by wind is thought to be one of the main causes of the pointing error, it is not clear how wind affects the telescope. Therefore, we researched the wind effects on the 45-m telescope. Since the deformation of the main reflector and position change of the sub-reflector yield the pointing error, we measured them and investigated the correlation with the pointing offset.

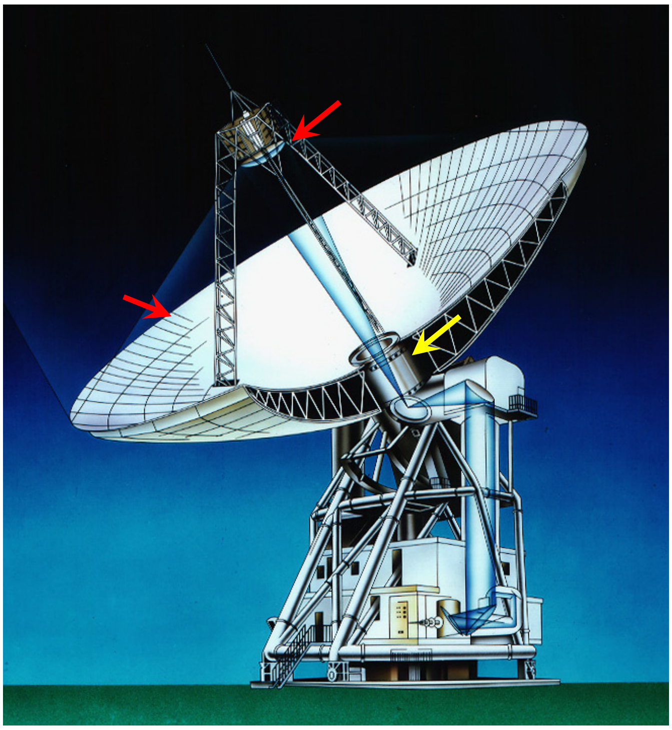

Fig.1 Illustration of the Nobeyama 45-m telescope. The positions of the LED lamps are indicated by red arrows. The central hub is indicated by yellow arrow.

2. MEASUREMENT SYSTEM

The measurement system is consists of optical telescopes with a CCD camera and target LED lamps (fig. 2). The optical telescopes are mounted on the central hub of the 45-m telescope, since the position of the central hub is not affected by wind. The aperture and the focal length of the optical telescope used for the measurements of the sub-reflector are 100 mm and 1000 mm, respectively, while those of the telescope for the main reflector are 70 mm and 900 mm. The images from the CCD cameras are acquired with a sampling interval of 100 ms by a personal computer. The position of the LED is measured by calculating the centroid in the CCD image. The LED lamps are fixed on the upper edge of the stay of the sub-reflector and the backing structure of the main reflector to measure the movement of the sub-reflector and the deformation of the telescope, respectively. We can measure position offset of the sub-reflector along azimuth and elevation direction. We have only one optical telescope for the main reflector. The LED lamp for the main reflector is on the left edge of the backing structure, when we look at the front of the main reflector. The position of the LED lamps and the central hub are indicated in fig. 1.

3. EFFECTS ON THE SUB-REFLECTER

A position offset of the sub-reflector of 1 mm corresponds to an offset of the telescope pointing of 9.8 arcsec. Fig. 3 shows examples of the movement of the LED lamp on the stay during observations. We measured position of the LED lamp along azimuth (*X*) and elevation (*Y*) directions. After some measurements, we found that when the wind speed is lower than about 10 m/s, the position change by wind is not significant (< 0.3 mm) (fig. 3a). When the wind speed, however, is higher, the position change can not be ignored, especially in the azimuth direction (*X*) (fig. 3b). Corrections for the position change of the sub-reflector are needed in that case.

4. DEFORMATION OF THE MAIN REFLECTER

Fig. 4 shows the correlation between pointing offset in azimuth direction and deformation of the main reflector. The pointing offset in azimuth was measured from the variation of the intensity by tracking the left limb of the moon at 23 GHz. We can get the relation between the intensity and the pointing offset by scanning the moon with a constant scan speed. Then, we converted the intensity into the pointing offset. Since we can measure the deformation of the main reflector only at one point which is expected to be correlated with the pointing in azimuth, we measured the pointing offset in azimuth. We can see a tight correlation between the pointing offset and the deformation of the main reflector in fig. 4. Therefore, the deformation of the main reflector can be regarded as the main cause of the pointing error in this case. Under the conditions like this, we may be able to know the pointing offset by measuring the deformation of the main reflector.

Fig.2 Left) Optical telescope mounted on the central hub of the 45-m telescope. The left white wall is the central hub. Right) The LED lamp fixed on the backing structure of the 45-m telescope.

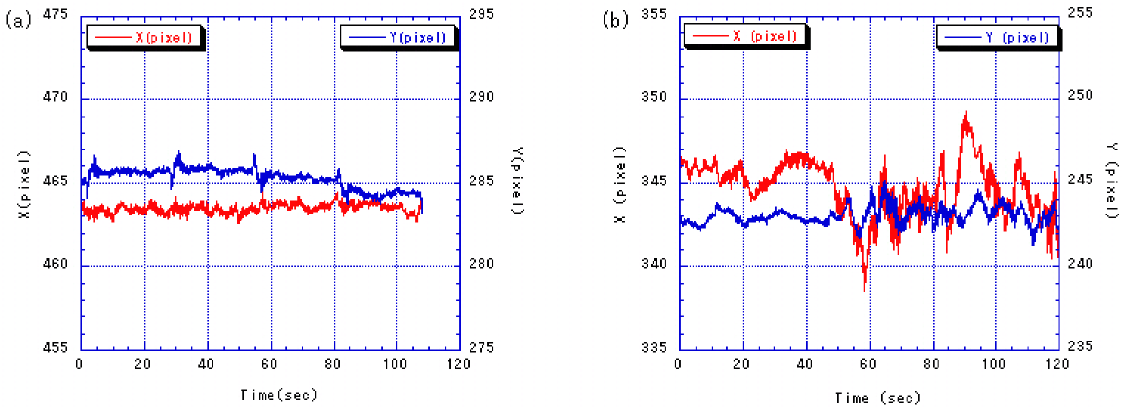

Fig. 3 Time variation of position of the LED lamp. *X* and *Y* are the position along the azimuth and elevation direction, respectively. The unit of the vertical axis is pixel of the CCD camera. 1 pixel corresponds to about 150 µm. (a) MWS (Maximum wind speed) = 6 m/s. The periodic bumps and the drift in *Y* are caused by the position switching of the telescope during the measurement. (b) MWS = 15 m/s.

When the wind is so strong, its effect is not only pointing error, but also the degrading of the efficiency of the telescope. The degrading of the efficiency is more apparent at higher frequency. We investigated the change of the beam shape due to the deformation of the main reflector by tracking Venus at two frequencies simultaneously and comparing the intensities. When the beam shapes are not deformed by the wind, the intensity ratio depends on the pointing offset. Actually, when the wind is not so strong, the intensity ratio corresponds with the expected curve (fig. 5a). On the other hand, when the wind is strong, the ratio deviates from the expected curve (fig. 5b). For this example, if we assume that the beam size at 86 GHz was enlarged to about 28" keeping the beam size at 43 GHz almost the same, the fitted curve can be explained. Since the wind was from front of the telescope, the focal length must have been changed. Then, the beam size must be enlarged because of the defocusing, especially at higher frequency. Therefore, this result seems to be reasonable. Using ray-trace simulations, we confirmed that the defocusing due to the deformation of the main reflector can change the beam size at 86 GHz significantly, although the influence at 43 GHz is small. If we assume the beam sizes, the pointing offsets derived from the intensity variations are consistent each other (fig. 6). These results show that we need not only corrections of pointing but also efficiency under these conditions.

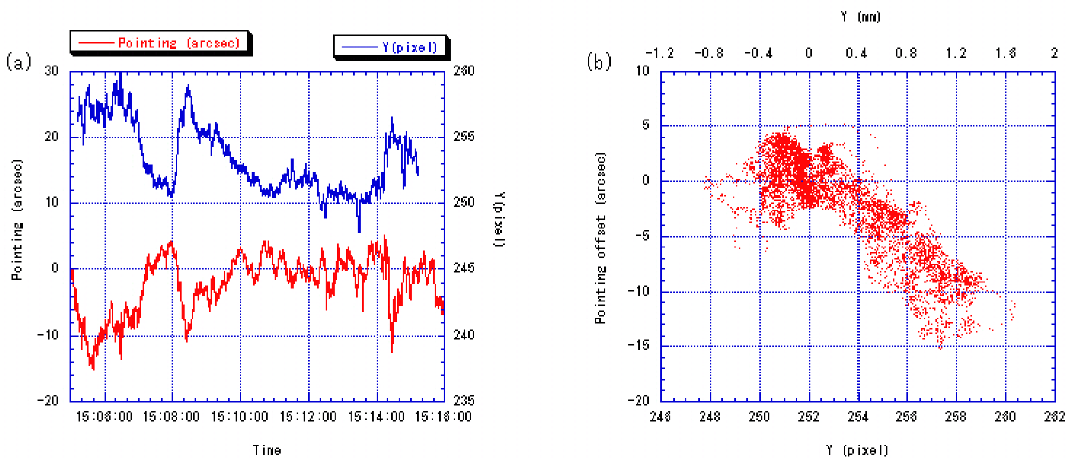

Fig. 4 (a) Time variation of the pointing offset (blue) and the LED position (red). *Y* is the position of the LED perpendicular to the surface of the main reflector. The unit of Y is pixel of the CCD. 1 pixel corresponds to about 200 µm. (b) Correlation between pointing offset and deformation of the main reflector.

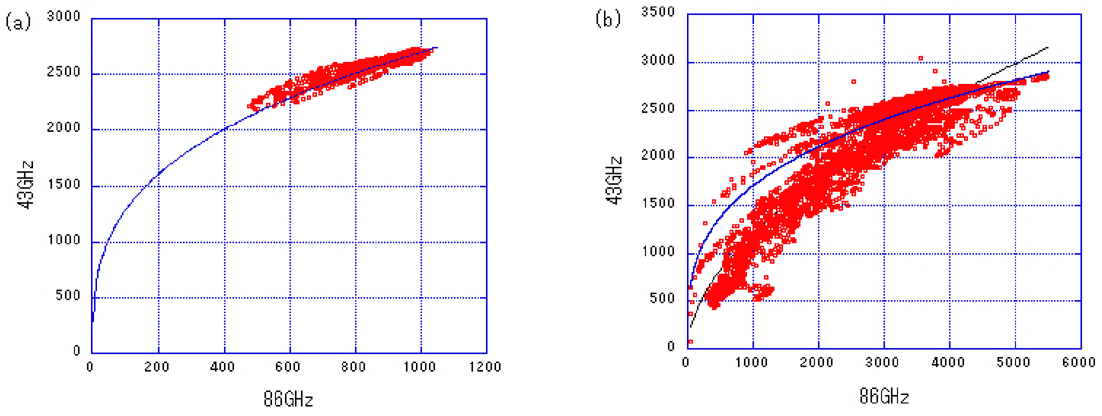

Fig. 5 Correlation between the intensities of Venus measured at 43 GHz and 86 GHz simultaneously. The unit of the intensity is arbitrary. (a) MWS = 5 m/s. The blue curve shows a model which assumes the beam sizes of 18.2" at 86 GHz and 38.4" at 43 GHz. (b) MWS = 15 m/s. The blue curve is the same in (a). The black curve shows the fitted curve of the data assuming that the ratio of the beam sizes is a free parameter.

5. FUTURE WORKS

To investigate the whole deformation of the main reflector, we will increase the measurement points for the main reflector. At least, we are going to measure 4 points of the main reflector. We expect that we can estimate pointing offset in both of azimuth and elevation using the data. Once we can establish a method to derive the pointing offset from the data of the deformation of the main reflector and the position of the sub-reflector, we will apply pointing corrections to OTF (On-The-Fly mapping) data. We can improve the position accuracy of the data by modifying the position information. Furthermore, we are thinking about pointing corrections in real time.

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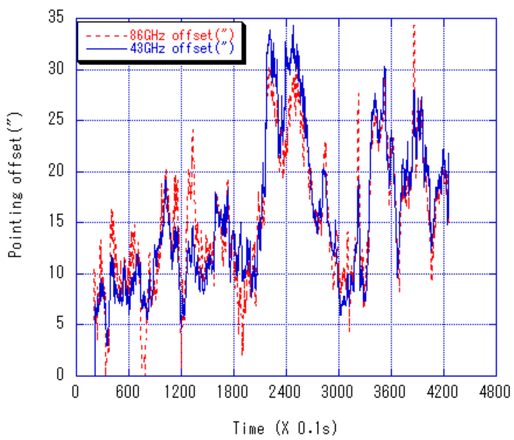

Fig. 6 Time variation of the pointing offset of the data shown in fig. 5b. The offset were derived from the intensity variation at 43 GHz (blue solid line) and 86 GHz (red dotted line) assuming that the beam sizes are 38.4" at 43 GHz and 28" at 86 GHz.