# Fast Switching Experiments with the Nobeyama Millimeter Array

K.-I. Morita and K. Handa

*Nobeyama Radio Observatory, National Astronomical Observatory, Minamimaki, Minamisaku, Nagano 384-1305, Japan*

Y. Asaki and Y. Kitamura

*The Institute of Space and Astonautical Science, Yoshinodai, Sagamihara, Kanagawa 229-8510, Japan*

S. Yokogawa

*Faculty of Science, University of Tokyo, Bunkyo-ku, Tokyo 113-0033, Japan*

M. Saito, D. W. Wilner, and P. T. P. Ho

*Harvard-Simithsonian Center for Astrophysics, Cambridge, MA 02139, USA*

N. Ohashi

*Institute of Astronomy and Astrophysics, Nankang, Taipei 115, Taiwan*

**Abstract.** Fast Switching (FS) experiments have been conducted with the Nobeyama Millimeter Array in order to know if the FS phase calibration improves the imaging performance. A very few cases showed that FS calibration is useful, although we confirmed that the imaging performance is improved in some cases. Orion-KL FIR4 data show that FS calibration with closer calibrators can significantly improve the resolution and the dynamic range of the image.

## 1. Introduction

At Millimeter and submillimeter wavelengths, phase fluctuations induced by atmospheric turbulence are serious problems of the radio interferometer observations and limit the image quality as dynamic range and angular resolution. In the last 5 years, several activities for correction of tropospheric phase fluctuations have been conducted at Nobeyama Radio Observatory (NRO) to improve imaging performance of the Nobeyama Millimeter Array (NMA, Morita 1994) and also to develop new calibration methods for the future large millimeter and submillimeter array project such as ALMA or LMSA.

In this paper, we report recent results of experiments using Fast Switching (FS) phase calibration with the NMA.

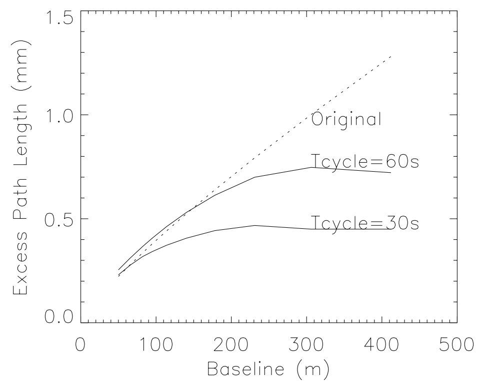


Figure 1. The root square of phase structure function calculated by using the phase screen model.

## 2. Limitation of Fast Switching

As shown by Carilli and Holdaway (1999), FS phase calibration is one of the promissng methods for the tropospheric phase correction. It is, however, only effectve for baselines longer than the length given by

$$B > h\Delta\theta - vT_{cycle}/2. \tag{1}$$

$\Delta\theta$ is a separation angle between a target source and a reference source, $h$ is height of phase screen, $v$ is wind speed at phase screen, and $T_{cycle}$ is switching cycle time. Even for $\Delta\theta = 0$, if $v = 10$ m s$^{-1}$ and $T_{cycle}$ =60 sec, then the minimum effective baseline length is almost 300 m, close to the maximum baseline length of the NMA AB array.

We have made more accurate calculation of the square root of phase structure function (SPSF) by using the phase screen model same as that proposed by Asaki et al. (1998). SPSFs before and after phase calibrations are shown in Figure 1. In this calcuration, we assumed that $v$ is 10 m s$^{-1}$, the baseline direction is pararell to the wind direction, and $\Delta\theta$ is 3 deg.

This calculation shows that we can expect some improvement by FS phase calibration for baselines longer than 200 m for $v = 10$ m s$^{-1}$ and $T_{cycle}$ =60 sec, which is shorter than the critical baseline length given by Equation 1.

## 3. Phase Structure Function after Fast Switching

In order to examine the performance of FS phase calibration, we have observed several pairs of quasars with the NMA AB array. $\Delta\theta$ ranges from 2 degree to 10 degree and $T_{cycle}$ ranges from 32 sec to 128 sec.

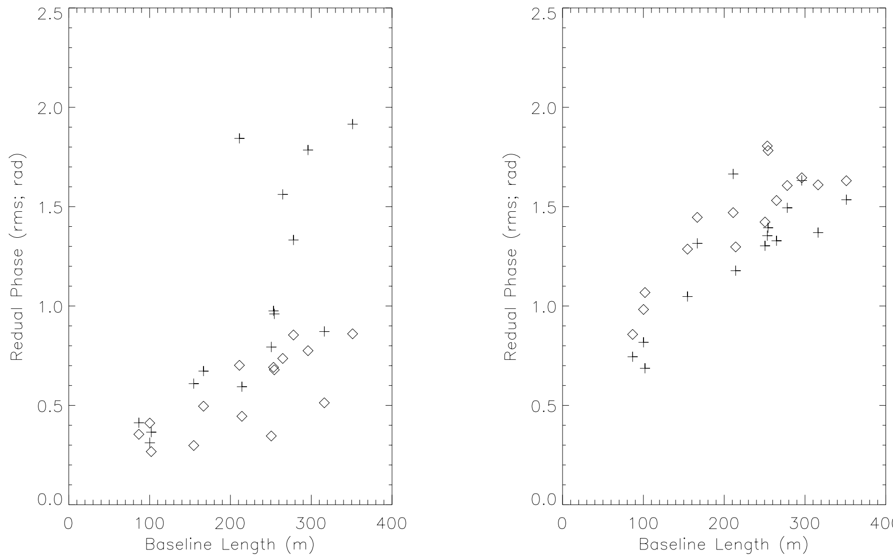


Figure 2. The square root of phase structure functions (SPSF) estimated from original visibilities of 1219+044 and visiblities after FS calibration by using 3C273 observed on Feb. 11, '99. Crosses are original PSF and diamonds are calibrated PSF. Left(example-1): 4:00 - 4:30 JST. $T_{cycle} = 64$ sec. Right (example-2): 1:00 - 2:00 JST. $T_{cycle} = 128$ sec.

Figure 2 shows the results of a quasar pair of 3C273 and 1219+044 with $\Delta\theta$ of about 3 degree. The observing frequency was 98 GHz. In the figure, crosses are SPSF estimated from original visiblities of 1219+044 and diamonds are SPSF after FS phase calibration by using 3C273. Clear improvements by FS is seen in example-1 (the left figure), although $T_{cycle}$ is longer than that of example-2 (the right figure). Since FS phase calibration with shorter $T_{cycle}$ is expected to have better performance as shown in Figure 1, these results indicate that the tropospheric condition was changed in a few hours. In our experiments, only a few cases showed that FS calibration worked well.

These results of the experiments are inconsistent with the prediction of theoritical calculation in the previous section. Two possibilities can explain this discripancy. One is that the phase screen model may be too simple to describe the seeing condition at Nobeyama. The other is that averaged wind speed at the phase screen may be much higher than 10 m $s^{-1}$ in typical winter at Nobeyama. Analysis of data from the radio seeing monitor at Nobeyama by Holdaway et al. (1999) supports the former possiblity.

## 4. Imaging of a dust core in Orion-KL

Orion-KL region is suitable for FS observations, because there is a strong SiO maser source in the center and we can use this maser source as a very close calibrator. Imaging observations of a dust core (FIR4), which is located about

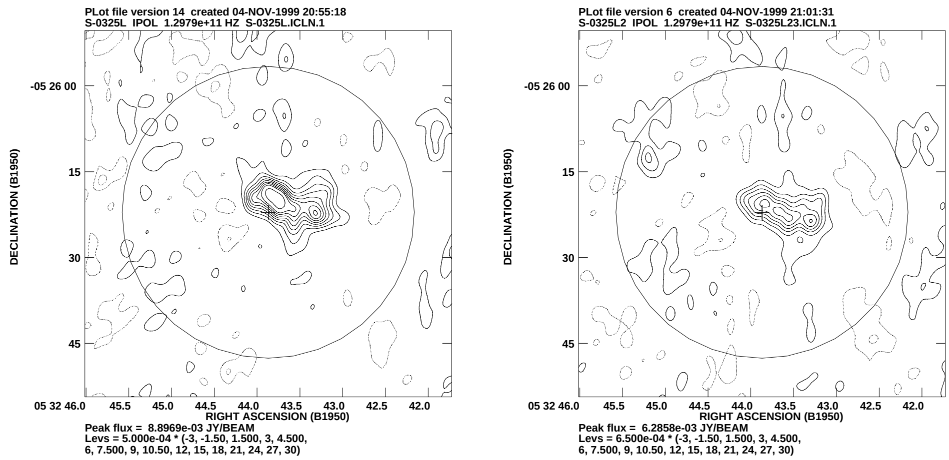


Figure 3. Continuum emission maps of Orion-KL FIR4 at 129 GHz. Calibration cycles of observations are 64 sec (left) and 30 min (right), respectively. These images are mapped from the same obaserved data.

3 arcmin south from the maser source, was conducted with the NMA C array (Maximum baseline is about 150 m) in March 1999.

A compact structure is clearer in the left image of Figure 3. The peak flux and dynamic range increase by more than 20 % and 100 % with FS, respecitively. As shown in Figure 1, we cannot expect significant improvement by FS calibration for baselines less than 150 m in normal winter condition at Nobeyama. The fact that some improvements of imaging performance were ls obtained, may suggest that the wind velocity at the phase screen was very slow.

## References

Asaki, Y., et al. 1998, Radio Science, 33, 1297.

Carilli, C. and Holdaway, M. 1999, MMA memo 262.

Holdaway, M., et al., 1999, NRO tech report, in preparation.

Morita, K.-I. 1994, in Proc of IAU Colloquiumm 140, ed. M. Ishiguro and Wm. J. Welch, ASP Conf. Ser. 19, 197.