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The Multi-Channel Millimeter Wave Receiver for VLBI

Seog-Tae Han, Do-Heung Je, Duk-Gyoo Roh, Sek-O Wi, Se-Jin Oh, Min-Gyu Song, Chang-Hoon Lee, Kwang-Dong Kim

KVN, Radio Astronomy Division, Korea Astronomy Observatory

Contact author: Seog-Tae Han, e-mail: sthan@trao.re.kr

Abstract

The most important thing in millimeter and sub-millimeter wave VLBI is how to calibrate the variations in the phase of an electromagnetic wave propagating through the troposphere. A lot of techniques for calibrating the phase fluctuations due to troposphere have been well proposed and demonstrated [1][2][3]. The millimeter wave multi-channel receivers system which can be used for phase calibration in millimeter and sub-millimeter wave VLBI observation are proposed. In this paper, a conceptual multi-channel receiver system and a quasi-optical filters which could be used in this receiver are described.

1. Introduction

In the past few decades centimeter VLBI observation has been extensively carried out in world wide radio astronomy observatories. However, recently it has been moving toward to millimeter wave and sub-millimeter waves VLBI observation.

The problems for the millimeter-wave and sub-millimeter waves VLBI observation could be categorized as 1) phase stability and noise of receiver system due to local oscillators, transmission lines and their components, 2) those of receiver noise temperatures are much higher than that of centimeter receivers, 3) atmospheric phase fluctuation due to a water vapor in troposphere which influences on the deterioration of the sensitivity and imaging capability. Both phase stability and receiver noise temperature of such millimeter and sub-millimeter receivers have been intensively well developed since last decade. It could be solved by advanced high technologies in such fields. However, the remain problem in millimeter and sub-millimeter wave VLBI is how to calibrate the variations in the phase of an electromagnetic wave propagating through the troposphere. A lot of techniques for calibrating the phase fluctuations due to troposphere, such as fast frequency switching, paired cluster antenna, rapid system temperature measurement, dual beam antennas and multi-frequency feed system have been well proposed and demonstrated [1][2][3].

In this paper, the multi-channel receivers system which can be used for phase calibration in millimeter and sub-millimeter wave VLBI are proposed.

2. Conceptual Configuration of Multi-Channel Receiver

The phase calibration by using the multi-channel receiver system is based on the phase contributions by a given amount of water vapor increasing linearly with frequency, that is, the troposphere is non-dispersive [3]. It was demonstrated that the tropospheric phase fluctuation in millimeter wave can be calibrated by centimeter wave observation results [2]. It clearly shows that not only phase calibration can be done by using the proposed multi-channel receiver system, but also validity of the non-dispersive model of the troposphere is well verified.

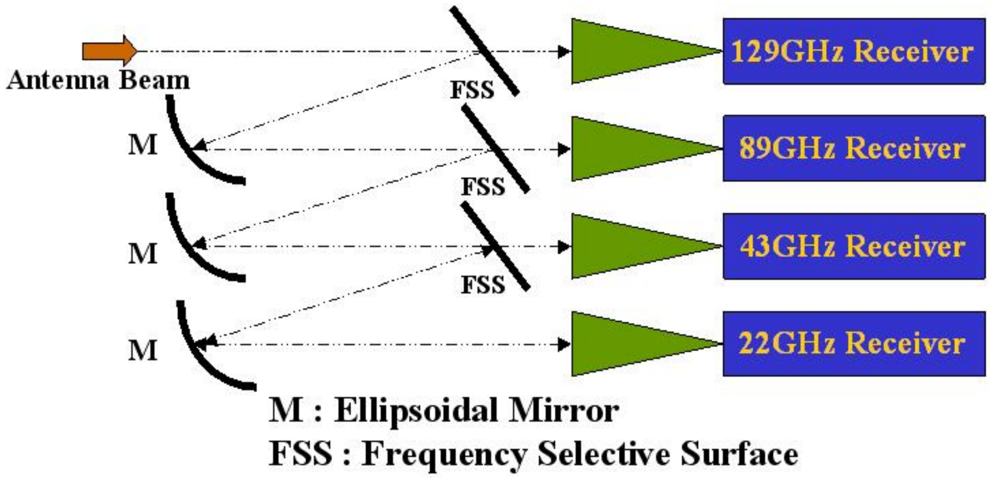

Figure 1. Multi-channel receiver system

The multi-channel receiver system is shown in figure 1. This system could employ a sequence of frequency-selective surface or perforated plate filter. The latter offer very good high-pass filter characteristics but are restricted to modest angles of incidence [4]. The bands of interest are 23 GHz, 43 GHz, 86 GHz and 129 GHz bands. The perforated plate filters are arranged so that 129 GHz band is encountered first by the beam coming from the antenna, and is transmitted to its feed horn. Lower frequency bands are reflected by first perforated plate filter and the beam transformed by ellipsoidal mirrors, sent to the 86 GHz band feed horn, and so on. Nevertheless the simultaneous observations for all bands by using this system can be done. Therefore 23 GHz band phase of source can be used for calibrating the phase of the same source of higher frequency bands observed at the same time.

The 129 GHz band interacts with the smallest number of optical components as shown in figure 1. It means that quasi-optical losses and antenna pointing errors could be minimized. The most important thing in this system is the properties of the perforated plate filter which have low transmission and reflection losses, low pass-band ripple, low cross polarization and wide pass bandwidth. Even 230 GHz band receiver and higher bands can be used in this system, if a good performance of perforated plate filter in these frequency bands could be made.

3. Quasi-Optical Filter for Multi-Channel Receiver

3.1. Perforated Filter as a High Pass Filter

The side view of perforated filter is shown in figure 2. A perfect conductor has several thousand array perforated holes with same given diameter. The number of holes is determined by the actual size of Gaussian beam at its location. The perfect conductor hole acts as a circular waveguide which has a high pass filter characteristic intrinsically. Therefore cut-off frequency of filter could be easily made by changing of diameter of perforated hole. As shown in figure 2, to make better performance of pass band ripple and losses, the impedance matching layer with dielectric material has been used both side of perfect conductor as well as holes filled with dielectric material.

Theoretical evaluation results by using CST [5] are shown in figure 3. A performance of filters

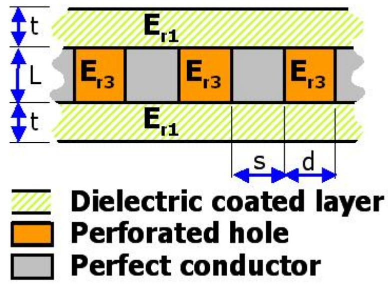

Figure 2. Perforated plate filter

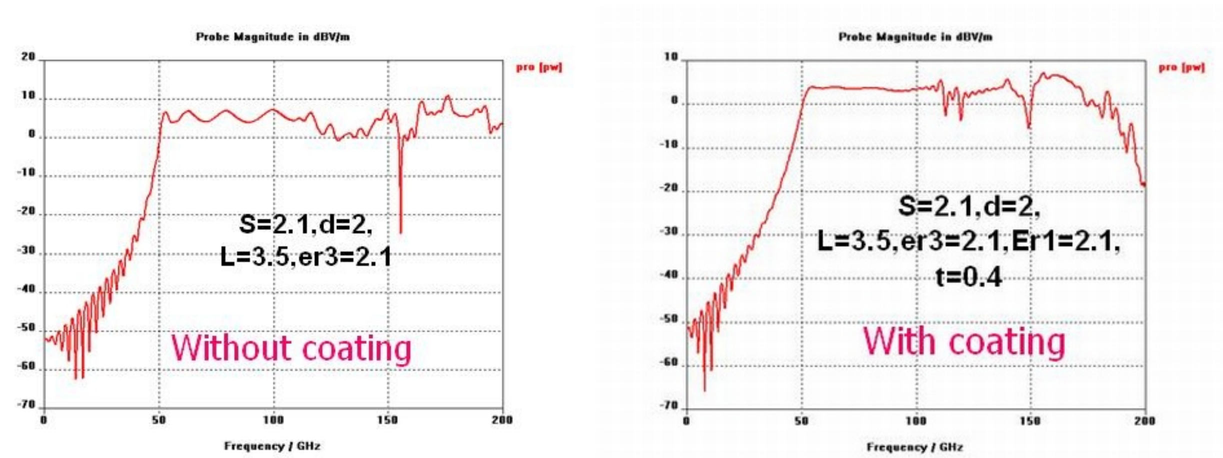

Figure 3. High pass filter characteristic, (a)without coating, (b)with coating

compared with coating layer with dielectric material and without coating layer is significantly different. It means that the filter should have such a impedance matching layer.

3.2. Metal Mesh Filter as a Low Pass Filter

The low pass filter with metal mesh grid which could be used on the multi-channel receiver and its performance are shown in figures 4 and 5, respectively. It has been developed by QMC & Thomas Keating, England. The cut-off frequency of low pass filter can be determined by changing a gird space and its diameter. The pass band ripple and rejection band as well as losses are good enough to be used in multi-channel receiver for quasi-optics.

4. Quasi-Optical System for Multi-Channel Receiver

The quasi-optical system for multi-channel receiver is shown in figure 6. All quasi-optical filters are located at Gaussian beam waist to minimize their sizes. The 22 GHz and 43 GHz band signals are transmitted, 86 GHz and 129 GHz band signals are reflected by the first low pass filter which is located at cassegrain focus. The reflected signals of 22 GHz and 43 GHz are re-collimated by an ellipsoidal mirror 3, then go to the low pass filter 2. Reflected signal of 43 GHz and transmitted

Figure 4. Low pass filter

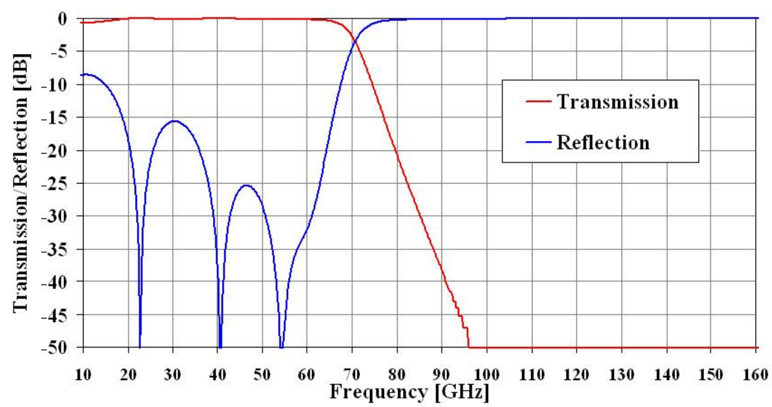

Figure 5. Low pass filter characteristic

signal of 22 GHz by the low pass filter 2 propagate through their own beam passages, and finally reach each feed horns. The 86 GHz and 129 GHz signals reflected by low pass filter 1 are re-collimated by ellipsoidal mirror 1, then go to their own feed horns through the low pass filter 3, respectively.

To minimize the losses at quasi-optical components, the beam selective system is chosen as shown in figure 6. For instance, we want to make observation 43 GHz and 86 GHz signals simultaneously, the beam selective system of LPF1 should be positioned at PPF, that of LPF2 is positioned at metal flat mirror, that of LPF3 should be positioned free space, respectively. All kinds of observational frequency channel modes can be done by combination of three set of the beam selective system.

5. Discussion

We expect that an insertion and a cross polarization losses at quasi-optics system would be absolutely dominated by quasi-optical filters and ellipsoidal mirrors. For better performance of

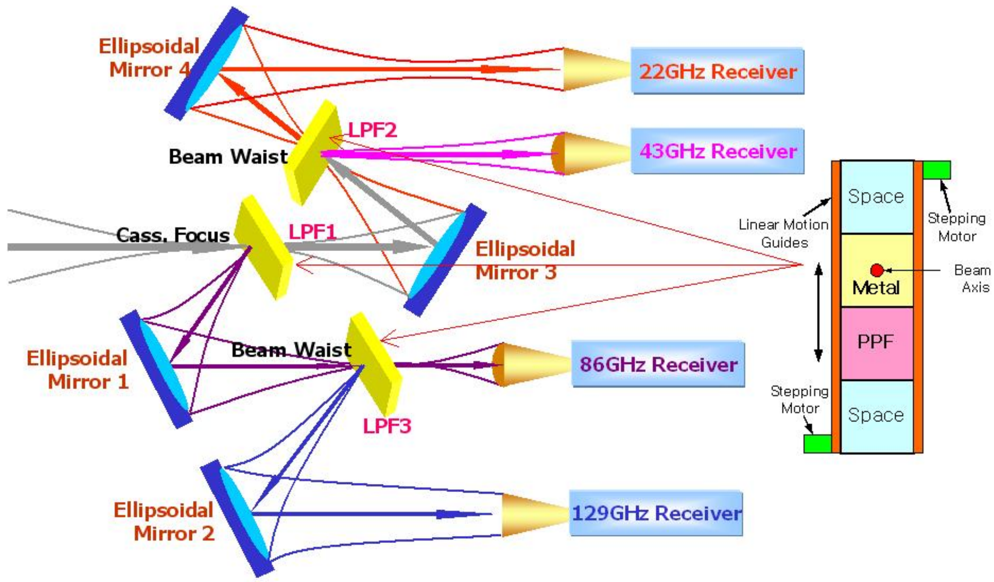

Figure 6. Quasi-optical circuit for multi-channel receiver

this system in term of losses, the further research of quasi-optical filter and mirrors should be required, and also be verified their properties by using special measurement system.

In addition, the pointing accuracy and aperture efficiency of antenna for each channel should be considered, because the proposed quasi-optical circuit is very complicated.

References

[1] Alef, W. et al., 2003, New Technologies in VLBI ASP conference series

[2] Asaki, Y. et al., 1998, Radio Science, 33, 1297

[3] Sasao, T., 2002, New Technologies in VLBI ASP conference series

[4] Goldsmith, P. F., 1998, Quasioptical systems, IEEE Press.

[5] CST Microwave Studio, http://www.cst-world.com