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Development of wideband feed with sharp cut-off frequency OMT for RFI

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Abstract

Wideband feeds and OMTs were developed for NICT Kashima 34 m antenna and two portable 2.4 m VLBI stations, named MARBLE 1 and 2. They were developed for the intercontinental wideband VLBI experiment, named Gala-V, to compare the optical lattice clocks linked to MARBLE 2 in Japan and 1 in Italy. These wideband feeds, named NINJA feed, are used with OMT(Orthogonal Mode Transducer) to receive two linear polarizations. At the first light of the 34m antenna with NINJA feed, strong RFI under 3 GHz was received. Thus, receiving of S-band was decided not to supported in Gala-V experiment and the feed and OMT was arranged to have sharp cut-off frequency under 3.2 GHz.

Index Terms— wideband antenna, quad ridged waveguide, OMT, RFI, cut-off frequency

1 Introduction

After the development of 6.5-16 GHz wideband feed, named IGUANA feed, for Kashima 34 m antenna[1], another wideband feed, named NINJA feed[2], was developed for intercontinental VLBI Time and Frequency Transfer experiment, named Gala-V[3]. The bandwidth of the deed was planed to have compatibility to VGOS observation[4]. Thus the bandwidth of the first model of NINJA feed was designed as 2.2-16 GHz. It was used with a wideband OMT developed simultaneously for receiving two linear polarizations. But strong RFI was observed at the first light of the 34 m with NINJA feed. Strong RFI increases the noise of the first LNA(Low Noise Amplifier) caused by inter modulation in the LNA, if that could not saturate it. Because the lowest frequency of Gala-V was planned 3.2 GHz[5], the new OMT with sharp cut-off frequency at 3.2 GHz was developed to cut RFI under 3.2 GHz and conventional S-band support was cut. Thus, for IVS observation, the S/X horn in 34 m has been used at the end of its life.

These OMTs are the transducers from TE10 mode in the diagonal waveguide of wideband feed to SMA connectors for LNAs, using tapered quad-ridged waveguide. The initial size of the waveguide of the NINJA feed was set to 70 mm x 70 mm for S-band support, but that was reduced to 52 mm x 52 mm to cut the RFI. And also length of the OMT was reduced and tapers and shape of the ridges were modified to have sharp cut-off at 3.2 GHz, using the resonance in the OMT. These wideband feeds and OMTs were developed in separately by the limitation of the computational memory size.

The first wideband feeds, IGUANA-H are the purely multimode horns that has narrow beam width for Cassegrain antennas. They have not be designed for wider beam width contrary to VGOS or SKA feeds[6]. The second wideband feeds, NINJA feed for the 34 m antenna and MARBLEs were a kind of axial corrugated horn with multimode excitation and lens. They can easily be arranged their beam width to fit narrow width as the secondary focus feed of conventional Cassegrain antenna like Kashima 34 m or more wider width as the primary focus feed of parabola antennas.

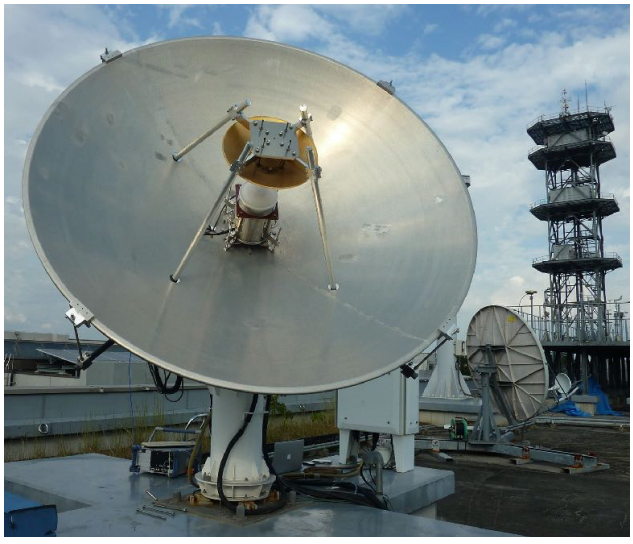

Figure 1. MARBLE 2 in NICT Koganei (It was changed in 2016 its optics from 1.6 m parbola dish with open boundary quad-ridged horn to 2.4 m Cassegrain with 3.2-16GHz NINJA feed to enhance its sensitivity and decrease RFI receiving).

2 Development of the Wideband OMT

Gala-V experiment were done as international geodetic VLBI sessions to compare the frequencies of the optical lattice clocks connected to each VLBI antennas in Japan(Figure 1) and Italy[7]. In the case of international session, the direction of the baseline seemed different form the celestial radio sources far away from the earth. Thus the polarization angles of the signals are different in each stations. That is the reason why the circular polarized receiver is used in conventional VLBI system. But it needs mode conversion in the waveguide before receiving. In the OMT, circular polarization waves coming from the feed are converted to linear polarizations for LNA output port to pick them up. This mode conversion uses the difference of the phase velocity in the two polarization, thus it is difficult to develop wideband mode converter.

In the conventional VLBI, the bandwidth of the receiver is enough narrow that can be develop circular to linear OMT. Thus each VLBI antennas can be operated with only one circular receiver if they have enough budget to receive both polarizations. But in the case of VGOS or SKA, dual linear polarization receivers must be used. Because, their bandwidth are so wide that has difficulty in development of the circular to linear OMT. Thus circular polarizations will be synthesized in the correlator after digitized signals are recorded and processed, if they are needed in observations.

Thus the OMT developed for Gala-V was designed for two linear polarization with two SMA output ports for LNAs(Figure 2 and 3). Development of the wideband feed for VGOS or SKA antenna included their OMT. Because the beam width of the feed, that is in proportion to the ratio of the aperture size of the feed over the wavelength, are wide, the aperture sizes of the feed are small compared to Cassegrain feed with narrow beam. That makes their development easier in available computational memory size than Cassegrain system.

But for Gala-V project, narrow beam feed was need for the 34 m Cassegrain focus. Thus feed and OMT were developed separately, because the feed had larger aperture than smaller beam feed and needed more computational resources. This strategy brought benefits to the Gala-V wideband system. One is in shorter developing time by reducing memory size and the other is that the combination of the feed and OMT become selectable freely. Simply to reject RFI in low frequency, just replacement of the OMT solves the problem.

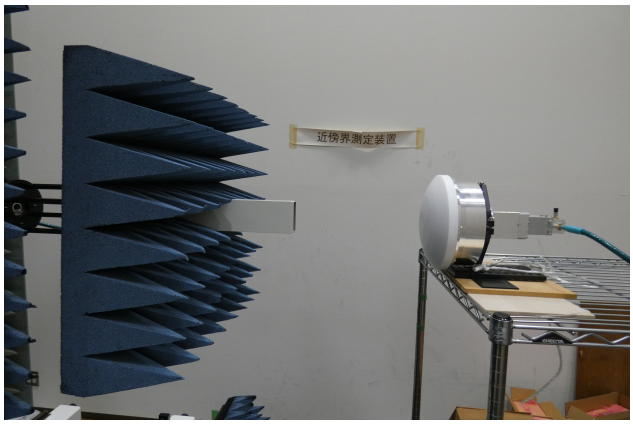

Figure 2. Far field beam patters of 3.2-16GHz NINJA with OMT for MARBLE 1 and 2 were measured in METLAB of RISH in Kyoto University.

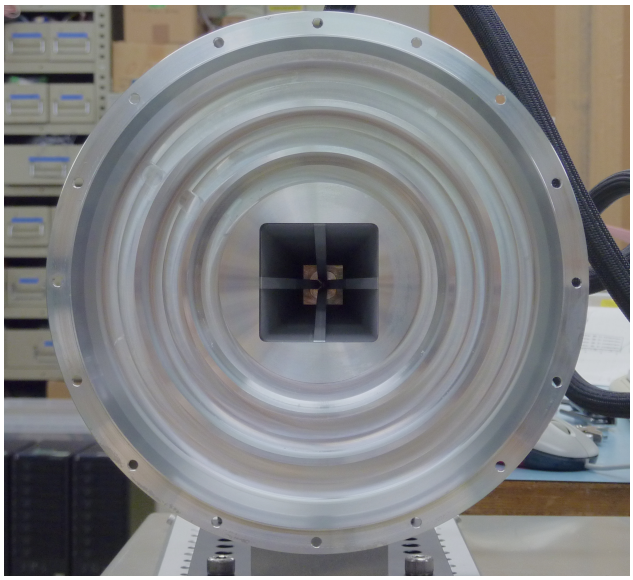

Figure 3. Front veiw of 3.2-16GHz NINJA feed and OMT.

Figure 2 and 3 shows 3.2-16 GHz NINJA feed and OMT. figure 4 shows its calcurated characteristics in 3D FEM simlator. This model used for Gala-V project. The OMT has designed without curves on the ridge and in the waveguide wall so that it could be made only by milling machine and wire-electrical discharge machine. Thus the designs are very simple and the OMT needs only three components, that are end-cap, SMA port section and tapered waveguide of feed interface.

Figure 4. Calcurated S-parameters of the OMT to cut RFI under 3.2 GHz used for Gala-V project (Port 1 and 2 are SMA connector port for LNAs. Port 3 and 4 are 52 mm x 52 mm square waveguide port for NINJA feed excited in TE10 mode).

3 Future Plans

Now, next generation radiometer and new wideband VLBI receiver system have been developing. Their 16-64 GHz wideband feeds enable simultaneous observations of water vaper, water in cloud and oxygen emission in the atmosphere in the same line of sight of VLBI session. That will bring us better estimation of the abundance of the water vaper and more precise correction of the delay time caused by the atmosphere.

For these experiment, MARBLE 2 in NICT Koganei will be refurbished with this new wideband feed. As shown in Figure 5, there is strong RFI at 3.5 GHz. Thus, the feed of MARBLE 2 will be replaced with 4-16 GHz NINJA feed that will be smaller than the current 3.2-16 GHz feed. That will make room for the new radiometer feed of 16-64 GHz. And new OMT will be developed to reduce the inter modulation noise caused by 3.5GHz RFI.

These higher frequency wideband feed will be also capable for VLBI in higher frequency. Inter modulation noise caused by RFI will change with antenna direction, thus that should be cut for better sensitivity and for precise measurement as a radiometer. In the future, RFI by 5 G applications may be affect the conventional radiometer. But this new radiometer has fine spatial resolution by its dish and the feed has narrow beam with small sidelobes. This Gala-V and following system have benefit for RFI suppression compared to current VGOS antennas with open-boundary quad-ridged feed with wide beam to easily receive RFIs from by its sidelobes.

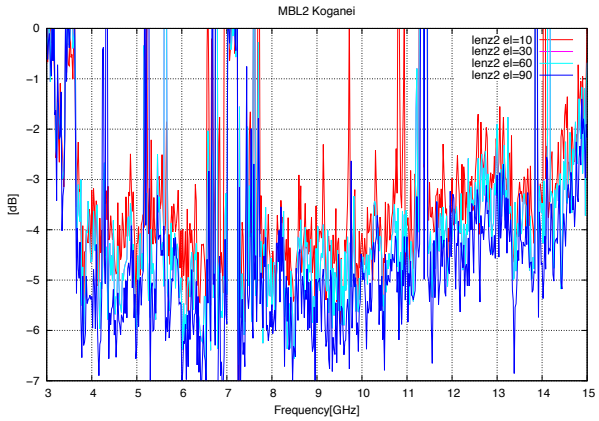

Figure 5. Measured spectrum with many RFIs (That is typcal spectrum received after the first LNA without the filter-bank of MARBLE 2 in NICT Koganei).

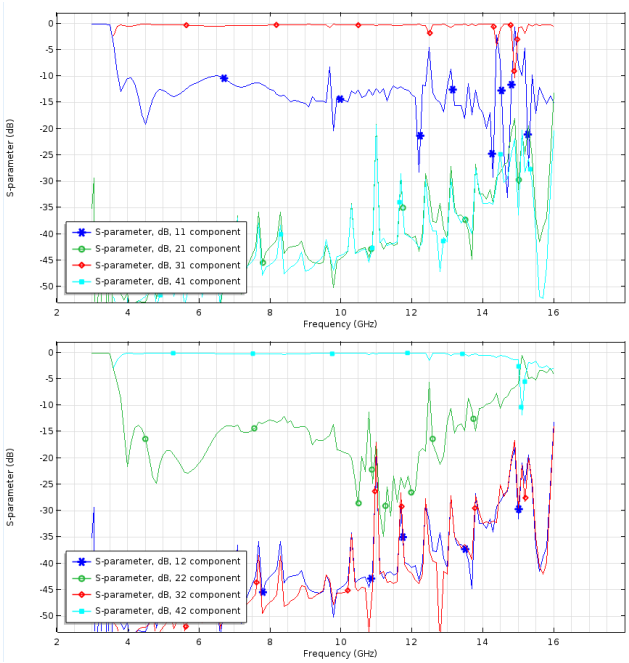

Figure 6. Calcurated S-parameters of the model of planed OMT to cut RFI under 3.6 GHz for future experiment with the wideband radiometer system (Port 1 and 2 are SMA connector port for LNAs. Port 3 and 4 are 52 mm x 52 mm square waveguide port for NINJA feed excited in TE10 mode).

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