Delopement of Mutimode Horns and Wideband Feed for Radio Telescopes

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Abstract

Multimode horns were developed for 8.4GHz, 22GHz, 43GHz receiver systems of ASTRO-G/VSOP-2 satellite for Space-VLBI, and for 6.7GHz of VERA 20m radio telescopes of National Astronomical Observatory in JAPAN and 25m Shanghai Radio telescope in China. Rational bandwidth of these horns in low cross polar level are 20-30%, and their thin walls without corrugation and shortened length are the best for the satellite use.
Also, wideband feeds will be presented, which are now developing for SKA and VLBI2010, which is a kind of Tapered Slot Antenna or other of traveling wave antenna.

1. Introduction

Corrugated horns are commonly used in radio telescopes, which has corrugated wall to achieve axisymmetric beam with low cross polar and nearly one octave bandwidth. However depth of the corrugation must be over 1/4 wavelength in center frequency. Thick wall causes heavy mass and expensive cost of corrugated horns, therefore the Author proposed multimode horns for VSOP-2/ASTRO-G satellite, following HALCA, which was planned to use in secondary Space-VLBI mission in JAPAN. 8.4GHz, 22GHz and 43GHz dual polarized receivers were individually placed on the focus of offset Cassegrain antenna of 9m diameter. Multimode horns achieve axisymmetric beam with low cross polar over rational bandwidth of 20%-30% by synthesis of fundamental mode and higher modes in the horn awaked at changing of flare angles, which also used to shorten axial length of the horn by 20%-30% compared to corrugated horn. Thin wall of multimode horns without corrugation are cost effective, realize extra low mass, which are best for satellite application.

Wideband feeds are developing for VLBI2010 and SKA project. They requires nearly over octave bandwidth feed. Some kind of Tapered Slot Antenna or other traveling wave antennas are developing and testing.

2. Multimode horns

22GHz and 43GHz receivers of VSOP-2/ASTRO-G satellite were planned to be cooled, thus heat conduction from the sun through the horn to cooled amplifier must be cut enough. Multimode horns with low heat conductivity was realized with Au plated CFRP wall proposed by T.KASUGA. However 8.4GHz receiver system was not cooled, however the horn is large because of the wavelength in 8.4GHz band, which must be low mass. Thus it was made aluminum of 2mm thickness. Therefore, these multimode horns are suitable for satellite applications. Figure 1 shows the last proposed designs of the multimode horns for VSOP-2/ASTRO-G satellite. They are 4-mode design, however, in lower frequency they are operated as 3-mode horn to extend bandwidth. Rapid changes of flare angles nearby

978-1-4244-6051-9/11/$26.00 ©2011 IEEE

waveguide end are higher mode generator from the fundamental, and other small changes to the aperture enable to shorten the axial length and beam shaping to fit the antenna optics. Figure 2 shows measured and calculated beam patterns of 43GHz band for examples. They were designed for same optics, almost same beam width and patterns.

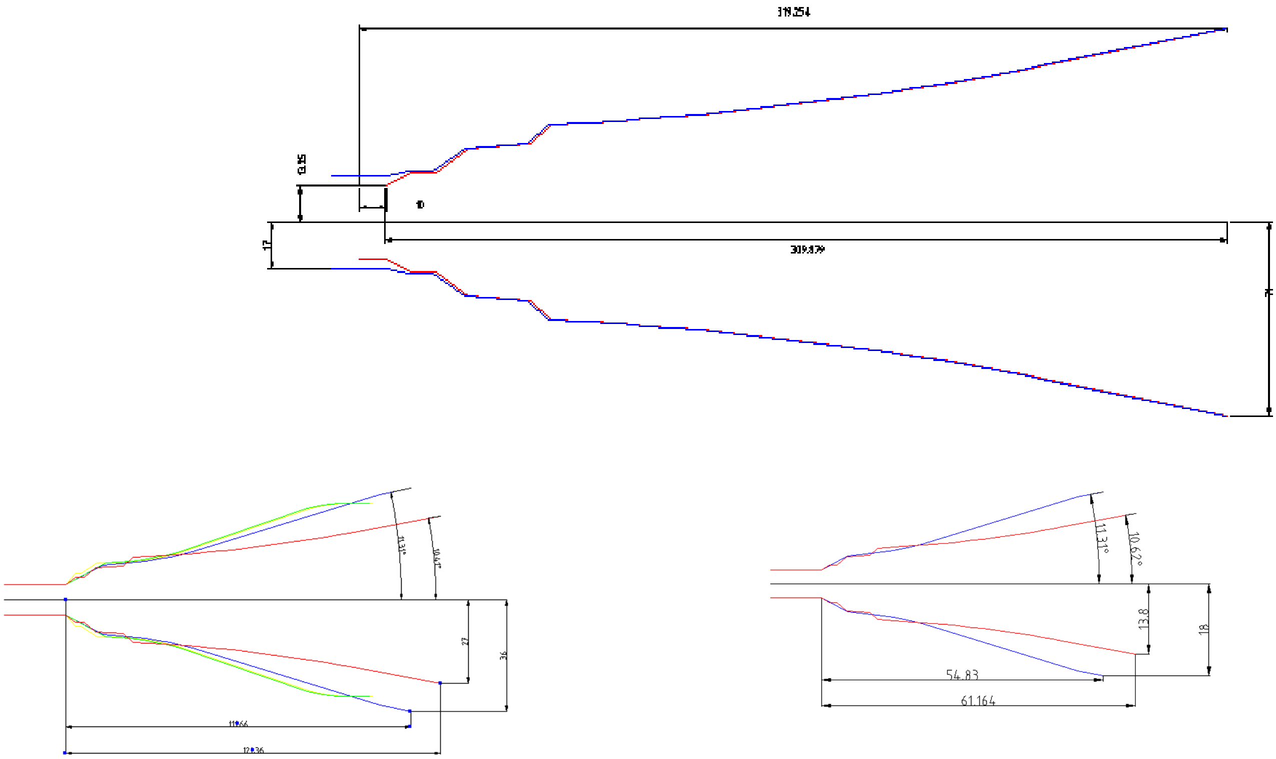

Fig 1. 8.4GHz, 22GHz and 43GHz multimode horns for VSOP-2/ASTRO-G. Blue Line for 8.4GHz is designed for 6.7/8.4GHz wideband polarizer. Red lines for 22GHz and 43GHz are the last designs.

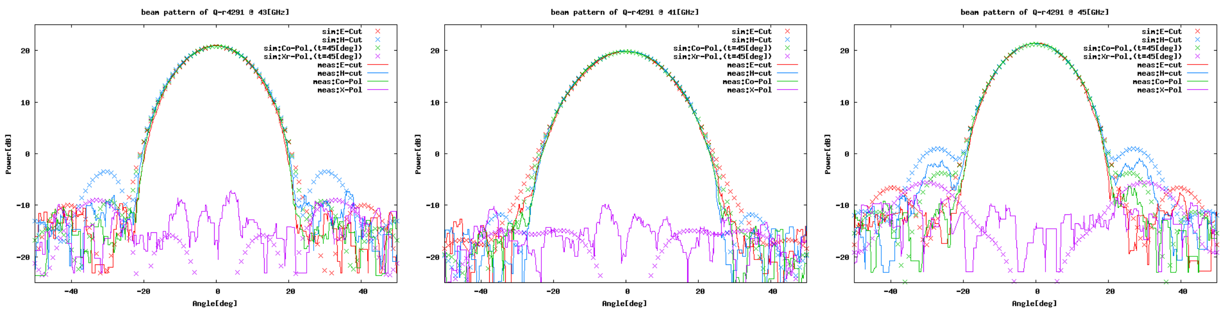

Fig. 2 Measured and calculated beam patterns of 4 mode horn for 43GHz band.

6.7GHz multimode horns are developed for VERA 20m radio telescopes in National Astronomical Observatory in Japan. VERA project has 4 stations to astrometry across JAPAN, however they have dual-mode horns for 22GHz and 43GHz for astrometry, and 2GHz and 8GHz spiral array for geodesy. 6.7GHz was not planed in their construction, thus they have no room for conventional horns in 6.7GHz methanol maser band. Multimode horns Thus multimode horns are designed to install additional band with aperture efficiency 50%. The first 2 horns were designed as basically 2-mode horn but flares are changes in along the horn to shorten the axial length under the limitation of 450mm. Secondary 2 horns are designed as 3/4-mode horns, they are slightly slim. 8 mode horn in 6.7GHz was designed for Shanghai 25m radio telescope, which requires so narrow beam such as -17.5dB at 8.3degree. 5GHz corrugated horn achieved required beam width of the optics with dielectric lens, however, the 8-mode horn can be used without lens, which is a low mass and low cost solution. Figure 3 shows designs of VERA horns and Figure 4 is for Shanghai. Their beam patterns are shown in Figure 6.

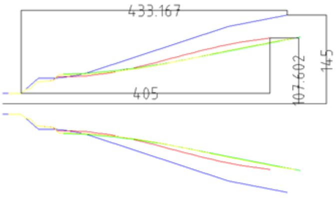

Fig. 3 Designs of VERA horns. Red Line is the secondary.

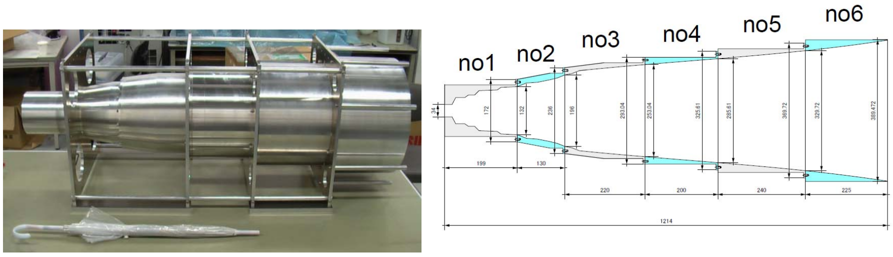

Fig .4 8 mode horn for Shanghai 25m radio telescope.

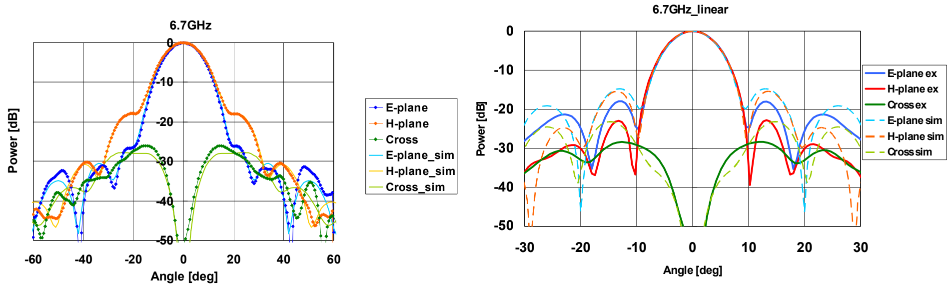

Fig. 5 Measured and calculated beam patterns at 6.7GHz. VERA horn is on the left and Shanghai horn is on the right.

3. Wideband Polarizer

Polarizers were designed by the group in OSAKA Pref. University. They are septum type and used with these multimode horns or another corrugated horns in many radio telescopes in JAPAN. Its bandwidth was increased by K.Matsumoto.6.7GHz and 8.4GHz by controlling its resonance frequency between astronomical band. Fig. 6 shows its characteristics.

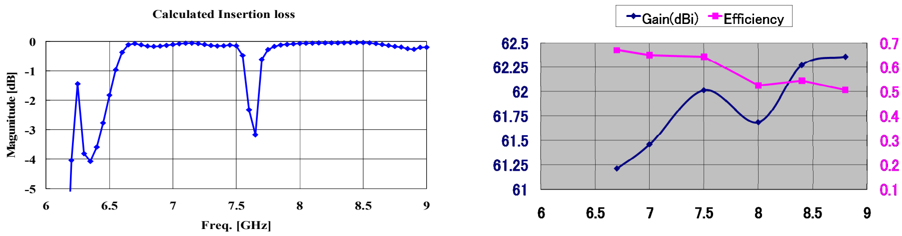

Fig.6 Insertion lose of wideband polarizer and estimated aperture efficiency of VERA 20m installed secondary designed 4-mode with wideband polarizer.

4. Wideband Feeds

Wideband feed are now developing for VLBI2010 and SKA. Their bandwidth is 1 or 2GHz to 10GHz or 14GHz, nearly decade width. However the beam width is not so narrow, and polarization of the feed can be linear. Therefore, Tapered Slot Antennas or other kinds of travelling wave antennas are developing and under testing. Figure 7 shows TSA and Figure 8 shows their beam patterns. HFSS was used for the simulation. Variations of beam width over operational frequency have to be controlled.

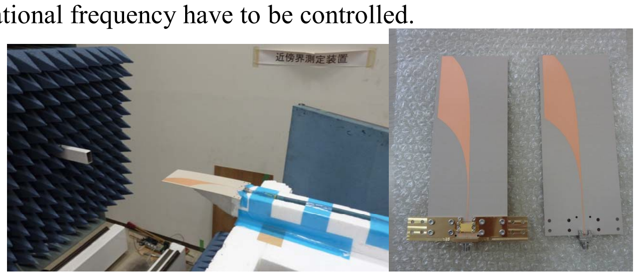

Fig. 7 TSA measured in METLAB

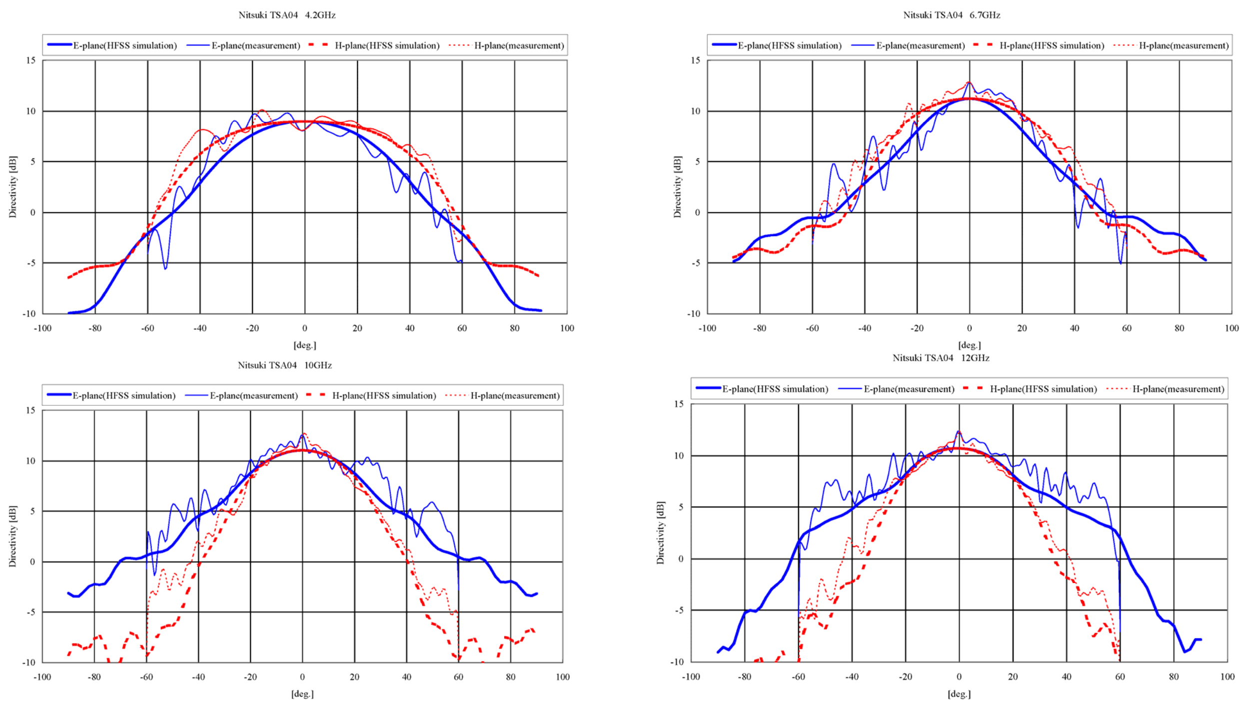

Fig. 8 Measured and calculated beam patterns of TSA.

5. Conclusion

Various multimode horns were developed for radio telescopes to satisfy the volume , weight, beam width limitations of ground and satellite radio telescopes. 6.7GHz multimode horns enabled additional VLBI network for methanol bands in and nearby JAPAN in low cost. Wideband polarizers were developed and wideband feeds are now developing to expand the frequency converges in astronomy and geodesy.

5. Acknowledgment

All beam patterns shown in this paper are measured at METLAB in Kyoto University.

7. References

1. Hiroyuki DEGUCHI,et.al,
"An Analysis of Multimode Conical Horn Antennas with Flare-Angle Changes
by using Generalized Telegraphist's Equation" IEICE Journal, Vol.J79-B-II, No.1 pp.33-41,1996

2. Takashi EBISUI and Osam ISHIDA,
"12/14GHz Bands Double Flare Type Triple-Mode Horn" IEICE Journal,Vol. J73-B-II, No.10, pp.546-553,1990

3. Hideki UJIHARA et. al. , "Mutlimode Horns for VSOP-2 Satellite", International Symposium on Antennas and Propagation 2007(ISAP'07).

4. Ichikawa, R., A. Ishii, T. Takiguchi, Y. Koyama, T. Kondo, K. Kokado, S.Kurihara, and S. Matsuzaka (2009): "Present Status and Outlook of Compact VLBI System Development for Providing over 10 km Baseline Calibration", IVS TDC-News October 2009., 30, 22-25

3. Jwo-Shim Sun and Guan-Yu Chen, "The Tapered Slot Antenna", ***2004* 4h** International Conference on Microwave and Millimeter Wave Technology Proceedings