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Designs and Development of Multimode Horns for ASTRO-G/VSOP-2 Satellite

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Abstract. The antenna optics of VSOP-2 satellite require low cross polarization, and the volume of the receiver box is limited. Thus, instead of conventional corrugated horns, multimode horns were proposed and designed in order to reduce the axial length and weight of the horns but still compatible with a low cross polarization. These multimode horns were designed for three observational bands of VSOP-2 at 8GHz, 22GHz, 43GHz, all with about the same antenna illumination size. However, the ratio of waveguide and wavelength are slightly different. The 22GHz-horn was designed at first, and the other horns were arranged around it. The properties of the horns were improved by controlling the complex amplitude of higher modes and by fitting the beam width to the antenna optics. The BBM models of horns were tested, and their measured beam patterns agree well with numerical simulations.

1. Multimode Horns for VSOP-2

A corrugated conical horn feed provides low cross polarized beam by using the hybrid propagation mode HE11. Such horns were planned to as the feed for offset Cassegrain reflector antenna of VSOP-2 in order to obtain high quality polarization data from radio sources. These horns also make efficient use of the small spatial volume they are allocated on-board the spacecraft and on the radio telescope. The main characteristic of the feeds to have three bands at X(8GHz), K(22GHz), Q(43GHz), each with good response over a10% bandwidth.

The concept of the multimode horn to use the dominant TE11 mode and higher order modes to control the beam pattern is given by (Love 1976, Ebisui et al. 1982, 1990). Their design also provides the 10% bandwidth and small spatial volume by having a short axial length and thin feed inner surface with no corrugations. Thus, I proposed the multimode horn feed for VSOP-2 satellite. The design generates and combines the TM11 mode with that of the dominant TE11 mode within a conical horn to create a high degree of axial symmetry, and with E-plane sidelobe suppression in the radiated beam over the 10% instantaneous bandwidth.

2. Design of the Horns

The TM11 and other higher modes are generated by an abrupt flare angle change in the waveguide, by appropriate sub-sections in the horn that provide radiation pattern synthesis of TE11 and TM11, and by other technical methods. The symmetric and low cross polarization beam was obtained by appropriate mixture of the modes using the flare angles and waveguide length in each horn section. The

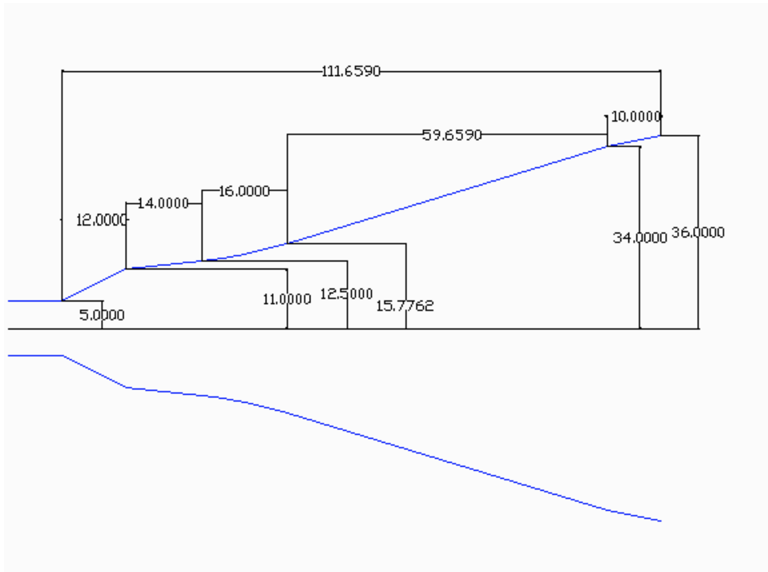

Figure 1. The final design of the 22GHz multimode horn for VSOP-2

determination of the best design parameters is complex and numerical optimization is needed, and the design procedure was simplified.

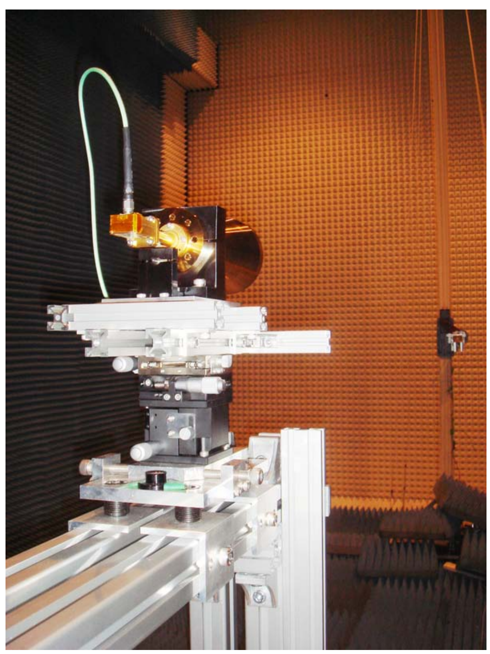

Figure 2. The far-field measurement in METLAB radio quiet room. A.U.T. is the K band multimode horn for VSOP-2.

The basic horn configuration, which is sketched in figure 1, was divided into two sections to be optimized numerically. The excitation section at one end of the waveguide produced the higher order modes, and the matching section for beamwidth shaping was at the other end near the aperture. Initially, each section was optimized using numerical simulations and then the two sections were joined and optimized together. All the VSOP-2 horns have a same beamwidth of approximately 14°, and an instantaneous bandwidth of 10%. We first designed the horn for K-band and then, the other two horns were derived from K-band horn. The first step of the optimization is to determine the amplitude and phase shifts for the higher modes at the aperture. The horn radius in the mode-converter is determine to minimize the level of cross polarization in the far field by numerically solving for the electric field distribution in the horn. The CHAMP software package, included the GRASP8 software, or, generalized telegraphist-fs equations () are used for the simulations.. The next step optimizes the beam patterns by changing the shape of flare-converter. For the last step, the radiation pattern, cross polarization level and bandwidth of the horn are checked. The K-band horn is shown in Fig. 1, and the equipment set-up for K-band horn in METLAB radio quiet room is shown in figure 2. The X-band, Q-band and VERA 6.7GHz horns were optimized in a similar manner.

3. Results of Measurement and Conclusions

The measurements have been carried out on an numbers of Bread Board Model (BBM) horns, and some of the results are given in figures.3. In each case, the solid curves are simulations and dots are measurements. The measured gains are corrected at the center of the beam by the simulations.

The multimode horns,developed using numerical optimization, are in good quantitative agreement with experimental data of the BBM horns. These multimode horns will by used as a feed for the offset-fed Cassegrain reflector of VSOP-2. The 22GHz and 43GHz horns will be fabricated with the GFRP thin wall in the engineering model, and FM will be used for thermal isolation of the cooled receivers. This feature is used by the multimode horns. Also, the co-polar and cross-polar patterns will be measured in order to simulate of entire optics with GRASP.

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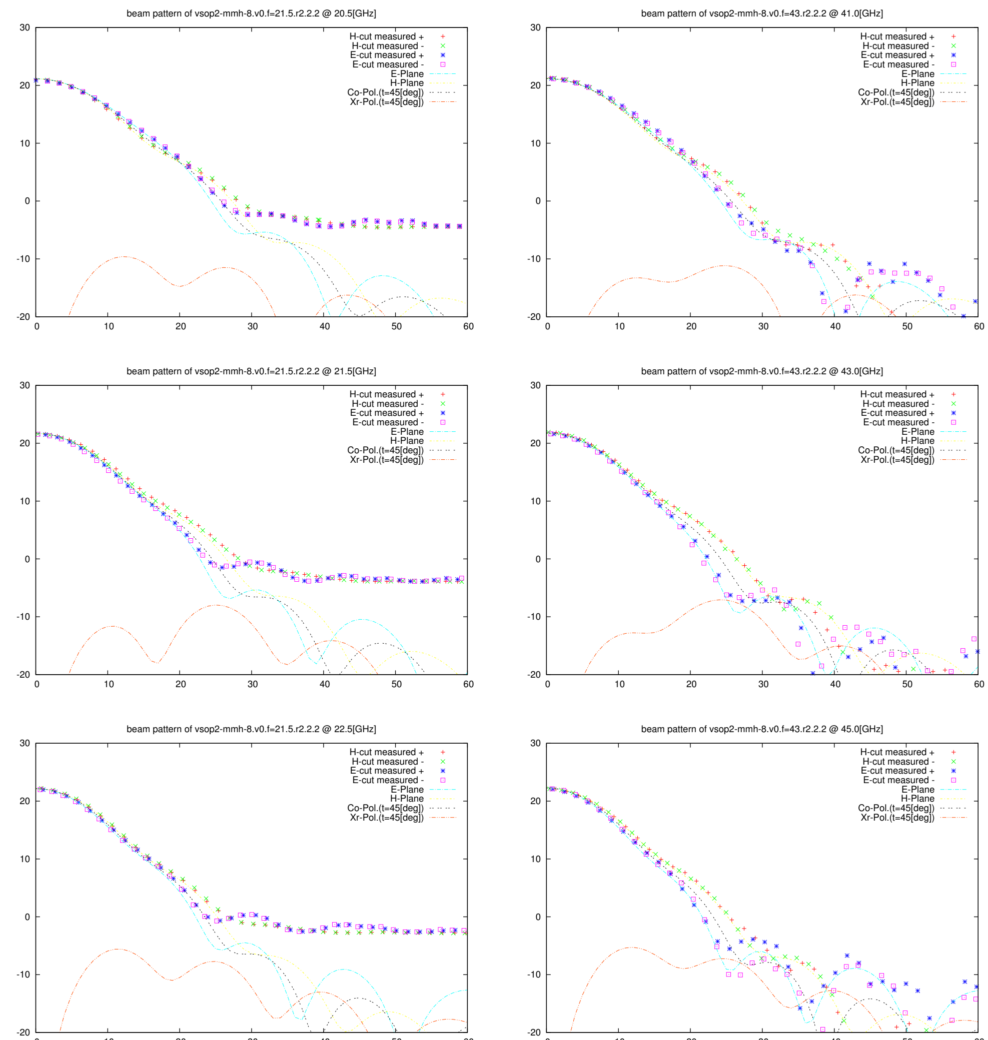

Figure 3. The numerical and experimental results for the multimode horns for the VSOP-2 22GHz (left side, 20.5GHz,21.5GHz,22.5GHz from the top) and 43GHz (right side, 41.0GHz,43.0GHz,45.0GHz from the top) .