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S/X/Ka Coaxial Feed for the Tri-band of the RAEGE Antennas

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Abstract

The tri-band cryogenic receiver for the first light observations of the first RAEGE project antenna in Yebes Observatory is being developed, in the framework of the VLBI2010 project.

The 13-m new ring focus antennas are suitable to be fed by a broad-band feed such as the Eleven Feed. However other feed configurations are possible in order to cover narrower bands, such as the S, X, and Ka bands. With this frequency arrangement, the feed makes possible backward compatibility with classical VLBI, and it will be especially useful for the Ka commissioning of the antenna. X/Ka simultaneous observations will also make it possible to link this antenna with other VLBI networks.

The feed, designed to illuminate the ring focus antenna, is made of a coaxial waveguide for the S- and X-bands and a circular waveguide for the Ka band. Four outputs from their corresponding field probes at S and X bands must be combined with 180° and 90° hybrid circuits to get dual-circular polarization. In the Ka band case, the dual-circular polarization is obtained with a septum polarizer. The feed, hybrids, and polarizer will operate at cryogenic temperatures.

1. Introduction

The RAEGE project is an ambitious VLBI2010 plan to have four antennas in Spain: one antenna at Yebes in the continental Spanish mainland, two antennas on the Azores Islands in Portugal, and one antenna on the Canary Islands. These four antennas fulfill the VLBI2010 recommendations [1], they are 13.2-m diameter, and the slew speeds are 6°/sec and 12°/sec in elevation and azimuth. Three of the antennas are going to be installed and operative in the next years. The fourth antenna on Flores Island under Portuguese management will be provided soon.

The first antenna is going to be installed at Yebes, the IGN main observatory, during 2013. The antennas designed by MT Mechatronics are operative up to 45 GHz due to the surface quality (200 μm), antenna back structure deformations, and pointing accuracy (20"). A new commissioning receiver is foreseen to be used as the first light receiver. It is highly recommended to have a high frequency receiver to test the antenna in the highest frequencies possible and it is also mandatory to assure backward compatibility with the previous S/X VLBI systems. The first light receiver will cover S/X/Ka bands simultaneously [2]. The feed of the receiver is a three-band feed for these frequencies that covers a narrow bandwidth around the S/X/Ka bands.

2. RAEGE Antenna in the VLBI2010 Project

It is a 13.2-meter antenna that follows the VLBI2010 recommendations in terms of size, slew speed, pointing, and surface accuracy. The optical configuration is given by the specification of broadband observation. The feeds available for continuous frequency coverage from 2 to 14 GHz such as the Eleven Feed and the Self Quasi Complementary Feed are low F/D ratio antennas [3],[4]. They achieve the maximum antenna aperture efficiency when they have to illuminate the reflectors over a wide flare angle. This is the case of primary focus antennas that are proven to be bad in terms of noise due to the ground noise spillover. The alternative to solve the noise problem is the dual reflectors, which are usually designed to have a large equivalent F/D. However, if a classical dual reflector (cassegrain or gregorian) is designed with a very low equivalent focal, the consequence is a highly blocked system, which is also unwanted.

The ring focus antenna solves the blockage problem in a dual reflector antenna. It is a displaced-axis dual reflector antenna. This optics is a special case of a Gregorian system, in which the focal axis of the main parabolic reflector is displaced from the symmetric axis. The prime focus of the elliptical sub-reflector is also located on this axis and not in the axis of symmetry. The secondary focus, where the feed must be placed, is located in the axis of symmetry. When the antenna revolves around its symmetry axis, the prime focus is a ring while the secondary focus is still a point.

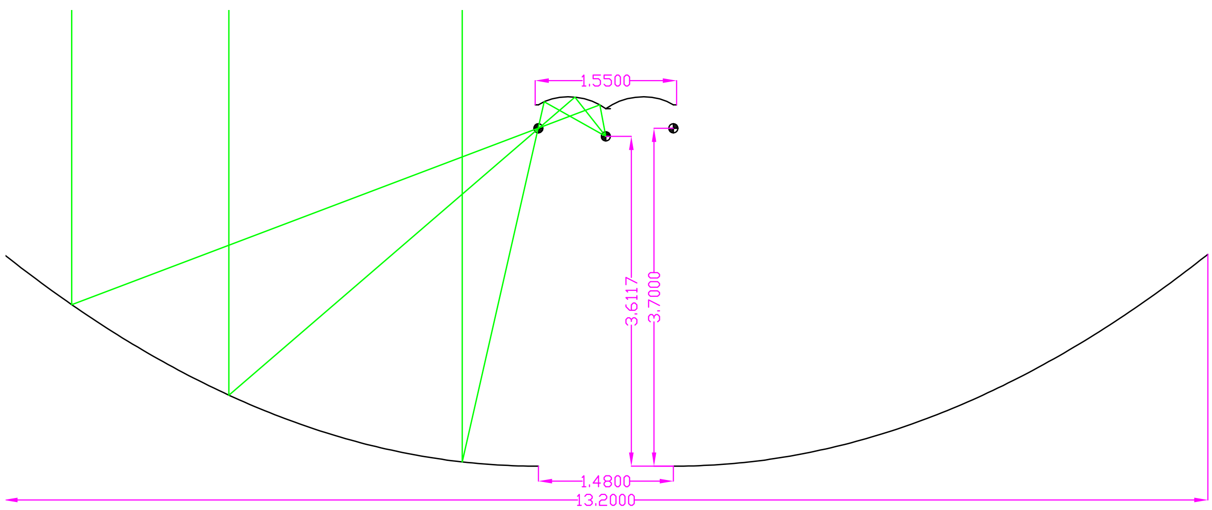

Figure 1. Ring focus optical configuration.

In Figure 1, the rays that are coming from a plane wave in front of the main surface are collimated in the secondary focus without any interception of the sub-reflector. This geometry is not blocked by the sub-reflector, at least from the geometrical point of view. The amplitude distribution is also disturbed by the antenna, and the rays that come near the edge of the main reflector go to the central area of the feed. The ring focus antenna geometry changes the amplitude distribution of the feed and it makes the distribution more uniform in the aperture of the main reflector. This has two effects: The aperture efficiency is increased with respect to the classical dual reflectors, and the side lobes' level is increased up to -13 dB with respect to the maximum gain.

Unfortunately the low F/D ratio is responsible for a loss of antenna efficiency due to the feed and sub-reflector misalignment, which could be more critical in high frequencies. In Figures 2 to 5 the graphs show the gain decrease when the feed or the sub-reflector is moved from its nominal position axially and laterally in the S, X, and Ka bands.

Due to the low equivalent F/D, the gain is very sensitive to feed positioning, which is unusual in dual reflectors. It depends on the frequency and it can be an issue for Ka band and above. The

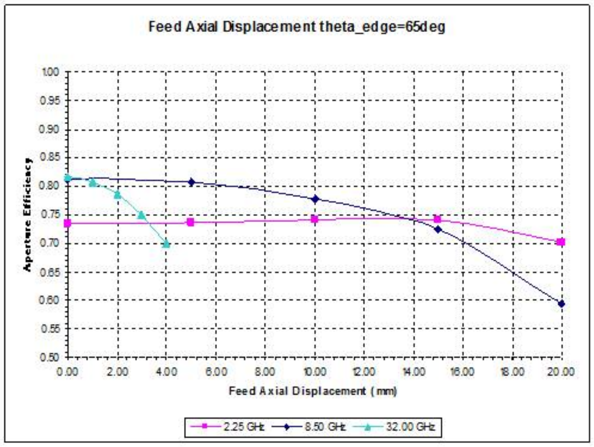

Figure 2. Computed aperture efficiency as a function of feed axial displacement.

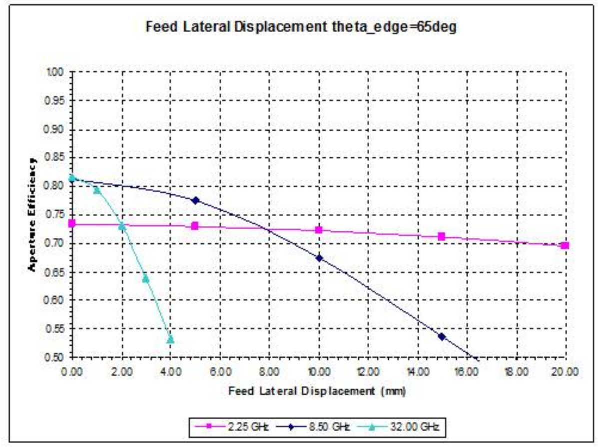

Figure 3. Computed aperture efficiency as a function of feed lateral displacement.

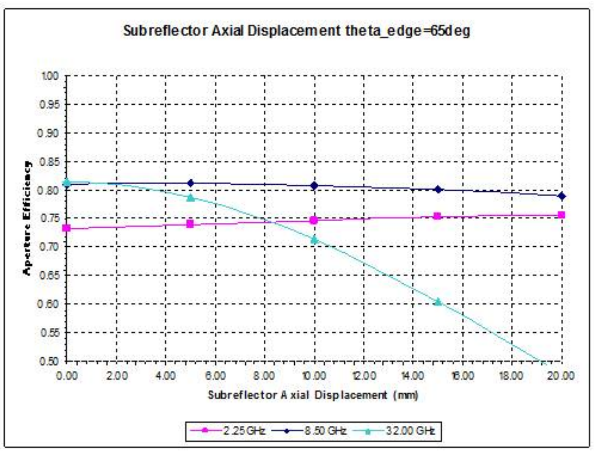

Figure 4. Computed aperture efficiency as a function of sub-reflector axial displacement.

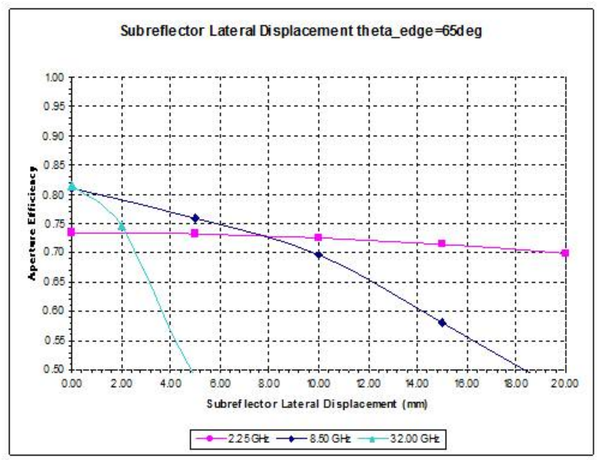

Figure 5. Computed aperture efficiency as a function of sub-reflector lateral displacement.

sub-reflector position is controlled by servos and with a sub-reflector motion strategy to correct the misalignments and keep the efficiency at an acceptable level.

3. First Light S/X/Ka Receiver

The tri-band receiver is based in a dual-circular super-heterodyne layout receiver for the three bands (2.2-2.7 GHz, 7.0-9.0 GHz, and 28.0-33.0 GHz). All the front-end components, including the feed, are going to be cooled down inside of a cryostat. See [2] for details.

4. Tri-band Feed Design

The tri-band feed is actually made of three individual feeds, one inside another of lower frequency (see Figure 6). Each feed has its own output connector to interface to the polarizer and the amplifiers. The biggest external feed is the coaxial S-band feed; the medium feed is the coaxial X-band feed, and the smallest feed is the Ka conical feed. Both the S and X feeds are fed by four ports with SMA connectors in the S-band feed and waveguide flanges WR-112 for the X-band. The Ka band feed output is a circular waveguide of 8.4 mm in diameter. The dimensions are 25 cm high and 20 cm in diameter, and it weighs 3 kg.

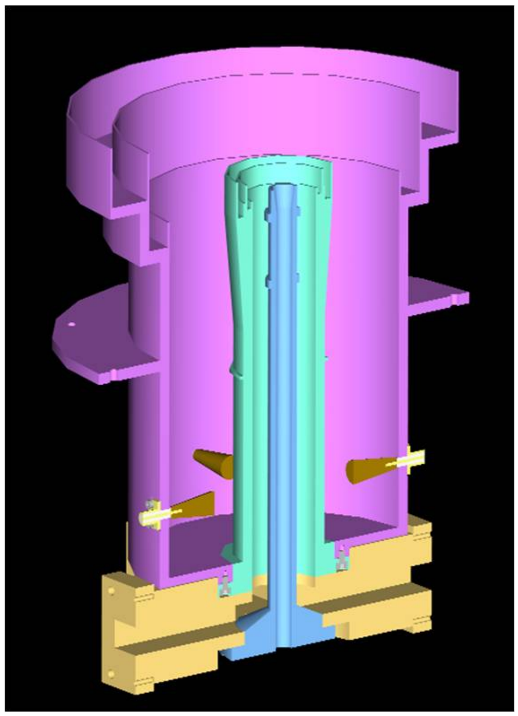

Figure 6. Inside view of RAEGE tri-band feed.

In the case of the coaxial feeds (S and X) the dual circular polarization can be achieved by combining the four ports conveniently. The linear polarization is excited in the two front ports with a 180° phase shift. The orthogonal linear polarization is obtained by exciting the perpendicular ports. Two 180° hybrids are necessary to combine the two ports of both linear polarizations. The circular polarization is obtained by shifting the two orthogonal linear polarizations 90°. A 90° hybrid is used at the 180° output hybrid. All the hybrids are cooled to reduce the input noise temperature.

The dual circular polarization in the Ka band is obtained by a stepped septum attached directly to the circular waveguide.

The feed and the antenna have been simulated with Physical Optics [5] to calculate the theoretical maximum directivity of the RAEGE antenna with the tri-band feed. In Figure 7 the aperture efficiency is shown, and it is above 70% for the tri-band feed.

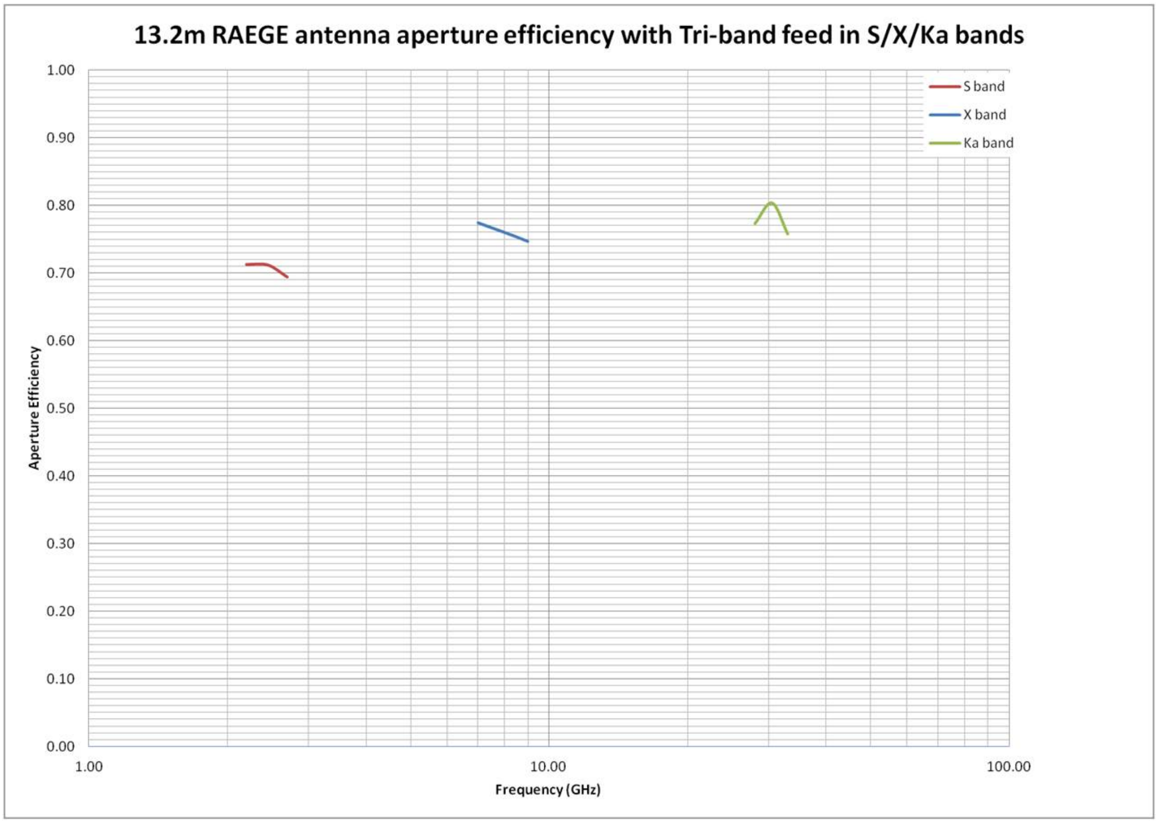

Figure 7. Computed aperture efficiency of RAEGE antennas with tri-band feed.

5. Conclusions

A first light receiver is being developed in Yebes for the first RAEGE antenna [2]. It is a tri-band receiver (S/X/Ka) based on a tri-band feed with dual circular polarization. The design of the feed is compact enough to fit inside the cryostat. The simulations of the feed and the antenna give 70% for the calculated aperture efficiency.

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[5] GRASP Reference Manual (www.ticra.com).