67-116 GHz Optics Development for ALMA Band 2-3 Receivers

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Abstract—**In this paper we report the first results of the optical components development and the overall optical design for a wideband receiver to simultaneously cover ALMA bands 2 and 3. Two types of feed horns and OMTs have been designed to couple to the ALMA telescope beam using a modified Fresnel lens. Both types of hardware have been manufactured and tested in a near field beam scanner. The measured beam patterns and optical efficiencies are in good agreement with simulations.**

I. INTRODUCTION

THE ALMA telescope [1] is already a functional instrument delivering great science. However, it is not equipped with all receiver bands, and particularly band 2 has not been approved for construction yet. Recent technological developments in cryogenic MMICs open an opportunity to extend the originally planned bandwidth of this receiver (67-90 GHz), and potentially combine the two ALMA bands 2 and 3 (84-116 GHz) within a single receiver. While the LNA development as of today may not be able yet to satisfy the noise and bandwidth requirements simultaneously and in full, we believe it is still worthwhile to develop the full band 2+3 optics receivers, and allow for the option to upgrade them with the wider bandwidth LNAs when they become available. This paper describes the first efforts to design wideband optics to cover both ALMA bands 2 and 3, from 67 to 116 GHz, using a profiled corrugated horn and a modified Fresnel lens. Development of a wideband LNA and a Local Oscillator to complete the cryogenic receiver are outside the scope of this research.

II. DESIGN

Two types of feed horns and OMTs have been designed and fabricated by INAF and UdC. The design by INAF is based on a sin-squared profile with corrugations with variable depth and length in the throat section in order to achieve the required bandwidth. The design by UdC is based on a spline profile and direct optimization of the parameters of all corrugations in the horn. Results show horns with good reflection loss, low cross-polarization, low sidelobes and good beam symmetry. INAF horn has been fabricated by stacking metal rings with individual corrugations, whereas UdC horn has been fabricated by direct machining of aluminum. INAF and UdC have contributed two different designs of OMTs, both based on turnstile junctions.

The lens was designed by NAOJ using WaspNET, a full-wave analysis software which implements a hybrid Mode Matching (MM) and Method-of-Moments (MoM) code. This allows to simulate the horn, the zoned lens, with antireflection coating, and the lens metal support structure simultaneously, considering all electromagnetic effects between them. The best results in terms of aperture efficiency were obtained for a modified Fresnel bi-hyperbolic lens. The achieved aperture efficiencies are between 81.5% and 86.2%, compliant with the ALMA requirement of >80%.

III. MEASUREMENT SYSTEM

Both types of optics have been fabricated and tested using a near-field beam measurement system. This system has been designed to accept any combination of optical components and allows testing from feed horns alone up to full configurations including the lens and also infrared filters. The system consists of a transmitting open-ended waveguide probe antenna attached to an X-,Y- scanner equipped with Z- rotation stage for co- and cross-polarization measurements, a room-temperature 2SB receiver, an electronics rack and a control PC. The block diagram of the measurement system is shown in Figure 1. The maximum scannable plane is 150 mm x 150 mm. The sampling rate in the XY plane is greater than 0.5λ in order to meet the Nyquist criterion. The signal of an RF synthesizer is frequency multiplied by 6 and fed to the probe antenna. The radiated RF signal is received by the DUT and down-converted to an IF frequency of 4 GHz with the 2SB receiver. The LO signal for the down-conversion is obtained by frequency multiplication by 6 of the signal provided by a second synthesizer. A reference signal with the phase information of the RF and LO signals is created by mixing samples of the RF signal and the low-frequency LO signal, with a harmonic mixer. The resulting reference signal at the IF frequency is compared in amplitude and phase with the IF signal from the 2SB receiver, and the result is read with the vector voltmeter. The near-field data is then transformed into far-field data by Fourier transform.

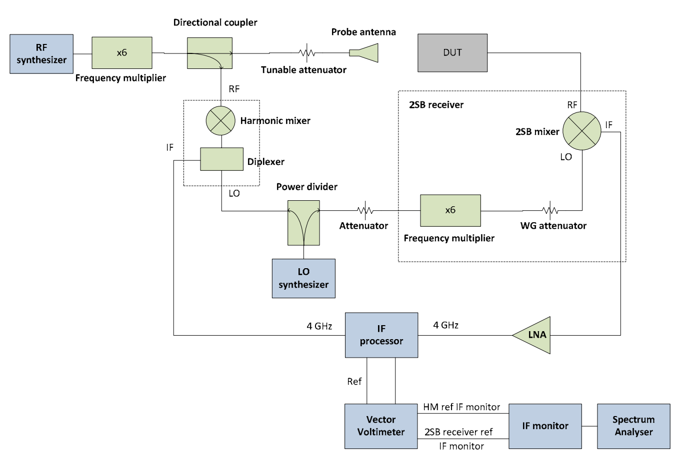

Fig. 1. Block diagram of the beam measurement test system.

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IV. Results

The measured far field patterns have been found very similar to the simulations. Figure 2 shows the comparison of the simulated and measured beam patterns of the UdC and INAF designed horn and OMT, without the lens.

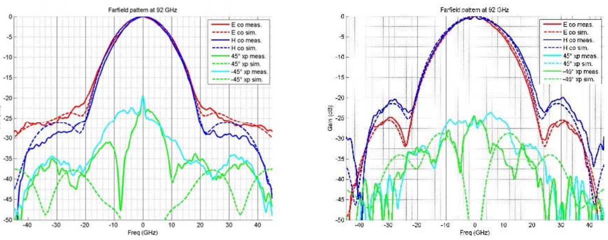

Fig. 2. Measured and simulated far-field beam patterns at 92 GHz for UdC horn and OMT (left panel), and INAF horn and OMT (right panel).

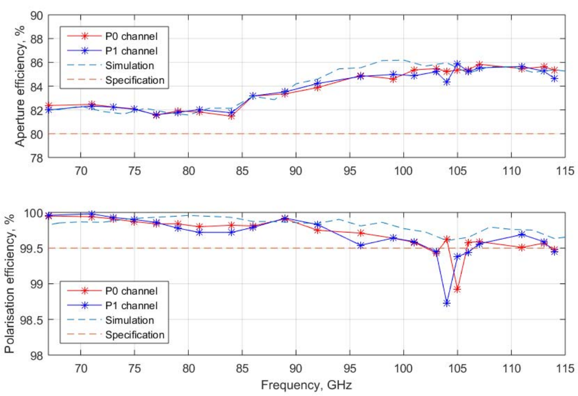

Fig. 3. Comparison between the measured and simulated aperture and polarization efficiencies for the full INAF system, including the lens. Aperture efficiencies are fully compliant to ALMA specification of >80% across full frequency range. Polarization efficiencies are mostly compliant to ALMA specification of >99.5%, with some degradation between 103-105 GHz.

Full optical systems, including the lens, have been so far measured with the INAF OMT only. The optical efficiencies are calculated and results are presented in Figures 3 and 4. Aperture efficiencies of both UdC and INAF optical designs are compliant to ALMA specifications of >80% across full frequency range.

Polarization efficiencies are mostly compliant to the >95.5% requirement as well, with some degradation above 101 GHz for both types of horns. The reason for this degradation is not clear yet and is being investigated.

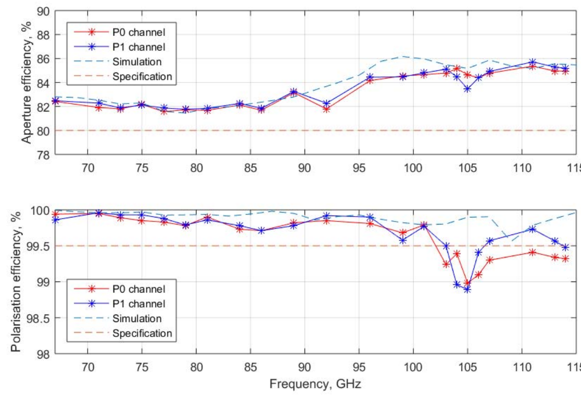

Fig. 4. Comparison between the measured and simulated aperture and polarization efficiencies for the UdC horn, including the lens, followed by INAF OMT. Aperture efficiencies are fully compliant to ALMA specification of >80% across full frequency range. Polarization efficiencies are mostly compliant to ALMA specification of >99.5%, with some degradation above 101 GHz.

References

[1] ALMA Observatory: www.almaobservatory.org