An ultra-broadband optical system for ALMA Band 2+3

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I. Introduction & Motivation

- ALMA is the largest mm/submm astronomical facility in the world: 66 antennas (54 of 12-m + 12 of 7-m) covering 35 – 900 GHz with 10 bands.
- ALMA has a permanent upgrading program of its different subsystems.
  - For the front end the immediate goals are completing the realization of all the bands and obtaining larger bandwidths (RF and IF) and better sensitivities.
- An international consortium has been formed to demonstrate a receiver that covers originals Bands 2 and 3 (67 to 116 GHz).
  - This represents a fractional bandwidth of 54% (in comparison, none of single ALMA bands exceeds 35%).
  - The receiver will use HEMT-based low-noise amplifiers and Schottky diodes
- Here we present the preliminary design, implementation and characterization of two optical systems covering the full range of ALMA Band 2+3.

II. General Concept

- Combination of strong constraints and demanding specifications.
- Several options have been considered (refractive and reflective).
- So far most promising is refractive solution (figure 1).

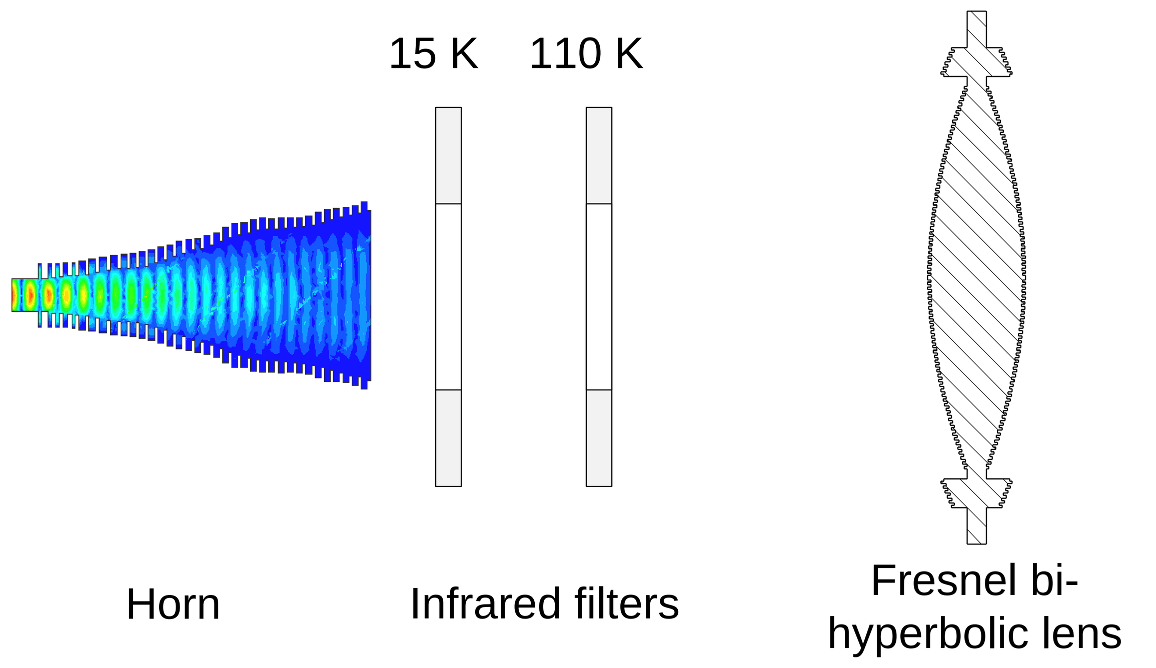

Figure 1. Basic layout of the optical (not to scale). Infrared filters are already installed in all ALMA cryostats and have been taken as restrictions in the optimization process.

IV. Measurement Setup

- Near-field beam-pattern setup mounted at ESO (figure 5).
  - The data is transformed into far-field data using a Fourier Transform.
- We have characterized the two optical systems formed with the components presented in section III.

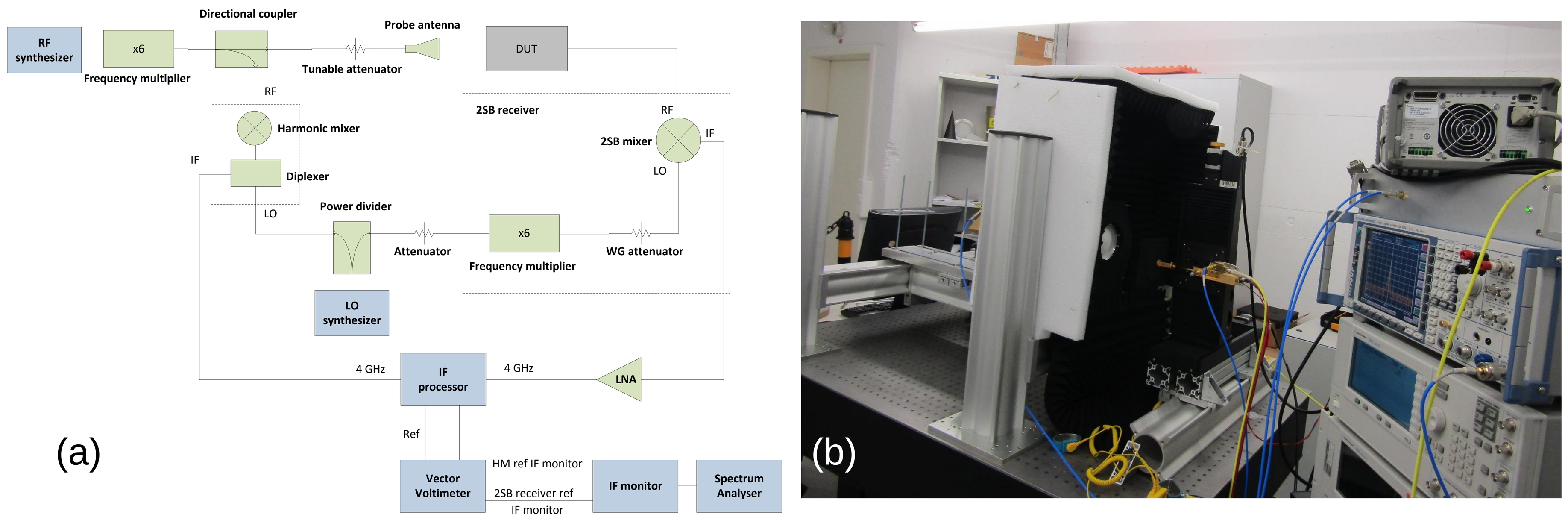

Figure 5. Beam-pattern measurement system. (a) Schematics. (b) Actual setup.

III. Components

- Two versions of corrugated horns (figure 2).
- Lenses optimized for every horn (figure 3).
  - Major contributor to total noise
- Two versions of turnstile OMTs (figure 4).

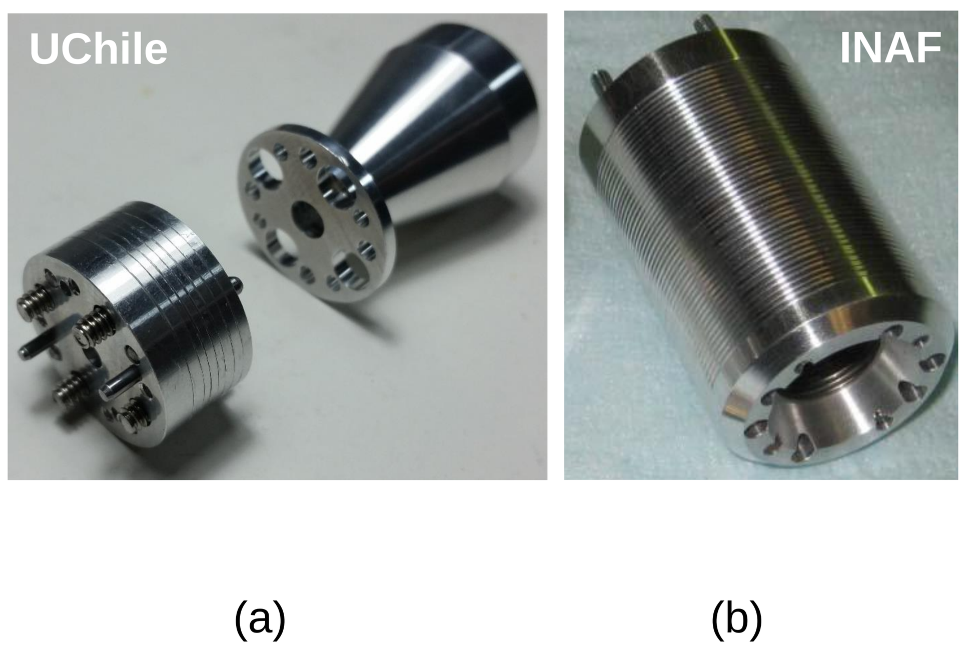

Figure 2. Corrugated horns. (a) Profile-optimized horn constructed as a single block and 8 stacked rings at UChile. (b) Sin-squared horn implemented with 44 stacked metallic rings at INAF.

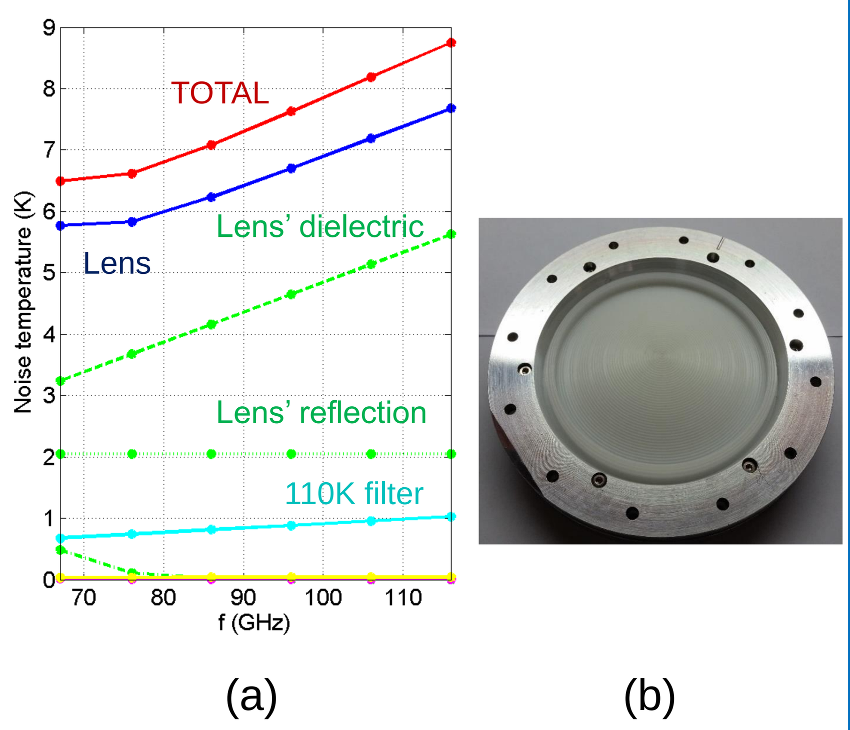

Figure 3. (a) Noise contribution of one of the studied lenses. (b) Implementation from an HDPE block.

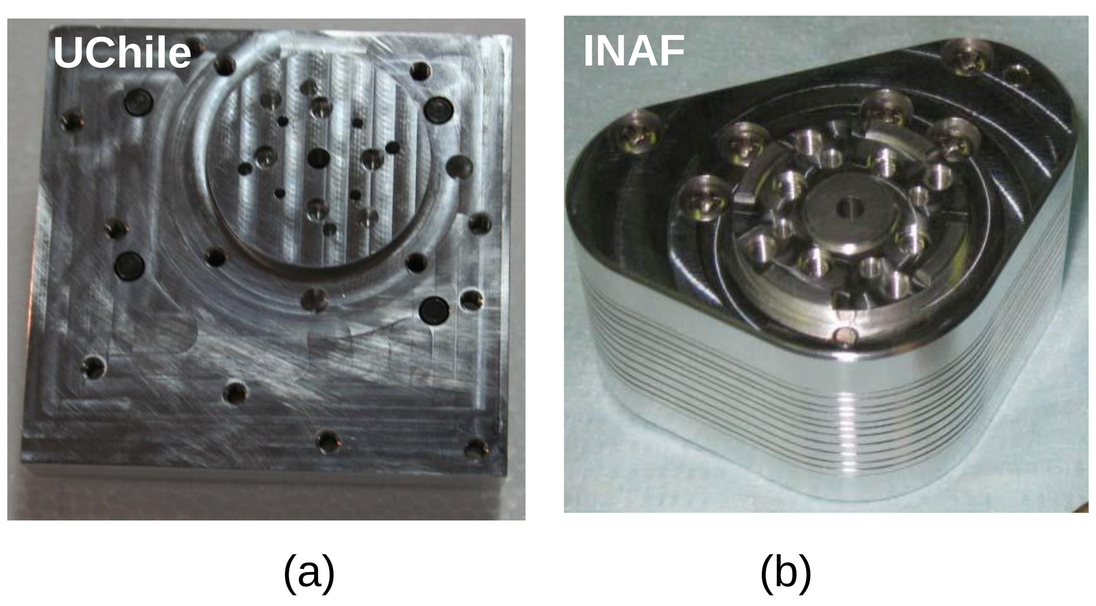

Figure 4. (a) OMT implemented in four plates at UChile. (b) OMT implemented in nine plates at INAF.

V. Results

- Two different optical systems were characterized.
  - One using the components developed at UChile.
  - Other using the components developed at INAF.
  - Lenses were designed at NAOJ and fabricated by UChile.
- Beam patterns were measured (figure 6).
  - Excellent co-polarization.
  - Cross-polarization larger than expected (small fabrication errors).
- Efficiencies were calculated from beam patterns (figure 7).
  - Good aperture efficiency.
  - Non-compliance in polarization efficiency may be attributed to fabrication errors of the horn and small misalignments.
  - All these problems are being addressed currently: new components and a second measurement campaign is being conducted at ESO.

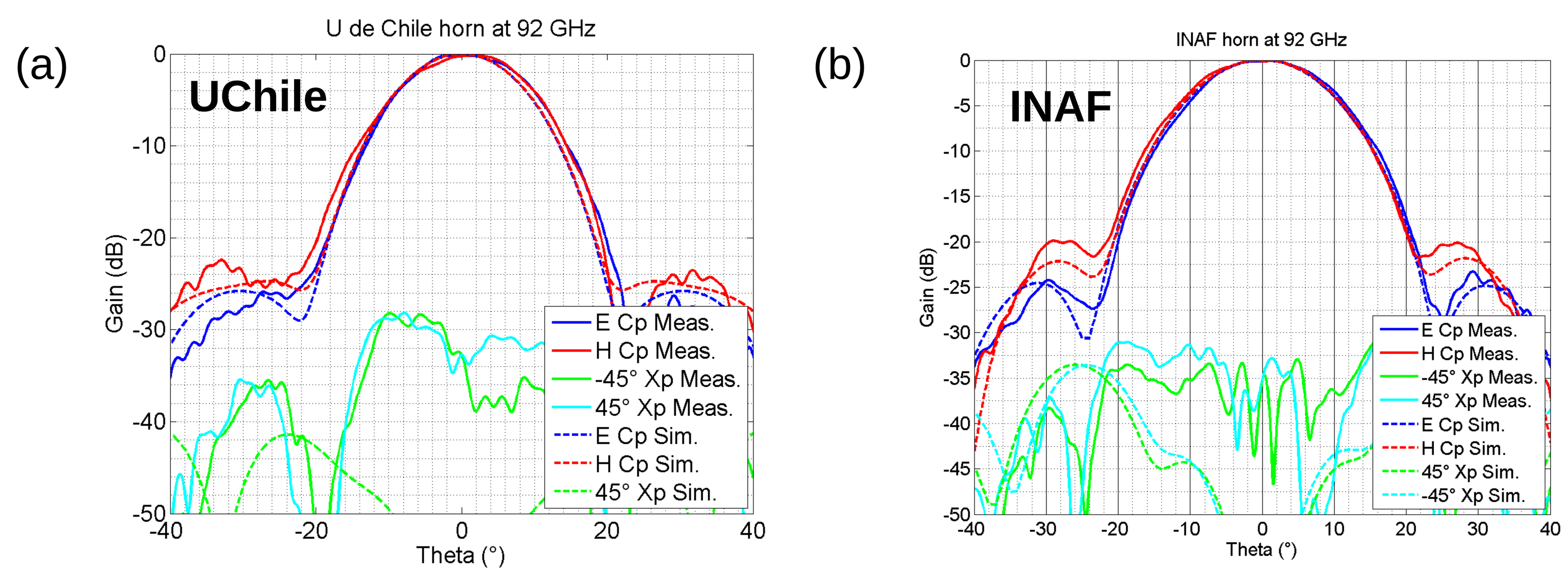

Figure 6. Example of far-field beam patters of the two different systems. (a) System developed at Universidad de Chile. (b) System developed at INAF.

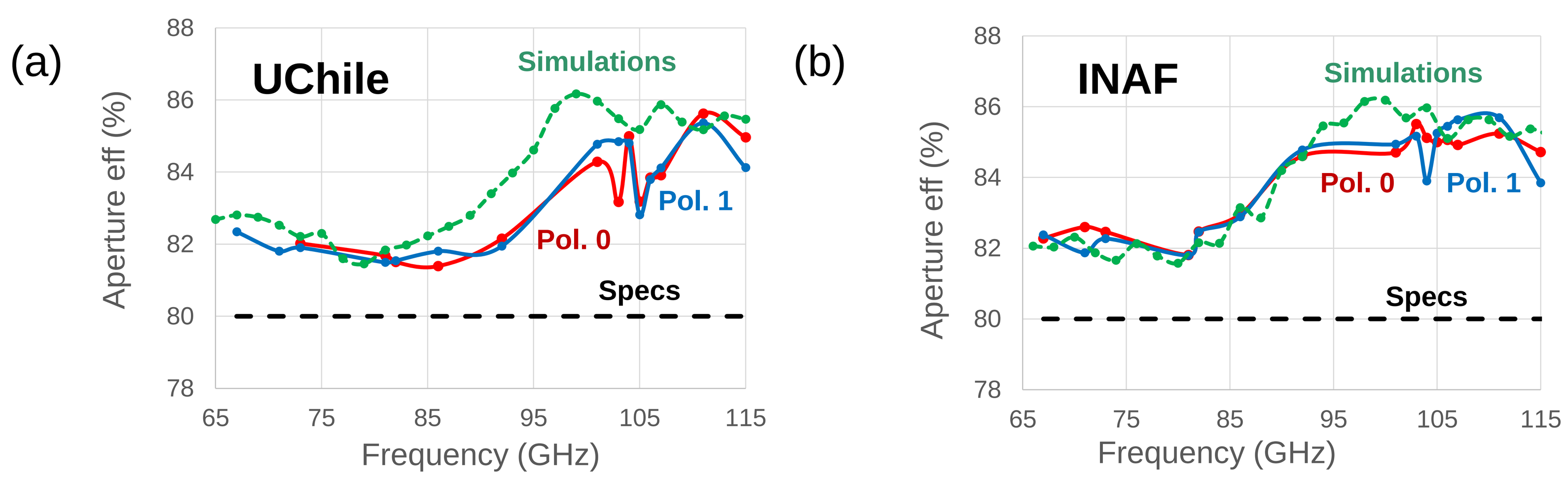

Figure 7. Measured and simulated aperture efficiencies. (a) System developed at Universidad de Chile. (b) System developed at INAF.

VI. Conclusions & Future Work

- First iteration towards obtaining an optical system that covers the frequency range corresponding to Bands 2 and 3 of ALMA.
- The preliminary implementations show excellent performance although more optimization is needed.
- A second campaign of measurements is being conducted with new versions of horns and OMTs.
- New materials for the lens are being studied. Particular attention will be given to high-purity silicon and quartz.