Atacama
Large
Millimeter
Array

The ALMA Amplitude Calibration Requirement

ALMA-90.03.00.00-00x-A-SPE

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Description Document

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Change Record

Revision	Date	Author	Section/ Page affected	Remarks
1	2006-02-04	Jeff Mangum	All	Initial Draft
2	2006-02-05	Jeff Mangum	All	Minor word tweaks
3	2006-04-24	Jeff Mangum	3/4	Changed 300 GHz to 370 GHz
4	2006-04-26	Jeff Mangum	1	Added some definitions

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Contents

1 Intent of this Document

The ALMA amplitude calibration specification has many facets. Subsets of the amplitude calibration specification relate to the accuracy of amplitude determination at a variety of levels in the ALMA system. Many of the terms used to describe these subsets of the amplitude calibration specification, such as "relative" and "absolute", have been used to describe multiple subsets of the specification. This document seeks to:

— Consistently define and explain the contributions to the amplitude calibration specification.
— Relate these definitions to existing reports and documents.

First, some important definitions which will be used throughout this document:

Accuracy: How close a measured value is to the true value. For example, how close a measured flux is to the true source flux.

Precision: The statistical error on a measurement. Synonymous with "repeatability".

Repeatability: Agreement of the fluxes for a non-variable point source observed at a specific frequency at different times.

Cross-Band Accuracy: Accuracy of flux ratios from measurements made in different frequency bands.

Relative Calibration Accuracy: Calibration with respect to the T_A^* (multi-load calibration system) scale (see Figure 1).

Absolute Calibration Accuracy: Calibration with respect to a specific calibration standard source (the T_R or S scale; see Figure 1).

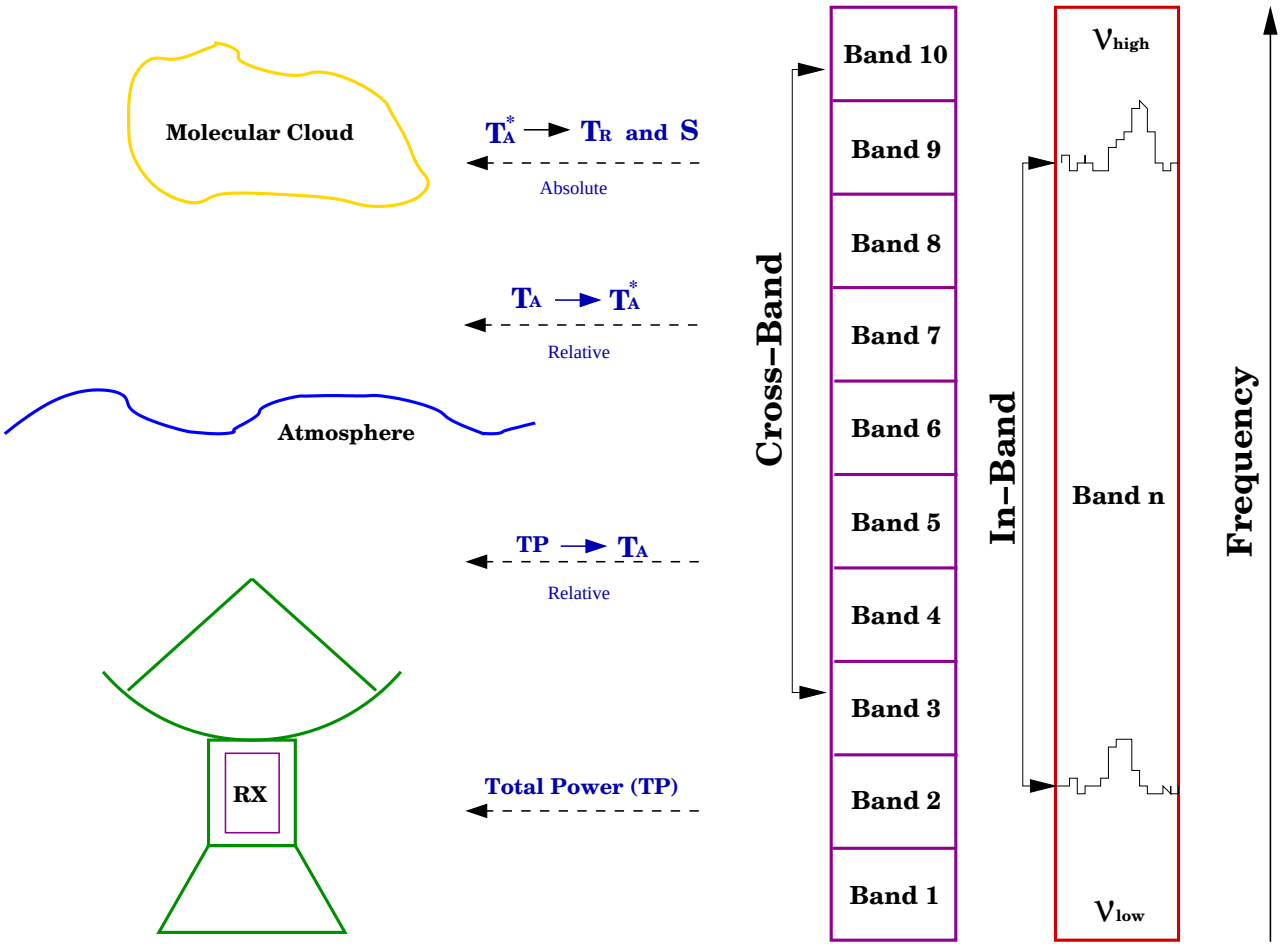

Figure 1: The amplitude calibration ladder and definition of terms. The left half of this diagram shows the steps taken to determine the absolute amplitude of a source, from total power (TP) measurement to application of a flux standard measurement (T_R and S). The right half shows the definitions of in-band and cross-band amplitude calibration.

Table 1: Rungs in the Amplitude Calibration Ladder

Measurement	System(s)	Precision	
		In-Band	Cross-Band
TP	FE/BE	$1/30\times10^{-4}$ over 1/300 sec	$1/30\times10^{-4}$ over 1/300 sec
T_A	FE/BE/CW	<1%	<1%
T_A^*	FE/BE/CW	1/3%	1/3%
T_R and S	FE/BE/CW	5%	5%

FE = Frontend: BE = Backend: CW = Chopper Wheel
Breakpoint for split precision at $\nu = 370$ GHz

2 The Amplitude Calibration Ladder

A description of the "amplitude calibration ladder" was given in Figure 1 of ALMA Memo 434 ([Mangum (2002)]). In Figure 1 we show a somewhat extended description of the amplitude calibration ladder which breaks-out the subsets of this specification which relate to the antenna and frontend systems.

3 Amplitude Calibration Steps

Referring to Figure 1, the steps in the amplitude calibration process and their required precision are listed in Table 1. Specifically:

TP: Total power measurement by the FE and BE.

T_A: Using the chopper wheel load calibration device, alternately measure loads at accurately known physical temperatures to convert TP to a temperature scale. This temperature scale is not referenced to any astronomical source properties.

T_A^*: Apply an atmospheric opacity correction to the T_A measurement to reference the antenna temperature scale to a point above the Earth's atmosphere.

T_R and S: Convert T_A^* into absolute brightness temperature units (T_R in K) for single dish, or flux density (S in Janskys) units for interferometric observations (or single dish observations of point sources). This step involves the measurement of a flux standard source (planet, asteroid, main sequence star, etc.) with well-modelled emission properties at the frequency of interest.

For more details on the actual process involved in each of these steps, see [Lucas & Mangum (2005)]. The definitions above should be consistent with recommendations made by the ASAC in their September 2003 ([ASAC Report: September 2003]) and October 2005 ([ASAC Report: October 2005]) reports, the ALMA Calibration Specifications and Requirements ([ALMA Calibration Specs and Reqs]), and the ALMA Science Specifications and Requirements ([ALMA Science Specs and Reqs]).

The "Amplitude Fluctuations" specification from the ALMA Scientific Specifications and Requirements is repeated here:

The corrected visibility amplitude fluctuations on time scales of 1 second to 300 seconds shall not exceed 1% at frequencies less than 370 GHz, 3% at higher frequencies, considering:

A. Antenna gain stability under changing wind and gravity conditions;

B. Ability to measure and correct for atmospheric opacity and emission fluctuations;

C. Instrumental gain fluctuations,
to provide repeatable precision in amplitude measurements. Accurate relative calibration (the ability to measure a flux ratio between frequencies in two different bands) requires absolute calibration to accuracy of 5% or better at all frequencies.

References

[Mangum (2002)] Mangum (2002), "Load Calibration at Millimeter and Submillimeter Wavelengths", ALMA Memo 434

[Lucas & Mangum (2005)] ALMA-90.03.00.00-00x-A-SPE: Amplitude Calibration Steps (2005-09-15 Draft)

[ASAC Report: September 2003] Report of the ALMA Science Advisory Committee: September 2003 Meeting

[ASAC Report: October 2005] ALMA Science Advisory Committee: Report from Meeting of October 1-2, 2005, Santiago, Chile

[ALMA Calibration Specs and Reqs] ALMA Calibration Specifications and Requirements

[ALMA Science Specs and Reqs] ALMA Science Specifications and Requirements