ALMA Antenna

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Abstract

The Atacama Large Millimeter Array (ALMA) is a millimeter and submillimeter astronomical observatory being built in northern Chile. The array consists of a 12-m array (50 12-m antennas) and of the Atacama compact array (4 12-m antennas and 12 7-m antennas). The ALMA antennas are required to meet very stringent technical specification such as pointing/tracking accuracy, fast motion capability, and surface accuracy etc. under operating conditions. The paper describes the design features and summarizes major performance of the ALMA antennas..

1. ALMA Antenna

The Atacama Large Millimeter Array (ALMA) is an astronomical observatory being built in northern Chile where the atmospheric transmission is good for observations at millimeter and submillimeter wavelengths (0.35 to 10 mm) [1]. The array consists of a 12-m array (50 12-m antennas) and of the Atacama compact array (ACA: 4 12-m antennas and 12 7-m antennas). The ACA 12-m antennas are used to make a single-dish image and the ACA7-m antennas are used to obtain the short baseline data [2]. The ALMA antennas are operated at the array operation site (AOS) at an elevation of 5000m above sea level and need to be transferred and relocated on antenna stations at AOS to change antenna configurations by a dedicated antenna transporter. EA (East-Asia: NAOJ) will deliver both 12-m and 7-m ACA antennas, EU (Europe: ESO) will deliver 25 12-m antennas, and NA (North-America: AUI) will deliver 25 12-m antennas.

2. Antenna Requirements

The antenna is a symmetrical paraboloid reflector, with Cassegrain geometry, at an Altitude over the Azimuth mount. The subreflector is supported by quadripod legs and the subreflector position is adjusted in translation and tilt. The antennas are designed to take into account that the antennas are relocated, operated, and to the possible extent, maintained at 5000m above sea level.

The ALMA antennas are required to meet very stringent technical specification such as pointing/tracking accuracy, fast motion, and surface accuracy. For example, the pointing/tracking accuracy shall not exceed 0".6 for the offset pointing for 15 minutes and the surface accuracy of the ALMA 12-m (7-m) antenna shall be less than 25 (20) μm rms including the main and second reflector. These requirements must be satisfied under the so-called primary operating conditions where ambient temperature ranges from -20 to 20 degrees and a wind velocity of 6.4 m/s with full solar heating (day) or a wind velocity of 9.5 m/s (night).

3. Antenna Design

The ACA 12-m antenna, the ACA 7-m antenna, the European 12-m antenna (EU antenna), and the North-American antenna (NA antenna) have slightly different design features for the antenna main components to achieve the ALMA specifications. The main reflector surface of the ACA antennas and the NA antennas are machined aluminum panels while that of the EU antennas is electro-deposited nickel panels. The back-up structure to support the main reflector are Carbon Fiber Reinforced Plastic (CFRP) truss structure for the ACA 12-m antenna, CFRP box structure for the EU and NA antenna, and steel truss structure for the ACA 7-m antenna. The receiver cabin of the EU antenna is also made of CFRP while that of the ACA and NA antennas are made of steel. The ACA, EU, and NA antennas are equipped with different metrology system which provides active correction for pointing errors caused by deformation by temperature distribution or wind-induced deformation. On the other hand, the yoke and base structure are made of steel for all the antenna design and are fully insulated to reduce structural deformation caused by thermal load.

4. Antenna Performance Evaluation

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The major performance of the ALMA antennas has been evaluated in various methods in the construction area and at AOS (e.g. [3]). The measurements of both the absolute (all-sky) and offset pointing are conducted with an optical telescope mounted on the BUS. More than 100 stars are observed to construct a pointing model and all the ALMA antennas have successfully demonstrated that the absolute pointing errors are less than 2” rms and that the pointing model is stable over a month. The offset pointing and tracking errors are measured from a cycle through the measurement sequence of 2 to 6 stars over 15 minutes by taking optical seeing (fluctuation of centroid motion of a star) into account. These pointing performances are further verified with the ALMA system in radio interferometric mode at AOS. The surface accuracy is measured in a radio holography method using a nearby transmitter mounted on the tower. Since the specification must be satisfied under ambient temperature change over different Elevation angles, the best surface needs to be much better than the requirement. For example, the ACA 7-m antenna has achieved 4.4 μm in spite of its 20 μm specification. Astronomical holography is also performed showing its consistent results with the tower holography. The antenna encoder position information is used to assess the fast motion capability of the ALMA antennas. All fast switching motions are obtained by commanding the antenna to alternately observe two sidereal positions (i.e. with sidereal tracking) separated by 1.5 degrees at various position angles on the sky. The non-repeatable residual delay is measured with a linear gauge for the mount structure and with the holography system for the main reflector.

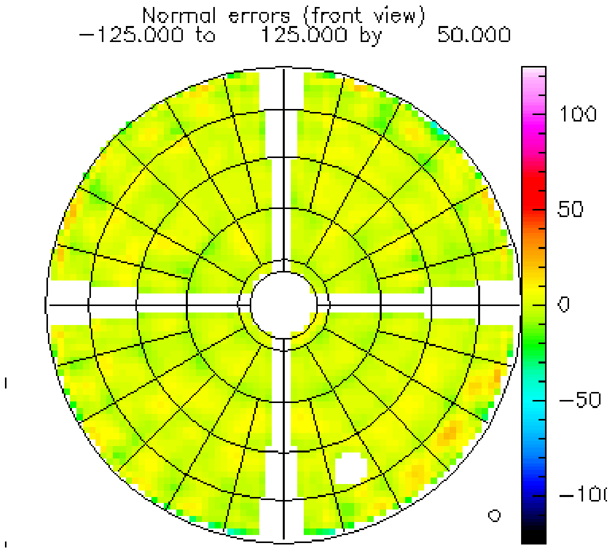

Figure 1: Surface error map of the ACA 7-m obtained with the NAOJ holography. The surface accuracy is 4.4 μm rms. The error scale in μm is denoted by a color bar and lines are boundary of the panels. Quadripod leg shadow and a hole for an optical pointing telescope are masked.

5. References

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