ALMA Prototype Antennas Testing and Production Antennas Contract Timeline
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Several Interconnected Tasks

2004/01/01-2005/07/01: *Production antenna procurement process*. This process entailed two separate groups, one organized by AUI (led by Pat Donahoe) and a second by ESO (led by Ian Corbett), which independently pursued contract negotiations with their preferred vendor. The preferred vendors where VertexRSI for AUI and "not VertexRSI" for ESO. This all culminated on 2005/07/01 with the following announcement from Fred Lo: *"The ALMA Board concurs with the ALMA Director's recommendation that the North American Executive proceed with the issuance of a contract to procure its share of the ALMA antennas. The Board Recognizes that authority to execute a contract is subject to NSF approval."* In fact, NSF had given approval to proceed with negotiating a contract to procure ALMA antennas the previous week.

2004/05/28: *Executive Summary of the results from the prototype antennas evaluation submitted by AEG.* This "summary", which was in fact 57 pages in length, provided summary information on the performance of both prototype antennas. The NA side of the project was in general satisfied with these results and the conclusions regarding the performance of both prototype antennas. The ESO side of the project was not, due largely to some long-standing concerns about the VertexRSI design (specifically, the segmented BUS structure and its potential impact on surface performance). It was also true, though ESO was not willing to admit it, that as the AEC prototype antenna was not released to the AEG for testing until January 2004 (though even at this time the antenna was not fully functional), the AEG's ability to fully test this prototype was severely time-constrained (the VertexRSI prototype was available for limited testing in March 2003). Massimo Tarenghi, ALMA Director at the time, insisted that the evaluation testing continue. This precipitated a series of measurements, including photogrammetry on the VertexRSI antenna (by both NRAO and VertexRSI), near-field holography, out-of-focus holography, radiometric beam-cut, and optical pointing measurements on both antennas.

2004/09/29-10/01: *Photogrammetry of VertexRSI prototype by VertexRSI [see ALMA-Anisotropic-Comparison-05-11-04.pdf]*. I don't know exactly why VertexRSI agreed to do these measurements, except perhaps due to the AEG statement in Section 4.7 (Focus Evaluation Conclusions) of their Executive Summary, which said: "The difference between the FEM and the measurements of the VertexRSI antenna suggests that the BUS is slightly less stiff and the quadripod more stiff than that predicted by FEM." Since ESO had concerns about the VertexRSI BUS design, I believe that this motivated VertexRSI to check their photogrammetry (they originally set the VertexRSI antenna surface with photogrammetry in November 2002). Both the November 2002 and October 2004 photogrammetry showed significant divergence from FEM prediction, which prompted VertexRSI to check the mounting of their BUS. This uncovered a number of loose/incorrectly torqued BUS connection bolts. No surface resetting was done after bolt tightening.

2004/12/01: *Final reports and documentation describing the results from the prototype antennas evaluation submitted by AEG*. Note that this reported only the results based on measurements made by the AEG until May 2004 and did not include measurements or analyses done since that time.

2004/12/17-2005/02/11: *Holography measurements of both prototype antennas [see "ATF Holography Winter 2004/2005", file name "Holography-ATF-Winter04.pdf"]*. On the VertexRSI prototype, two rounds of surface measurement and setting were made. The first round of measurement and setting where designed to remove the deformations introduced by the BUS segment bolt tightening error. This first surface adjustment was made on 2004/12/28. While we were making these holography measurements, the holography measurement reference plane inconsistency, where the holography measurements were incorrectly referenced to the antenna rotation (Az/El intersection) axis rather than the aperture midplane. The details regarding how this error was discovered are described in Section 4 of the "ATF Holography Winter 2004/2005" report. Uncovered this correspondence in a series of emails between Robert, Jaap, and myself dated January 11 through 19, 2005 (in my ALMA/Holography email folder). This resulted in the so-called "donut", or spherical aberration, residual deformation pattern on both prototype antennas. Lucas discovered the corrected this error in his analysis software on 2005/01/18. Subsequent holography measurements were used to adjust the surface again on 2005/02/04 to remove the nearfield referencing spherical aberration.

2005/01-02: *Photogrammetry of both VertexRSI and AEC antennas [see "Preliminary Results from Photogrammetry, Jan 2005", file name "Preliminary Results from Photogrammetry.pdf"]*. Note the coincidence of these photogrammetry measurements (VertexRSI antenna done 2005/01/17-18) and Lucas' realization that the holography reference plane was wrong (2005/01/18). The photogrammetry did measure the donut pattern, but I am not aware of Lucas having known about that measurement. Richard Hills tried to measure focus changes from these photogrammetry measurements, but I don't believe that anything definitive came from this analysis.

2005/01-03: *OOF and Beam Cut measurements on both prototype antennas*. Other than a confirmation of what we learned from the preceding holography measurements, I don't recall anything else substantial coming from these measurements.

2005/07/01: *ALMA North American given the go-ahead to sign a contract for its share of the ALMA production antennas*. See above. This resulted in a contract signed for up to 32 antennas from VertexRSI.

2005/07/11: *On behalf of the ALMA North American Executive, Fred Lo signs a contract with VertexRSI to procure up to 32 ALMA antennas.*

2006/11: *Holography system integration and testing at the ATF [see "A possible change in the surface of the Vertex antenna prototype", file name "Holography-Preliminary-Report-*

Dec2006.pdf"]. This was done in preparation for using the tower holography system at the ALMA OSF for VertexRSI production antenna acceptance. Darrel Emerson, Robert Laing, Robert Lucas, Baltasar Vila Vilaro, and myself were responsible for doing this system integration and testing. Quite by accident, though, we discovered that the VertexRSI prototype antenna had developed an astigmatic pattern to its surface since the surface had been last set in January 2005 (see above). The precipitated an engineering survey done by the NA Antenna IPT, led by Jeff Zivick, which found that the upper feed leg had become detatched from the apex cylinder (failed glue joint). See 2007/02/26 item for details.

2006/12/03-04: *Photogrammetry of VertexRSI and AEC prototype antennas [see "ATF Photogrammetry December 2006", file name "Photogrammetry-Nov2006.pdf"]*. Done, I believe, as a precautionary check of the holography measurements done around the same time. This uncovered, though, some significant deformations in the AEC prototype antenna which seemed to have appeared since the antenna surface was last reset in January 2005. We refrained from trying to analyze this new deformation of the AEC antenna and simply provided the information to ESO.

2006/12/27: Darrel Emerson reforms the ALMA North American Technical Advisory Committee (ANATAC) to "investigate, independently of Vertex, possible causes for the apparent deformation in the Vertex antenna that seems to have happened over the last 9 months." The "apparent deformation", which was in fact an astigmatic structure, was discovered through tower holography measurements made in November 2006 (see above). Investigation uncovered damage to the upper-feedleg connection to the apex cylinder that was identified as the culprit (ANTD-32.01.04.01-001-A-REP dated 2007/03/05). The epoxy bond between the INVAR insert bolting flange and the outer shell CFRP tube had failed. See next timeline item.

2007/02/26: *Engineering study of VertexRSI antenna by NA Antenna IPT [see "Vertex Prototype ALMA Antenna: Astigmatism Engineering Survey and Analysis", file name "070305_Technical Note – Antenna Astigmatism and Quadrapod Damage.pdf"]*. The study found "damage to the attachment point where the inner chord of the upper, vertical Quadrapod leg joins to the central Apex cylinder was identified. The epoxy bond between the INVAR Insert bolting flange and the outer shell CFRP tube failed. This was clearly seen as a gap between the two elements of approximately 1mm. Subsequent engineering analyses by the NRAO AIPT using the Prototype ANSYS FEA Model confirmed the 1mm gap at this joint would cause the observed astigmatism in the primary reflector surface."

2008/07: *Surface accuracy acceptance measurements of the first VertexRSI prototype antenna at the ALMA OSF using tower holography measurements are made*. I am not aware of any further measurements made of the ALMA prototype antennas.