ALMA Memo 563

Suggestions for SMA Connector Use on ALMA

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13 November 2006

Introduction

With over 600 receiver cartridges, ALMA will have several thousand SMA connectors, many of which will be subjected to periodic cryogenic cooling. At present, ALMA has no specifications on the proper torquing of SMA connectors nor on whether any type of staking should be used. This note summarizes the experience of a number of engineers involved with receiver construction for radio astronomy and satellite instruments, and suggests SMA connector tightening procedures for ALMA.

There are differing reports on the reliability of SMA connectors in radio astronomy receivers. At the NRAO NTC, the only instances of SMA connectors being found loose after thermal cycling or shake testing have occurred when it was possible that the connector had not been properly tightened initially [1]. The same is reported from the CSIRO ATNF [2] which also has long experience with cryogenic receivers. However, at both organizations, SMA connectors are routinely torqued to the recommended torque, "plus a bit", the extra "bit", which is deemed important to long term reliability, being at the discretion of the assembler. This is not sufficiently well defined for use as an ALMA standard procedure.

The recent shake tests of the ALMA (room-temperature) cartridge LO assembly produced no loose SMA connectors [3]. They had been torqued to 8 lb-in (88 N-cm). But experience at NRAO Green Bank is that SMA connectors in dewars *are* liable to work loose, and they now stake those connectors with an epoxy stripe [4][5]. They find that even staking does not guaranty that the connector will not loosen.

The U. Mass QUARRY and SEQUOIA receivers each have ~30 cooled SMA connectors, none of which have loosened in many years of operation [6]. They do not use a torque wrench!

A failure mode, which has occurred, particularly with 0.085" stainless steel cables, is a fracture of the solder joint between cable jacket and connector body. This can be exacerbated by having an insufficient expansion loop in the stainless steel cable, and also by allowing the connector body to twist while tightening the nut – which can be prevented by using a second wrench on the back of the connector to prevent rotation of the body. The ALMA Band 9 receiver group at SRON [7] are using SMA connectors with a hexagonal section at the rear [8] which facilitates the use of an anti-torquing wrench while tightening the connector. A factor with stainless steel cables is the difficulty of making a good solder joint which extends over the intended length of cable and connector. For this reason, it may be preferable to use welded or crimped SMA connectors on stainless steel cables. Such assemblies are available commercially.

ESA procedure for SMA connectors

Jaap Evers [9] writes: "In HIFI the mate/demate requirements for SMA connectors is distributed over a couple of general procedures and manufacturing travelers. The ESA specification for the torque level is 80-120Ncm. HIFI uses 100Ncm. .... We use counter wrenches or clamps to avoid rotation of the semi rigid cable because when the cable nut of connector is fixed. Without doing so the cable has a residual torque which could result in either an unintentional loosening or in breakage of solder joints in the connector. To avoid unintentional loosening of the nut by people and during launch (vibration) HIFI locks the cable nut with the chassis body, on the outside, with epoxy Scotch-Weld EC-2216 B/A. Only one drop (3-6 mm diameter) is used as this assures that the epoxy is not cracked when cooled to cryogenic temperatures. This epoxy has a long standing, good, history for use in cryogenic space instruments. Only the outgassing property T(otal) M(ass) L(oss) is a little bit more than the 1% required for most space projects. In all projects we got a waiver for that. Another advantage of this epoxy that it can be removed quite easily when an unexpected demate has to be made. Applying epoxies on the thread of the connectors is not recommended as demating after that can hardly be done than without damaging both the chassis and cable connector..." Scotch-Weld EC-2216 B/A comes in three viscosity formulations, distinguishable by color. Evers told me they use the medium viscosity formulation specified as "Scotch-Weld EC-2216 B/A Gray".

NASA procedure for SMA connectors

Ed Wollack [10] writes: "For cryogenic applications ...the standard 8 in-lb torque is employed with a torque stripe to increase drag and to allow one to tell if the connector has been compromised... The torque stripe material consists of Epon 828/ Versimid 140/ Ti02 Titanium Dioxide/ Cab-O-Sil, 5:5:5:1 mix ratio. The binder would be the Epon/Versimid which is an epoxy. The Ti02 is used for pigmentation and the Cab-O-Sil is a thickener. This the typical torque stripe material that is used for flight applications... although some projects use a polyurethane that does not give a very good indicator when the torque is broke and generates excessive debris if it is necessary to remove. This material can be obtained from Appli-tec (Formula 0430, www.appli-tec.com) in a premixed 5cc manual syringes / frozen (-70C) formulation. When the material arrives an incoming inspection (hardness test) is preformed for the lot and document on a receiving inspection WOA and confirm the contents on the certificate of compliance from the manufacturer. After passing the incoming inspection the material is given a control number and ready for flight use. It is applied as a single bead ~1mm in width in a line centered on the SMA connection across the exterior of the connector in a line ~3-4mm in length."

Torque considerations

Although most engineers torque SMA connectors to 8 in-lb (88 N-cm), some connector manufacturers specify different torques depending the material of the connector body [11]. Amphenol, however, specifies the same torque for both brass and stainless steel connectors [12][13]:

Minimum: 2 inch pounds (22 N.cm)
Recommended: 7-10 inch pounds (80-110 N.cm)
Maximum: 15 inch pounds (170 N.cm)

Galen Watts [14] writes: "...I use a procedure where I bring the SMA to full torque (wrench click), wait a couple seconds, full torque again, wait a couple seconds, full torque a third time, all while counter torquing with a plain wrench when possible or pressing lightly on rigid/semi rigid coaxial cable counter to the torquing direction when applicable. Following this procedure I have not yet seen loose SMA connectors in cryogenic applications after multiple temperature cycles..." He notes that *"...the SMA shell will frequently turn a little farther on the second and often the third application of the same torque."*

Striping, staking, or gluing

Striping an SMA connector with a thin axial bead of adhesive has two possible functions: (i) the adhesive helps to prevent the nut from loosening, and (ii) if the nut does loosen, the broken glue line may provide a visible indication of the failure.

The fact that NASA and ESA both require epoxy striping of SMA connectors suggests there is at least a potential reliability problem in space applications.

Recent experience at NRAO/GB with striping SMA connectors was less than satisfactory: "...Armstrong A-12 seemed to work about as well as the Scotch-Weld 2216 to stake connectors, and we felt a little more comfortable using it inside cryostats because of previous experience. Neither stuck very well to the connectors particularly the cylindrical part of the nut. We had cases where the nut rotated, breaking the epoxy joint underneath the bead, but leaving the bead intact so that it was not obvious the nut was loose..." [15]

In a brief experiment conducted at the NRAO/NTC [16], the ESA striping procedure (above) was used on connector pairs which had been torqued to 8 in-lb. A typical striped connector pair is shown in the photograph. Scotch-Weld EC-2216 B/A Gray was applied after cleaning the connector assembly with hexane, acetone, and alcohol. As can be seen, the adhesive forms too thin a layer over edges to give a clear indication of whether a fracture has occurred. After a two-week cure at room temperature, the torques needed to undo three similarly striped assemblies were between 4.0 and 7.5 in-lb, compared with 5.3-6.6 in-lb for similar unstriped assemblies — not a clear improvement. Cleaning the connectors for re-use was difficult because of the adhesive which had run into the inaccessible region between the connector body and the (non-removable) nut.

Applying an adhesive to the threads of an SMA connector, as opposed to striping, is considered undesirable for the following reasons: (i) During connector engagement, the adhesive can be

squeezed onto the electrical contacts, rendering them intermittent. (ii) Adhesive on the thread changes the coefficient of friction and therefore, probably, the necessary tightening torque. Some adhesive, particularly "thread-lockers," have significant "drag", thereby significantly increasing the torque which needs to be applied to the connector. (iii) If reassembly is required, removing the residual adhesive is difficult, especially from the inaccessible region between the nut and the connector body. Solid remnants of the old adhesive can degrade contact reliability.

Suggestions for ALMA

(i) The connector should be tightened to a torque of 8 in-lb (88 N-cm) unless otherwise specified by the manufacturer.
(ii) The torque wrench should be applied three times in succession.
(iii) A second wrench should be used where appropriate to prevent rotation of the body of the connector. This is facilitated by the use of male SMA connectors with a hexagonal section behind the nut and female SMA connectors with a hexagonal section behind the thread [8].
(iv) Striping or gluing SMA connectors should not be done unless it becomes clear during early ALMA operation that it is necessary.

References

[1] Neil Horner, NRAO/NTC — private communication, June 2006.

[2] Russell Bolton, CSIRO — private communication, June 2006.

[3] Jim Muehlberg, NRAO/NTC — private communication, June 2006.

[4] Roger Norrod, NRAO/GB — private communication, June 2006.

[5] Gary Anderson, NRAO/GB — private communication, June 2006.

[6] Neal Erickson, U. Mass — private communication, June 2006.

[7] Andrey Baryshev, Brian Jackson, Ronald Hesper — private communication, July 2006.

[8] Tensolite makes SMA connectors with a hexagonal rear section which facilitates use of an anti-torque wrench while tightening – *e.g.* models 5285-0-4, 5319-0-1, 5286-1, 5286-2. See http://www.tensolite.com/product_documents/RF_MicroCatalog%20LoRz.pdf

[9] Jaap Evers, SRON — private communication, June 2006.

[10] Ed Wollack, NASA/GSFC — private communication, June 2006.

[11] Chip Scott, NRAO/GB — private communication, June 2006. See, *e.g.*, http://www.hubersuhner.com/products/hs-p-rf.

[12] Galen Watts, NRAO/GB — private communication, June 2006.

[13] http://www.amphenolrf.com/products/sma.asp.

[14] Galen Watts, NRAO/GB — private communication, June 2006.

[15] Roger Norrod, NRAO/GB — private communication, June 2006.

[16] Mike Lambeth, NRAO/NTC — Memo. SMA Connector Torque Measurements, Aug. 2006.