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Brief history

ATA funded by Paul Allen (and others, including the US Navy) to build a 350-dish array -- 6.1m diameter with 20:1 feeds, yielding large field of view, and wide-band frequency coverage. Dotcom bust, and other funding constraints meant that the ATA reached 42 dishes, with mark1 wideband feeds (cooled LNA, uncooled feed arms). Was being used for SETI and other science, when California funding crisis caused UCB to pull out of HCRO all together, “giving” the site ownership to SRI.

SRI have maintained the site ever since -- ATA42 has been operating as collaboration between SI and SRI.

N years ago, Antonio feeds were funded -- aimed for improved sensitivity, with cryogenics and reduced but still large(!) ~10:1 band. Not all ATA42 dishes have these fields -- the hope is that reliability of these feeds can be improved, such that it becomes feasible to retrofit all dishes.

Over the last ~6 months of review, some failure modes have been identified -- some fatigue-related, others due to catastrophic failure modes.

Mark 1 Feed

LPDA -- uncooled feed arms, operating from 500MHz to 10GHz. Tip is larger than Antonio feed. Mk1 feed includes cryo for LNA, inside the pyramid centre (similarly to current design). Cooling is ion-pump based, can cause problems when recovering from power outages or outgassing -- cooling capacity is very low. Early concerns about dewar inside feed losing vacuum.

Downstream analog electronics (PAM / fiber drivers) go to ~12 GHz, LNAs go to ~14GHz.

Antonio Feed

In order to improve the high-end of the band, cooling was added to the feed arms.The feed was shortened by droping the 500-1GHz band, allowing the entire feed to be placed under vacuum. Copper pyramid + arms are cooled to 70K - expecting Noise temperatures 25-65K from 2-12GHz.

Challenges:

* Heat load
* Thermal gradients along arms/pyramids which cause physical displacement
* Cooler vibration / tip damage
* RF design of tip
* Glass chamber inducing reflections.

Key design features -- see MF’s presentation

Can use power draw of turbo pump as a proxy for vacuum performance. This is used as a cheaper alternative to installing a pressure sensor / gauge.

Rexolite standoffs hold feed arms above inner pyramid. Physical tip dimensions are sized for 18GHz radiation. Polyethylene cap at top of feed is an antireflection mechanism, and improves performance in top half of band.

Main thermal load comes from radiation load on to cold surfaces. On hot days the thermal load can lift the temperature of the LNAs. In winter cooler runs at 190W, in summer they often run full power at 240W

LNAs -- output is SMA. Input is not connectorized, owing to lack of availability of parts at size / impedance required.

1st generation tip connector was wire + discrete L/C. Difficult to assemble. Didn’t survive vibration

2nd gen had custom PCB to implement L/C with tuned areas / thicknesses. Copper traces fatigued too easily.

3rd gen -- added link elements made out of BeCu chemically milled to shape and soldered in place.

* During cooldown there are significant displacements -- pyramid growth 0.086”. Max relative arm/pyramid motion 0.010”
* Measured tip vibations using laser vibrometer on both shake-table and under cryo-pumping.

Cooler induces axial motion. Cooler is mounted on a tuned spring mount. Added bellows at front, and flexible rear support to isolate cooler from feed. This passive dampening system reduces vibration by a factor of 5-6. This was deemed adequate to prevent fatigue-induced failure.

Some failures still occur but may be:

* Failure / misconfiguration of dampener
* Failure of vacuum causing cooler overdrive

BeCu used at tip is half-hard or better [ED: I don’t know what this means]. MF wanted full hard but went with what was available.

Recently tested manufacturer’s active dampener. In most cases this was better than the passive systems, \*but\* one presumably perfectly balanced passive dampener was better than active. Based on measurements at the base plate (part of housing where pyramid is mounted).

For a “bad” passive balancer, strong vibrations at 120Hz -- worse in lateral dimensions than axial.

Active dampener better than (most) passive dampener especially in lateral directions. These aren’t controlled by the active electronics so presumably (MF) is due to better springs / mechanics.

Conclusion:

Most units in the field could be improved with the active balancer. But learning from the mechanics from the active mechanics could help improve the passive configurations.

Vibration approximately independent of heat load (cooler power draw)

Historical failure modes

* 24V failure causes vacuum / controller failure. Cooling can runaway, cause ice and crack belows - causing severe vibration.
  + This has been mitigated using a software shutdown in the case of 24V failure.

Possible improvements

* Physically restrain the tip to prevent vibrations. Requires careful attention to RF performance implications. Also care needed to make sure thermal expansion doesn’t degrade connection of outer coax conductor. One proposal is a teflon “hat”.
* Could make tip components physically larger and more robust. Would need to investigate RF tradeoff.
* Size of components can be scaled with top frequency of feed. Current top-end of feeds set by a) SETI’s desire for covering microwave window b) interaction with the Air Force suggesting interest at Ka band. Relaxing high-freq requirement could ease design.
* Custom feed control board includes accelerometer. But position of sensor on the controller board is not representative of feed motion. Experimenting with moving this sensor to base plate(?). Could use this data a) to inform a study into improving passive dampener b) detect feeds with high vibration and shut them down prior to failure.
* The smaller the flex-link elements the longer they last. Smaller might be possible

Elaborate fixes:

* 3D print entirety tip with metal and dielectric parts. But would require redesign of thermal system.
* Fuzz-button connection. Haven’t yet come up with a way to engineer this into the design.

Suggestions from call

* GD: add 90 degree rotation in flex-link so that it is sprung in two dimensions.
* What if flex-link was not soldered to feed tip, but was a sprung friction connection? Could be viable mechanically \_if\_ electrical performance is adequate. Various mechanical configurations for this connection. Slots / shelves in feed arm tip; split flex-link around arm; pogo-pin style connection; fuzz-button; etc.
* Change resonance of feed structure so as to reduce coupling to cooler vibrational modes. Could load the feed with mass (not necessarily near the tip, therefore, easier).

Q/A

* When telescope slews are there other loads on the feeds? Support of feed arms by rexolite should support during motion.
* Is vibration different for different pump orientations? Not much different noticed
* How much does vibration affect (modulate) RF signal? Hasn’t been measured. Relevant for narrowband SETI performance. Could test in a lab.
* Is there a broader correlation between feed RF performance and accelerometer data.
* Is RF data available while feed is operating on shake table? Not currently (and feed is uncooled when on shaker)
* Would opening up a working feed provide useful data to learn why these feeds haven’t failed? Could be done -- JR’s software update will allow monitoring of vibration. May show correlation between survival & motion. Could find an accelerometer than runs fast enough to do useful FFT.