The GBT K-Band Focal Plane Array Receiver

Mechanical design summary for the Critical Design Review, January 2009.

I. Introduction:

The requirement of a close-packed seven feed receiver necessitated several new approaches to traditional dewar design. The GBT turret is currently overweight, so designing with an eye toward keeping things small, integrated, and lightweight is helpful. Minimizing dewar component weight speeds the cool down time, which helps given the limited time available for GBT receiver room access. Wherever possible, penetrations into and out of the cryostat were minimized or eliminated. We have balanced good thermal isolation between 300K and the cold stages with minimized transmission line length. This helps to minimize gain instabilities.

II. Pattern of individual elements in the array:

Several geometries were considered for the arrangement of the feeds used in the array. It has been determined that a close packed hexagonal array was best. See "Feed Pattern topic" found at: https://safe.nrao.edu/wiki/bin/view/Kbandfpa/SciPlanning. The feedhorn has an aperture diameter of 3.40", so the goal from a mechanical standpoint was to fit all the EM components within the dewar behind the "shadow" of the feed. This makes the hexagon pattern of the array as compact as possible.

Individual feed horns are easily removed if needed. A pressurized Gore-Tex radome will cover all 7 feeds.

III. Top and bottom dewar plates:

Unlike most other GBT receivers, the dewar top plate on the KFPA also serves as the turret mounting plate. This is done to reduce overall weight of the receiver. Currently the GBT turret is loaded with approximately 6000lbs of receivers; double the 3000 lb original specification for maximum turret equipment weight.

The large area needed for the 7 feedhorns requires strength members to be formed into the top and bottom plates. Any flexing of the plates due to vacuum pressure will in-turn stress the EM components in the dewar. We typically use aluminum alloy 6061-T6 for dewar construction. The KFPA rx will use Alcoa MIC6 cast alloy. Unlike 6061-T6, it is extremely stable during machining. This alloy has been successfully used for EVLA cryostats.

To reduce the number of penetrations which require o-ring seals (potential vacuum leaks) into the dewar vessel, we have integrated the vacuum windows into the top and bottom plates. This also helps to reduce overall weight and number of bolted connections.

IV. Dewar components:

Vacuum windows are Ecco-Foam PS102. Kapton is used over the foam plug to provide a vapor seal. It has been tested over 18-28Ghz and exhibits good insertion and return loss.

The circular waveguide components use tight-tolerance male/female boss's to hold alignment. The circular waveguide input transition is a compact unit that's been optimized for weight, strength, and performance.

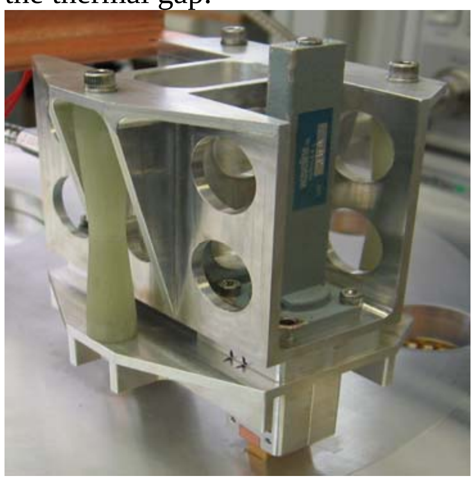
Calculations show that the dewar components "shrink" in length by about 0.150" when cooled to 15K. The complete input stack of EM parts is bolted to the dewar top plate. This doesn't allow any flexing as the receiver is cooled. Several methods were considered for getting the amplifier RF signal out of the dewar, while at the same time accommodating the thermal expansion/contraction.

Methods considered:

1. Stainless coax: By its nature coax can flex if it has a loop in it, while also providing thermal isolation, and several GBT receivers use this technique to deal with the thermal flexing. The cryogenic amplifiers are supplied with WR-42 waveguide in/out, and the downconverter use a wg input. Using coax to connect the cryo amps to the downconverters would require several coax to waveguide transitions. Reliability with so many components/connectors is a concern. The length needed to get proper thermal isolation is about 18" each, so cable management is difficult.
2. Flexible WR42 waveguide: Like coax, corregated flexible waveguide requires a loop to provide flexing and long length to provide thermal isolation. With both coax and flexible waveguide, gain stability is a concern.
3. Long stainless steel waveguide bent in an "S" form: Pictured is a prototype we fabricated. Calculations show that about 18" of stainless wg is needed to provide thermal isolation. The shape was selected to provide thermal flexing while at the same time fitting into the feed shadow. The translation from copper to stainless was needed because stainless wg is extremely difficult to bend into shapes. Special jigs are required to make the 14 identical assemblies needed. Care is needed to solder the stainless to copper. Unfortunately, the orientation of the bends with respect to the waveguide flanges doesn't allow for easy flexing, and we were concerned with long-term reliability.

4. Integrated sliding waveguide thermal transition: Shown is the assembly used in the 1 pixel test receiver during lab tests. Each unit provides thermal isolation and flexing for the two polarizations from a single pixel. Waveguide from the cyro amps output is connected to the top. The top portion is cooled to 50K, the bottom part remains at

300K. A short section of stainless WR-42 waveguide is connected between the cryo amps and the top of the transition to provide thermal isolation between 15K and 50K. G10 rods are used to separate the 50K from 300K, the gap being 0.010”. The lower half contains the sliding WR-42 waveguide. This includes a short section of waveguide bonded into the dewar bottom plate. This slides into a slightly oversized waveguide cavity. The RF seal uses two pieces of conductive elastomer. The cavity slides over the elastomer during thermal flexing. Considerable testing was done on this unit, and it displays good S21 and S11 performance. We also checked cross coupling between the two waveguide ports and found isolation to be excellent. Careful measurements confirmed that no significant energy is radiated out of the thermal gap.



V. Thermal issues:

Past experience with other GBT receivers has shown that if care is taken to reduce the thermal loading on any refrigerator, the result is a longer run time between refrigerator maintenance.

We will be using the CTI model 350 refrigerator. Green Bank has extensive experience with this refrigerator, and it typically provides 12-15 months between maintenance. We have calculated the refrigerator loads expected, and the two-stage CTI 350 will provide sufficient cooling capacity.

Many dewar components were specifically optimized for strength, weight, and manufacturability. The OMT is now fabricated out of aluminum. It weighs 1/3 that of brass which has been used in the past. Thermal transitions are also aluminum. The lower mass helps to reduce cool down and warm-up time. With limited access time to the GBT receiver room, quick cool downs are valuable for refrigerator maintenance.

Wherever possible, all dewar components are gold plated. This includes the EM components, waveguide, and radiation shields. Polished gold lowers the emissivity, thereby lowering the thermal loading on the refrigerator. The stainless steel dewar cylinder will be electro-polished, which passivates the surface and lowers the emissivity.