Notes on the Mixer-Preamp to Cartridge Interface for Band 6 — 211-275 GHz

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Each polarization channel of the band 6 receivers will consist of a balanced sideband-separating mixer (BSSM) with integral IF preamps. Each BSSM contains four elemental SIS mixers and is attached to two IF preamps whose outputs are combined in an IF quadrature hybrid to separate the downconverted USB and LSB signals.

Connections to the 4-K stage:

Mixer bias -- 6 wires per mixer x 4 component mixers = 24 wires per channel —> 48 wires per cartridge.
Magnetic bias -- 2 wires per channel —> 4 wires per cartridge.
Mixer temperature monitor -- 2 wires per channel —> 4 wires per cartridge.
Mixer heater (for degaussing) ?? -- 2 wires per channel ?? —> 4 wires per cartridge ??
Preamp bias -- (7 wires + 2 wires for LED's) x 2 preamps = 18 wires per chan —> 36 wires per cartridge.
LO connection to multiplier -- 1 waveguide (overmoded) per channel —> 2 waveguides per cartridge.
Coaxial output connection -- 2 cables per channel (USB and LSB) —> 4 coaxial cables per cartridge.

TOTAL mixer-preamp connections at 4 K: 96 wires + 2 w/g's + 2 coaxial cables per cartridge

Thermal loading: (Note, in the following, the importance of ~15 K heatsinks on conductors terminated at 4 K.)

IR loading -- depends on IR filtering and optics configuration.
Each mixer bias-T will dissipate 0.25 mW max (assuming 1k series protection resistors). There are 4 bias-T's per BSSM —> 1 mW max per BSSM —> 2 mW max per cartridge.
Each IF preamp will dissipate ~9 mW —> ~18 mW per BSSM —> ~36 mW per cartridge.
Temperature sensor, 1.6 V at 10 uA —> 16 μW ber BSSM —> 0.03 mW per cartridge.
Bias wiring -- 96 wires, 36 AWG BeCu, 6" long:
15 K to 4 K —> 0.4 mW per cartridge.
(cf.: 80 K to 4 K —> 14 mW per cartridge).
LO waveguide -- WR-10 (overmoded) 304 SS, 0.010" wall, 2" long, plated inside 50 μ-in Cu:
15 K - 4 K —> ~ 0.7 mW per waveguide —> ~ 1.4 mW per cartridge.
(cf.: 80 K- 4 K —> ~ 28 mW per waveguide —> ~ 56 mW per cartridge.)
IF coaxial cable -- 0.085" coax with SS outer/SS inner/PTFE, 3" long:
15 K - 4 K —> 0.23 mW per cable —> 0.9 mW per cartridge.
(cf.: 80 K - 4 K —> 9 mW per cable —> 36 mW per cartridge.)

TOTAL 4 K heat loading = (IR loading + 41 mW per cartridge) assuming conductor dimensions as above and heatsinking of all conductors at 15 K.

4-K Hardware:

IF quadrature hybrid (one for each BSSM): The CDL is evaluating a commercial 4-12 GHz quadrature hybrid for 4 K operation.

Connectors:

Multi-pin: The CDL is using Nanonics Dualobe connectors [3] for mixer-preamp development. These have 25-mil pin spacing and are available in a variety of styles, *e.g.*, surface mount, through-hole mount, and pre-wired with any desired type of wire. They are approved by NASA for space applications.

Coaxial: Wiltron type-K female connectors will be used at the output of the IF preamplifiers. (K–connectors are compatble with SMA connectors.)

Waveguide flanges: Waveguide flanges should be of the flat or anti-cocking type, compatible with the MIL spec UG-387 type of flange but with improved dimensional precision, as recommended in ALMA Memo 278 [4]. It is not clear yet whether the feed horn for band 6 will be fabricated as an integral part of the mixer block or as a separate component with a waveguide flange. The LO input to the mixer block will be by waveguide, probably overmoded waveguide to reduce the loss between the final LO multiplier and the mixer.

4-K RFI filters: See section on RFI filters. Probably not required for the band-6 ALMA cartridge.

Heat strap connections: According to Rose-Innes: "...heat transfer between gold surfaces is about 20 times better than between copper surfaces...," which is in approximate agreement with our measurements of the thermal resistance of various bolted joints at 4 K (EDTN 163 [1] and addendum [2]). Gold plated copper should therefore be used for thermal connections. Indium gaskets are not necessary.

Rose-Innes also states that the thermal conductance of a bolted joint in a vacuum is proportional to the contact force but independent of the area. The current developmental design for the BSSM/preamp has provision for attachment of two heat straps, one to each preamplifier body, each with up to 10 #2-56 screws in an area approximately 0.4" x 0.6".

Heatsinks -- All conductors need to be well heatsunk to ~15 K before connection to the 4 K stage.

Multi-wire cables: The CDL is experimenting with two types of heatsink for multiconductor cables: one uses a PC board mounted on an anodized aluminum plate with thermally conductive epoxy, and the other uses a thin kapton pc board with its copper groundplane soldered to the heatsink.

Coaxial cables: Current NRAO practice is to use cables with SS or beryllium copper outer conductors, solid PTFE dielectric, and a center conductor of SS, beryllium copper, or SPCW (silver-plated copperweld). From a thermal point of view, a small-diameter all-SS cable is best. Heatsinks are attached only to the outer conductor -- it is assumed that radial thermal conduction through the PTFE dielectric is sufficient to cool the center conductor. It is possible that the IF hybrids will provide an effective 4 K heatsink for the two coaxial coaxial cables to the IF amplifiers on the 15 K stage.

Waveguide: LO waveguides from 15 K should not require heat sinking to 4 K before the mixers. (LO waveguides from 80 K may require 4 K heatsinks.)

RFI filters: Most NRAO SIS receivers have low-pass RFI filters on all wires entering the dewar and also a low-pass filter at 4 K in the mixer bias leads.

Room-temperature RFI filters: Electrical interference coupled into the bias circuits of SIS receivers is often troublesome, and it has been found that interference levels in telescope receiver cabins can be worse than in the laboratory. To ensure that RFI is not coupled into the mixer or IF amplifier bias wiring *inside* the dewar, the ALMA receiver dewars and cartridges should be well shielded against electrical interference, and *all* connections entering the dewar or cartridge should do so through low-pass RFI filters, even leads to temperature sensors, heaters, solenoids, *etc*... The RFI filters should be mounted in a metal wall which completely separates the electrically quiet and noisy regions, as in the RFI filter pods used on the 12-m telescope receivers. The filters used in the CDL test receivers are:
SIS bias: Spectrum Control 9001-100-1010 (0.375" dia., pi-circuit, nominally 39 dB at 150 kHz).
All other conductors: 0.140" dia. solder-in filters -- model no. ??

4-K RFI filters: The simple bias-T's used in most NRAO SIS receivers do not have very high IF isolation between the DC bias connector and the IF amplifier port. It has been found that thermal noise on the bias wires between room temperature and 4 K can couple enough noise into the IF to add a few degrees to the receiver noise temperature. For this reason, NRAO SIS receivers have a simple 4-K low-pass filter (a capacitor to ground) at the 4-K heat sink in each mixer bias lead. In the new mixer bias circuit for 4-12 GHz being used in the CDL, the bias-port isolation is greater and there should be no need for further 4-K RFI filters.

References:

[1] ftp://ftp.cv.nrao.edu/NRAO-staff/akerr/EDTN163.pdf
[2] ftp://ftp.cv.nrao.edu/NRAO-staff/akerr/EDTN163addendum.pdf.
[3] http://www.nanonics.com/dualobe.html.
[4] http://www.mma.nrao.edu/memos/html-memos/alma278/memo278.pdf