NATIONAL RADIO ASTRONOMY OBSERVATORY

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Specification/Interface Document
GBT K-band Focal Plane Array Receiver

A02920N001 Rev. A

Revision	Date	Author	Comments
---	19Feb08	R. Norrod	Original
A	22Jan09	R. Norrod	Update to missing quantities.

1 Introduction

This document summarizes the technical and interface requirements for the GBT K-band Focal Plane Array (KFPA) receiver front-end. It is intended to help guide and document the development project initiated in response to the proposal ***A Modular K-Band Focal Plane Array for the Green Bank Telescope***, 20 September 2007, archived as document A02920D004. It covers mechanical and electrical interfaces, both external and internal between subsystems.

The KFPA primary role will be as a spectral-line mapping machine. Critical performance criteria are high antenna G/T, efficient mapping, and stable spectral baselines.

2 General Requirements

1. **Frequency Range:** 18-26.5 GHz; goal 17-27.5 GHz with degraded performance.
2. **Instantaneous Bandwidth:** 1.8 GHz minimum.
3. **Number of Pixels:** Seven; expandable up to 61.
4. **Noise Temperature:** 36 K maximum 18-26.5 GHz; 25K maximum over 75% of band; referenced to feedhorn aperture.
5. **Aperture Efficiency:** 55% minimum, any pixel, exclusive of GBT surface efficiency.
6. **Polarization:** Dual circular polarization
7. **Polarization Axial Ratio:** 1 dB maximum.
8. **Polarization Isolation:** 25 dB minimum (within a pixel).
9. **Pixel-Pixel Isolation:** 30 dB minimum; goal 40 dB; any two channels.
10. **Gain:** The IF output total power shall be -25.5 ± 5 dBm when Tsys = 95 K.
11. **Output Flatness:** The IF output power flatness shall be less than 3dB p-p measured over the IF frequency bandwidth, at any tuning within the RF frequency range.
12. **Linearity:** With 300K input source temperature, the total noise power shall be at least 30 dB below the 1dB compression point, measured at any point in the receiver chain. At any Tsys between 25K and 300K, the receiver gain shall not deviate from linear by more than 1%.
13. **Noise Calibration Accuracy:** 5%
14. **Image Rejection:** TBS
15. **Spectral Baseline Stability:** For a 50 MHz bandwidth position switched observation, 2 minute on – 2 minute off periods, and 1 hour integration, the sensitivity shall be better than 1.2 times that predicted by the radiometer equation.

3 Subsystems

Figure 1 shows the KFPA major subsystems and system interfaces.

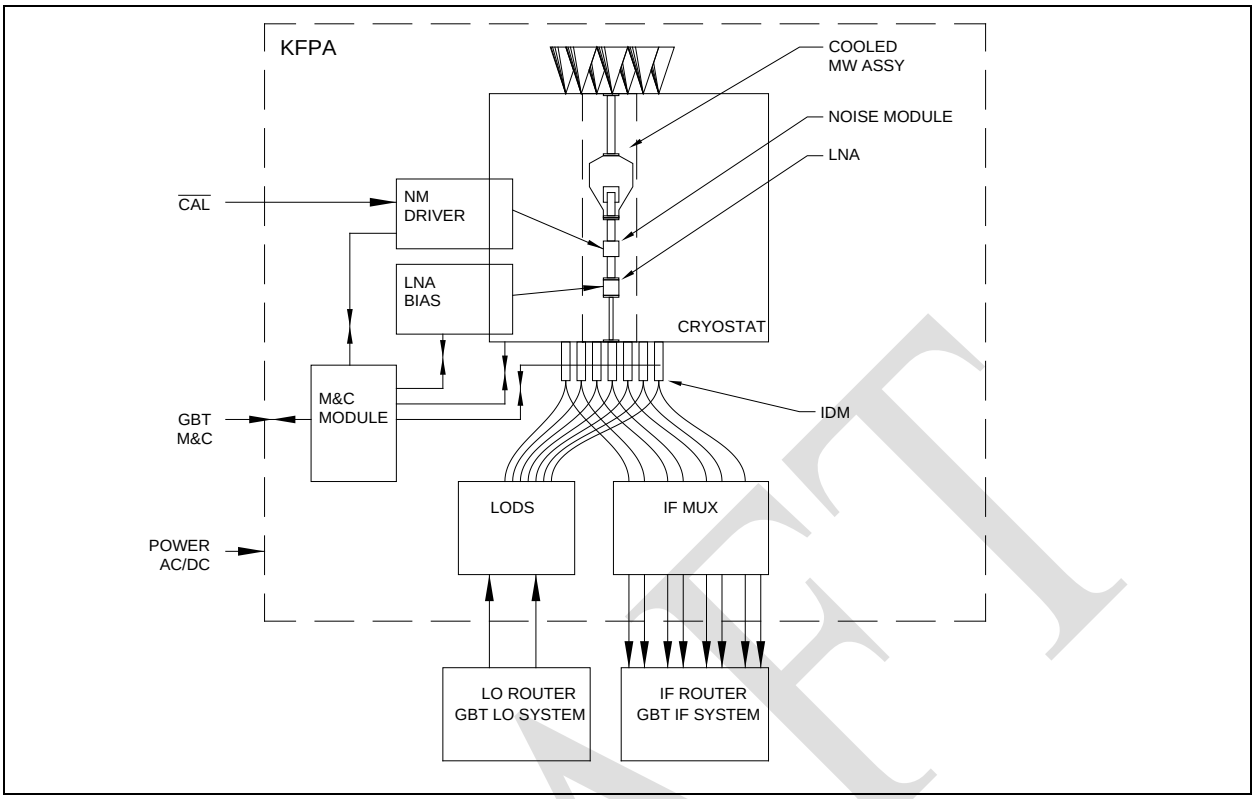

Figure 1: KFPA subsystems and GBT systems interfaces.

3.1 Cryostat

The cryostat is a vacuum vessel with a closed-cycle refrigeration system for the cooled microwave assemblies. It provides hermetic connections required to accomodate in-vacuum active components, the feedhorn array radome, temperature and vacuum sensors, and sensor conditioning circuitry. The Cryostat also provides mechanical attachment to the turret, and mechanical support for other subsystems.

3.2 Cooled Microwave Assembly

For each pixel, the CMA includes the circular polarizer, ortho-mode transducer (OMT), noise module, two low noise amplifiers (LNA) with input isolators, and interconnecting waveguide. Thermal transitions between ambient temperature and the 15K components, and microwave vacuum windows at the feedhorn and IDM interfaces, are also considered part of the CMA. Active components in this assembly are the noise module and the low noise amplifiers.

3.2.1 Noise Module and Driver

The noise module (NM) is a waveguide device that injects a specified level of broadband noise into both polarizations of a pixel. It is situated between the OMT outputs and the LNA isolators. The NM Driver circuitry controls all pixel's noise injection under the direction of the GBT system NOT CAL signal. Interfaces defined are:

1. **RF In/Out:** WR42 waveguide, UG595/U Flange Equivalent
2. **RF Channel Isolation:** 40 dB minimum

3. **Equivalent Injected Noise:** 1.5 – 6 K.
4. **Dissipated Power:** 15 mW maximum to the refrigerator 15K stage.
5. **Response Time:** 100 uS maximum Rise/Fall.
6. **Stability:** ±3% over 4 hours.
7. **Electrical:** Connector ITT Cannon MTB1-5SS. Bias supply shall be a constant gate voltage supply. Typical bias is Vds=0.7V, Vgs=-0.5V, Ids=6mA.
8. **M&C Interface:** The M&C subsystem shall monitor Vds, Vgs, and Ids for each of the seven noise control modules. The M&C subsystem shall have the ability to independently vary, for each of the seven NMs, Vds from 0 to 1.5V and Vgs from -1.0 to 0 V. The M&C subsystem shall provide a BNC jack for External Cal interface to the GBT Receiver Room CAL signals. For Ext Cal = TTL Low, the noise injection shall be ON; set Vds=Vds(ON). For Ext Cal = TTL High, noise injection shall be OFF; set Vds=0V. Vgs shall always remain at nominal value.

3.2.2 Low Noise Amplifiers and Bias Circuitry

The LNA is a four-stage HFET amplifier of NRAO design. An input waveguide isolator will be incorporated with the LNA. Interfaces defined are:

1. **RF In/Out:** WR 42 waveguide, UG595/U Flange Equivalent.
2. **Dissipated Power:** 22 mW maximum to the refrigerator 15K stage.
3. **Electrical:** Voltage, current, connectors TBD
4. **LNA DC Connector:** 15 pin Micro-D
5. **Bias:** Fixed drain voltage, constant drain current by servo of gate voltage. Independent control of each stage.

3.3 Integrated Downconverter Module

The IDM is a dual-channel module which converts both polarizations of a pixel to IF signals. Two types of IDM are required (see discussion under IF Multiplexer): Type I produces 1.2-3.0 GHz IF outputs, and Type II produces 5.9-7.7 GHz IF outputs. The IDM RF inputs connect to Cryostat RF output ports. IDM LO input signals are supplied by the LO Distribution System. Interfaces defined are:

1. **RF In:** WR42 waveguide, UG595/U Flange Equivalent (Qty 2)
2. **RF In Return Loss:** -17 dB
3. **IF Out:** SMA Jack (Qty 2)
4. **IF Out Return Loss:** -17 dB
5. **Channel Isolation:** 40 dB minimum
6. **LO1 In:** 24.8 – 34.3 GHz, Level as specified, 2.92 mm (K-conn) Jack (Qty 1).
7. **LO1 In Return Loss:** -15 dB.
8. **LO2 In:** 8.9 GHz, Level as specified, SMA Jack (Qty 1).
9. **LO2 In Return Loss:** -15 dB.
10. **Electrical:** ±5V, 0.8A max. 9-pin Micro-D connector.

11. **Gain Adjustment:** A remotely controlled level-set attenuator shall be incorporated in each channel to allow compensation for variations in Cryostat gain and input source temperature.

3.4 LO Distribution System

The LODS accepts two independent local oscillator signals from the GBT LO Router and then buffers, splits, and distributes the signals to all IDMs. Because the GBT system LO frequency range is limited to 20 GHz, the LODS incorporates a doubler for the LO1 signal. Interfaces defined are:

1. **LO1/2 In:** 12.4 to 17.2 GHz, -6 dBm, SMA Jack.
2. **LO2 In:** 8.9 GHz, 0 dBm, SMA Jack.
3. **Input Return Loss:** -15 dB.
4. **Outputs:** Frequency ranges and power levels as required by the IDM LO1 and LO2 inputs, powers measured at the IDM connectors. See section 3.3.
5. **Output Return Loss:** -15 dB.
6. **Electrical:** ±5V DC, current TBD, connectors TBD.
7. **Output Channel-Channel Isolation:** 15 dB minimum.

3.5 Monitor and Control Module

The M&C module interfaces with the GBT M&C system, and with the KFPA subsystems requiring control or providing monitor points. Details are documented in A02920N002.

3.6 IF Multiplexer Module

The GBT IF system provides eight 1-8 GHz fiber links between the Receiver Room and the Equipment Room in the Jansky Lab. In order to get all channels of the seven-pixel KFPA to the GBT Spectrometer, frequency-division-multiplexing will be used to place two IF signals on each fiber channel. Four of the seven pixels will use Type I IDMs, and three will use Type II. The IF Multiplexer Module then combines the fourteen IDM IF signals as shown in Figure 2.

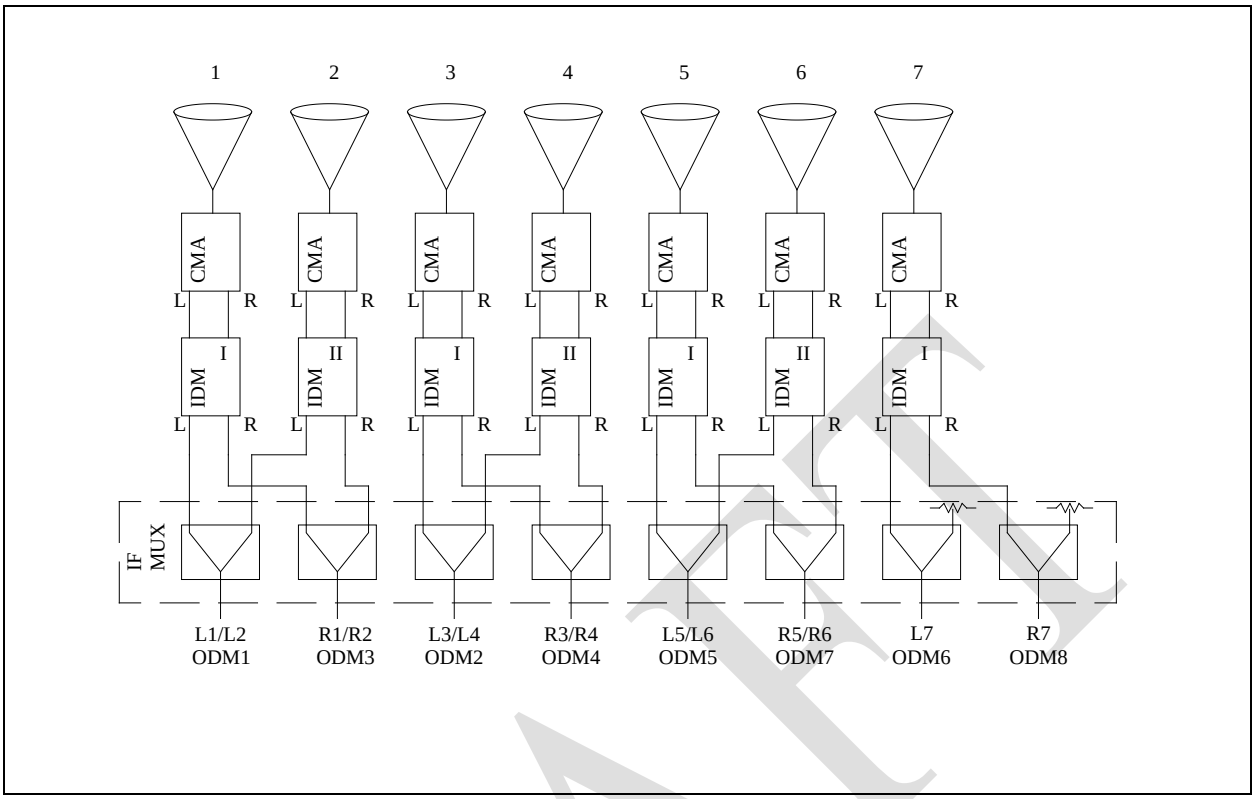

Figure 2: IF Connections to the GBT fiber IF Optical Driver Modules.

Interfaces defined are:

1. **IF Inputs:** 1-8 GHz, SMA Jack (Qty 16).
2. **IF Outputs:** 1-8 GHz, SMA Jack (Qty 8).
3. **Output Channel-Channel Isolation:** 40 dB minimum.
4. **Insertion Loss:** 1dB maximum.
5. **Return Loss In/Out:** -17 dB maximum

4 General External Interfaces

The KFPA must operate, and must be tested, in situ with the existing GBT systems. This section covers mechanical, environmental, cryogenic, and electrical interfaces.

4.1 Mechanical and Environmental

The KFPA will mount on the GBT turret, in any of the 36 inch receiver mounting slots as defined by the relevant NRAO and Comsat/RSI drawings, and confined by other installed equipment. The KFPA mass shall be the minimum possible, and requires approval by the head of the GBT Telescope Operations Division.

The KFPA portion above the turret mounting flange will be subjected to the outside environment including rain, snow, icing, and ambient temperature extremes. The KFPA shall prevent water or air penetration into the Receiver Room. Dry air at a pressure of 1.5 PSI is provided for the

purpose of pressuring feed radomes. In addition, a blower system is incorporated in the turret to blow warmed air over radomes.

The GBT Receiver Room, housing the portion of the KFPA below the turret mounting flange, is specified to maintain temperature stability to ±1.5 F (±0.8 C). In practice, the interior temperature typically exhibits rapid 1-2 C temperature swings as the HVAC system operates. Figure 3 illustrates a typical 24 hour period.

4.2 RFI

The GBT Receiver Room is designed to be a shielded enclosure, and when installed the KFPA shall not degrade the shielding effectiveness of the room. A RFI gasket is required at the receiver/turret mounting interface. The design shielding effectiveness shall be 60 dB, 0.1-10 GHz.

The KFPA will be in close proximity to other GBT front-ends operating between 0.3-50 GHz. No KFPA subsystem shall radiate interfering signals externally to the Receiver Room at levels above requirements set by the Green Bank Interference Protection Group. For design purposes, Receiver Room shielding of 60 dB may be assumed.

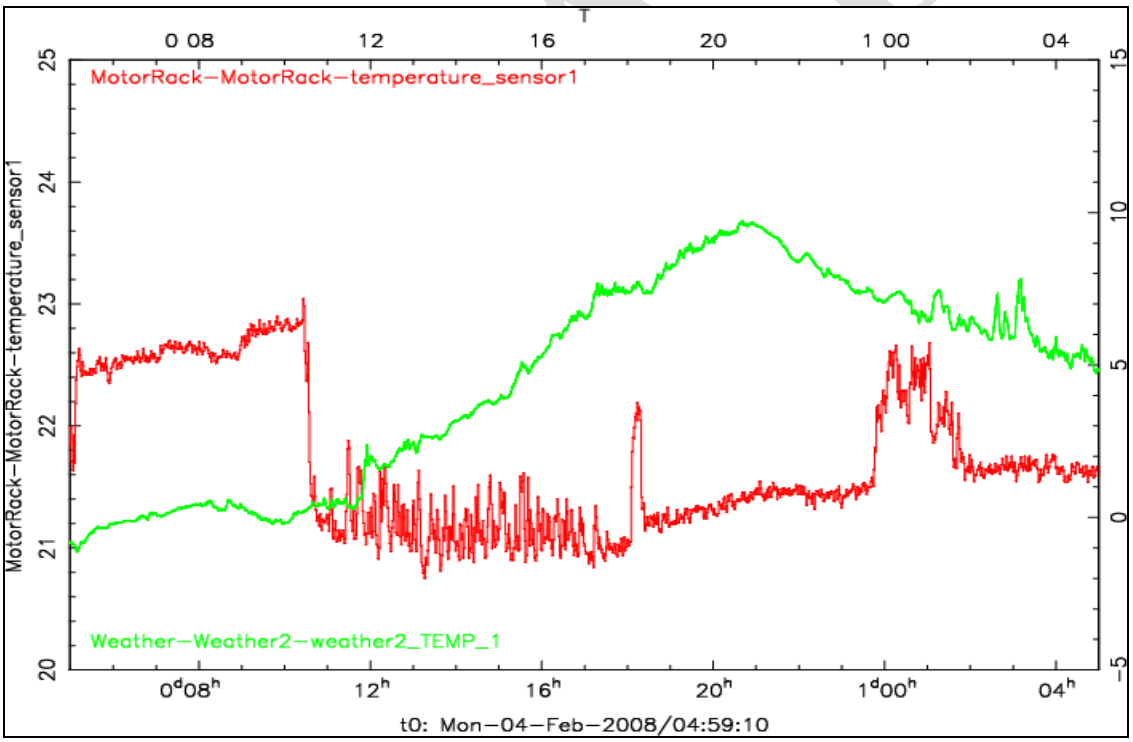

Figure 3: Receiver Room (red – left axis) and outdoor (green – right axis) temperatures over a 24 hour period.

4.3 Cryogenics

Refrigerator power supplies compatible with CTI refrigerator motors are available in the GBT receiver room, and helium compressors located on the alidade level supply helium at up to 270 PSI. The KFPA shall provide a KF-40 type vacuum roughing port.

4.4 Electrical

System DC power supplies are available for each turret slot providing: +15V, -15V, +5V, and +28V. Any other voltages required by the KFPA shall be derived from these, or from the 120VAC line.