ALMA Test Interferometer Project Book, Chapter 6.

Evaluation Frontends

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Last changed 2000-January-30

Revision History:
1998-11-18: Major revision
1999-05-02: Minor specification changes in Table 5.1, revised deadlines in Table 5.2.
Section 5.1.7 on Cryogenics added, and Evaluation Receiver General section 5.1.8 added.

2000-01-30: Major revision to comply with the ALMA Test Interferometer and now chapter 6.0

Definitions : **A "Frontend" is the overall mechanical (frame) package containing various millimeter wave receivers together with their associated dewar, cryogenics and electronics. The frontend is mounted in the antenna electronics cabin on the axis of the cassegrain focus.**

A "Receiver Insert" is the removable mechanical package holding the receiver components that bolts into the dewar. The receiver insert is divided into two main sections, one inside the dewar carrying the cooled receiver components and the other outside the dewar where the room temperature IF and LO components mount.

6.1 Evaluation Receivers

Summary

The receiver development plan consists of two distinct efforts. One will result in receivers suitable for the evaluation of the first antenna. A copy of these receivers will be constructed at the end of the D&D phase permitting the first interferometry tests to proceed on delivery of the second antenna. These receivers are designed to be "throw-away" items, although many of the components and techniques developed will be used in the final receivers for the ALMA project. These initial receivers are referred to in this Chapter as "Evaluation Receivers" and are mounted in the "Evaluation Frontend". The specifications for these receivers are given in Table 6.1 and the principal milestones in Table 6.2.

The second effort will be to develop plans and some prototype components for the final receivers that will enable the construction of the receivers to proceed in a timely manner at the end of the D&D phase. Here these receivers are referred to as the "Production Receivers."

6.2 Introduction

The receivers designed for the evaluation of the first antenna and the initial interferometer tests will be independent of the receivers that will finally be mass-produced for the ALMA. Some components will be similar or identical and efforts will be made to design the receivers in such a way that some parts of the design will be transferable to the production receivers. However the focus of the effort will be to produce in over a given time a receiver Frontend that is suitable for the initial tests. This will involve the use of many components identical to those used in the present NRAO Tucson receivers.

RF Frequency Band	**Receiver Element**
31.3-45 GHz	HFET amplifier
83-95 GHz	HFET amplifier
89-116 GHz	SIS mixer
210-270 GHz	SIS mixer
All bands are dual linear polarization.	

Table 6.1 Specifications for The Evaluation Receivers.

Task	Date
Optics decision	February 2000
4k refrigerator selection	November 1999
Dewar design	March 2000
All components delivered	July 2000
Receiver assembly complete	December 2000
Receiver tests complete	March 2001
Deliver receiver to VLA site	June 2001

Table 6.2 Principal Milestones for Evaluation Receivers during D&D Phase.

6.3 Specifications

The Evaluation Frontend will be an autonomous unit equipped with four independent frequency bands of :-

31.3-45 GHz (HFET), 83-95 GHz (HFET), 89-116 GHz (SIS) and 211-270 GHz (SIS).

The cryogenics will comprise a two stage GM refrigerator (70K and 20K) coupled to a 4K Joule Thomson expansion system as developed by NRAO, JPL and CSIRO. HFET receiver inserts will be attached to the 20K stage and SIS mixers inserts to the 4K system.

All receivers will be dual channel receiving orthogonal linear polarizations.

Because existing SIS mixers design are employed the I.F. will be 4-6 GHz for the 3 mm and 1 mm SIS receivers, and 4-12 GHz for the HFET systems. An IF switch will select the required pair of orthogonal channels to be sent to the IF-LO equipment rack.

The noise performance of the receivers will be the best that can be obtained with today's components and will be more than adequate for the initial measurements. An important point is that continuum measurements will be needed to measure aperture efficiency at the various frequencies. Beam switching with the nutating sub-reflector will be used and, due to the mechanical nature of the switching mechanism, it is necessary for the detected output of the receivers to have a power spectrum that is flat down to a few Hz. There seems to be some doubt that the high frequency HFET amplifiers will satisfy this requirement and this is discussed in more detail below.

The AC supply for the helium compressor and the frontend will be 400 volts 50 Hz 3 phase and 230 volts 50Hz single phase respectively to comply with the Chilean/European power standards.

6.4 Frontend Mechanical Package.

The frontend is contained in a welded extruded aluminium frame no bigger than 900mm wide by 900mm deep by 1500mm high. This frame is divided into several compartments to facilitate the mounting of the following equipment. The frame will be enclosed with removable side panels and provision for air ducting if required.

A large dewar containing the four receiver inserts and helium refrigeration system.
A turbo molecular vacuum pump and associated valving.
A helium line interface with JT supply pressure regulator and flow gauge
The phase locked LO system. (which has to be in close proximity to the receiver inserts)
An IF selection switch module
Appropriate power supplies
Electronic modules for SIS and LNA bias
Electronic modules for the extensive remote monitor and control of the frontend.
A local monitor and control front panel
Bulkheads for terminating cables
And if space permits a roughing vacuum pump.

All calibration loads and rotating mirrors or choppers will be mounted above the frontend package and be independent of that package.

A system for transporting and installing the frontend package in the antenna receiver cabin is being investigated.

The frame bolts to an indexed 'frontend interface plate' mounted in the ceiling of the receiver cabin. It is also envisaged that the bottom of the frame will be mounted to a plinth which in turn is bolted to the floor.

Refer to document ALMA-US ICD No.1 "Antenna / Receiver Interface".

The unit containing the helium compressor and crosshead power supply is mounted outside the receiver cabin.

6.5 The Receivers' Optics.

For the Evaluation Frontend, we plan a simple optical arrangement with "clean" optics that follow the suggestions in MMA Memo #215 .

The feed horns of the receiver inserts will be located in a circular pattern around the vertical axis of the dewar as close to the axis as is mechanically and thermally possible. The required receiver will become operational, simply by offsetting the antenna pointing.

It is envisaged that the 31.3 to 45GHz band feed horn will be at room temperature and thus mounted on top of the dewar with a wave guide connection to the OMT and LNAs mounted to the 20K stage.

The 83 to 95GHz HFET receiver will employ an existing design for the feed horn mounted in the dewar and attached to the 20K stage together with the waveguide OMT and LNAs. The correcting lens however may be outside the dewar.

The 89 to 116GHz SIS receiver will use an existing design for the feed horn mounted to the 4K stage with the waveguide OMT. The correcting lens may be outside the dewar.

The 210 to 270GHz SIS receiver will use an existing lens corrected feed horn with the lens and horn mounted to the 4K stage together with a waveguide OMT now under development.

Calibration widgets such as hot loads and choppers will be mounted above and independent of the frontend then switched into the antenna beam on demand.

6.6 Polarization Diplexing

In the past, the NRAO receivers have used room temperature wire grid polarization diplexers. Recently, a full waveguide band diplexer (ortho mode transducer, OMT) has been developed for the 31.3 – 45GHz, is under development for the 83 – 95GHz and 89 – 116GHz bands and it is hoped to extend this technique to the 211 – 275GHz band.

Reference to E. Wollach et al.

This will result in lower receiver noise as the OMT will operate at cryogenic temperatures. As mentioned above the 31.3 - 45GHz and the 83 - 95GHz HFET receiver OMTs will be attached to the 20 K stage of the refrigerator and the 89 – 116GHz and 210 – 270GHz SIS receiver OMTs attached to the 4K stage.

If there are insurmountable problems with the 210 – 275GHz band OMT then a wire grid type polarization diplexer with associated mirrors could be substituted and mounted on top of the receiver insert within the dewar. This demonstrates the beauty of a receiver insert.

6.7 Evaluation Frontend Block Diagram

The aim is to make the evaluation frontend as self contained as possible with DC supplies, LO systems, vacuum pumps and Local/remote control and monitoring all built in.

This reduces the external interfaces to the frontend to AC power, helium line connections, refrigerator drive power, LO reference signals, IF outputs and CAN bus connections.

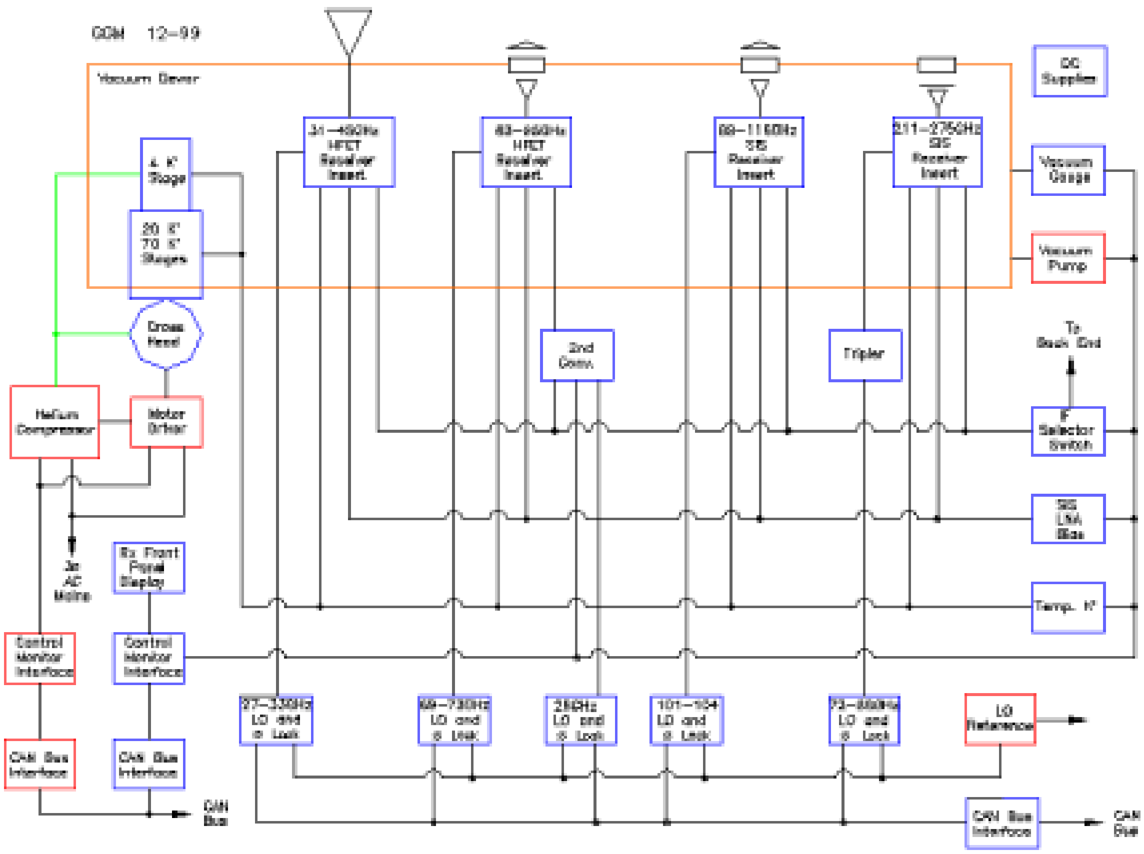


Figure 6.2 shows the major components in the Frontend package.

6.8 The Receiver Dewar

The layout of the dewar will be similar to that shown in Figure 1, which may be regarded as a baseline design. This layout follows the ideas that are used in the present Tucson Frontends with the exception that the change in frequency bands is achieved by simply changing the pointing of the antenna rather than rotating external optics. This system results in errors due to off-axis operation (see MMA Memo 175_), but these errors, coma, etc., are shown to be negligible.

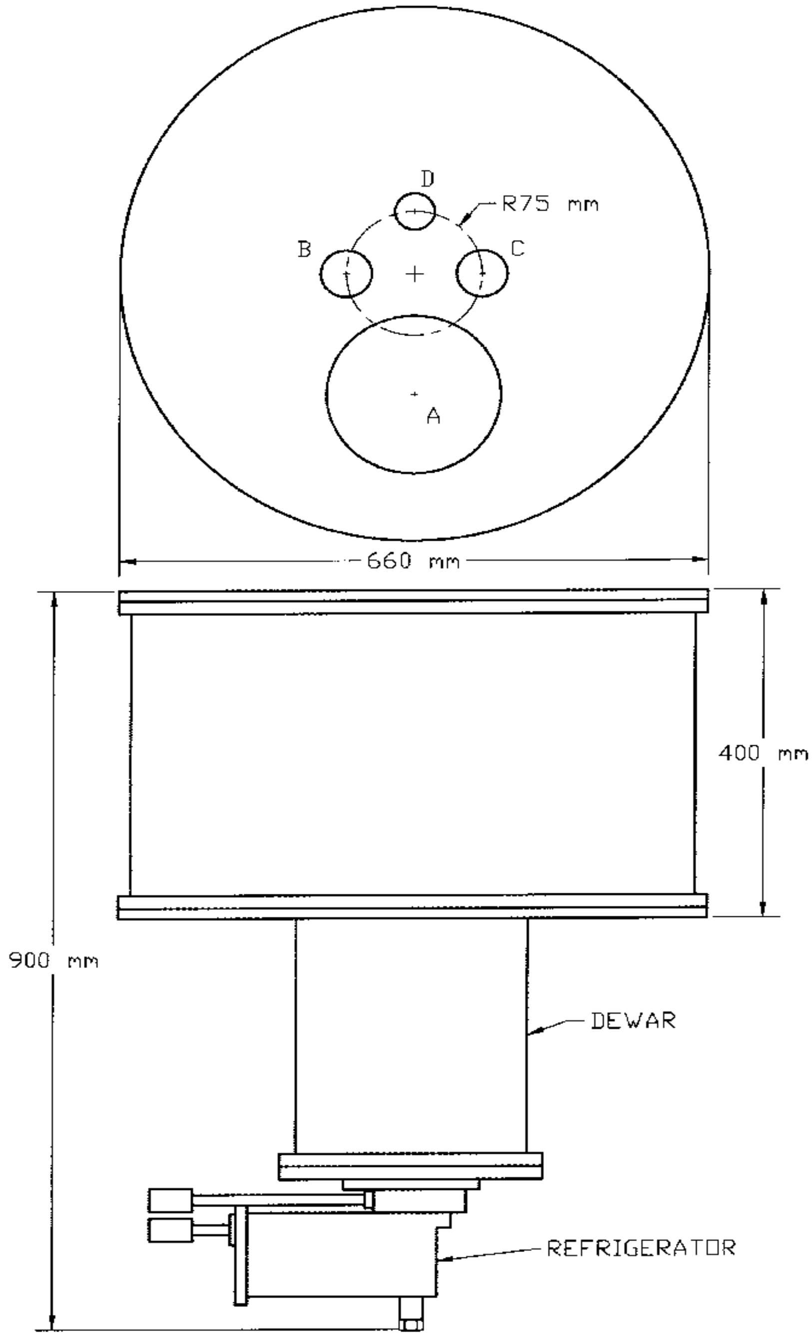


Figure 6.3 The Evaluation Frontend Dewar

6.9 Receiver Insert Block Diagrams

Each Receiver Insert covers an RF band as specified earlier. It is planed that the mechanical structure of the receiver insert within the dewar carry the cooled RF components and the structure outside the dewar be used to mount the room temperature IF and some of the LO components. This will enable a complete receiver (insert) to be tested as an entity independent of other inserts and the main dewar.

There is uncertainty at present about the performance of the HFET amplifiers for use at W-band frequencies. What is proposed here is that the evaluation receivers contain two receivers inserts in this band : one, a dual polarization receiver using HFET amplifiers, the other a receiver using SIS mixers. In this way we hope to make an evaluation of the low frequency post detection noise that will be critical for continuum observations using the nutating sub-reflector.

Although it should be possible to evaluate the receiver performance in the laboratory prior to telescope observations it is felt that telescope observations will give the most unambiguous results. Block diagrams of both these receivers are shown in Figures 6.4 and 6.5. The 89 to 116GHz SIS receiver will use the tuneable mixers that are in use on the Tucson 12m antenna today.

6.9.1 The 31-45 GHz HFET Receiver

The simplified block diagram for the 31.3 to 45 Ghz receiver insert is shown in Figure 6.4. This illustrates a single upper sideband conversion from the RF input band to an IF of 4 to 12 GHz. The waveguide OMT and the LNAs will be mounted on the 20K stage of the refrigerator. It is TBD if the mixer is cooled or mounted external to the dewar.

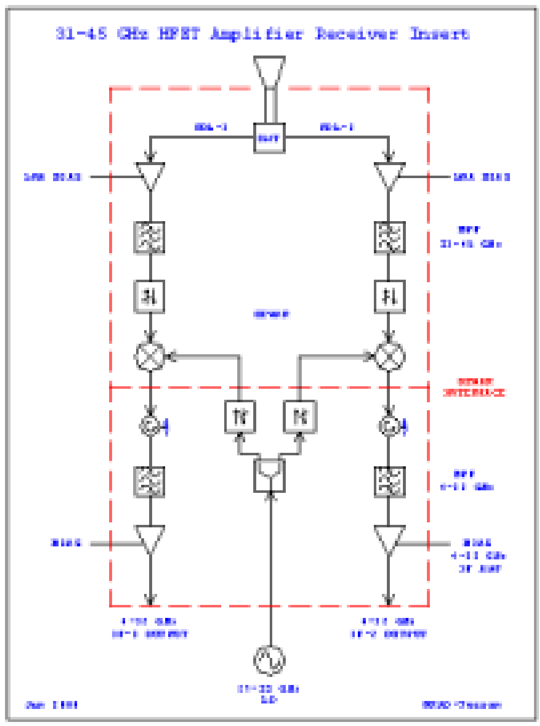


Figure 6.4 The 31-45 GHz HFET Receiver.

6.9.2 The 83-95 GHz HFET Receiver

The simplified block diagram of the 83 to 95 GHz HFET receiver insert is show in figure 6.5 and depicts a double conversion system with a tunable 1st LO and a fixed 2nd LO.

The RF frequency band was chosen to cover both the SiO maser at 86.2 GHz and the Holography beacon at 92.4 GHz. Another band setting factor is the RF, LO and IF bandwith of commercially available mixers. Under an NRAO VLBA project a coolable mixer covering approximately 80 to 96 GHz is being developed and should be suitable for this evaluation frontend insert.

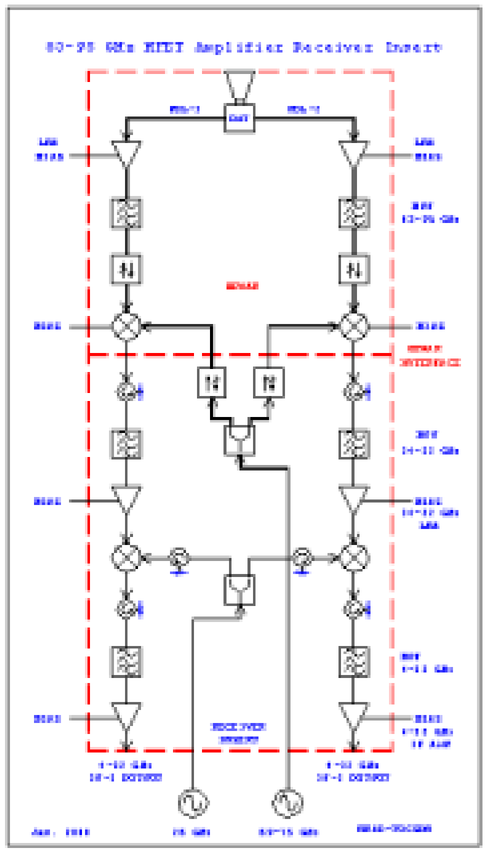


Figure 6.5 The 83-95 GHz HFET Receiver.

6.9.3 The 89-116GHz SIS Receiver

A block diagram of the single conversion 89 to 116 GHz SIS receiver insert is shown in figure 6.6 . This receiver insert will utilize an existing NRAO design for a tunable SIS mixer to save development time and money. Other components found in the 3mm receivers on the 12M antenna in Tucson will also be used.

The major development is in the waveguide OMT as described by E.Wollack add ref.

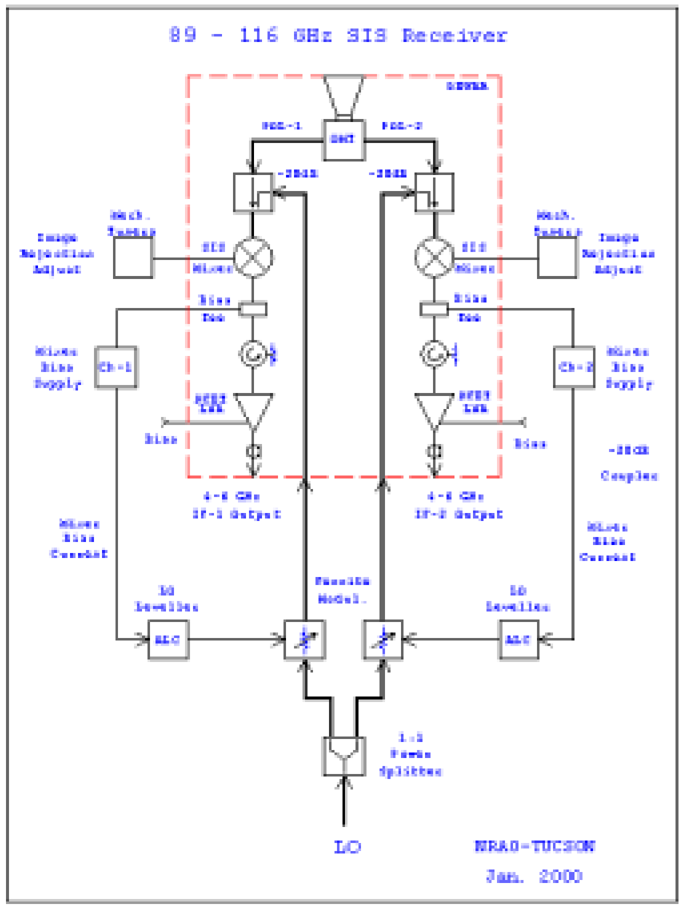


Figure 6.6 The 89-116 GHz SIS Receiver.

5.9.4 The 210-270 GHz SIS Receiver

A simplified block diagram of this single conversion SIS receiver is shown in Figure 5.7 The components are all today's technology, although it is anticipated that a major effort will go into achieving phase stability.

The fixed tuned mixers used have been manufactured by the National Research Council of Canada using NRAO designed mixer chips.

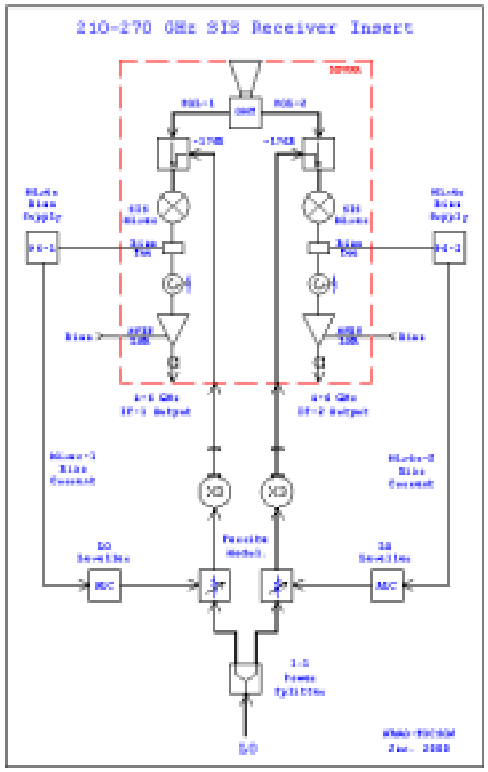


Figure 6.7 The 210-270 GHz SIS Receiver.

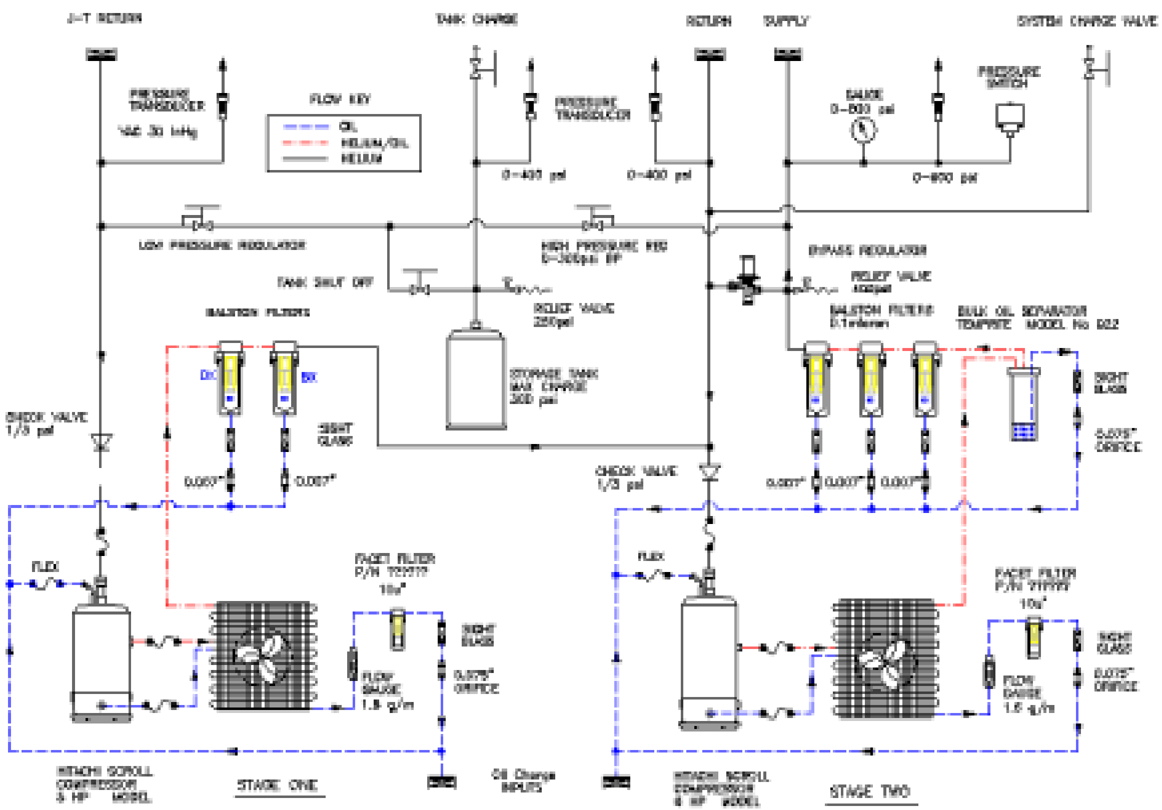
6.10 Evaluation Frontend Cryogenics

6.10.1 Helium Compressors

A decision has been made to power all electronics and helium compressors from 400 Volt, 3 phase 50 Hz, or 230 Volt single-phase 50 Hz ; this corresponds to the standard Chilean power grid. As a result of the 50 Hz mains frequency the rotational speed of the compressor motors will drop by ~17%, lowering the helium flow rate proportionally. To provide sufficient helium flow to the GM refrigerator a new prototype compressor system will be developed using a 5HP Scroll compressors for the GM section, and a 5HP scroll for the JT circuit. The altitude, ambient temperature and air density at the Chilean site where these compressors could operate will be considered when designing the heat exchangers and specifying components.

Comprehensive local and remote monitoring of all critical pressures, temperatures and electrical systems will be installed together with a local/remote power on/off. The remote monitor /control will be via a CAN bus interface.

See figure 6.8 for a schematic diagram of the helium compressors.



TWO STAGE SCROLL COMPRESSOR

6.10.2 Cryogenic Refrigerator System.

The Evaluation Frontend will employ a two stage CTI 1020 GM helium refrigerator to provide the 70K and 20K cold stations. Coupled to this refrigerator will be a standard NRAO 4K JT system. The refrigerator motor drive power supply (Scott Tee transformers) will be located in the helium compressor chassis. This supply has sufficient capacity and voltage taps to simultaneously drive up to four CTI refrigerator motors in combinations of models 1020, 350 and system 22.

The JT helium supply regulator and a flow meter will be mounted in the frontend with suitable monitoring via the CAN bus.

6.10.3 Dewar Vacuum System.

It is planned to incorporate an automated evacuation system utilizing a turbo molecular pump and a scroll roughing pump for the first stage. The turbo pump will be attached as close to the dewar as practical with the associated, manual valve for maintenance, and electromechanical valving for automatic pump down. It is hoped that the roughing pump can be continually connected and mounted in the bottom of the frontend frame.

6.11 IF Switching Module

The dual polarisation IF outputs from the four receiver inserts are sent to a double pole multy way microwave switch which by way of a control command selects the required pair of signals to be sent to the backend equipment. The IF switch module may contain band pass filters, amplifiers, line equalisation and the necessary control and monitoring circuitry with a local display interface. The module will be designed to cover the full ALMA IF band of 4 to 12 GHz.

The output power available at the connector bulkhead will be –30dBm / Ghz.

6.12 Local Oscillator system

The initial LO sources will be tunable phase-locked Gunn oscillators with a tripler for the 210 to 270GHz band. (To be completed)

6.13 Power Supplies

The evaluation receivers will be equipped with an integral power supply system. (To be completed.)

6.14 Control and Monitoring

Local control and monitoring will be provided through a Receiver front panel and remote control and monitoring via a simple I/O interface bus. (To be Completed.)