

# Tri-band System for the Russian Interferometer

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**Abstract** This report describes the tri-band receiving system for the 13.2-m antenna. Block diagrams and construction details are given. The measuring method for the noise temperature is described, and calculations and measurement results are compared. For the receiver feed, the results of the power pattern calculations and the measurements are presented.

**Keywords** VGOS, tri-band, receiver, cryogenic

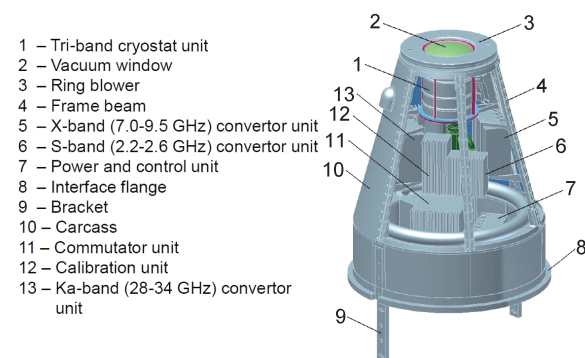
## 1 Introduction

Two stations of the interferometer are under construction at the Zelenchukskaya and Badary observatories. The telescopes will use multiband feed and low noise amplifiers placed into a single unit (cryostat) of the receiver and cooled there to the hydrogen temperature level. This report describes the designed cryostat of the focal container for the radio telescope with a radio-transparent covering and a dielectric thermal screen to support the cooling process. The construction of the feed gives the possibility for cooling and operating with dual circular polarization simultaneously.

## 2 Tri-band Receiving System

This system operates in the following bands: S (2.2–2.6 GHz), X (7.0–9.5 GHz), and Ka (28–34 GHz). All receiver units are placed in the focal container (Fig-

ure 1), which is disposed in the secondary focus of the antenna.



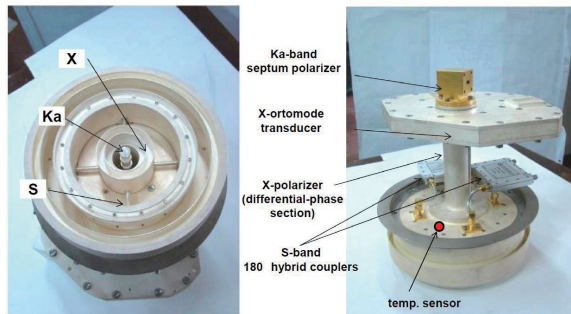
**Fig. 1** Tri-band receiving system focal container.

The container is specially designed for an antenna with a 13.2-m dish, and it is housed in a rigid airtight framework. The construction of the focal container provides air circulation inside and its input has a window compatible with a cooled unit input. The external radio-transparent covering of this window is blown with warm air through a special hose to protect it from atmospheric precipitation.

The tri-band feed and input amplifiers with microwave isolators installed in the cryostat of the focal container are cooled there by the closed-cycle cryogenic system to the temperature of liquid hydrogen.

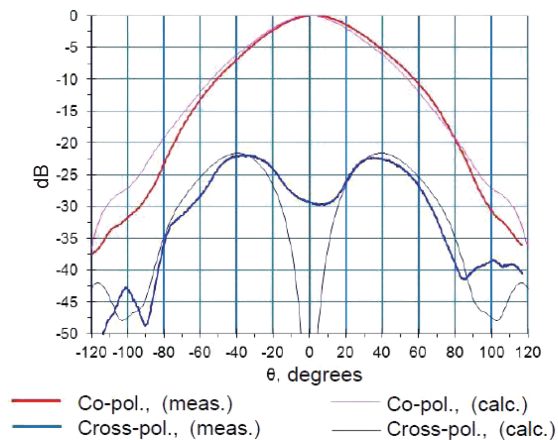
The aperture part of the feed is constructed with the use of circular waveguides of the S, X, and Ka bands placed coaxially (Figure 2). The Ka-band has a circular waveguide with a dielectric cone and waveguide septum polarizer. In the X-band, the signal reaches the horn, passes through the differential-phase section, and divides over the orthomode transducer. In S-band,

quarter-wavelength inductive pins and hybrid couplers are applied.



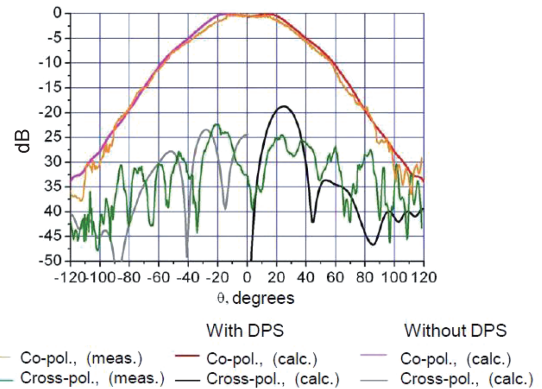
**Fig. 2** The cooled unit feed.

During the development of the feed, it was modeled with software. Figures 3–5 show the calculated and measured power patterns. The measurements and calculations were made in co-polarization and cross-polarization. For the X-band, the influence of the differential-phase section was analyzed. The actual characteristics are enough close to the calculated ones. One of the main feed parameters is the beam width, and on the level of  $-15$  dB, it is about  $130$  degrees.

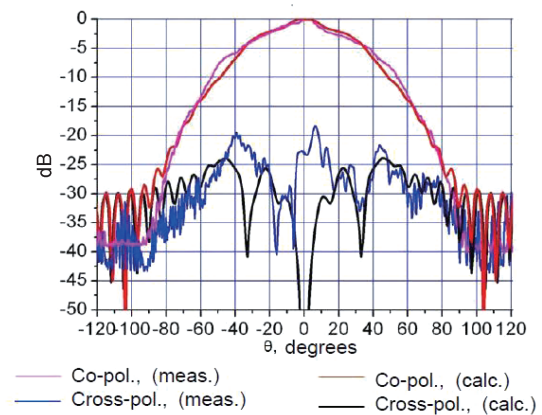


**Fig. 3** Power patterns (S-band).

All the equipment of the cooled unit (Figure 6) for both polarizations of all three bands is tightly placed in the space between the feed and coldhead flange. The S and X band signal lines are coaxial, and the Ka-band is fully a waveguide. The equipment is closed with the metal heat shield. The infrared filter is placed between



**Fig. 4** Power patterns (X-band).



**Fig. 5** Power patterns (Ka-band).

the feed and the vacuum window. It is  $0.1$  mm teflon film.

The vacuum window (Figure 7) is closed with a radiotransparent cover, which consists of two parts. The external sealing surface is made of Mylar film that is  $0.05$  mm thick. The film is supported by an inner layer of solid foam polyester that is  $17$  mm thick.

Focused with the antenna, electromagnetic waves get to the feed inside the cooled unit through the radio-transparent cover. They are separated to three bands and two circular polarizations, mixed with the noise and phase calibration signals and amplified with cooled low-noise transistor amplifiers (LNA). Almost all the equipment located inside the cryostat is cooled to the temperature of near  $20$  K, significantly reducing the noise temperature of the “radio telescope-radiometer” system.

All amplified signals go to the intermediate frequency converter units. These units provide subchannel

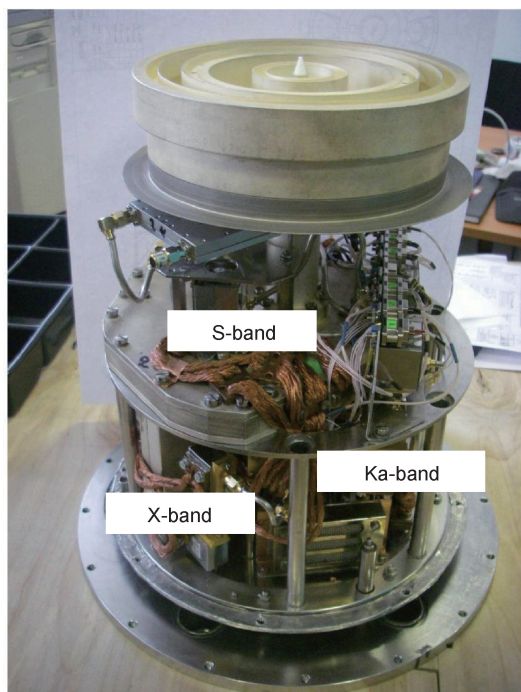


Fig. 6 The cooled unit assembly.

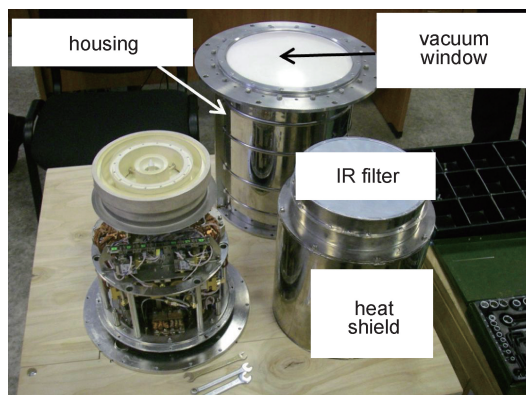


Fig. 7 Cooled unit heat shield, carcass, and vacuum window.

splitting and frequency converting to the band of the digital acquisition system. The subchannels to record are selected by the commutator unit.

The calibration unit contains an adjustable noise source for each band. External picosecond pulses for the phase calibration are used, and the calibration unit has a special input for them.

The receiving system is powered with a unified supply voltage and controlled via the Ethernet interface. A large amount of telemetric information such as temper-

atures, supply voltages, and consumption of current, is gathered.

### 3 Low Noise Amplifiers

The cryogenic low noise amplifiers (Figure 8) for S- and X-band are connected modules. They have a gain of more than 30 dB, and their noise temperature is not higher than 5 K. The Ka-band waveguide amplifiers are prototypes; they have excess gain and noise. Their parameters will be improved in the future.

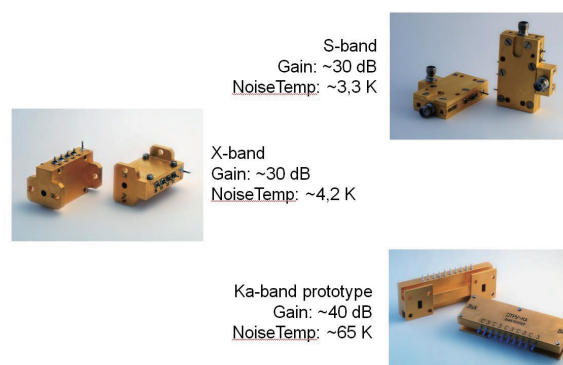


Fig. 8 Low noise amplifiers.

### 4 Cooled Unit Tests and Measurement Results

The cooling process (Figure 9) with the use of the Sumitomo closed cycle refrigerator takes seven hours. The measured feed physical temperature is about 26 K, and the temperature of the amplifiers is about 20 K.

For measuring the noise temperature of the cooled unit, a special broadband matched load was applied (Figure 10). It is a low temperature wide-aperture load, which is enclosed in a dewar with liquid nitrogen. The load is mounted on a mobile base, allowing it to be matched with the device under test during the movement. For matching the sizes of the vacuum window and the load aperture, the blends are located between the load and the cryostat. This equipment provides the <<cold>> load. The absorbent material plate with the room temperature is applied as a "hot" load.

**Table 1** Cooled unit prototype measured and calculated parameters (S-band).

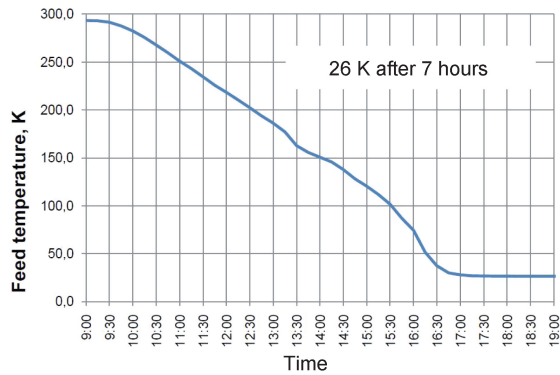
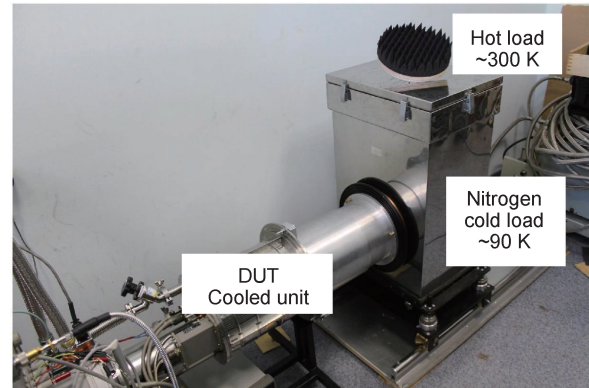
Parameter	Cover	IR-filter	Feed	Bridges	Dir. Coupler	From cal. input	Isolator	LNA	Isolator
Gain/Loss, dB	-0.02	-0.01	-0.35	-0.45	-0.1	-27	-0.2	30	-0.2
Phys. temperature, K	300	70	20	20	20	300	20	20	20
Noise temperature, K	1.4	0.2	1.5	2.0	0.5	0.6	0.9	3.3	0.9
Noise contribution, K	1.4	0.16	1.55	2.15	0.55	0.6	1.11	4.23	0.001
Total unit noise, K	11.8								
Measured noise, K	15 (RFI)								

**Table 2** Cooled unit prototype measured and calculated parameters (X-band).

Parameter	Cover	IR-filter	Feed	Bridges	Dir. Coupler	From cal. input	Isolator	LNA	Isolator
Gain/Loss, dB	-0.03	-0.01	-0.15	-0.1	-0.1	-27	-0.2	30	-0.2
Phys. temperature, K	300	70	20	20	20	300	20	20	20
Noise temperature, K	2.1	0.2	0.7	0.5	0.5	0.6	0.9	3.3	0.9
Noise contribution, K	2.1	0.16	0.69	0.48	0.49	0.6	0.98	3.67	0.001
Total unit noise, K	9.1								
Measured noise, K	10								

**Table 3** Cooled unit prototype measured and calculated parameters (Ka-band).

Parameter	Cover	IR-filter	Feed	Bridges	Dir. Coupler	From cal. input	Isolator	LNA	Isolator
Gain/Loss, dB	-0.04	-0.01	-0.2	-0.1	-0.1	-27	-0.2	40	-0.2
Phys. temperature, K	300	70	20	20	20	300	20	20	20
Noise temperature, K	2.8	0.2	0.9	0.5	0.5	0.6	0.9	64	0.9
Noise contribution, K	2.7	0.16	0.91	0.48	0.49	0.6	1.0	74.3	0.0001
Total unit noise, K	80.7								
Measured noise, K	80								

**Fig. 9** The cooling process.**Fig. 10** Noise temperature measurements.

## 5 Conclusions

The results of the noise temperature measurements and calculations in different ranges are presented in Tables 1–3. The difference between the left and right circular polarization channels is insignificant. The main noise contribution comes from LNA. Other significant contributors are the radio-transparent cover, the feed, the bridges and polarizers, the direct coupler, and the

ferrite isolators. The measurements of noise temperature in the S-band were obstructed by the strong RFI, but the result is not higher than 15 K. The measured and calculated temperature in X-band is about 10 K. The Ka-band is prototyped, and its noise temperature is about 80 K and will be improved.