New C-band receiver for RT-32 radio telescope IAA RAS Quasar network

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The report focuses on the new equipment developed in IAA RAS for the astrophysics VLBI 4.5-5.5 GHz (6.2 cm, C-band) band receivers in radiointerferometric complex «Quasar». The purposes were to increase the operational receiver reliability, to improve the technical characteristics and to expand the operating frequency band from 500 to 900 MHz. Low noise amplifiers in cryoelectronic frontend units were replaced with modern and more reliable ones. New dual channel frequency conversion units with integrated local oscillators were designed. Spectral characteristics of local oscillators were improved. Dual channel noise generators units with amplified compensating noise density were developed, their design and technical parametres are given.

Modernization of the C-band receivers reduced the number of receiver units and increased overall operational reliability. Due to extended 900 MHz band the improvement of all basic receiving channel parameters is expected.

Introduction

New C-band receiver designed in IAA RAS is purposed for replacement of previous generation receiver equipment [1] in QUASAR VLBI network RT-32 radio telescopes. These radio telescopes are based in «Svetloe», «Zelenchuckskaya» and «Badary» stations. It is supposed, that new receiver will solve the following problems:

· extending the output working bandwidth from 500 to 900 MHz;
· improving some technical parameters, such as phase characteristics of local oscillators;
· reducing the total number of units and increasing operational reliability

Receiver configuration

Schematic diagrams of previous and new generation C-band receivers are shown on the fig. 1-2. Both receivers include units following:

- cryoelectronic frontend unit (cryounit, fig. 3) for primary amplification of signal with minimum noise.
- FCUs (frequency conversion units) for downconversion of input 4.6-5.5 GHz C-band to 100-600 MHz (for old receiver) or 100-1000 MHz (new one). New FCUs are dual-channel with integrated local oscillator.
- NGUs (noise generation units) for generation of amplitude calibration signal. This signal injects to calibration input of cryounit. New NGUs are made dual-channel.
- PCM (power, control and management) subsystem units, including power unit, control unit and distributing unit. These units supply voltages, produce control commands and gather status information from all receiver units.

For connecting PCM subsystem with central computer supervisor unit is used. The supervisor unit is able to communicate with 10 sets of PCM subsystem simultaneously.

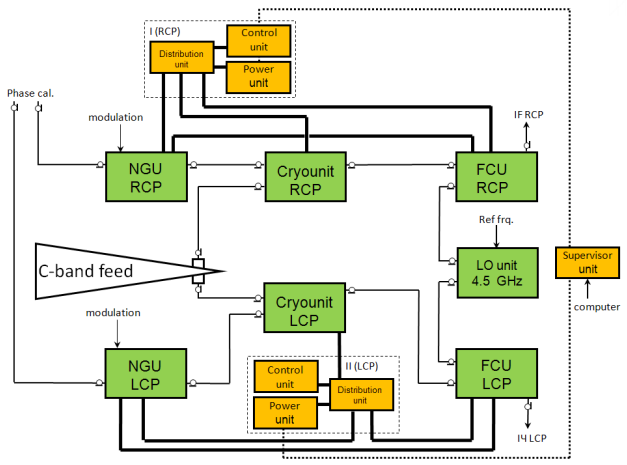

Fig. 1. Schematic diagram of previous generation C-band receiver

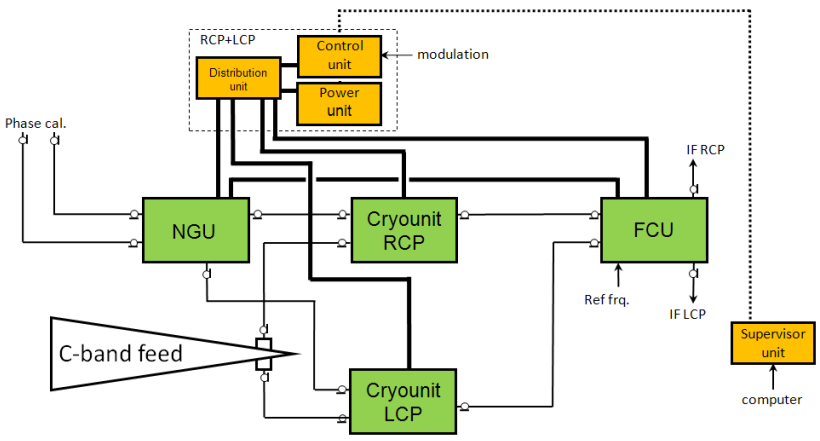

Fig. 2. Schematic diagram of new C-band receiver

Cryounit

Noise temperature and gain of cryounit have the most influence on the total system parameters. New cryounits must match the requirements following

- extended bandwidth from 4.6-5.1 GHz to 4.6-5.5 GHz;
- 30±1 dB gain;
- noise temperature below 15 K
- input/output SWR less than 1.3 in working bandwith
- 25±1 dB coupling factor for calibrating input.

These requirements were met due to use of new LNAs. New LNAs are isolated with ferrite circulators and contain integrated directional couplers. For these LNAs new secondary power supply sources were implemented. All remained parts of cryounit, such as cryostat with coldhead, waveguide signal input and coaxial calibration input and signal output, were not changed. One cryounit works with one circular polarization of input signal.

Fig. 3. C-band cryounit

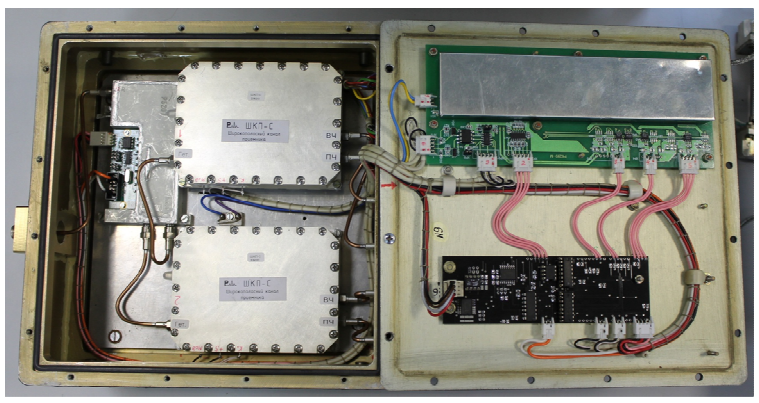

Fig. 4. Dual-channel FCU with integrated LO subunit

Frequency conversion unit

For improving parameters of FCUs new design (fig. 4) technology was used. Main operation principle of unit is the same as in old system. Signal amplified by cryounit in 4.6-5.5 GHz band is pre-filtered, amplified, mixed with LO tone at 4.5 GHz, and amplified with filtering to 100-900 MHz IF band. In order to function as Dikke-type radiometer mode, FCU has the controllable switch, attenuator and circulator chain at the input. Instead of connecting separate coaxial modules, all this equipment was developed as microstrip modules and packed in channel subunit. This solution has drastically lowered the dimensions and mass of channel equipement, providing enough space to place two channel subunits in one old-dimensioned case. LO was also developed as relatively small subunit based on microstrip technology. This device has two outputs and provides tone with improved parameters. According to measurements data given (fig. 5), phase noise and total jitter was decreased in comparison with the old LO units.

New RF submodules required new supply and control equipment, which was developed and placed in the same unit. Some additional functions as secondary power voltages control, temperature monitoring and reference frequency lock detection were added. Unit thermal stability equipment uses the separate power and control interface. It was replaced from unit to PCM. Thus the unit contains only executive part (Peltier battery) and sensor. Unit requires the standard power supply of +24V and consumes 0.8 A.

Noise generator unit

NGU is purposed for generation, adjusting and mixing together two separate noise signals. One of them is relatively high (200000 K and more) for compensation in Dikke-type radiometer mode and another is low calibration noise (20000 K). In addition to this, external picosecond pulses of phase calibration signal are also mixed. Total signal is injected to receiver input through cryounit calibration port, with 25 dB loss at the directional coupler.

Like the FCU submodules, NGUs were developed as microstrip modules. In these modules two IMPATT diodes generate noise in 4.6-5.5 GHz band, which is adjusted by p-i-n-attenuators with voltage control. Mixing of all noise signals and phase calibration pulses is designed as microstrip directional coupler.

One of the problems successfully solved was insufficient compensating noise level. Uncooled receiver noise temperature is about 120 K. With loss of compensating noise in Dikke-type mode modulator (10 dB) and additional cryounit coupler loss (25 dB) we need more than 380000 K, which exceeds nominal power of IMPATT diode. So the diode noise was amplified (+10 dB) and the switch was added to provide modulation of noise with constant amplifier power supply. Total compensating noise measured at subunit output exceeds 1000000 K.

Two noise-generating channels are placed in one old case. For power supply and controlling of modulator switch and attenuators, two similar PCBs are used. Controlling voltage for all attenuators is generated with 4 10-bit DACs, connected to I^2C bus. Thermal stability equipment is the same as used for FCU. NGU requires the standard power supply of +24V and consumes 0.2 A.

Power, control and monitoring system

Deep changes made in receiver FCU and NGU led to another PCM units. Power unit, providing different dual-polarity voltages for old receiver units, now uses two similar sets of +24V power subunit and thermal stability unit. Thermal stability unit uses primary ~220 V power and contains controller, which monitors the resistance of thermal sensors and controls the heat flow through Peltier battery with PWM pulses through H-bridge.

Receiver units use the same I^2C bus which let the control unit to gather information and send control commands. Information gathered includes:

- Cryounit LNA voltage condition and current consumption
- Cryounit temperature on coldhead stages
- FCU submodules secondary voltages condition
- LO reference frequency lock detection
- Temperature in FCU, NGU and control unit itself
- NGU and FCU serial number identification info

Control unit also receives external modulation signals and, according to mode set, forms compensating noise, calibrating noise and FCU modulator control signals separately.

The most serious change in control unit is Ethernet adapter [1] which lets to use this modern, reliable and high-speed communication interface instead of RS-485 in previous generation. This change also requires the upgrade of RT-32 controlling software.

Parameters

Laboratory measurements of cryounits confirmed the parameters preassigned. Unit tested has 10 K of noise temperature, measured by hot-cold match load method. The gain and coupling is in limits required in 4.6-5.5 GHz system working bandwith.

FCU measured with noise figure analyzer (fig. 5) has the gain about 33±1 dB and noise temperature 250±40 K. This value is low enough to have no effect on total noise temperature. The results of spectral characteristics measured are shown on fig. 6.

The spectral density of NGU noise is higher than nominal noise from IMPATT diode and covers extended bandwith of 4.6-5.5 GHz.

According to preliminary field tests, new receiver compared with previous generation one has less than 10 K noise temperature. New NGUs show exceeded compensating noise temperature signal, which was improved from 200 to 1400 K. More complicated field tests require the upgrade of controlling software due to new Ethernet interface.

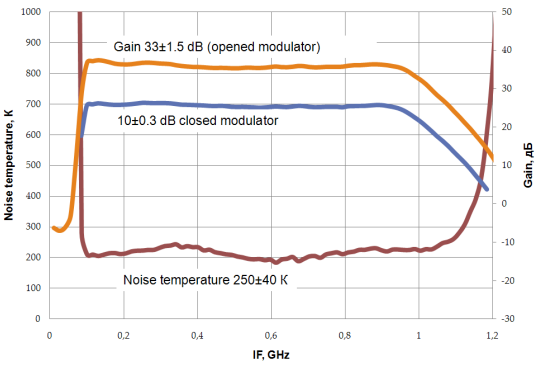

Fig. 5. FCU parameters

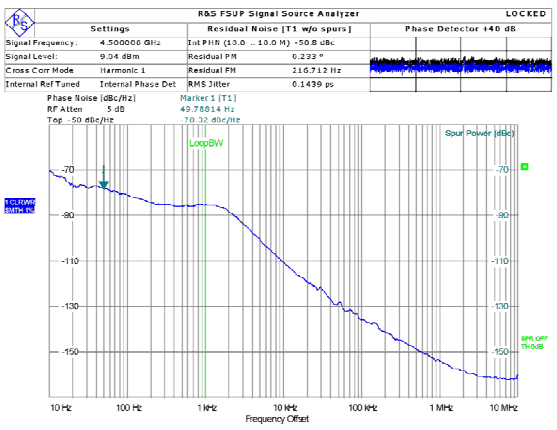

Fig. 6. Phase noise of improved C-band LO

Conclusion

The development of new C-band receiver led to positive changes following:

- cryounits were implemented with new LNAs with 900 MHz bandwith;
- receiving channels bandwidth was extended up to 900 MHz. Two channel with LO were united in one dual-channel FCU. The spectral characteristics of LO were improved;
- dual-channel NGU with extended compensating noise temperature was developed;
- all receiver units were adapted to work with new PCM subsystem;
- new PCM system with Ethernet interface and high controlling abilities was developed;
- total system units number was reduced from 7 to 4 (RF units) and from 6 to 3 (PCM subsystem units).

References