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 4.6–5.5 GHz (6.2 cm, C-band) band receivers in radiointerferometric network "Quasar". The purposes were to increase the operational receiver reliability, to to expand the operating frequency band from 500 to 900 MHz and improve the technical characteristics. 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.

Keywords: VLBI, C-band, radioastronomic receiver, "Quasar" network.

1 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 local oscillators phase noise;

— reducing the total number of units and increasing operational reliability.

2 Receiver units

Schematic diagram of new generation C-band receiver is shown on the Fig. 1.

It includes units following:

— cryoelectronic frontend unit for primary amplification of signal with minimum noise;

— FCU (frequency conversion unit) for downconversion of input 4.6–5.5 GHz C-band to 100–1000 MHz. New FCU is dual-channel with integrated local oscillator;

— NGU (noise generation unit) for generation of amplitude calibration signal. This signal injects to calibration input of cryounit. New NGU is 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.

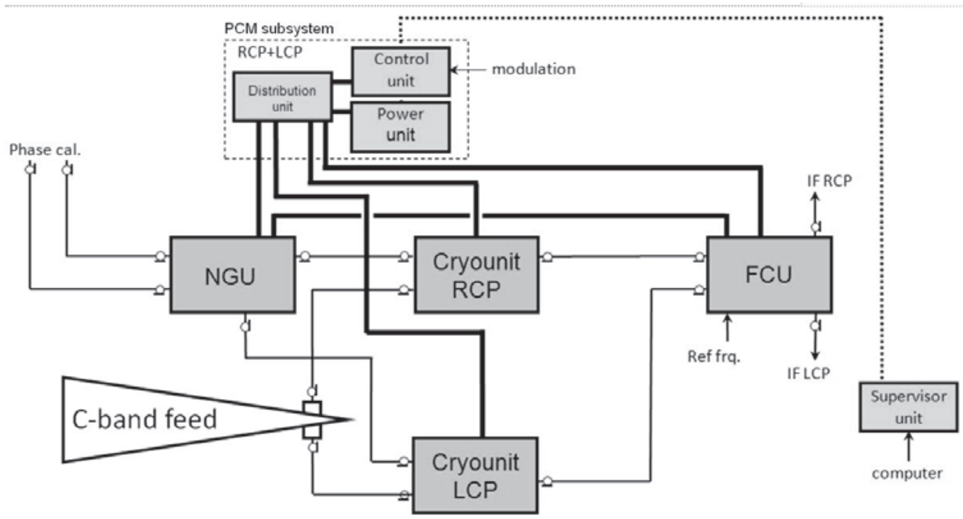

Fig. 1. New C-band receiver block diagram

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.

3 New receiver units

Noise temperature and gain of cryounit have the most influence on the total system parameters. New cryounits of extended bandwidth (from 4.6 to 5.5 GHz) has 30 ± 1 dB gain and noise temperature below 15 K.

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.

For improving parameters of FCUs new design 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, 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 +24 V and consumes 0.8 A.

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. One of diodes generate relatively high (200000 K and more) noise for compensation in Dikke-type radiometer mode and another produces 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. Total compensating noise measured at subunit output exceeds 1000000 K.

4 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 has the gain about 33 ± 1dB and noise temperature 250 ± 40K. This value is low enough to have no effect on total noise temperature. The spectral density of NGU noise is 10 dB 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.

5 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 RMS of LO phase noise was improved up to $0.3°$;

— 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

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