The Institute of Applied Astronomy
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# The parameters of the RT-13 radio telescopes of the "Quasar" VLBI network of the IAA RAS in S/X/Ka bands

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Measurement results of the parameters of the RT-13 radio telescopes of the "Quasar" VLBI network of the IAA RAS in S/X/Ka bands are presented in this paper. The receiver noise temperature and calibration signals are measured by special wide-aperture noise load. Load is installed at the receiver feed and cooled by liquid nitrogen. The calculated and measured system noise temperatures are compared. Focusing and directional pattern measurements are performed by point cosmic radio sources, differing for *S*/*X*/*Ka* bands. SEFD and antenna efficiency are measured by reference cosmic radio sources. The dependences of the system noise temperature, SEFD, antenna efficiency from the antenna elevation angle are obtained.

Since the receiving system input is tri-band feed, cooled in cryostat [1], for the noise temperature measurements special noise load – wide aperture low temperature noise generator (WLNG) is developed by FSUE «VNIIFTRI» (Yurchuk E. F. and others) [2]. WLNG is wide aperture radiator, placed in dewar for liquid nitrogen. The WLNG is mounted on the receiver input (fig. 1) and the noise temperature is measured by Y-factor method. Receiver output signals are measured at «warm» load (WLNG without liquid nitrogen), than the WLNG is cooled by liquid nitrogen during 8 hours, than the «cold» load levels are measured. Radiometric control unit (RCU) is used for output signals registration. The spectrum analyzer is also used in *S*-band as a spectral-selecting registration system due to the presence of RF interference (mainly communication networks 3G and Wi-Fi) Physical temperature of radiators are controlled by 9 precision thermosensors. The system noise temperature is measured by calibration signals, injected trough directional coupler before low-noise amplifiers and also measured in K degrees using

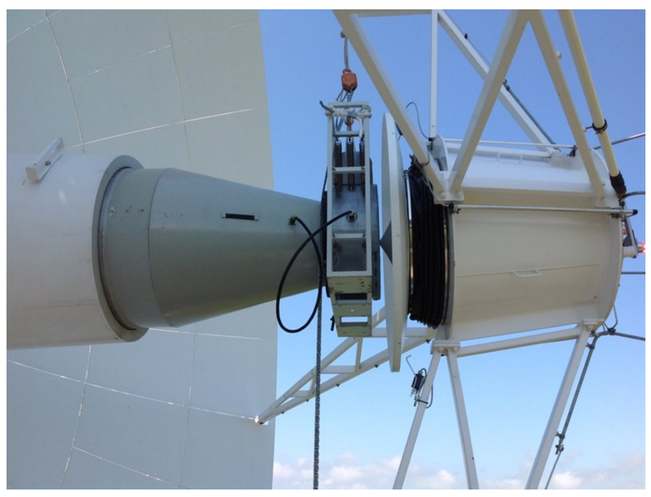

Fig.1 RT-13 noise temperature measurements by using wide aperture low temperature noise generator

The results of the receiver *T*rec and the system noise *T*sys temperatures measurements are presented at Table 1. The antenna temperature *T*ant is calculated in developed program as the integral over the sphere of the product of the antenna directional pattern and the sky and ground brightness temperatures. The surface weather model, used by JPL and NASA's DSN for antenna calibrations [3], is applied taking into account absorption by water vapor and molecular oxygen. The model is suitable for calculations in fair weather, as the liquid water content in the atmosphere is not taken into account. The input data for the calculation in the program are temperature, humidity, pressure and observatory altitude. As can be seen from Table 1 the calculated values of *T*sys (*T*sys =*T*rec+*T*ant) are close to the measured values. So, the calculated value of *T*ant may be used in fair weather as the value of «cold» load for the receiver noise temperature evaluation, while absorber can be used as «warm» load. This technique is fast and does not require long cooling of «warm» load.

Table 1 Noise temperature measurement results at «Badary» station

| Band | *T*rec (meas), K | *T*ant (calc), K | *T*sys (calc), K | *T*sys (meas), K |
|---|---|---|---|---|
| *S* RCP | 21 | 17 | 38 | 37 |
| *S* LCP | 24 | 17 | 41 | 40 |
| *X* RCP | 17 | 9 | 26 | 27 |
| *X* LCP | 20 | 9 | 29 | 30 |
| *Ka* RCP | 47 | 15 | 62 | 63 |
| *Ka* LCP | 52 | 15 | 67 | 68 |

Focusing, antenna adjustment and investigation of other parameters of radio telescope RT-13 are carried out by measurement technique, developed by IAA RAS and institute of IRE ANAS. Focusing and directional pattern measurements (beamwidth and sidelobs level) are performed by point cosmic radio sources for corresponding band: by CAS A in *S*-band, Cygnus A in *X*-band, Venus and Jupiter in *Ka*-band. System equivalent flux density (SEFD) and antenna efficiency are measured by reference cosmic radio source CAS A , taking into account the ratio of the angular size of the source (4'x4') and antenna beamwidth of RT-13, that is important in *Ka*-band. The antenna efficiency is determined from the measured values of the noise temperature of the SEFD. Observation of radio source Taurus A simultaneously in S/X/Ka bands is presented at fig. 3. There is a problem with powerfull radio sources in Ka-band. For focusing and sidelobes level measurements only sources Venus and Jupiter appeared to be suitable (fig. 4). The dependences of the system noise temperature, SEFD, antenna efficiency from the antenna elevation are presented at fig. 5–7 for «Badary» station..

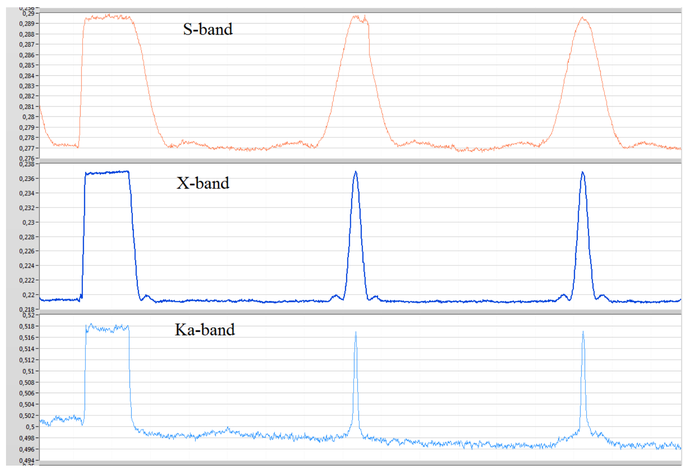


Fig. 3 Source «Taurus A» observations simultaneously in S/X/Ka bands at «Badary» station

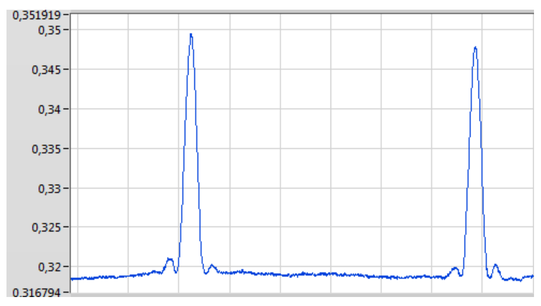


Fig. 4 Source «Venus» Observations Venus at «Zelenchukskaya» station

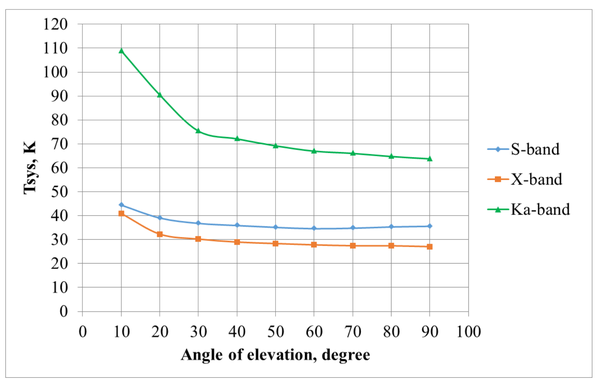


Fig. 5 System noise temperaure vs. angle of elevation at «Badary» station

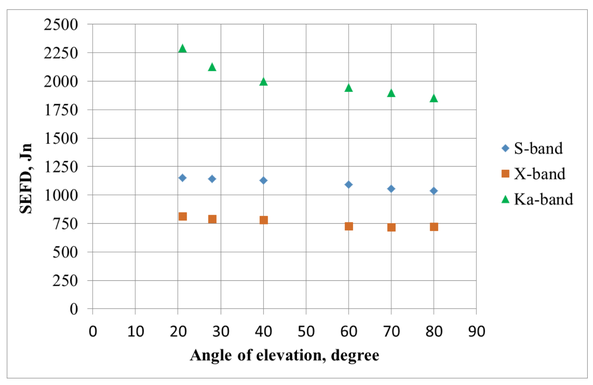


Fig.6 SEFD vs. angle of elevation at «Badary» station

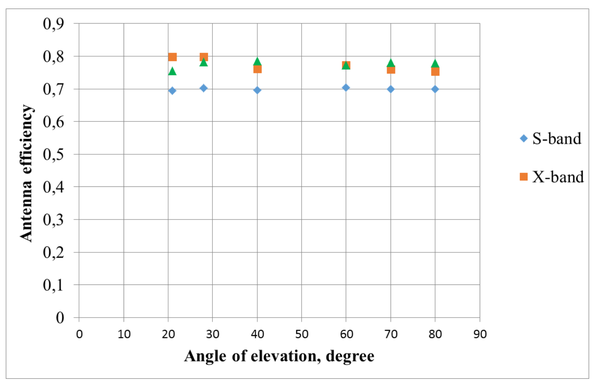


Fig.7 Antenna efficiency vs. angle of elevation at «Badary» station

Measurement results of the parameters of the RT-13 radio telescopes at 60° elevation angle at «Badary» and «Zelenchukskaya» stations are presented at tables 2 and 3.

Table 2. Measurement results of the parameters of the RT-13 at «Badary» station

| Band | *T*rec, K | *T*sys, K | SEFD, Jn | Efficiency | Beamwidth $\Delta\theta_{0,5}$ | Sidelobes, dB |
|---|---|---|---|---|---|---|
| *S* | 21 | 38 | 1100 | 0,7 | 34' | -13 |
| *X* | 17 | 27 | 730 | 0,78 | 10' | -14 |
| *Ka* | 47 | 67 | 1740 | 0,78 | 2'30" | -13 |

Table 3. Measurement results of the parameters of the RT-13 at «Zelenchukskaya» station

| Band | *T*rec, K | *T*sys, K | SEFD, Jn | Efficiency | Beamwidth $\Delta\theta_{0,5}$ | Sidelobes, dB |
|---|---|---|---|---|---|---|
| *S* | 24 | 40 | 1120 | 0,7 | 36' | -12 |
| *X* | 18 | 30 | 770 | 0,8 | 10' | -13 |
| *Ka* | 48 | 70 | 1890 | 0,75 | 2'30" | -13 |

## References

[1] *Khvostov E., Chernov V., Evstigneev A., Evstigneeva O., Ivanov D., Ipatov A., Ipatova I., Lavrov A., Mardyshkin V., Pozdnyakov, Vekshin Y., Zotov M*. The S/X/Ka receiver system for radio telescope RT-13 of Quazar VLBI Network // EVN -2016, St. Petersburg, 2016.

[2] The noise temperature measurement technique of the radio telescope receiving system of the two-element radio interferometer on collocation sites by working standard noise temperature unit KSK RSHT // IAA RAS, FSUE "VNIIFTRI", 2015.

[3] *Reid M. S.* Low-noise systems in the deep space network // Wiley, February 2008.

[4] The measurement technique «Investigation of characteristics of radio telescope RT-13 IAA RAS in the S, X and Ka bands on two circular polarizations // IAA RAS, IRE ANAS, 2014.