Calibration of a three-band microwave radiometric system by an external noise signal source

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**Abstract.** The article considers a method of solving the problem of calibration of a tri-band microwave radiometric system by an external source of noise signal. The peculiarity of the given method of calibration is the location of the calibrated noise signal source in the base of the common antenna mirror with reception to the common aperture of the system's illuminator. The questions of technical realization of a noise source as a broadband noise generator taking into account frequency dependence of output noise power value supplemented by an attenuator for obtaining a two-level calibration signal are considered. In article the theoretical positions underlying the given way of calibration in values of measured radio-luminous temperature are resulted, and time dependences of measurements of radio-luminous temperature of atmosphere are shown at an antenna direction in a zenith with inclusion of an external source of a noise signal at performance of calibration of microwave radiometric system.

1. **Introduction**
In systems of microwave radiometric remote sensing of the atmosphere, an important issue determining the possibility of assessing meteorological parameters and making forecasts is the question of selecting the calibration method and method of its implementation [1-3].

In microwave radiometric systems, calibration provides unambiguous correspondence of the output signal level to the value of the radio-noise power of atmospheric emission at the antenna input, characterized by the radio-luminous temperature of the atmosphere.

Known variants of internal and external calibration of microwave radiometric systems. At internal calibration on an input of the receiver "low-temperature" and "high-temperature" sources of a noise signal are periodically connected and parameters of the accepted linear connection of an output signal and antenna temperature are estimated. When performing external calibration of the system it is necessary to ensure the presence of calibrated sources of noise signal in the far zone of the antenna. As a result of external calibration the parameters of the linear relation of the radio brightness temperature at the antenna input and the value of the signal at the output of the radiometric system are determined. The main difficulty in implementing an external calibration is to create full-size calibrated external noise signal sources and to ensure their stability [4-6].
In this work we consider a variant of calibration by the external noise signal of the noise generator, located at the base of the antenna mirror and providing the possibility of rapid assessment of the correspondence of the output signal level of the system to the radio brightness temperature, formed at the input of the horn of the mirror antenna.

2. Theoretical considerations for the method of calibrating a microwave radiometric system by an external source of noise signal located at the base of the antenna mirror

The antenna temperature of a three-band microwave radiometric system with sequential formation of the radiometer input signal in the mirror antenna illuminator is given by the expression [7]:

\[ T_a = (\overline{T}_x (1 - \beta) + \overline{T}_\phi \beta + T_\theta (1 - \eta))k_{obs}, \]

where \( \overline{T}_x \) and \( \overline{T}_\phi \) are averaged values of radio brightness temperature over the region of space, corresponding to the angular area of the main lobe and scattering area of the antenna radiation pattern; \( \beta \) - is the scattering coefficient of the antenna; \( \eta \) - the efficiency of the antenna; \( T_\theta \) - thermodynamic temperature of the antenna; \( k_{obs} \) - transmission coefficient of the antenna emitter in a given frequency range.

The presence of a noise source at the base of the mirror will result in an additional component in the antenna temperature whose magnitude is proportional to the noise temperature of that source:

\[ \Delta T_a = T_u \gamma u k_{obs}, \]

where \( T_u \) - radioburst temperature of the noise signal source; \( \gamma u \) - the coefficient, taking into account noise power reduction at the illuminator input due to spatial radiation divergence, formed by noise signal source.

As a first approximation the coefficient \( \gamma u \) can be estimated by the formula:

\[ \gamma u = \frac{\Theta_{obs}}{\Theta_x}, \]

where \( \Theta_x \) - is the width of the main lobe of the noise signal source antenna; \( \Theta_{obs} \) - part of the angular area of the main lobe of the noise signal source antenna, corresponding to the exposure of the mirror antenna of the microwave radiometric system.

The use of a two-level noise signal source will create two different antenna temperature gains at the input of the illuminator, which is necessary to estimate the parameters of the linear dependence of the system output signal - the steepness of the characteristic S and the initial reference \( U_0 \):

\[ u_a = ST_u + U_0, \]

where \( u_a \) - amplitude of signal voltage at the radiometer's output.

To obtain the calibration characteristic with respect to the measured radio brightness temperature we can consider three output signals:

- an output signal corresponding to the reception of radio-thermal radiation from the direction to the zenith, provided that a sufficiently accurate estimate of the radio-luminous temperature of the atmosphere is possible;
- two differential output signals equal to the difference of the output signals in the presence and absence of noise signal sources when receiving radio-thermal radiation of the atmosphere in the zenith direction.

3. Practical issues of microwave radiometric system calibration by an external noise signal source

The considered variant of calibration by an external noise generator provides the introduction of a noise signal into the path of the reflector antenna of a tri-band microwave radiometric system with the realization of consecutive extraction of input noise signals in three working ranges with central...
wavelengths of 7.5 cm, 3.2 cm and 1.35 cm [8-10]. In the system the reception is performed on a mirror antenna with a diameter of the opening $D = 2400$ mm.

In order to provide input into the antenna-feeder path signal from noise generator to its output is connected a horn with the size of the opening 10 mm, which is set in the hole in the center of the microwave mirror of the radiometric system. To obtain two calibrated samples, the noise signal from the noise generator passes through an attenuator with an adjustable attenuation of 3 dB. Figure 1 shows a schematic diagram and the appearance of the noise signal source and antenna of a three-band microwave radiometric system.

![Figure 1. Antenna of the three-band microwave radiometric system with an external broadband noise signal source: 1 - noise generator; 2 - attenuator; 3 - noise signal source horn; 4 - irradiator of the three-band microwave radiometric system; 5 - three-band radiometer.](image)

As a source of noise signal was used microwave noise generator module on M31305-4. To determine the noise temperature, its relationship with the noise power spectral density level was taken into account:

$$T(f) = 300H(f),$$

(5)

where $H(f)$ is the frequency response of the equivalent noise temperature.

The value of coefficient $\gamma_w$, which takes into account divergence of radiation produced by microwave noise generator was evaluated based on directional properties of the broadband noise source horn and distance from the system mirror base to the three-band irradiator (in the experiment the mirror has 1200 mm radius of opening, and the distance from microwave noise generator horn to the antenna emitter opening is 835 mm).

4. Results of microwave radiometric measurements of radio-thermal radiation of the atmosphere with the introduction of an external noise signal source into the system

To assess the conditions for the implementation of the calibration of the three-band microwave radiometric system were carried out measurements of radio-thermal radiation of the cloudless
atmosphere in the zenith direction at periodic switching of the noise generator, which provides two levels of radio-noise signal power differing by 3 dB.

The obtained results of measurements in the values of radio brightness temperatures are shown in figure 2.

![Figure 2](image)

**Figure 2.** Results of measurements by a three-band microwave radiometric system of cloudless atmospheric radiation when performing calibration by an external noise generator.

The results of measurements of the three-band microwave radiometric system are shown in Figure 2 in the values of radio brightness temperature when calibrated by the external noise signal of the broadband noise generator when receiving radio thermal radiation in the zenith direction.

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**Conclusion**

The obtained results of the research have shown the principal possibility of implementing the calibration of the three-band microwave radiometric system by the radio noise emission of an external broadband source - noise generator simultaneously in the three working ranges when receiving on a common mirror antenna irradiator with subsequent frequency separation of the signals of two polarizations.

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