International Journal of Engineering Applied Sciences and Technology, 2018
Vol. 3, Issue 1, ISSN No. 2455-2143, Pages 1-5
Published Online May 2018 in IJEAST (http://www.ijeast.com)

THE THEORETICAL RESEARCH METHODOLOGY OF METROLOGICAL PARAMETERS OF UNIVERSAL SPECTRAL RADIOMETER

Ruben Asatryan
Dep. of Theoretical Metrology
National Institute of Metrology
Yerevan, Armenia

Norayr Khachatryan
Dep. of Theoretical Metrology
National Institute of Metrology
Yerevan, Armenia

Hamlet Karayan
Department of Physics
Yerevan State University
Yerevan, Armenia

Abstract - **The creation of optoelectronic devices and systems with the best metrological parameters that enable the operational analysis of basic physical and environmental parameters, and distant monitoring of the atmosphere and air infrared environmental control of vast forest spaces (for detection of fires in the early stages of their development) and pipelines of natural gas is a very important task. The present work is devoted to presenting the results of research and development work on the development of metrological providing methods and theoretical research of metrological parameters of developing by us universal spectral radiometer "USR-A", for the purpose of spectral and radiometric studies of atmospheric and thermal objects ecological parameters in the wavelength range from 0.4 to 14 microns. "USR-A" is intended to measure the spectral density of the brightness and radiation temperature (or drops) of point and extended sources of infrared radiation in the laboratory and field conditions, as well as for remote spectral analysis of hot gas facilities.**

Keywords - **Universal infrared spectral radiometer, metrological parameters. Thermal objects, ecological parameters.**

I. INTRODUCTION

Currently sharply increased interest in environmental issues, which is primarily due to the ever-increasing contamination of the environment.

According to the latest data on the study of atmospheric pollution in industrial developed countries [1-4] the main sources of pollution are industrial and energy facilities and transport, which accounted for over 80% of the total amount of pollution. The major components of air pollution are gaseous compounds of carbon, nitrogen and sulphur, as well as solid and liquid aerosol formation, which are of particular concern for the normal functioning of humans and other biological objects [5-6].

Significant contamination of air space and its devastating effects on human health, climate and vegetation is also due to macroscopic leaks (or sometimes emissions) of natural gas pipelines and extensive fires, particularly forest areas.

In ecological researches of a terrestrial atmosphere, rather great value measurements of quantity water vapour and carbonic gas in an environment have. On the basis of the experimental data received on measurements of a spectral transparency of atmosphere in the wave lengths from 2.5 up to 5.5μm where there are strong band of absorption water vapour (on 2.7μm) and carbonic gas (on 4.3 μm), and with the help of existing empirical dependences between a spectral transparency and quantity of absorbing molecules it is possible to determine concentration H_2O vapour and CO2 on a site of measurements.

The study of gaseous components in the atmosphere plays a significant role in the sphere of ecological researches. One of main tasks of environmental control is the spectral study of chemical composition of atmosphere pollution, as well as analysis of gaseous outbursts of either industrial processes or ground transport

Important value has also distant measurements of radiation temperatures of point and extended sources of thermal radiation in an industry and in atmosphere.

Therefore, the creation of optoelectronic devices and systems with the best metrological parameters that enable the operational analysis of basic physical and environmental parameters, and distant monitoring of the atmosphere and air infrared environmental control of vast forest spaces (for detection of fires in the early stages of their development) and pipelines of natural gas is a very important task.

The present work is devoted to presenting the results of research and development work on the development and manufacturing of optical-electronic instruments for environmental purposes to explore the basic physical and ecological parameters of the atmosphere, as well as monitoring forest spaces and main gas pipelines.

II. Universal Spectral Radiometer

For the purpose of spectral and radiometric studies of atmospheric and thermal objects parameters in the wavelength range from 0.4 to 14 microns, we have developed and manufactured a universal spectral radiometer “USR-A”, a detailed description and principle of operation is presented in [7-8].

“USR-A” is designed to measure the spectral density of the brightness and radiation temperature (or drops) of point and extended sources of infrared radiation in the laboratory and field conditions, as well as for remote spectral analysis of hot gas facilities.

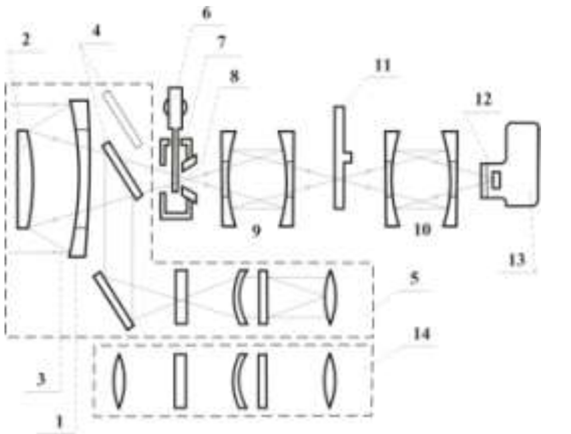

Fig. 1. OMB Optical Scheme:1-Primary mirror lens; 2-secondary mirror lens; 3-radiation from the object; 4-retractable flat mirror; 5-sight; 6-modulator; 7-bearing cavity; 8-field stop; 9,10-projection lens; 11-disk interference filters; 12-sensitive area of the photo detector; 13-dewar of liquid nitrogen; 14-visual tube

Structurally spectroradiometer made up of two parts: optical-mechanical (OMU) and the electronic control unit (ECU). The electrical connection between the units is by means of cables. Full spectral range of the instrument is covered by three sets of interchangeable filters and photo detectors sub bands: from 0.4 to 1.1 microns from 2.5 to 5.5 microns and from 8 to 14 microns. Optical scheme OMU is shown in Fig.1.

An Electronic Control Unit constructively desktop performance: all organs and display controls are located on the front of the ECU. We note some of the benefits we developed IR spectroradiometer "USR-A" as compared to the existing close analogues (see for example [9]). To extend the functionality of spectral studies of thermal objects, except for the broadband interference filters for spectral regions from 0.4 to 1.1, from 2.5 to 5.5 and from 8 to 14 mm, the device is also provided with the ring tuneable optical filters [10].

In order to eliminate chromatic aberrations in the optical system of the device includes two pairs (Fig. 1) mirror projection lenses, in the focus of which are installed filters and photo detectors tipple.

At the end of this section, we note that after some design improvements in the optical system spectroradiometer "USR-A" (adding the input deflecting mirror) in [11] described in detail the method of air environmental control of forest spaces and gas main pipelines.

III. Methodology of Metrological Attestation and The Metrological Characteristics of a Universal Spectroradiometer “USR-A”

On the metrological attestation appears the spectral radiometer “USR_A”, intended for measuring of radiation temperature of the infra-red (IR) sources, and also for the distant ecological control (infra-red monitoring) of environment.

1. Metrological Characteristics to Determination During Attestation

During the realization of metrological certification of the radiometer “USR-A”, must be certain following metrological parameters, indicated in Table 1.

Table 1: Basic Metrological Parameters of the “USR-A”

Name of Metrological Parameters and Measuring Unit	Basic Value	Possible rejection	Note
Working spectral regions, μm			Providing by Spectral Filters
I Channel	0,45 – 1,1	10%	
II Channel	2,5 – 5,5	10%	
III Channel	7,9 – 13,5	10%	
Field of View, mrad, no more			
I Channel	4	10%	
II Channel	4	10%	
III Channel	4	10%	
Difference of radiation temperatures, Equivalent to noise, ΔT_{eqN} ^{o}C			
II Channel	0,5	10%	
III Channel	0,5	10%	

Range of measureable radiation temperatures, ^oC II Channel III Channel	 from $5\Delta T_{eqN}$ to 45^oC		
Basic absolute error of measuring difference of radiation	Temperatures at level $(20\pm5)^oC$		

2. *Facilities of Meteorological Attestation*

During realization of metrological attestation of "USR-A" radiometer, must be applied the facilities indicated in Table 2.

Table 2. List of metrological attestation facilities

Name of measuring facilities	Type	Basic normative characteristic
Metrological measuring complex	MMC-0,3 – 15	Measuring spectral range from 0,3 to 15 mkm
Model ABB	AGA – RS – 10	Range of the reproduced temperatures from 289 to 373 K
Voltmeter	B7 – 23	Measuring limits from 10mV to 1000V
Table turning	TT – 630	Corner of turn $\pm10^o$, through 1
Line instrumentation		

3. *Conditions of Realization of Metrological Attestation*

- Temperature of the air - (293±5) K, $(20\pm5)^0C$;
- Atmospheric pressure - from 84 to 104,6 kPa;
- Relative humidity - (65±15)%;
- Voltage of feed-in network - (220±22)V;
- Frequency of feed-in network - (50±0,5)Hz.

4. *The Metrological Characteristics of a Universal Spectroradiometer "USR-A"*

Metrological attestation was conducted in accordance with the universal spectroradiometer specially designed program of (AEL2.807.007PMA, [12]). In metrological evaluation determined device characteristics shown in Table 3. In carrying out metrological attestation spectroradiometer "USR-A" to apply the necessary instrumentation and equipment referred to in [12]. Measurements to determine the difference between the radiation temperature equivalents to noise $\Delta T_{eq.N}$, performed with the setup diagram of which is shown in [12]. Value of noise equivalent temperature difference determined by the formula: $\Delta T_{eq.N} = U_N/K_{\Delta T}$ was found to be 0.05 within ± 10%.

To determine the basic error of measurement of radiation temperature difference Spectroradiometer, on the installation of attestation established blackbody temperature in the range of 288 to 298 and in increments of 1^0 K, five times the output signals of the device checked.

The standard deviation of the measurements was determined by the formula:

$$S_{Usr} = \sqrt{\frac{\sum_{i=1}^{n}(Usri - Usr)}{n(n-1)}}$$

Reduced error in the measurement of the difference between the spectroradiometer radiation temperatures was within ± 15%.

Table 3: Metrological Parameters of the Equipment "USR-A"

Name of Metrological Characteristics and Measuring Unit	Nom. Values	Permissible Declinations	Comment
Working spectral regions, µm I Channel II Channel III Channel	 0.40-1.1 2.50-5.50 7.9013.5	 10% 10% 10%	Providing by Filters
Field of View, mrad, no more I Channel II Channel III Channel	 3 3 3	 10% 10% 10%	
The difference in noise-equivalent radiation temperatures, ΔT_{eqN} K, no more than: II Channel III Channel	 0,05 0,05	 10% 10%	
Summary reduced			

measurement error of the temperature difference between the radiation range of 0.5 to 20^0 at the level 293 ± 5^0 K, no more than:			
II Channel		15%	
III Channel		15%	

IV. Infrared Monitoring of Large Forest Space and Gas Main Pipelines (GMP)

The IR radiometer is mounted in the helicopter [11,13] and, with the help of a deflecting plane mirror, by its field of vision scans (through the bottom hatch, along the helicopter motion routing) terrestrial surface of large forests, see Fig. 2.

Fig. 2: Helicopter IR scanning of large forests

In the presence of fire hearths the radiation temperature in this region (within the wavelength range of 2.5 to 5.5 µm considerably increases that is registered by the electronic control unit.

Fig. 3: Helicopter IR canning of GMPS

At the helicopter flight altitudes of 200, 500 and 700 m the radiometer covers, with its field of vision, surface areas of about 120, 750 and 1500 sq.m, correspondingly.

The IR radiometer scans the Earth's surface along the GMPs routes within its field of view through the bottom hatch. If there are macroscopic gas leaks in this region, the radiation temperature (in the wavelength region 8–14µm) drops significantly [14] and is recorded by the ECU.

At helicopter flight altitudes of 200 and 150 m, the radiometer fields of view on the ground encompass surfaces with radius of ~6 and ~2.5 m, respectively, see fig. 3.

With the helicopter speed of 150-200 km/hr the time of one measurement cycle is 0.1 sec.

V. CONCLUSION

The developed optical-electronic systems offer the possibility of remote sensing of physical and environmental parameters of the atmosphere and IR sources. The experimental results of the metrological characteristics developed devices confirm the high accuracy of the measurements.

The developed method of infrared air monitoring can be widely used for remote environmental monitoring forest spaces and natural gas main pipelines.

Mobile version of the complex created instruments can be used successfully for the rapid assessment of physical and ecological state of the atmosphere, as well as for the distant researches of thermal objects.

Application of the given method of remote ecological monitoring of vast forest spaces and extended gas pipelines will undoubtedly bring to the considerable technical-economical effectiveness and will also have a great importance in the problem of preventing the fire occurrences, especially of large-scale ones, and also will be imported in solving the problem of monitoring atmospheric pollution from natural - gas emissions.

VI. REFERENCE

[1] S.M. Musaelyan, the Problems of Clean Air. -Yerevan: Armenia, 1985 – 225 p.

[2] A.G. Bannikov, A.K. Rustamov, the Nature Conservancy. Second ed., Rev. and add. - M. Agropromizdat, 1985 – 287 p.

[3] O.S. Owen, Protection of Natural Resources / Transl. from English. - Moscow: Kolos, 1977-416 p.

[4] Y.T. Feldman, Hygienic Evaluation of Motor Vehicles as a Source of Air Pollution. - M., - 1975, – 187 p.

[5] Laser Monitoring of Air Pollution: SO2, NO2, Ozone, Benzene, Toluene and Aerosols.- ELIGHT, Laser systems, GmbH, Berlin. - 2000.

[6] A.A. Popov, S.V. Kachin, Computerized Analytical Systems for Environmental Monitoring.- Devices and control systems. 1994 - № 9 –p. 15-17.

[7] R.S. Asatryan, R.A. Epremian, H.G. Gevorkyan and others, Universal Infrared Spectral Radiometer. - Intern. Journal of IR and MM Waves.-2003-V.24, № 6–p. 1035-1046.

[8] R.S. Asatryan, Yu.A. Abrahamyan, H.G. Gevorkyan and others, IR Spectral Method of Monitoring the Industrial Gas Ejections in Atmosphere. - Dubai Intern. Confer. on Atmospheric Pollution: 21-24 Feb 2004 - Dubai, UAE-2004.-Proceed. –p. 134-139.

[9] Dual Channel Radiometer - Patent Internationally U. S. Pat. 3476914.-1998.

[10] Ring Price filter for Tunable Optical Spectral Range from 1.8 to 5.6 Microns- OST-5683- 84.

[11] Ruben S. Asatryan, Hamlet S. Karayan, Norayr R. Khachatryan. Air Infrared Radiometer, (2016), Journal of Scientific and Engineering Research, 3(2), 187-192.

[12] R.S. Asatryan, Development and Manufacturing of Infrared Spectroradiometer "Wedge". (1987) – Report R & D (final) p/ya- A-1376: № 4115-DSP, Erevan. 143 p.

[13] R.S. Asatryan, N.R. Khachatryan, H.S. Karayan, (2015), “On the Method of Distant Infrared Monitoring of Forest Spaces and Gas Main Pipelines, American Research Journal of Agriculture, Vol.1 Issue 2, April :Page, 1-6.

[14] Shilin, B.V. and Molodchinin, I.A.,(1992) Kontrol’ sostoyaniya okruzhayushchei sredy teplovoi aeros” emkoi (Monitoring of Environment by IR Aerial Survey), Moscow: Nedra, Pages 186, (in Russian).