

MR170 type IR Radiometer Calibration Technology

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Abstract. Infrared radiometer measuring experiment, infrared radiometer calibration is extremely important part, which determines the correctness and accuracy of infrared radiation characteristics of the background and objectives of the radiometer measurements. Article first introduces the necessity of an infrared radiometer and infrared radiometer calibration, focusing on the MR170 type IR radiometer calibration method for analysis. Experiments using cavity blackbody radiation as a standard, and then analyzed using MATLAB to fit the measured data to obtain the desired curve fitting and fitting function. Finally, the article summarizes the experimental and analytical precision experiments.

Introduction

Temperature is higher than the thermodynamic nature of all zero (i.e., absolute zero) objects are in the form of electromagnetic waves to the outside radiation energy , the radiation including a wavelength , wherein the wavelength range between 0.75-1000 μ m called infrared light . Usually visible radiation mainly from the high-temperature radiation source , and all objects at room temperature, low temperature or after heating are present infrared radiation. Infrared technology as a typical dual-use technology, which has been widely used in military, paramilitary, medical, energy, industry, agriculture, and other technologies play an irreplaceable role. Nearly 40 years of the most rapidly developing infrared technology, this is one of today's high-tech focus of the study countries , to some extent in terms of infrared technology marks a country's military and technological strength[1-3].

Measuring the infrared radiation characteristics precisely in order to accomplish the latter part of the background and objectives, you must first select the appropriate infrared radiometer, followed must accurately grasp the characteristics of the infrared spectrum radiometer. Master performance radiometric system is correct and fundamental prerequisite to ensure the radiation measurements, otherwise it will be ignored when the actual measurement of the results of some influential factors may eventually lead directly to the failure of the experiment. Radiometer calibration is a complex task, independent of the characteristics of the radiation source calibration values radiometer, and blackbody radiation and environmental factors associated with it. In this paper, the radiation response function to express calibrated infrared radiometer , and get all the required parameter values . Proper calibration of infrared radiometer directly affects the latter goal source emission rate, and therefore solving the infrared radiometer calibration, spectral energy to solve energy and other radiometer measurements are extremely important part.

2. Radiometer Introduction

Infrared spectroscopy is used to measure objects radiometer radiation flux instrument, usually generated by narrowband radiated monochromator and measuring the radiation power radiometer components. Development of infrared spectroradiometer experienced prism spectra radiometer , grating spectral radiometer , CVF infrared spectrum radiometer , more of these types of radiometers are belong to the traditional spectral radiometer . However, with the rapid development of infrared radiometer is used widely and science and technology, the traditional spectral radiometer difficult to meet our needs. Since the 70s of last century, they have appeared in a circular gradient filter infrared radiometer and Fourier transform infrared spectroscopy radiometer. Fourier transform infrared spectroscopy radiometer is based on the dual-beam interference , and the use of the mathematical principles of the Fourier transform of the spectral radiation measuring instruments to

achieve this type of radiometer has now been widely used[4].

Radiometer is generally related to the period from the front of the optical system, chopper amplifiers, infrared detectors and signal acquisition and other components. Chopper located before the entrance slit of the monochromator, the effect is to reduce interference to the surrounding background radiation measurements. In order to ensure the reception area and the infrared detector imaging optical system of the same size, generally on the focal plane of the detector unit pre-card system. Output signal modulated input signal processed by the amplifier to obtain high SNR, the signal is then digitized by the post-acquisition data processing corresponding to the computer through the serial interface output. Infrared radiometer signal processing diagram shown in Figure 1:

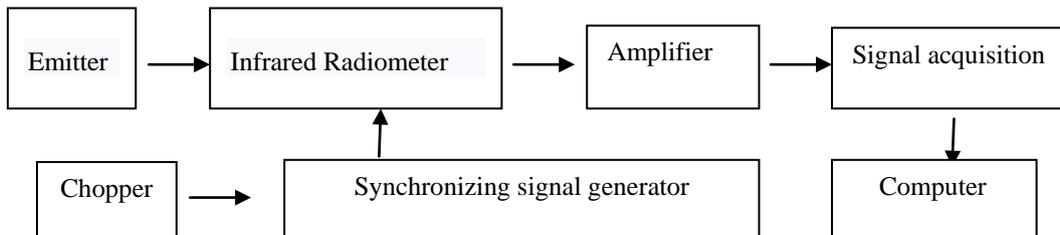


Figure 1: Schematic radiometer signal

The calibration of the test object for MR170 infrared spectral radiometer, ABB Bomen produced by the United States, the radiometer has WAMDII wide angle Michelson interferometer design structure, portable measuring instruments for remote sensing spectral characteristics of technology, its high resolution and the scanning speed and other characteristics also makes the radiometer occupy a leading position in the industry. This type of scanning radiometer rate of 31 times / sec, the available spectrum ranges 2-13.5 μ m. MR170 infrared spectroradiometer has indium antimonide (InSb) and mercury antimony (MCT) two liquid nitrogen cooled detectors, and with manual iris can be connected to a laptop computer. IR spectral radiative properties MR170 radiometer can be used to measure the warships, tanks, aircraft, and other targets of infrared decoy and a smokescreen infrared spectral transmittance. Which either automatically track the moving target and the rotary table is measured, and can be placed on a tripod on a fixed target is measured. This type of infrared radiometer has numerous advantages, so many in the international aerospace research has been widely used.

3. Radiometer calibration method

IR radiometer calibration has become an important part of modern radiation measurement technology. Known radiation source used for the calibration is called calibration source, under normal circumstances, the standard blackbody calibration source is a radiation source. Blackbody radiation, also known as full-body black body is widely used in the long-wave infrared radiation detection system of absolute calibration[5]. Currently widely used as a standard blackbody radiation calibration program, and its calibration accuracy is generally less than 8%. Because area blackbody radiation plate and the standard temperature uniformity is difficult to ensure, so experiment chosen cavity blackbody radiation as a standard infrared radiation on the MR170 calibrated spectral radiometer[6-8]. The traditional blackbody calibration generally indirect measurement, i.e. known blackbody emissivity ϵ and blackbody temperature T after the set is calculated based on Planck formulas absolute blackbody radiance[9]. MR170 infrared radiometer for calibration, the main purpose is to determine the relative spectral response of the model radiometer, and get their spectral response range. Relative spectral response is the radiometer receiving different wavelengths when irradiated with light, with the change of the wavelength, the response rate of the case of infrared radiometer consequent change is a function of the relative response of the detector and the incident wavelength.

Usually based on the size of the field of view and focal distance of the detector, the calibration method is divided into: small remote source method, a source close to the small point source

method and distance method. Remote source method is generally applicable to a small field of view detector angle is less than 10mrad, while focusing distance radiometer tens of meters away. Blackbody calibration source at the surface of the opening angle of the radiometer is usually greater than four times the detector field of view radiometer usually focusing to infinity, the use of remote -point source method in this case. When the field radiometer angle greater than 10mrad, calibration method using a source close to the small infrared radiometer . In the experiment, usually close to a small source method, because the use of a small source close to the existing law under laboratory conditions to be calibrated radiometer is usually more accurate. Use radiometer radiation source, measured spectrum includes not only the radiation spectrum of the measured object, further comprising a spectral surroundings, radiometer heat spectroscopy . Before the use of radiation measured object field experiments usually require calibrated radiometer. Radiometer calibration purposes is standard using the appropriate equation for a radiation source (black body) parameters were calculated. Calibration of radiation can be divided into three types: the spectral radiance calibration; spectral irradiance calibration; spectral radiant intensity calibration. Spectral radiance referred radiance refers to a unit solid angle per unit area of the object for each wave number of the radiation power, Unit is: $W/cm^2 \cdot sr \cdot cm^{-1}$; Irradiance per unit area refers to the wave number of the radiation power . Unit is: $W/cm^2 \cdot cm^{-1}$; Spectral radiation intensity refers to the object in the radiation power per unit solid angle of each wave number, Unit is: $W/sr \cdot cm^{-1}$.

3.1 Target source full -field radiometer

In the calibration, when the target source is full field of view of the radiometer, if the response of the detector is the radiation intensity varies linearly , then for a given frequency , between the radiation source and the detector intensity measured intensity exists a linear relationship . This relationship can be expressed as:

$$M = a_0 + a_1 \times L \quad (1)$$

In the formula: M is radiometer radiation intensity measured; a0 is infrared radiometer itself or dark current offset value caused; a1detector responsivity; L is Brightness values of black body radiation. If the known value of the blackbody temperature, the blackbody radiation luminance value ,Lt can use the Planck Law get the result. The Planck Law:

$$L_t = \frac{\varepsilon}{\pi} \int_{W^*} C_1 \lambda^{-5} \left(e^{C_2/(\lambda T_b)} - 1 \right)^{-1} d\lambda \quad (2)$$

In the formula: ε is blackbody emittance; W^* is Integral band; T_b is Blackbody temperature; C1 and C2 are the first and second infrared radiation constant .
 $c_1 = (3.7415 \pm 0.0003) \times 10^8 (W \cdot m^{-2} \cdot um^4)$, $c_2 = (1.43879 \pm 0.00019) \times 10^4 (um \cdot K)$.

If the above obtained correlation value, the spectral emissivity of the radiation source of any can also be obtained by the following formul :

$$L = (M - a_0)/a_1 \quad (3)$$

3.2 Target source is not filled field radiometer

When the calibration source is not full when the target field radiometer, if the response of the detector is the radiation intensity varies linearly, but the target source is not filled field radiometer , and the use of the background , then the following linear relationship :

$$M = a_0 + a_1 \times k \times L + (1 - k) \times M_B - a_0 \quad (4)$$

In the formula: MB is background intensity; K is field fill rate. Area of the detector field of view of the area ratio of the measured object, The formula is as follows:

$$K = \frac{AT}{AF} \quad (5)$$

In the formula: AT is Target detection coverage; AF is field of view coverage, field of view coverage of general formula:

$$AF = \pi \left(\tan\left(\frac{\theta}{2000}\right) R \right)^2 \quad (6)$$

In the formula: θ is radiometer detector probe angle field of view; R is distance from the radiation source and the detector. Experiments are usually based on the observation lens to see the target source is full field of view, and then select the appropriate mathematical model calibration.

4 Radiometer Calibration examples

MR170 type IR radiometer with two detectors indium antimonide (InSb) and mercury antimony (MCT), Both detectors measure different infrared wavelengths, indium antimonide (InSb) detector is generally used to measure the 3-5 μ m waveband of infrared radiation, mercury and antimony (MCT) are generally used to measure the 8-14 μ m waveband infrared radiation. Generally the higher the temperature of the object, its low-band infrared radiation energy is relatively strong. Instead a relatively lower temperature of the object, the higher its high energy infrared radiation band . Therefore, according to the measured object temperature ranges use different detectors. For example, when the late fighter skin measuring infrared radiation energy spectrum , generally used in MCT detector , because aircraft in flight status tail skin temperature far below the temperature of the nozzle and plume , so measuring the skin 's energy field generally used mercury antimony (MCT) detector when distribution. For example, when the late fighter skin measuring infrared radiation energy spectrum , generally used in MCT detector , because aircraft in flight status tail skin temperature far below the temperature of the nozzle and plume , so measuring the skin 's energy field generally used mercury antimony (MCT) detector when distribution.

At room temperature 27 °C, relative humidity of 40% of the indoor environment, the calibration distance of about 0.5m, according to the requirements of a blackbody source is set to 5 temperature points (333K, 353K, 393K, 443K, 493K). In order to reduce the error introduced by the black body temperature shift, the black body temperature was raised to a temperature value after the tone to wait 30 minutes before measurement experiments. Measuring each temperature blackbody output value - when degree of radiation emitted, the temperature needs to be 3 times the test point , and taking the average of three tests and record the following table . Experimental data are as follows:

Table 1: MCT calibration experiment data of reddetector

Blackbody temperature K	Blackbody radiation brightness values W/cm ² · sr · cm ⁻¹	MCT detector output value W/cm ² · cm ⁻¹
333	61.47	696.71
353	77.92	866.08
393	121.80	1342
443	190.92	2194.55
493	269.92	3323.66

According to the experimental data obtained using the least squares method for blackbody radiation measured brightness and energy values obtained by fitting analysis, the graph shown in Figure 2 . Fitting function as : $M=12.57L-129.96$, the responsivity of detector is 12.57 , Offset

value of the radiometer is 129.96.

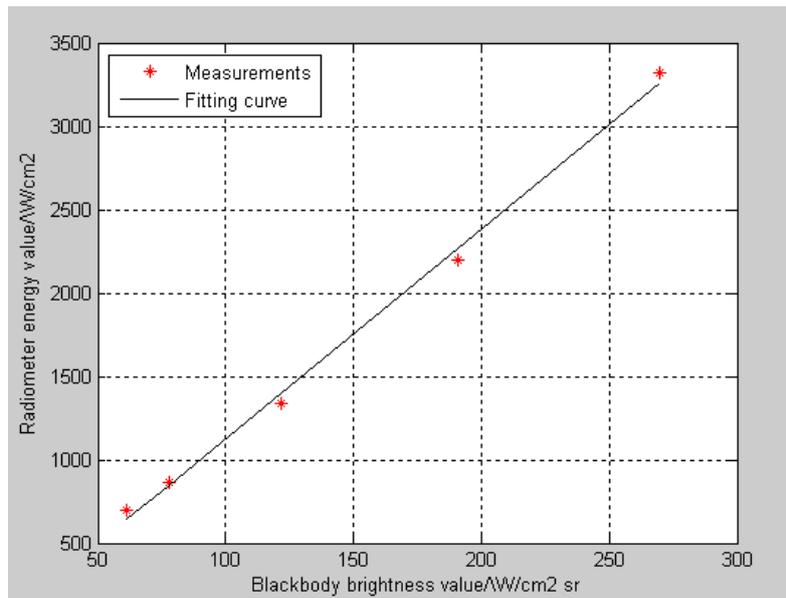


Figure 2: is based on the brightness of the least squares method for blackbody radiation was measured energy values of the fitted curve

5 Conclusion

This paper presents the experimental IR radiometer calibration method, and the data fitting analysis, finally got the fitted curve, and the corresponding fitting function. In fact the experiment will be some error, error sources are: (1) The temperature of the experimental error cavity blackbody radiation source used; (2) MCT detector spectral errors caused by unevenness; (3) Laboratory atmospheric disturbance factors such as background radiation error. By the corresponding calculation MR170 infrared radiometer spectral calibration laboratory accuracy of better than 4% [11-12]. Master performance MR170 type radiometer is the basic guarantee correct radiometric measurements, otherwise it will ignore some of the factors affecting the results in the actual measurement experiments; or with the same amount of the same measurement system under different measurement conditions, might get quite different results. The laboratory personnel do not know why, it is difficult to determine the accuracy and usability of the measured data, resulting in failure of the measurement, and thus need to re-test. In this paper, MR170 infrared radiometer calibration method can learn to calibrate other related spectrum system, with a wide range of practical applications of calibration study has its significance.

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