Materials used for the measurement of the PIR detector in far infrared range

R. Drga, D. Janáčová, H. Charvátová, V. Vašek

Abstract— The work deals with the limitations of parasitic sources of radiation environment in preparing the workplace for measuring the spatial characteristics of PIR detectors in the infrared region. Performs shading measurement sensors and detectors, defines the characteristics of the radiation source, the reflective properties of its surroundings, removes the effect of heat radiation operator.

Keywords— Shielding material, mathematical model, PIR detector, IR radiation, conductivity.

I. Introduction

When measuring the workplace for measuring IR-radiation in the far field measurement PIR detectors were often influence parasitic radiation from various heat sources. The basic configuration is workplace in Figure 1.

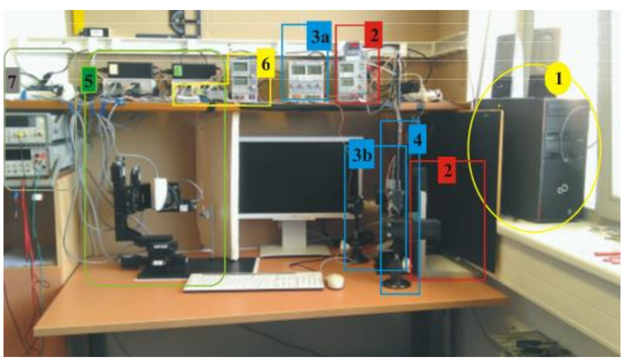

Fig. 1 Workplace for measuring IR radiation in the far field measurement PIR detectors

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On the right side you can see the control one computer on which the operating system Microsoft Windows 7, run applications created with NI LabView environment. This is connected via USB bus with two controllers for motion control positioner, the picture is a group of five devices, which are seen two sources, two control units and each unit go from 3 cables to individual drives the positioner, the unit left is for straight drive movements and rotational movements to the right, for a total of 6 drives.

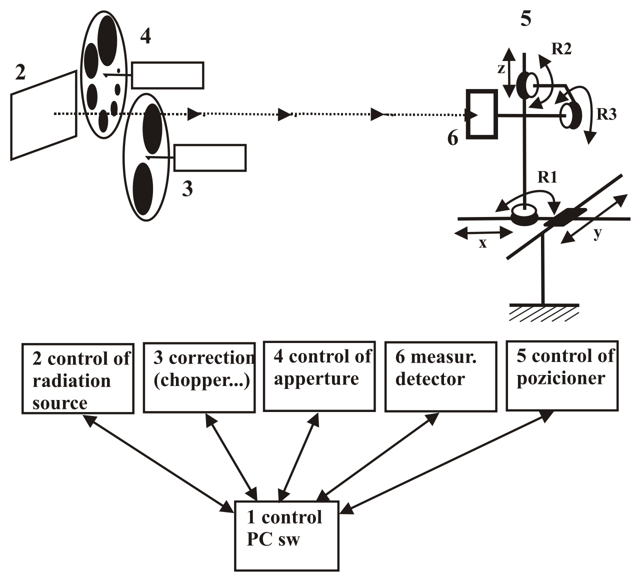

Fig. 2 Hardware concept of workplace

On the positioner is placed detector, whose output goes to the input-output units USB6008, which is on the image located in area 6. With this unit, you can then also control the function of aperture, focus the laser beam scanning and other features. Source 3 is used to control the speed of the chopper, which includes the drive is physically located on a pedestal on the table - the area 3b. In area 4 is located aperture - drive, disc aperture and optical adjusting the position. Area 2 represents the temperature control radiation source 2 (top) and its own Peltier element located down.

The whole workplace can be thought of as illustrated in Figure 2, which is an important source of useful 2 simulating an intruder, then parasitic - unwanted sources of radiation from the chopper drives 3, aperture 5 and positioner 5, as will be mentioned.

II. Methods for the Detection of Spurious Radiation Sources

Any material having a temperature greater than absolute zero (- 273 ° C) emits infrared radiation whose intensity corresponds to the temperature. The diagram in Figure 3 shows the emission characteristics of the body at different temperatures. It is apparent that the body at high temperatures emits a small amount of visible radiation.

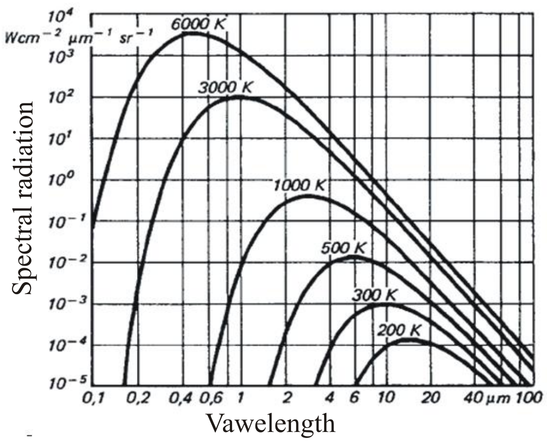

Fig. 3 Blackbody radiation characteristics depending on its temperature

Emitted energy over the full spectral range (area under each curve) increases with the fourth power of the temperature according to the Stefan-Boltzmann law (1) and it is clear that the peak wavelength of radiated energy can be determined by temperature.

$$Q_0 = H_0 \cdot S_1 = \delta_0 \cdot T_1^4 \cdot S_1 \tag{1}$$

where: Q_0 - total radiant flux [W]
H_0 - total intensity of radiation [W/m^2]
S_1 - area of a black body [m^2]
T1 - absolute temperature of the body
δ_0 - Stefan-Bolzman constant 5,67.10-8 [Wm^{-2}K^{-4}]

Characteristics expresses the dependence of the shift, where the maximum value of spectral power densities shifted to shorter wavelengths with increasing temperature emitters - equation (2) which is known as Wien's law.

$$\lambda_{\max} = \frac{b_w}{T_1} \tag{2}$$

where: λ_{max} - wavelength of max.emission [m]
T_1 - temperature of the body [^oK]
b_w- Wien constant, b_w = 2.898 mmK

The spectral density of radiation in this maximum is proportionately fifth power of temperature,

$$W_1 = konst \cdot T_1^5 \ . \tag{3}$$

For the area of IR radiation, wherein the simulated movement of an intruder, a person whose temperature is about 36 °C according to the characteristics set forth in Figure 3 can be deduced that the peak in the region of 10 micron wavelength.

To measure the surface temperature can be two measurement methods:

1. Contact measurement of surface temperatures - useful to define the source of radiation
2. Contactless measurement - suitable for parasitic difficult to define in advance the radiation source

using pyrometer
using IR cameras

III. Spurious Radiation Sources Workplace

Primary sources of workplace transmitting IR radiation, which negatively affect the results of measurements include imaging and display devices, drives the moving parts, elements of design workplace and radiation physical operator workplace. Each of these elements has a direct effect on the response PIR detector, because using the positioner to move parallel to the detector relative to the environment and even static object with a higher temperature can change the radiation incident through the optics to pyroelement.

A. Imagin and indicating equipment

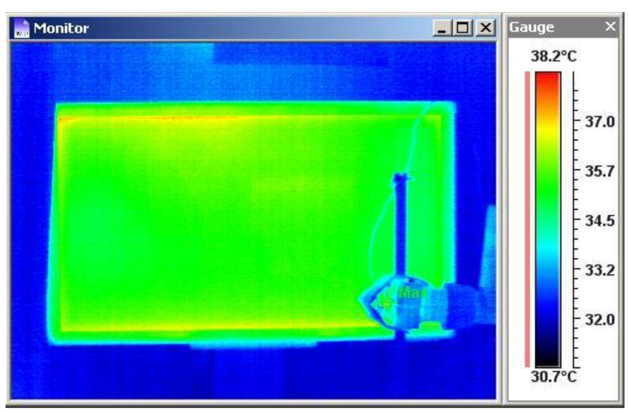

Fig. 4 IR image LCD monitor

B. Drives moving parts workplace

The first version was used to drive the chopper DC motor with gearbox. In Figure 5 it is seen that the temperature in the actuator reaches 34 °C.

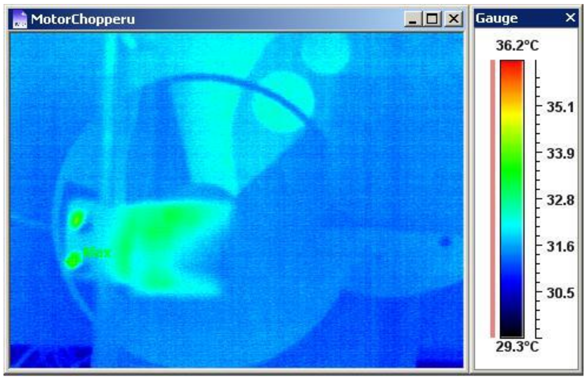

Fig. 5 IR image of the chopper drive

In Figure 6 shows the IR image drives the positioner. This situation is worst of all, because the positioner is placed directly own detector and the radiation source is very close to its own sensor, thus pyroelementu.

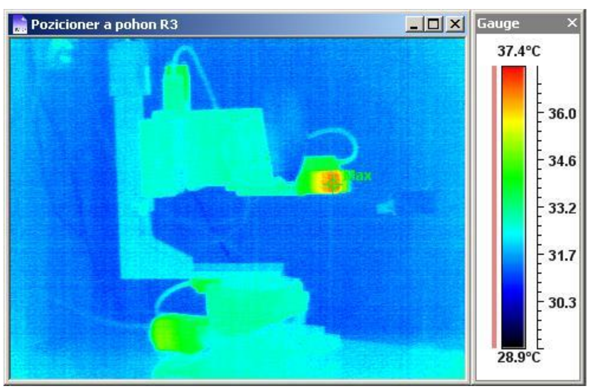

Fig. 6 IR image of the chopper drive

C. Component design workplace

In the defined area around the radiation source - the Peltier element leads to flow of heated air that accumulates in the upper part of the workplace and so heats the design of this source. Here, the temperature reaches 29.4 °C, as shown in Figure 7.

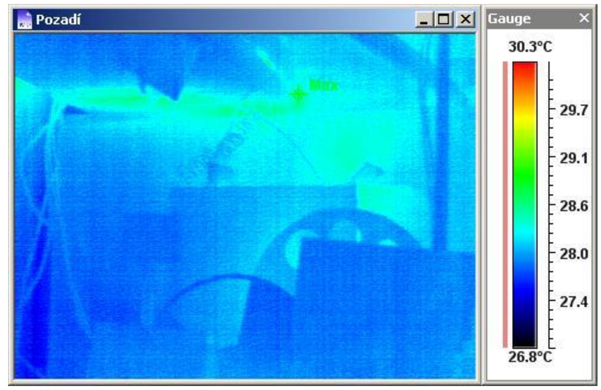

Fig. 7 IR image of construction workplace

IV. Problem Solving of Spurious Radiation Sources

For removal of spurious radiation sources can be used several basic methods:

- relocation of radiation sources outside the workplace
- reduce power consumption of drives
- reduce shielding of radiation sources
- the closure of roads radiation into heat tunnel

A. Moving sources of radiation outside workplace

For drive of the chopper was reduced power consumption own drive using a different type of drive and shading toward the detector. For drives of positioner is not possible to reduce the power consumption, because these drives are realized using stepper motors and they are fed well in the rest position when the shaft does not rotate because they have to ensure the stability and accuracy of the set position, as seen from the structure, presented in Figure 8. Longitudinal drives are marked blue color and red rotary drives.

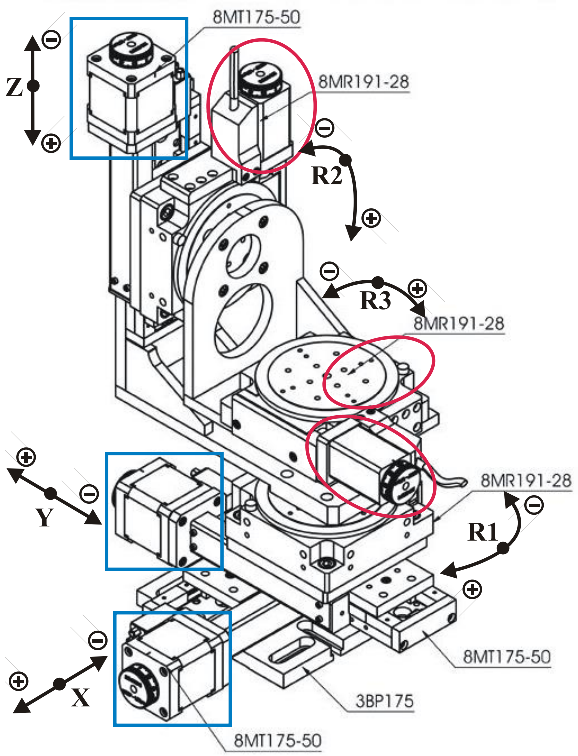

Fig. 8 Construction of positioner

B. Separation operators area and the workplace

For the separation space and operators workplace was used plexiglass, as shown in Figure 9. This material acts as a filter which suppresses IR radiation operators in far area.

Fig. 9 Separation workplace and operator

For the separation of the useful heat radiation from the surroundings proved insulating material Tubex shaped stepped tube, as shown in Figure 10.

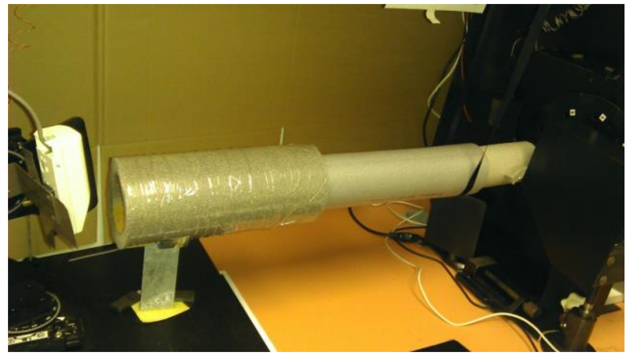

Fig. 10 Separation workplace and operator

C. Shading radiation sources

For shading can be preferably used a few basic materials according to the required functions:

cardboard
galvanized iron sheet
aluminum sheet

These materials are shown in Figure 11 and can be further adjusted by using a surface coating, matte black, thus increasing the coefficient of emissivity.

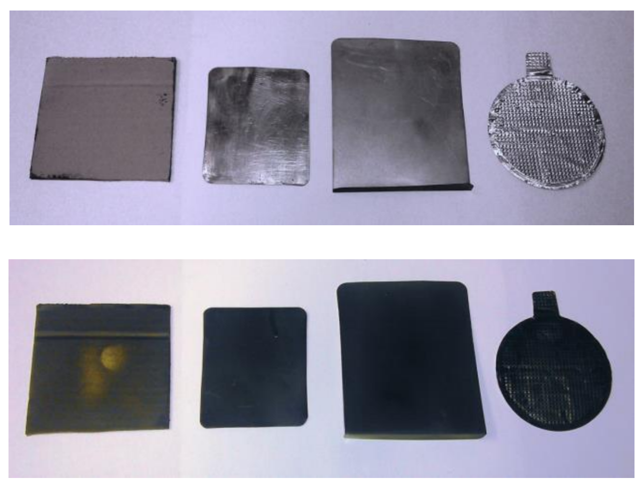

Fig. 11 Materials for shielding radiation sources

To describe the material temperature after the impact of heat radiation come out from equation (4), which defines the intensity of the radiation heat flux q incident on the shielding material:

$$q(\tau) = \sigma.C(T_2^4 - T_1^4)\,. \qquad (4)$$

where: σ - Stefan-Boltzmann constant
C - constant represents emission surface and geometric properties
T_2 - source temperature
T_1 - temperature of the heated surface, in our case the surface temperature of the shielding plate

The equation is then a modification of the relationship that is used to heat radiation.
The heat that hit the surface of the material to spread further conduction, as described in equation (5)

$$\frac{\partial T}{\partial \tau} = a.\frac{\partial^2 T}{\partial x^2}. \quad (5)$$

Apply the boundary condition (6):

$$\lambda\left(\frac{\partial T}{\partial x}\right)_{x=b} = q \quad (6)$$

and the initial condition (7):

$$T = T_p \quad \text{for} \quad \tau = 0 \quad (7)$$

where: b - half the thickness of the sensor
x - direction coordinate

$$\frac{T-T_p}{T_c-T_p} = K_i\left[Fo + \frac{1}{2}\left(\frac{x}{b}\right)^2 - \frac{1}{6} - 2\sum_{n=1}^{\infty}\frac{\cos\left(\frac{x}{b}p_n\right)^{(-Fop_n{}^2)}}{p_n{}^2\cos\ p_n}\right]. \quad (8)$$

where: Ki - Kirpitch criterion
Fo - the Fourier criterion
p - roots of the equation

V. Conclusion

By measuring the temperature of the actuator R3 as shown in Fig 12, wherein the front shading reached maximum temperature 37 °C, after shading the temperature decreased to 28 ºC. It was possible to calculate the amount of heat absorbed partially shielding material. Based on measurements of surface temperatures was possible to compare these values with the calculated temperature of the solved mathematical model. Results varied approximately 2%. It can be said that the mathematical model for the above case is valid.

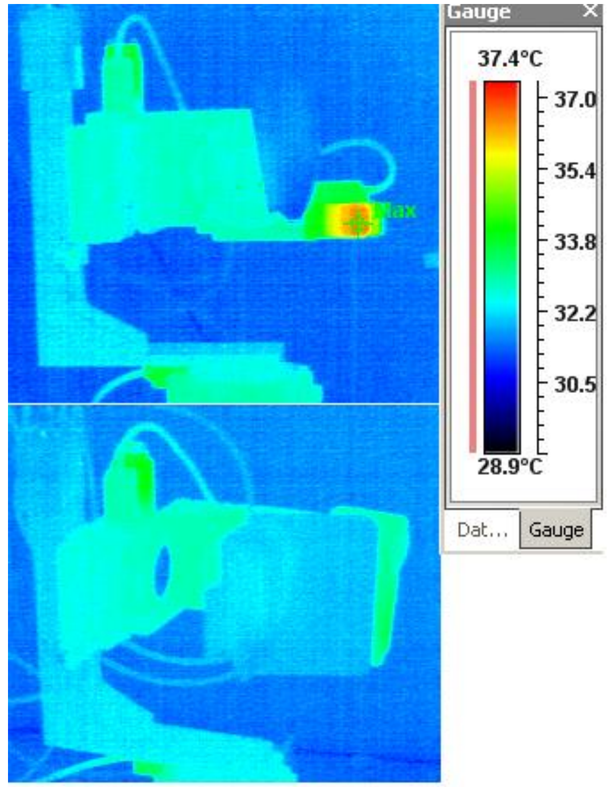

Fig. 12 Comparison of temperatures drive without shielding and with shielding

Using the described methods and materials were implemented workplace, where it was possible successfully to measure the spatial characteristics of the PIR detector. Without the use of these materials and methods of measurement would not be feasible.

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