Thermal Portraits of Objects in the MM and IR Wave Bands

V. A.. Golunov, A.. Yu. Zrazhevsky, Ye. P, Novichikhin, A. P. Chernushich

Institute of Radioengineering and Electronics, Russian Academy of Sciences, Fryazino branch, RUSSIA

Abstract—**The experimental polarized thermal images at the 3.2 mm wavelength and in the IR band obtained for different meteorological conditions are discussed. The dependence of the uprising of the own brightness contrast on the emissivity, wavelength and temperature is determined. The method of colored imaging, showing polarization features of the object is suggested. Moreover, the method of obtaining of polarized stereo pictures on the computer monitor is offered.**

I. The Relationship Between The Emissivity And Brightness Temperature

FOR comparative analysis of the capability thermal vision in MM and IR range it is used the following relation, obtained from Plank's formula:

$$T_b = \frac{hc/k\lambda}{\ln\left[\exp(hc/k\lambda T) + æ_\lambda - 1\right] - \ln æ_\lambda}, \quad (1)$$

where T_b is the brightness temperature, $æ_\lambda$ is the emissivity, T is the thermodynamic temperature, λ is the wavelength, h and k are Plank's and Boltzmann's constants respectively, c is the velocity of light.

The dependences of $T_{я}$ on $æ$ for λ = 1 mkm (curves 1 - 3), 10 mkm (4 – 6) and 3 mm (7 – 9) with different T are presented in Fig 1.

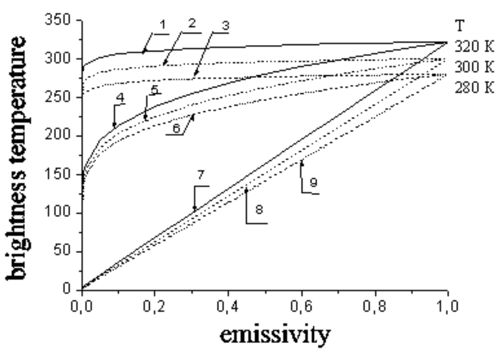

Figure 1.

One can see from the presented figure that the slope of the plot $T_b(æ)$ is significantly determined by the wavelength at $æ > 0.1$. As æ increases from 0.5 to 1.0 the brightness temperature increases by factor 2 at λ = 3 mm, by factors 1.13 - 1.15 at λ = 10 μm and by factors 1.012 – 1.016 only at λ = 10 μm. In IR band the steeply curved plot $T_b(æ)$ is observed at $æ << 0.1$ that is at values corresponding to metals. At $æ > 0.1$ the brightness temperature $T_{я}$ is determined by thermodynamic temperature of the body and dependences $T_{я}$ vs. emissivity is weak.

So, in IR band the brightness contrasts of different objects (excluding metals) are determined by theirs thermodynamic contrasts. On the other hand in the MM wavelength band the brightness contrasts are mainly determined by the difference in their emission coefficients.

The latter gives to radiovision systems in MM band some useful properties in comparison with to radiovision systems in IR band. Namely, the radiovision systems in MM band have possibility of observation and recognition of different objects when thermodynamic contrasts are absent.

II. Polarized Thermal Object Portraits In The MM Wavelength Range.

Polarized scanning radiometer (f = 94 GHz, Δf = 4 GHz) was fixed on the moving platform, providing opportunity of stereo receiving. On the distance 20 m the linear spatial system resolution was not worse than 0.15 m. Polarized radiation features of ground surfaces for different samples (sand, crushed stone, asbestos cement, ceramics, water, polyethylene medley, metal) with almost flat interfaces were investigated experimentally [1].

The tractor trailer was used as a base object of observation A plastic container and different metallic objects were located beside the tractor trailer.

The usage of difference in received radiation on two polarizations (vertical and horizontal) gives us the extra information , which is contained in the sign and value of the signal on the exit of the different polarized channel ([2]).

The polarized difference in contrast was calculated for background and objects, namely $\Delta U = U_v - U_h$, where U is output radiometer voltage, indexes «*v*» and «*h*» designate vertical and horizontal polarization, respectively.

The initial radio images were visualized in black-white palette, and the polarization difference contrast images were transformed into colour pictures by using both red and green. Then the initial black-white images were superposed with colour polarization difference contrast images. After that the couple of original superposed pictures were transformed into one coloured image in YUV – space, which is used in NTSC and PAL systems, as physiologically the most correct colour coding in conditions of limit of the colour information transmission channel [3]. In contrast to RGB model, in YUV model the colour information and brightness are independent values – so they can be defined the next way:

978-1-4244-2120-6/08/$25.00©IEEE.

$$
\begin{aligned}
&Y(x,y) = (\mathrm{Y_h}(\mathrm{x},\mathrm{y}) + \mathrm{Y_v}(\mathrm{x},\mathrm{y}))/2 \\
&U(x,y) = Y_h(x,y) - Y_V(x,y) \\
&V(x,y) = \begin{cases} U(x,y) < 0, U(x,y) \\ U(x,y) > 0, -U(x,y) \end{cases}
\end{aligned} \tag{2}
$$

Where Y_h и Y_v - is the point brightness in horizontal and vertical polarization, agreeably.

Intensities for U and V colors were chosen empirically.

When painting the polarized images it's necessary to take measures for reducing of the influence of possible apparatus and methodical peculiarities of the experiment, which produce mistakes in different polarized image of the object and, agreeably, in its colour picture. An equalizing of zero levels and gain coefficients of channels at the reference elements in the frame were used for image correction. Moreover, limitation of sensitivity of channel of polarized difference was also used by setting the separate thresholds for values U and V.

In the Fig. 2 is shown the result of the presentation in pseudocolour.

Figure 2.

III. The Forming Of Stereo Images

The discovered stability of stereo effect to the nebulosity of the image allows one to apply stereo images in MM band also.

For getting stereo images the method of "glasses with gates" is used. The idea is in alternate showing the pair of stereo images to different eyes. On the screen of the monitor the pictures for the right and the left eye are changing with the high frequency. Simultaneously the corresponding gates on the operator's glasses are opening and closing.

It was created a wireless system of simultaneous observation of the stereo images by a few operators with control from IR port, which realizes the method "glasses with gates". The program was written on C++. For increasing of productivity the optimizing compiler «Intel C++ Compiler for 32-bit Applications» was used. The algorithms were realized, which gives possibility to create the pairs from pictures with shifts in axes, or with different scales and defects.

As a result volumetrical, coloured, radio thermal portraits of objects, adjusted in accordance with peculiarities of the human perception and containing color information about polarized features of the object were observed on the monitor of the computer.

The getting of the polarized stereo radio images, in which the different polarized peculiarities of the object surface are presented in colour, enlarges the possibilities of the Millimeterwave radio vision systems.

In conclusion, the authors thank prof. Sokolov A.V. for continuous interest and attention to the work, the principal engineer Zhulin V.I. and principal programmer Martynova Z.A. for their assistance in experiment realization and in result processing.

Bibliography

1. Zrazhevsky A.Yu., Golounov V.A., Smirnov M.T., Novichikhin Ye.P., Loskutov B.S., Yermakov D.M. " The polarized radio thermal portraits of the different objects in MM wave diapason". (In Russian) Izv. Vuzov-Radiofizica., 2005, v.48,№10-11, p.917-925

2. Zrazhevsky A.Yu., Golounov V.A., Gaponov S.S., Novichikhin Ye.P, Terentiev Ye.B., Chernushich A.P. "Feaures and abilities of polarization stereoradiovision in the millimeter wave region" (In Russian). Radioteknika, 2006, № 5, p. 19-29.

3.Recommendations of the CCIR, 1990, (Also Resolutions and Options), Volume XI - Part 1, Broadcasting Service (Television), pp 95-104