REMOTE IDENTIFICATION OF SMALL-SIZE RADIATORS BY THE THERMAL RADIATION OF THEIR STOCHASTIC TOTALITY

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A physical possibility of exploiting the relation between the mean value of an arbitrary macroscopic quantity and its variance as a source of a certain physical information about the macroparameters of a stochastic system is established. We consider the basic feasibility for the remote identification of the parameters of small-size thermal radiators which constitute a part of the nebulous stochastic totality ("cloud") of particles noninteracting with one another. The density of thermal radiation energy within the radiator cavity, the total number of radiators in the cloud, anf the size of radiators are fluctuating. Herein, the optical images of individual particles are unavailable. Within the black-body model, it is shown that there is a basic possibility to calculate the averages of the number of radiators in a cloud, temperature, and their size in the certain approximations based on the data on the mean power and the fluctuation power variance for two different wavelengths in an idealized situation.

1. Introduction

As is well known, thermovision and its practical branch, thermography, are successfuly applied in medicine, ecology, space technology, etc. However, the general problems of the physics of thermal radiation (TR) which have been already solved by now do not cover a number of specific problems related to the growing practical interest in such areas as, for example, the remote identification of small-size radiators and the control over the temperature of elements of VLSIs or small biological objects. In the present work, the main attention is given to the detection of TR under ideal conditions (without reactive losses on a route), but with the application of the laws of physical statistics to the TR of small physical objects [1, 2]. We consider the problem of remote identification of a stochastic totality ("cloud") of small-size radiators (SRs) of TR in the case where an observer registers the TR of a "cloud," but the optical image of its components, SRs, is unavailable by virtue of fundamental optical limitations. In such a situation, we use the natural fluctuations of TR as a phenomenon which includes the additional physical information on the source of TR [3—6]. This additional information is conditioned by the obvious fact that the natural fluctuations of TR are formed, in the ideal case, in the scope of the radiating cavity and, hence, can include the information on, at least, the cavity size. Such an aspect of the photodetection of TR was not considered in the literature. The problem will be solved here within the model of black body (BB) being most developed theoretically (see, e.g., [7—10]) and confirmed in practice.

2. Starting Positions

The physical information contained in TR fluctuations is derived by means of the application of the well-known relation between the variance $\langle \Delta F^2\rangle$ of a macroscopic physical quantity F and its mean value $\langle F\rangle$. For a number of topical statistics, the mentioned relation can be reduced to the following form:

$$\langle \Delta F^2\rangle = q_F\langle F\rangle, \tag{1}$$

where q_F is the fully defined physical quantity which corresponds quantitatively and by its content to the internal microparameters of the stochastic system [6] and depends on the macroscopic parameter F under consideration. As usual, one uses the notion of standard deviation or relative variance, $\langle \Delta F^2 \rangle^{1/2} \langle F \rangle$, in which the direct quantitative connection with the physical sense of the parameter q_F is lost.

On the basis of available data (see, e.g., [7, 8, 10]), the factor q_F can be associated, by using the commonly accepted designations, with the following physical quantities (this aspect is discussed in work [6] in more details):
— for the ideal gas in the state of thermodynamic equilibrium, these are 1 (one particle from their total number N), kT (the probable thermal energy of a particle), V/N (the volume per one particle), etc.,
— for electric phenomena, these are e (the electron charge), $i_q = e/t_i$ (the elementary random pulse of the current of an equilibrium electron for the time interval between collisions t_i), etc.,
— for TR in the cavity of BB, these are the number of photons $(1+\langle n \rangle)$, the energy of photons $(1+\langle n \rangle)h\nu$ corresponding to this number, and its volumetric density $(1+\langle n \rangle)h\nu/V$ (where V is the volume of the cavity of BB). While considering the TR power fluctuations on the entry of a photodetector (PD), we also use the relevant formula [6] for the flux power $(1+\langle n \rangle)h\nu\Delta\nu_q$. Here, $\langle n \rangle = (\exp h\nu/kT - 1)^{-1}$ is the Planck function, and the frequency band $\Delta\nu_q$ or the time factor adequate to it is defined by the cavity parameters, in particular by its volume. We note that the definition of the band $\Delta\nu_q$ was not given in [6]. In order to derive the explicit expression for $\Delta\nu_q$, it is sufficent to write the power of TR $= P_{A\Omega}$ (which is emitted by plane A normally to its surface in the scope of a small solid angle Ω) in terms of the total energy of TR in a cavity of BB, $E(\lambda) = V\varepsilon(\lambda)$, rather than in terms of the energy density of TR in the cavity, $\varepsilon(\lambda)$, as was made in [11—13]. That is, one should perform the identity transformation of the known formula [11—13], namely,

$$P_{A\Omega} = \frac{V}{V}\varepsilon(\lambda) \cdot \frac{1}{2} CA\Omega =$$

$$= \frac{1}{2}\left[\frac{hC}{\lambda}\langle n \rangle \frac{C}{R}\right]\left[V\frac{8\pi}{\lambda^3}\frac{\Delta\lambda}{\lambda}\right]\left[\frac{A}{R^2}\Omega\right] \equiv$$

$$\equiv \frac{1}{2}[\text{ one-mode power}][\text{ number of modes in a cavity}]\times$$

$$\times[\text{ aperture factor}]. \quad (2)$$

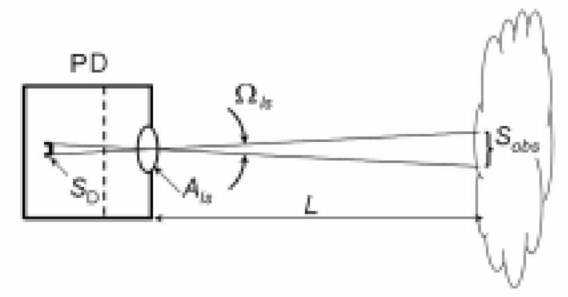

Fig. 1. Optical scheme corresponding to the accepted approximation

It is clear that this simple trick allows us to separate the band $\Delta\nu_q = $ C/R as a phenomenologically understandable time factor which define the one-mode power.

In [14], we have considered the basic possibility to identify a single SR by its TR under the absence of an optical image.

3. Specification of an Optical Model

Let the above-mentioned "cloud" be observed. In this case, we assume that

1) all three parameters under consideration are fluctuating in the scope of that part of the "cloud" which is observed in the given aperture S_{obs}, namely the TR energy density (or the temperature) of a SR $\varepsilon(\lambda)$, the linear size of a SR R_i, and the number of SRs N in the scope of S_{obs}; 2) the optical image of an individual SR in the "cloud" is absent; 3) the thermal background is created by the "cloud" itself; there is no extraneous background; 4) the optical scheme corresponding to the accepted (see below) approximation is borrowed from [11] and is presented in Fig. 1. The adequate optical relations [15] look as

$$F\frac{S_{\text{rad}}A_{ls}}{L^2} = F\frac{S_D A_{ls}}{f^2}. \quad (3)$$

Here, F is the flux of photons per unit area of the emitting surface in a unit solid angle, $S_{\text{rad}} = NS_i$ is the emitting area, and L is the distance from a radiator to the input lens, A_{ls} is the area of PD, S_D is the area of the photosensitive layer of PD, f is the focal distance of the input lens; and $\Omega_{ls} = \frac{A_{ls}}{L^2}$ is the solid angle. The flux F is fully focused on S_D.

4. Input Equations and Approximation

By using the known formula [7,8,10—13] for the equilibrium TR density of a SR in the cavity with regard for the size factor [1, 2] (given below in the square brackets)

$$\varepsilon_i(\lambda) = \frac{hC}{\lambda}\frac{8\pi}{\lambda^3}\left(\frac{\Delta\lambda}{\lambda}\right)\langle n\rangle\left[1-\frac{\lambda^2}{4R_i^2}\right], \quad (4)$$

we can write the total (from all SRs) TR power, emitted normally to the emitting surface $S_{\rm rad}$, at the entry of PD as a product of random quantities $\varepsilon(\lambda), N, S_i$), and the constant $\left(\frac{C}{2}\frac{\Omega_{ls}}{2\pi}\right)$:

$$P_{N\rm ph} = \left\{\varepsilon(\lambda)\sum_{i=1}^{N} S_i\right\}\left(\frac{C}{2}\frac{\Omega_{ls}}{2\pi}\right). \quad (5)$$

On the basis of the well-known theorems [17, 18], the variance $\langle \Delta P^2_{N\rm ph}\rangle$ corresponding to (5) (below, we denote ${\rm Var}F \equiv \langle \Delta F^2\rangle$) is reduced to

$$\langle \Delta P^2_{N\rm ph}\rangle = {\rm Var}\left\{\varepsilon(\lambda)\sum_{i=1}^{N} S_i\right\}\left(\frac{C}{2}\Omega_D\right)^2 =$$

$$= \left\{\langle\Delta\varepsilon^2\rangle{\rm Var}\left[\sum_{i=1}^{N} S_i\right] + \langle\varepsilon\rangle^2{\rm Var}\left[\sum_{i=1}^{N} S_i\right] +\right.$$

$$\left.+\left\langle\sum_{i=1}^{N} S_i\right\rangle^2\langle\Delta\varepsilon^2\rangle\right\}\left(\frac{C}{2}\frac{\Omega_{ls}}{2\pi}\right)^2. \quad (6)$$

As for the sum $\left[\sum\limits_{i=1}^{N} S_i\right]$, we use the Bourges theorem on variance [19] in the accepted approximation when the particle size S_i $\langle\Delta S_i^2\rangle$ and the number of particles N fluctuate with variances $\langle\Delta S_i^2\rangle$ and $\langle\Delta N^2\rangle$, respectively, and the mean values satisfy the relation $\left\langle\sum\limits_{i=1}^{N} S_i\right\rangle \cong \langle N\rangle\langle S_i\rangle$. In this case, we get

$${\rm Var}\left[\sum_{i=1}^{N} S_i\right] = \langle S_i\rangle^2\langle\Delta N^2\rangle + \langle N\rangle\langle\Delta S_i^2\rangle.$$

The final full formula for the variance $P_{N\rm ph}$ reads

$$\langle \Delta P^2_{N\rm ph}\rangle = \left\{(\langle\Delta\varepsilon^2\rangle + \langle\varepsilon\rangle^2)\times\right.$$

$$\times\left[\langle S_i\rangle^2\langle\Delta N^2\rangle + \langle N\rangle\langle\Delta S_i^2\rangle\right] +$$

$$\left.+\left\langle\sum_{i=1}^{N} S_i\right\rangle^2\langle\Delta\varepsilon^2\rangle\right\}\left(\frac{C}{2}\frac{\Omega_{ls}}{2\pi}\right)^2. \quad (7)$$

We emphasize that the variance of the TR density in the cavity (7) can be represented in the form (1) in terms of the mean value and the relevant quantity q_ε, i.e. as [5,6]

$$\left\langle[\Delta\varepsilon(\lambda)]^2\right\rangle = q_\varepsilon\langle\varepsilon(\lambda)\rangle, \quad (8a)$$

$$q_\varepsilon = \frac{hC}{\lambda R_i^3}\left(\langle n\rangle + 1\right). \quad (8b)$$

If the number N obeys the Poisson distribution in the scope of the observed part of the “cloud” surface, i.e. $\langle\Delta N^2\rangle = 1\cdot\langle N\rangle$ [17, 18], then, after the obvious algebraic transformations, we get the general formula for the TR power variance $P_{N\rm ph}$ at the entry of PD:

$$\langle \Delta P^2_{N\rm ph}\rangle = \left(\frac{C}{2}\frac{\Omega_{ls}}{2\pi}\right)\left\{(q_\varepsilon + \langle\varepsilon_i\rangle)\left(1+\frac{\langle\Delta S_i^2\rangle}{\langle S_i\rangle^2}\right)\times\right.$$

$$\left.\times\langle S_i\rangle + \langle N\rangle\langle S_i\rangle q_\varepsilon\right\}\left[\langle\varepsilon_i\rangle\frac{C}{2}\langle S_i\rangle\langle N\rangle\frac{\Omega_{ls}}{2\pi}\right]. \quad (9)$$

It seems reasonable to accept that the ratio $\langle\Delta S_i^2\rangle\langle S_i\rangle^2 \ll 1$ holds, i.e. the differences in sizes of SRs are characterized by a quite moderate dispersion. Since the product of parameters outside the braces in (9) is the mean TR power at the entry of PD,

$$\langle P_{N\rm ph}\rangle = \langle\varepsilon_i\rangle\frac{C}{2}\langle S_i\rangle\langle N\rangle\frac{\Omega_{ls}}{2\pi}, \quad (10)$$

we arrive at a working version of the TR power variance at the entry of PD

$$\langle \Delta P^2_{N\rm ph}\rangle \approx \left(\frac{C}{2}\langle S_i\rangle\frac{\Omega_{ls}}{2\pi}\right)\times$$

$$\times\{(q_\varepsilon + \langle\varepsilon_i\rangle) + \langle N\rangle q_\varepsilon\}\langle P_{N\rm ph}\rangle \quad (11)$$

which includes three unknown quantities (the temperature T, the number N, and the area $S_i \approx R_i^2$ of the emitting side of a particle).

5. Possible calculations

5.1. Currents on the output of PD

We consider that the photocurrent I_{PD} on the output of an ideal PD is composed from three components:

1) the mean stationary photocurrent I_{st}, proportional to the total mean stationary power of TR at the entry of PD (10),

$$\langle I_{\mathrm{st}}\rangle = \frac{e\eta}{h\nu}\langle\varepsilon_i\rangle\left(\frac{C}{2}\langle R_i\rangle^2\langle N\rangle\frac{\Omega_{ls}}{2\pi}\right) \tag{12}$$

where η is the quantum efficiency of PD [12] we set to be equal to 1 in our calculations,

2) the mean square current of the Schottky noise $\langle I_{\mathrm{sn}}^2\rangle$ on the output of PD proportional to the current $\langle I_{\mathrm{st}}\rangle$ [19]:

$$\langle I_{\mathrm{sn}}^2\rangle = 2e\Delta f\langle I_{\mathrm{st}}\rangle \tag{13}$$

where Δf is the frequency band of the electronic circuit of PD. This noise is conditioned by the stochastic processes of generation (of generation-recombination in semiconductors, e.g.) [12, 13],

3) the mean square stochastic component of the photocurrent which is conditioned by the natural fluctuations of the TR power on the entry of PD (10); it is proportional to the variance of this power $\langle\Delta P_D^2\rangle$ [11]:

$$\langle I_{N\mathrm{ph}}^2\rangle = \left(\frac{e}{h\nu}\right)^2\langle\Delta P_{N\mathrm{ph}}^2\rangle\left(2\frac{\Delta f}{\Delta\nu}\right). \tag{14}$$

The factor $(2\Delta f\Delta\nu)$ in (14) appears as a result of the spectral analysis of the output chaotic current of PD [11]. From the phenomenological viewpoint, this factor is that part of input fluctuations of the TR power which is registered, in fact, in the form of a current chaotic in time on the output PD in the scope of the band Δf .

By using formulas (12)—(14) for the powers of output noise currents which should be measured, we get the expression for the coefficient $q(\lambda, R_i, N, T)$ corresponding to (1). Measured at two different wavelengths, λ_1 and λ_2, the values of $\langle I_{\mathrm{st}}\rangle_{1,2}$, $\langle I_{\mathrm{sn}}^2\rangle_{1,2}$ and $\langle I_{N\mathrm{ph}}^2\rangle_{1,2}$ allow us to derive two formulas for specific values of $q_{1,2}$. With regard for (4) and (9), these formulas involve all three required quantities R_i, N, and T:

$$q_{1,2} = 2e\Delta f\left[1 + \frac{\Omega_{ls}}{4\pi}\left\{\frac{8\pi}{\lambda_{1,2}^2}\langle n\rangle\left(\langle R_i\rangle^2 - \frac{\lambda_{1,2}^2}{4}\right) + \right.\right.$$

$$\left.\left. + N\frac{\lambda_{1,2}\langle n\rangle\exp(hC/(\lambda_{1,2}kT))}{\langle R_i\rangle(\Delta\lambda/\lambda)}\right\}\right]. \tag{15}$$

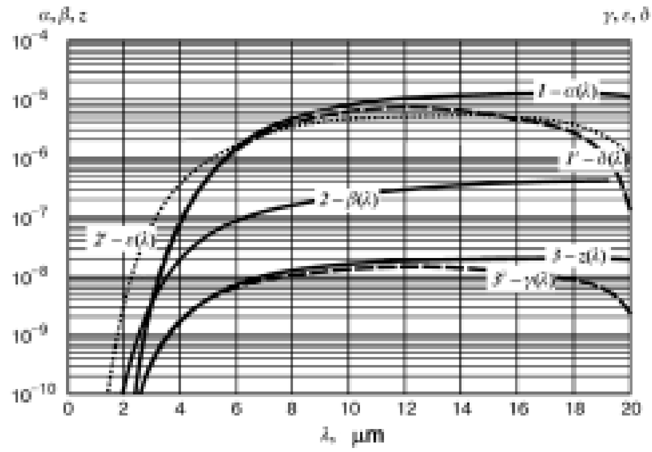

Fig. 2. Frequency dependences of the output currents of PD

With the purpose to estimate and to compare the expected values of the currents which should be measured for the successive calculations of the required quantities, we give their spectral distributions in Fig. 2 for the parameters

$$T = 300\ \mathrm{K},\quad S_{\mathrm{obs}} = 10^4\ \mathrm{cm}^2,\quad \Omega_{ls} = 10^{-6}\ \mathrm{sr},$$

$$\langle R_i\rangle = 10\,\mu\mathrm{m},\quad \langle S_{\mathrm{rad}}\rangle = \langle R_i\rangle^2\langle N\rangle = S_{\mathrm{obs}}\ \mathrm{cm}^2.$$

In Fig. 2, curve *1* presents the stationary current $\alpha(\lambda) \sim \langle I_{\mathrm{st}}\rangle_{\mathrm{ABB}}$; curve *2* shows the stochastic current corresponding to the Schottky noise $\beta(\lambda) \sim \sqrt{\langle I_{\mathrm{sn}}^2\rangle_{\mathrm{ABB}}} = \sqrt{2e\Delta f\langle I_{\mathrm{st}}\rangle_{\mathrm{ABB}}}$; and curve *3* gives the stochastic current corresponding to the variance of the TR of the "cloud", $\gamma(\lambda) \sim \sqrt{\langle\Delta I_{\mathrm{ABB}}^2\rangle} = \sqrt{\left(\frac{e}{h\nu}\right)^2\langle\Delta P_{\mathrm{ABB}}^2\rangle\left(2\frac{\Delta f}{\Delta\nu}\right)}$. The adequate dependences are presented also for the emission of the "cloud" of SRs: curves *1′*, *2′*, and *3′* give, respectively, the stationary current of the TR of the "cloud" $\delta(\lambda) \sim \langle I_{\mathrm{st}}\rangle_{\mathrm{SR}}$, formula (12), the stochastic current corresponding to the Schottky noise $\varepsilon(\lambda) \sim \sqrt{\langle I_{\mathrm{sn}}^2\rangle_{\mathrm{SR}}}$, formula (13), and the stochastic current corresponding to the variance of the TR of the "cloud" $z(\lambda) \sim \sqrt{\langle I_{N\mathrm{ph}^2}\rangle_{\mathrm{SR}}}$.

The results presented in Fig. 2 indicate the following: 1. The Schottky noise (curves *2* and *2′*) is lesser by at least two orders than the natural noise of the TR power (curves *3* and *3′*); 2. Even at the same temperature ($T = 300$ K) and emitting areas ($\langle S_{\mathrm{rad}}\rangle = \langle R_i\rangle^2\langle N\rangle = 10^{-6}\cdot 10^{10} = 10^4 = S_{\mathrm{obs}}$ cm^2), the natural noise of the

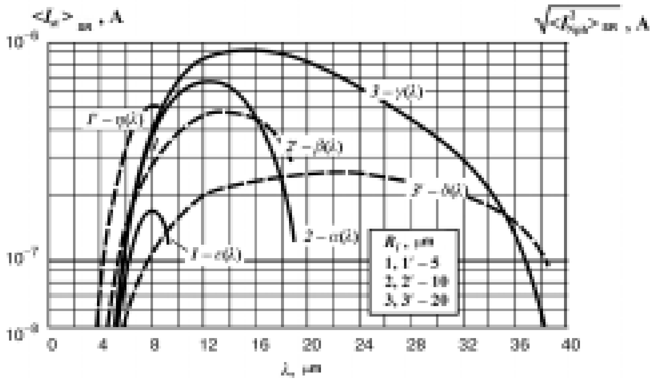

Fig. 3. Spectral distributions $\langle I_{\rm st}\rangle_{\rm SR}$ (continuous curves) and $\sqrt{\langle I_{N{\rm ph}}^2\rangle_{\rm SR}}$ (dashed curves) for three sizes of SRs

TR power of the "cloud" of SRs (curve *3′*) exceeds significantly that of a "solid" radiator, BB. In addition, Fig. 3 shows the spectral distributions $\langle I_{\rm st}\rangle_{\rm SR}$ and $\sqrt{\langle I_{N{\rm ph}}^2\rangle_{\rm SR}}$ for three sizes of SRs.

It is seen from Fig. 3 that the relative power variance of TR $\sqrt{\langle I_{N{\rm ph}}^2\rangle_{\rm SR}}/\langle I_{\rm st}\rangle_{\rm SR}$ has a tendency to a growth up to a value greater than 1 (curves *1* and *1′*) with decrease in the size of SRs. The results of calculations given in Figs. 2 and 3 indicate that there is no problem of measurement of the TR power variance $\langle I_{N{\rm ph}}^2\rangle_{\rm SR}$ in the quantitative aspect in a quite wide range of the physical parameters of SRs.

5.2. Calculation of the physical parameters of a "cloud"

After a simple transformation of relation (15), we get two (for λ_1 and λ_2) cubic equations for $\langle R_i\rangle$:

$$\langle R_i\rangle^3 - \left[\left(\frac{q_{1,2}}{2e\Delta f}-1\right)\frac{2\pi}{\Omega_{ls}}\frac{1}{\pi\langle n_{1,2}\rangle}+1\right]\times$$

$$\times\frac{\lambda_{1,2}^2}{4}R_i + \langle N\rangle\frac{\lambda_{1,2}^3\exp\left(\frac{hC}{\lambda_{1,2}kT}\right)}{8\pi\left(\Delta\lambda/\lambda\right)} = 0. \qquad (16)$$

Since the parameters of the "cloud" remain constant at two different wavelengths λ_1 and λ_2 (in particular, the quantities $\langle R_i\rangle$, $\langle N\rangle$, and T) and $\lambda_{1,2}$, $\Delta\lambda/\lambda$, and Ω_{ls} are set by conditions of the experiment, the solution of any of Eqs. (16) will give the same value of $\langle R_i\rangle$. On the other hand, this can be realized only if the coefficients in the both equations (for λ_1 or λ_2) are the same, i.e. we can equate them. For example, by equating the coefficients of $\langle R_i\rangle$, we get

$$\left(\pi\Omega_{ls}+\left(\frac{q_1}{2e\Delta f}-1\right)\left(\exp\left(\frac{hC}{\lambda_1 kT}\right)-1\right)\right)\frac{\lambda_1^2}{4\pi\Omega_{ls}} =$$

$$=\left(\pi\Omega_{ls}+\left(\frac{q_2}{2e\cdot\Delta f}-1\right)\left(\exp\left(\frac{hC}{\lambda_2 kT}\right)-1\right)\right)\frac{\lambda_2^2}{4\pi\Omega_{ls}}. \qquad (16^*)$$

This equality includes only one unknown, the temperature T. But we can find it only with regard for the equality of the free terms of Eq. (16), namely

$$\lambda_1^3\exp\left(\frac{hC}{\lambda_1 kT}\right) = \lambda_2^3\exp\left(\frac{hC}{\lambda_2 kT}\right). \qquad (16^{**})$$

Then, by substituting, e.g., $\exp(hC/(\lambda_1 kT)$ from (16**) in (16*), we can derive the formula for the temperature in terms of the measured and known parameters

$$T = \frac{1.439}{\lambda_2}\left[\ln\left(1-\frac{Q_2}{\pi}\right)-\left(1-\frac{Q_1}{\pi}\right)\frac{\lambda_1^2}{\lambda_2^2}-\right.$$

$$\left.-\ln\left(\frac{Q_1}{\pi}\frac{\lambda_2}{\lambda_1}-\frac{Q_2}{\pi}\right)\right]^{-1}. \qquad (17)$$

Here, we have introduced the designations $Q_{1,2} = \left(\frac{q_{1,2}}{2e\Delta f}-1\right)2\pi\Omega_{ls}^{-1}$. In view of the fact that the temperature (17) is known now and using the mean values of the stationary photocurrents $\langle I_{\rm st}\rangle_{1,2}$ (12) measured at two wavelengths $\lambda_{1,2}$, we get an equation for $\langle R_i\rangle^2$ which can be easily solved. Substituting $\langle R_i\rangle^2$ in any relations (16) allows us to find the mean number $\langle N\rangle$ of SRs in the scope of the observed part of the "cloud" surface.

Thus, we may assert that the use of relation (1), at least in the ideal case(i.e., the model of BB, the ideal PD, and the absence of additional fluctuations of the TR flow on the route "SR – PD"), allows us to solve the problem of the remote identification of SRs which belong to the stochastic system, the "cloud", even if the adequate optical image of an individual SR is absent. It is natural that such a result is reached if we can measure the mean TR power and the variance of natural fluctuations of this power.

It is seen from the above-presented that there exists a rather simple way to the solution of the quite complex problem due to the use of the internal eigenparameter of BB, q_ε (8b), in relation (1) for the TR power variance. Just this parameter of BB presents the specific information on the "eigenstate" of TR in the BB cavity and its size.

It is clear that such a result can be reached in the cases where the statistical character of the chaos allows one to endow the quantity q_F in relation (1) by the corresponding statistical properties.

6. Conclusions

1) The use of the notion of "natural microamount of chaos" [5,6] (in the above-considered case, it is related to $q_\varepsilon = \frac{hC}{\lambda R_i^2}(\langle n\rangle + 1)$, or $q_p = \frac{hC}{\lambda}(\langle n\rangle + 1)\frac{C}{R_i})$ indicates the basic possibility to solve the problem of the remote identification of SRs by the heat emission of their stochastic totality in the situation where the volumetric energy density TR $\varepsilon(\lambda)$, the sizes of SRs R_i, and their number in the "cloud" N fluctuate, even if the optical images of individual SRs are absent.

It is clear that a practical realization of the developed approach requires an adequate statistical treatment of electrical signals at the output of PD which present the necessary required information on TR.

2) Besides the given example of the identification of small radiators of TR, the real usefulness of the determination of the quantity q_F consists also in the following:
— the comparison of the quantities $\langle\Delta F^2\rangle_{\rm exp}$ derived experimentally by integrating the noise spectrum $S_F(\omega)$ or by calculating the correlation function $K_F(0)$ and $\langle\Delta F^2\rangle_q$ constructed according to relation (1) upon a certain assumption as for q_F gives the information on the adequacy of our ideas of the physical mechanism of fluctuations in the system under consideration, - if the information on the stochastic phenomenon is scanty, the determination of a numerical value of q_F on the basis of the application of relation (1) to the variance $\langle\Delta F^2\rangle_{\rm exp}$ derived from the experimentally measured quantities $S_F(\omega)$ and $K_F(0)$ defines quantitatively the basic microparameter of the fluctuating system.

This microparameter can be an input element in the construction of a physical model of the stochastic phenomenon.

1. *Kolokolov A.A., Skrotskii G.V.* // Opt. Spektr. — 1974.— **36.** — P.217—221.

2. *Baltes H.P., Kneubuhl F.K.* // Helv. Phys. acta. — 1972. — **45.** — P.481—529.

3. *Salkov E.A., Svechnikov G.S.* // Proc. SPIE. — 1996. — **2894**. — P.66—73.

4. *Salkov E.A.//* Ibid. — 1997. — **3182** — P.78.

5. *Salkov E.A.* //Opto-Electr. Rev. — 1998. — **6**. — P. 251— 256.

6. *Salkov E.A.* // Semicond. Phys., Quant. Electr. Optoelectr. — 1998. — **1**. — P.116—120.

7. *Heer C.V.* Statistical Mechanics, Kinetic Theory, and Stochastic Processes. — New York: Academic Press, 1972.

8. *Landau L.D, Lifshits E.M.* Statistical Physics. — Moscow: Nauka, 1964 (in Russian).

9. *Wolf E., Mandel L.* // Rev. Mod. Phys. — 1965. — **37.** — P.231—287.

10. *Loudon P.* The Quantum Theory of Light. — Oxford: Clarendon Press, 1973.

11. *Kingston R.H.* Detection of Optical and Infrared Radiation. — (Springer Series in Optical Science. Vol.10). — Berlin: Springer, 1978.

12. *Luk'yanchikova N.B.*. Fluctuation Phenomena in Semiconductors and Semiconductor Devices. — Moscow: Radio i Svyaz, 1990 (in Russian).

13. *Smith R.A., Jones F.E., Chasmar R.P.* The Detection and Measurement of Infra-Red Radiation. — Oxford: Clarendon Press, 1957.

14. *Salkov E.A., Svechnikov G.S.* // Semicond. Phys., Quant. Electr. Optoelectr. — 2003. — **6**. — P.205—209.

15. *Wolf U.* // Applied Optics and Optical Engineering / Eds. R.R. Shannon, J.C. Wyant. — New York: Academic Press, 1980.

16. *Landsberg G.S.* Optics. — Moscow: Nauka, 1976 (in Russian).

17. *Gnedenko B.V.* A Course of Probability Theory. — Moscow: Nauka, 1969 (in Russian).

18. *Levin B.R.* Theoretical Foundations of Statistical Radiotechnique. — Moscow: Sov. Radio, 1969 (in Russian).

19. *Van der Ziel A.* Noise. Sources, Characterisation, Measurement. — Englewood Cliffs: Prentice-Hall, 1970.

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ДИСТАНЦІЙНА ІДЕНТИФІКАЦИЯ МАЛИХ ВИПРОМІНЮВАЧІВ ЗА ТЕПЛОВИМ ВИПРОМІНЮВАННЯМ ЇХ СТОХАСТИЧНОЇ СУКУПНОСТИ

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Р е з ю м е

Обгрунтовано фізичну можливість використання співвідношення між середнім значенням випадкової макроскопічної величини і її дисперсією як джерела певної фізичної інформації про мікропараметри стохастичної системи. Розглянуто метод дистанційної ідентифікації фізичних параметрів малих випромінювачів теплового випромінювання, що утворюють хмароподібну стохастичну сукупність ("хмару") невзаємодіючих між собою частинок. Флуктуюють густина енергії випромінювання у порожнині випромінювача, кількість випромінювачів у “хмарі” і розміри випромінювачів. При цьому оптичне зображення окремих частинок відсутнє. Показано, що у моделі абсолютно чорного тіла (АЧТ) існують наближення, коли на основі даних про середнє значення потужності, отриманих при двох довжинах хвиль, і дисперсії власних флуктуацій цієї потужності в ідеалізованій ситуації існує принципова можливість обчислити середні значення кількості випромінювачів у ”хмарі”, температури і розміру випромінювача.