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STATISTICAL SYNTHESIS OF MICROWAVE SCANNING RADIOMETER

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This paper presents a synthesis of algorithms of optimum and quasioptimum signal processing of its own thermal radiation of spatially distributed objects in radiometers with a scanning pattern. It is shown that the optimal algorithm contains the following operations: multiplication of an observation by the function describing the antenna pattern at the current moment of time, decorrelation, convolutions with inverse uncertainty function of the radiometer, square-law detection, integration and compensations of power of the internal radiometer noise which is measured at the calibration phase. The block-diagram corresponding to the synthesized algorithm is developed which, unlike the known compensation scheme, contains operations of multiplying an observation by the operation describing the antenna pattern at the current moment of time, decorrelation and convolutions with the inverse uncertainty function of the radiometer.

Keywords: optimum microwave scanning radiometer, estimation of brightness temperature of spatially-distributed objects.

INTRODUCTION

Radiometric systems are widely used in problems of remote sensing and radioastronomy. The power estimate of own signals of objects at the output of such systems can be converted to brightness temperature. If available the corresponding mathematical model of its own thermal radiation the brightness temperature can be counted in the evaluation of electrodynamic, physico-chemical and statistical characteristics of objects [1]. The quality of estimates depends on the radiometer type. The analysis showed that the empirical approach usually used for the construction of modern radiometric systems. In order to estimate the closeness of these and optimal systems is necessary to solve the synthesis problem of radiometric system by using the modern theory of optimal estimation of signal parameters [1] and the methods of functional analysis [2, 3]. Important results of the statistical synthesis of radiometric systems were obtained in [1, 4-5]. However, in these works is not enough attention given to the question of observation processing in the scanning radiometers.

The contribution of this paper is statistical synthesis of optimum and quasioptimum algorithms of brightness temperature or power estimation of the spatially-distributed objects in the scanning radiometer and development of their block diagrams.

1. FORMULATION OF OPTIMIZATION PROBLEMS. THE OBSERVATION EQUATION

In the currently t is necessary to give the optimum estimate (in terms of selected quality criteria) of the spectral-angular power density $B(f,\theta)$, which is a radiometric image as a function of direction cosines θ.

It is assume that the antenna boresight θ_0 varies with time, i.e. $\theta_0(t)$. The signal $s(t,\theta_0(t))$ at the antenna output is mixed with the internal noise $n(t)$ in a predetection section of the receiver which characterized by amplitude-frequency response $\dot{K}(j2\pi f)$. Additive regularizing noise $n_p(t)$ is introduced in the observation equation. It is white zero-mean Gaussian noise with a low spectral power density N_p. This addition eliminates singularities of integral equations solution. The observation equation has the following form:

$$u(t,\theta_0(t)) = \left[s(t,\theta_0(t)) + n(t)\right] \otimes h(t) + n_p(t)\,, \qquad (1)$$

where

$$s(t,\theta_0(t)) \otimes h(t) = s_h(t,\theta_0(t)) =$$
$$= \int_\theta \int_{D'} \int_{-\infty}^{\infty} \dot{A}(f,\theta) \dot{I}(f,\vec{r}\,') \dot{K}(j2\pi f) \times$$
$$\times \exp\left\{ j2\pi f \left(t - \vec{r}\,'\left(\theta - \theta_0(t)\right) c^{-1} \right) \right\} df d\vec{r}\,' d\theta$$

is the useful signal at the output of the predetection section of the radiometer; $\dot{A}(f,\theta)$ denotes the spectral-angular density of the complex amplitude of the radiation source; $\dot{I}(f,\vec{r}\,')$ denotes the amplitude-phase distribution in antenna aperture, $\vec{r}\,' = (x', y') \in D'$ is the coordinates of the receiving antenna aperture; θ is the direction cosines; $\theta_0(t)$ denotes antenna boresight as function of the time t; c is the velocity of wave propagation in free space; $h(t) = \int_{-\infty}^{\infty} \dot{K}(j2\pi f) \exp\{j2\pi f t\} df$ denotes the impulse response of the predetection section of the radiometer; $\otimes$ denotes the convolution operator;

$$n_h(t) = n(t) \otimes h(t) = \int_{-\infty}^{\infty} n(\tau) h(t-\tau) d\tau$$

is the internal noise at the output of the predetection section of the radiometer.

All processes in observation equation are mutually independent zero-mean white Gaussian noise. It is assumed that the following condition is true [1]

$$\left\langle \dot{A}(f_1,\theta_1) \dot{A}^*(f_2,\theta_2) \right\rangle = B(f_1,\theta_1) \delta(f_1 - f_2) \delta(\theta_1 - \theta_2)\,, \qquad (2)$$

i.e. $\dot{A}(f,\theta)$ is uncorrelation in frequency domain and in angular coordinates. Here $\langle \cdot \rangle$ is the expectation value. The spectral-angular density of power $B(f,\theta)$ in equation (2) must be found.

In solving optimization problems by the maximum likelihood methods requires a knowledge of the correlation function of the observation (1). The preliminary assumptions is being entered. First of one, it is assumed that the antenna is a frequency-independent ($\dot{F}(f,\theta)=\dot{F}(f_0,\theta)$). Second, the function $B(f,\theta)$ is monotone in frequency domain, so is used the mean value theorem and will be considered the value of the spectral brightness as constant within the radiometer bandwidth, i.e. $B(f,\theta)=B(f_0,\theta)$. Then the correlation function of observation (1) has the following form:

$$R_u(t_1,t_2,\lambda(\theta))=0{,}5\left[B_\psi(f_0,\theta_0(t_1),\theta_0(t_2))+N_0\right]\times \times R_h(t_1-t_2)+0{,}5N_p\delta(t_1-t_2), \quad (3)$$

where

$$B_\psi(f_0,\theta_0(t_1),\theta_0(t_2))= \mathrm{Re}\int_\theta B(f_0,\theta)\dot{F}(f_0,\theta-\theta_0(t_1))\dot{F}^*(f_0,\theta-\theta_0(t_2))d\theta;$$

$$R_h(t_1-t_2)=\int_{-\infty}^{\infty}\left|\dot{K}(j2\pi f)\right|^2\exp\{j2\pi f(t_1-t_2)\}df\ .$$

In deriving (3) was used the expression (2).

It is assumed that the amplitude-frequency response $\dot{K}(j2\pi f)$ of the predetection section is ultrawideband, then the expression (3) can be written as ($t_1-t_2=\tau$)

$$R_u(t_1,t_1-\tau,\lambda(\theta))= =0{,}5\left[B_\psi(f_0,\theta_0(t_1))+N_0\right]R_h(\tau)+0{,}5N_p\delta(\tau), \quad (4)$$

where

$$B_\psi(f_0,\theta_0(t_1))=\int_\theta B(f_0,\theta)\left|\dot{F}(f_0,\theta-\theta_0(t_1))\right|^2d\theta\ .$$

Spectrogram is given by the equation [7]

$$G(f,t_1,\lambda(\theta))= =0{,}5\{\left[B_\psi(f_0,\theta_0(t_1))+N_0\right]\left|\dot{K}(j2\pi f)\right|^2+N_p\}. \quad (5)$$

2. SOLUTION OF OPTIMIZATION PROBLEM

The optimization problem can be solved by the maximum likelihood method:

$$\delta\ln p\left[u(t,\theta_0(t))\,|\,\lambda(\theta)\right]/\delta\lambda(\theta)\Big|_{\hat{\lambda}(\theta)=\lambda_{opt}(\theta)}=0\ , \quad (6)$$

where $\lambda(\theta)=B(f_0,\theta)$; $\hat{\lambda}(\theta)$ and $\lambda_{opt}(\theta)$ are estimated and the optimum parameters;

$$p\left[u(t,\theta_0(t))\,|\,\lambda(\theta)\right]= =k(\lambda(\theta))\exp\{-0{,}5\int_0^t\int_0^t u(t_1,\theta_0(t_1))\times \times W_u(t_1,t_2,\lambda(\theta))u(t_2,\theta_0(t_2))dt_1dt_2\}$$

is the likelihood functional; $W_u(t_1,t_2,\lambda(\theta))$ denotes the inverse of the correlation function found from the following integral equation

$$\int R_u(t_1,t_2,\lambda(\theta))W_u(t_2,t_3,\lambda(\theta))dt_2=\delta(t_1-t_3)\ ; \quad (7)$$

$k(\lambda(\theta))$ denotes a parameter that depends on $\lambda(\theta)$; $\delta/\delta\lambda(\theta)$ denotes the variational derivative.

Solution of equation (7) in the time domain is difficult. To equation (6) is being applied the Fourier transform and is being calculated the variational derivatives [2, 3]. The solution is given by

$$\int_0^t\int_{-\infty}^{\infty}\left|\dot{F}(f_0,\theta-\theta_0(t_1))\right|^2\left|\dot{K}(j2\pi f)\right|^2\times \times G^{-1}(f,t_1,\hat{\lambda}(\theta))dfdt_1= =\int_0^t\int_0^{t_1}\int_{-\infty}^{\infty}\left|\dot{F}(f_0,\theta-\theta_0(t_1))\right|^2\times \times\left|\dot{K}(j2\pi f)\right|^2G^{-2}(f,t_1,\hat{\lambda}(\theta))\exp\{j2\pi f\tau\}dfd\tau dt_1. \quad (8)$$

The left-hand side of equation (8) multiply and divide by $G(f,t_1,\lambda(\theta))$. Then the equation (8) can be given by the following relation

$$0{,}5\int_\theta B(f_0,\theta')\Psi_{FG}(f_0,\theta'-\theta,\hat{\lambda}(\theta'))d\theta'+ +N_0C(\theta,\hat{\lambda}(\theta))+N_pC_W(\theta,\hat{\lambda}(\theta)), \quad (9)$$

where

$$\Psi_{FG}(f_0,\theta'-\theta,\hat{\lambda}(\theta))=2\int_0^t\left|\dot{F}(f_0,\theta'-\theta_0(t_1))\right|^2\times \times\left|\dot{F}(f_0,\theta-\theta_0(t_1))\right|^2\Delta F(t_1,\hat{\lambda}(\theta))dt_1 \quad (10)$$

is the radiometric uncertainty functions;

$$2\Delta F(t_1,\hat{\lambda}(\theta))=\int_{-\infty}^{\infty}\left|\dot{K}(j2\pi f)\right|^4G^{-2}(f,t_1,\hat{\lambda}(\theta))df= =\int_{-\infty}^{\infty}\left|\dot{K}(j2\pi f)\right|^2\left|\dot{K}_W(j2\pi f,t_1,\hat{\lambda}(\theta))\right|^2df$$

is the bandwidth of the predetection section of the radiometer after matched and decorrelation filters;

$$\left|\dot{K}_W(j2\pi f,t_1,\hat{\lambda}(\theta))\right|^2=\left|\dot{K}(j2\pi f)\right|^2G^{-2}(f,t_1,\hat{\lambda}(\theta))$$

is the frequency response of the decorrelation filter;

$$2\Delta F_W(t_1,\hat{\lambda}(\theta))=\int_{-\infty}^{\infty}\left|\dot{K}(j2\pi f)\right|^2G^{-2}(f,t_1,\hat{\lambda}(\theta))df= =\int_{-\infty}^{\infty}\left|\dot{K}_W(j2\pi f,t_1,\hat{\lambda}(\theta))\right|^2df$$

is the bandwidth of the decorrelation filter;

$$C(\theta,\hat{\lambda}(\theta))=2\int_0^t\left|\dot{F}(f_0,\theta-\theta_0(t_1))\right|^2\Delta F(t_1,\hat{\lambda}(\theta))dt_1 \quad (11)$$

and

$$C_W(\theta,\hat{\lambda}(\theta))=2\int_0^t\left|\dot{F}(f_0,\theta-\theta_0(t_1))\right|^2\Delta F_W(t_1,\hat{\lambda}(\theta))dt_1. \quad (12)$$

The right-hand side of equation (8) has the following form

$$\int_0^t\int_0^t\int_{-\infty}^{\infty}\dot{F}(f_0,\theta-\theta_0(t_1))\dot{F}^*(f_0,\theta-\theta_0(t_2))\times \times\left|\dot{K}(j2\pi f)\right|^2G^{-2}(f,t_1,\hat{\lambda}(\theta))u(t_2,\theta_0(t_2))\times \times u(t_1,\theta_0(t_1))\exp\{j2\pi f(t_1-t_2)\}dfdt_1dt_2. \quad (13)$$

For the wideband frequency response of the predetection section we have the following relation

$$G^2(f,t_1,\hat{\lambda}(\theta))\approx G(f,t_1,\hat{\lambda}(\theta))G(f,t_2,\hat{\lambda}(\theta))\ . \quad (14)$$

Then the equation (13) is being written

$$\int_{-\infty}^{\infty} |\dot{K}(j2\pi f)\int_0^t \dot{F}(f_0,\theta-\theta_0(t))G^{-1}(f,t,\hat{\lambda}(\theta))\times$$
$$\times u(t,\theta_0(t))\exp\{-j2\pi f t\}dt|^2 df = \quad (15)$$
$$=\int_{-\infty}^{\infty}\left|\dot{K}(j2\pi f)\dot{U}_{tFG}(f,\theta)\right|^2 df = \int_{-\infty}^{\infty}\left|\dot{U}_{tFW}(f,\theta)\right|^2 df,$$

where

$$\dot{U}_{tFG}(f,\theta)=\int_0^t \dot{F}(f_0,\theta-\theta_0(t))G^{-1}(f,t,\hat{\lambda}(\theta))\times$$
$$\times u(t,\theta_0(t))\exp\{-j2\pi f t\}dt,$$
$$\dot{U}_{tFW}(f,\theta)=\dot{K}(j2\pi f)\dot{U}_{tFG}(f,\theta).$$

Using the Parseval theorem, we then deduce

$$\int_{-\infty}^{\infty}\left|\dot{U}_{tFW}(f,\theta)\right|^2 df = \int_0^t u_{Fd}^2(t,\theta)dt, \quad (16)$$

where

$$u_{Fd}(t,\theta)=F^{-1}\left[\dot{U}_{tFW}(f,\theta)\right] \quad (17)$$

and $F^{-1}[\cdot]$ denotes the operator of the inverse Fourier transformation.

Using equations (9) and (17), we then deduce the solving of equation (16) in the following form

$$0{,}5\int_{\theta}\hat{B}(f_0,\theta')\Psi_{FG}(f_0,\theta'-\theta,\hat{\lambda}(\theta'))d\theta' =$$
$$=\int_0^t u_{Fd}^2(t,\theta)dt - 0{,}5[N_0C(\theta,\hat{\lambda}(\theta)) - N_pC_W(\theta,\hat{\lambda}(\theta))]. \quad (18)$$

The left-hand side of expression (18) has a smooth by the uncertainty function $\Psi(\theta'-\theta)$ estimate of radio brightness as a function of angular coordinates $\hat{B}(f_0,\theta')$. To restore $\hat{B}(f_0,\theta')$ assume that there is an inverse function $\Psi_{FG}^{-1}(f_0,\theta''-\theta,\hat{\lambda}(\theta))$ which satisfies the integral equation

$$\int\Psi_{FG}(f_0,\theta'-\theta,\hat{\lambda}(\theta))\times$$
$$\times\Psi_{FG}^{-1}(f_0,\theta''-\theta,\hat{\lambda}(\theta))d\theta=\delta(\theta'-\theta'').$$

Multiplying both sides of expression (18) on $\Psi_{FG}^{-1}(f_0,\theta''-\theta,\hat{\lambda}(\theta))$ and integrate over θ can be obtain the following optimal algorithm

$$\frac{\hat{B}(f_0,\theta'')}{2}=\int_{\theta}\Psi_{FG}^{-1}(f_0,\theta''-\theta,\hat{\lambda}(\theta))\int_0^t u_{Fd}^2(t,\theta)dt\,d\theta -$$
$$-0{,}5N_0R(\theta'',\hat{\lambda}(\theta'')) - 0{,}5N_pR(\theta'',\hat{\lambda}(\theta'')), \quad (19)$$

where

$$R(\theta'',\hat{\lambda}(\theta''))=$$
$$=\int_{\theta}\Psi_{FG}^{-1}(f_0,\theta''-\theta,\hat{\lambda}(\theta))\,C(\theta,\hat{\lambda}(\theta))d\theta, \quad (20)$$
$$R_W(\theta'',\hat{\lambda}(\theta''))=$$
$$=\int_{\theta}\Psi_{FG}^{-1}(f_0,\theta''-\theta,\hat{\lambda}(\theta))\,C_W(\theta,\hat{\lambda}(\theta))d\theta. \quad (21)$$

The algorithm (19) gives the optimum estimate of brightness temperature of a spatially-distributed object.

For practical implementation it is expedient to make some simplifications in the algorithm (19). Assume that the decorrelation filters are not adaptive, but depend on some average value $\hat{\lambda}$. Then the half-width of the bands appearing in (19) are equal $\Delta F(t_1,\hat{\lambda}(\theta))\approx\Delta F(\hat{\lambda})$ and $G(f,t,\hat{\lambda}(\theta))=G(f,\hat{\lambda})$ and the expression (10) will have the following form:

$$\Psi_{FG}(f_0,\theta'-\theta,\hat{\lambda})=2\Delta F(\hat{\lambda})\int_0^t\left|\dot{F}(f_0,\theta'-\theta_0(t_1))\right|^2\times$$
$$\times\left|\dot{F}(f_0,\theta-\theta_0(t_1))\right|^2 dt_1 = 2\Delta F(\hat{\lambda})\Psi_F(f_0,\theta'-\theta), \quad (22)$$

$$\Psi_{FG}^{-1}(f_0,\theta'-\theta,\hat{\lambda}(\theta))=0{,}5\Delta F^{-1}(\hat{\lambda})\Psi_F^{-1}(f_0,\theta'-\theta) \quad (23)$$

and

$$\int\Psi_{FG}(f_0,\theta'-\theta,\hat{\lambda}(\theta))\Psi_{FG}^{-1}(f_0,\theta''-\theta,\hat{\lambda}(\theta))d\theta=$$
$$=\int\Psi_F(f_0,\theta'-\theta)\Psi_F^{-1}(f_0,\theta''-\theta)d\theta=\delta(\theta'-\theta''). \quad (24)$$

Using equations (22) – (24), we then deduce:

$$C(\theta,\hat{\lambda})=2\Delta F(\hat{\lambda})\int_0^t\left|\dot{F}(f_0,\theta-\theta_0(t_1))\right|^2 dt_1,$$
$$C_W(\theta,\hat{\lambda})=2\Delta F_W(\hat{\lambda})\int_0^t\left|\dot{F}(f_0,\theta-\theta_0(t_1))\right|^2 dt_1,$$
$$R(\theta'')=\int_0^t\int_{\theta}\Psi_F^{-1}(f_0,\theta''-\theta)\left|\dot{F}(f_0,\theta-\theta_0(t_1))\right|^2 d\theta dt_1,$$
$$R_W(\theta'',\hat{\lambda})=\Delta F_W(\hat{\lambda})\Delta F^{-1}(\hat{\lambda})R(\theta''),$$

and the quasioptimum algorithm has the following form

$$\hat{B}(f_0,\theta'')=\Delta F^{-1}(\hat{\lambda})\int_{\theta}\Psi_F^{-1}(f_0,\theta''-\theta)\int_0^t u_{Fd}^2(t,\theta)dt\,d\theta -$$
$$-N_0R(\theta'')-N_p\Delta F_W(\hat{\lambda})\Delta F^{-1}(\hat{\lambda})R(\theta''). \quad (25)$$

Using the Nyquist theorem, we then deduce (expression (25) is being multiplied on $\Delta F(\hat{\lambda})$)

$$\hat{P}(\theta'')=\int_{\theta}\Psi_F^{-1}(f_0,\theta''-\theta)\int_0^t u_{Fd}^2(t,\theta)dtd\theta -$$
$$-P_0(\hat{\lambda})R(\theta''), \quad (26)$$

where $\hat{P}(\theta'')=\hat{B}(f_0,\theta'')\Delta F(\hat{\lambda})$, $P_0(\hat{\lambda})=N_0\Delta F(\hat{\lambda})$, $P_p(\hat{\lambda})=N_p\Delta F_W(\hat{\lambda})$ and was being considered the assumption $P_0(\hat{\lambda}) << P_p(\hat{\lambda})$.

The unknown power $P_0(\hat{\lambda})$ of the radiometer internal noise is calculated during the system calibration.

The quasi-optimal algorithm (26) has the following operations: multiplication of observation to the antenna pattern, decorrelation of the input sequence and quadratic detection, convolution with an inverse uncertainty function and the compensation of power of the internal receiver noise.

The block diagramme satisfying to the quasi-optimum algorithm (26) is being created. The quasi-optimum algorithm (26) is being written in following form

$$\hat{P}(\theta'')=\int_{\theta}\Psi_F^{-1}(f_0,\theta''-\theta)\times$$
$$\times\int_{-\infty}^{\infty}|\dot{K}(j2\pi f)G^{-1}(f,\hat{\lambda})\int_0^t\dot{F}(f_0,\theta-\theta_0(t))\times$$
$$\times u(t,\theta_0(t))\exp\{-j2\pi f t\}dt|^2 df\,d\theta - \quad (27)$$
$$P_0(\hat{\lambda})\int_0^t\int_{\theta}\Psi_F^{-1}(f_0,\theta''-\theta)\left|\dot{F}(f_0,\theta-\theta_0(t_1))\right|^2 d\theta dt_1.$$

The block diagram corresponding to (27) is shown in Fig. 1.

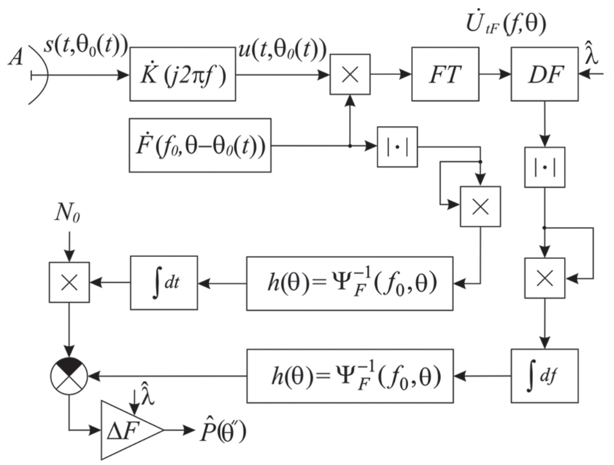

Fig. 1. The block diagram of quasioptimum signal processing in the microwave scanning radiometer

The observation $u(t,\theta_0(t))$ is being multiplied with the antenna pattern $\dot{F}(f_0,\theta-\theta_0(t))$ and after that arrives on the block of Fourier transformation (FT). This subcircuit describes the following part of optimum processing:

$$\dot{U}_{tF}(f,\theta)=\int_0^t \dot{F}(f_0,\theta-\theta_0(t))u(t,\theta_0(t))\exp\{-j2\pi f t\}dt.$$

The signal $\dot{U}_{tF}(f,\theta)$ is being processed in the decorrelation filter (DF) with amplitude-frequency characteristic $\dot{K}_W(j2\pi f,\hat{\lambda})=\dot{K}(j2\pi f)G^{-1}(f,\hat{\lambda})$ (we assume that $G(f,t,\hat{\lambda}(\theta))=G(f,\hat{\lambda})$) and after that in the following blocks: magnitude $|\cdot|$, square-law detector and integrator. Output signal is angular function and it has the following form

$$\int_{-\infty}^{\infty}|\dot{U}_{tF}(f,\theta)|^2\,df=0{,}5\int_\theta \hat{B}(f_0,\theta')\Psi_{FG}(f_0,\theta'-\theta,\hat{\lambda})d\theta'$$

$$+0{,}5N_0C(\theta,\hat{\lambda})+0{,}5N_pC_W(\theta,\hat{\lambda})=\int_0^t u_{Fd}^2(t,\theta)dt.$$

After that this signal enters into the block with the following impulse response

$$h(\theta)=\Psi_F^{-1}(f_0,\theta,\hat{\lambda}),$$

where

$$\Psi_F(f_0,\theta,\hat{\lambda})=\int_0^t\left|\dot{F}(f_0,\theta-\theta_0(t_1))\right|^2\left|\dot{F}(f_0,\theta_0(t_1))\right|^2 dt_1 .$$

Output signal has narrower autocorrelation function and it can be given by the following relation

$$\begin{aligned}&\Delta F^{-1}(\hat{\lambda})\int_\theta \Psi_F^{-1}(f_0,\theta''-\theta,\hat{\lambda})\times\\&\times\int_0^t u_{Fd}^2(t,\theta)dt\,d\theta=\hat{B}(f_0,\theta'')+\\&+N_0R(\theta'')+N_p\Delta F_W(\hat{\lambda})\Delta F^{-1}(\hat{\lambda})R(\theta'').\end{aligned}\tag{28}$$

After the block with the impulse

$$h(\theta)=\Psi_F^{-1}(f_0,\theta,\hat{\lambda})$$

is. On the secondary input of subtractor is the following signal

$$N_0R(\theta'')=N_0\int_0^t\int_\theta \Psi_F^{-1}(f_0,\theta''-\theta)\left|\dot{F}(f_0,\theta-\theta_0(t_1))\right|^2 d\theta dt_1.$$

This signal is being formed from the function $\dot{F}(f_0,\theta-\theta_0(t_1))$, which describe the antenna pattern. For this purpose function pass through following blocks: calculation of the module of function, the square-law detector, the block with the impulse response $h(\theta)=\Psi_F^{-1}(f_0,\theta,\hat{\lambda})$, integrator and multiply with N_0.

Assume that the condition $N_p \ll N_0$ is true and then last summand in expression (28) can be neglected. Using the amplifier with gain constant $\Delta F(\hat{\lambda})$ we obtain the power estimate as angular function in following form

$$\begin{aligned}&\hat{P}(\theta'')=\int_\theta \Psi_F^{-1}(f_0,\theta''-\theta)\int_0^t u_{Fd}^2(t,\theta)dt\,d\theta-\\&-N_0\Delta F(\hat{\lambda})\int_0^t\int_\theta \Psi_F^{-1}(f_0,\theta''-\theta)\left|\dot{F}(f_0,\theta-\theta_0(t_1))\right|^2 d\theta dt_1.\end{aligned}\tag{29}$$

The prior knowledge about the measurable parameter $\hat{\lambda}$ is necessary for calculation of decorrelation filter and its bandwidth $\Delta F(\hat{\lambda})$ therefore we enter $\hat{\lambda}$ on the secondary inputs of the decorrelation filter and amplifier.

CONCLUSION

In this paper, the algorithms of optimum and quasioptimum signal processing in the scanning radiometers have been synthesized. The quasioptimum algorithm has the following operations: multiplication of observation to the antenna pattern, decorrelation, convolutions with inverse uncertainty function of radiometer, square-law detection, integration and compensations of power of internal radiometer noise which measured at the calibration phase.

The block diagram satisfying to optimum algorithm has been developed. This block diagram, in contrast to known compensation scheme, contains following operation: multiplication of observation to the antenna pattern, decorrelation and convolutions with inverse uncertainty function of radiometer.

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В работе синтезированы алгоритмы оптимальной и квазиоптимальной обработки сигналов собственного радиотеплового излучения пространственно распределенных объектов в радиометрах со сканирующей диаграммой направленности. Показано, что оптимальный алгоритм содержит следующие операции: умножение наблюдения на функцию, описывающую диаграмму направленности антенны в текущий момент времени, декорреляцию, свертки с функцией, обратной функции неопределенности радиометра, квадратичного детектирования, интегрирования и компенсации мощности внутренних шумов радиометра, которую измеряют на этапе калибровки системы. Разработана соответствующая структурная схема радиометра, которая, в отличие от схемы компенсационного радиометра, содержит операции умножения наблюдения на функцию, описывающую диаграмму направленности антенны в текущий момент времени, декорреляции и свертки с функцией, обратной функции неопределенности радиометра.

Ключевые слова: оптимальный сканирующий радиометр, оценка яркостной температуры пространственно-протяженных объектов.

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У роботі синтезовані алгоритми оптимальної і квазіоптимальної обробки сигналів власного радіотеплового випромінювання просторово розподілених об'єктів у радіометрах зі сканувальною діаграмою спрямованості. Показано, що оптимальний алгоритм включає такі операції: перемноження спостереження на функцію, яка описує діаграму спрямованості антени в поточний момент часу, декорреляцію, згортання з функцією, яка є зворотною до функції невизначеності радіометра, квадратичного детектування, інтегрування та компенсації потужності внутрішніх шумів радіометра, яку вимірюють на етапі калібрування системи. Розроблено відповідну структурну схему радіометра, яка, на відміну від схеми компенсаційного радіометра, включає операції перемноження спостереження на функцію, яка описує діаграму спрямованості антени в поточний момент часу, декорреляції та згортання з функцією, яка є зворотною до функції невизначеності радіометра.

Ключові слова: оптимальний сканувальний радіометр, оцінка яскравісної температури просторово розподілених об'єктів.

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