Analysis of Potential Indicators of Radio Observation Efficiency Based on Information Characteristics

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Abstract. Synthetic aperture radar (SAR) is a powerful tool for remote sensing of the Earth's surface. The variety of practically important characteristics of a radar image quality and the radio observation conditions that determine them make it reasonable to introduce an unified indicator allowing at least a qualitative estimation of the influence of various factors on the potential radar observation efficiency, regardless of the signal processing method. As such an indicator, the amount of information contained in the reflected signal regarding the state of the observed object can be taken. Ratios are provided for decision-making on the efficiency of various approaches to the radio observation based on information-theoretic methods in terms of the indicators characterizing the amount of information received about the state of the observed object. The qualitative consideration carried out in this study ensures specifying the amount of information as a measure of the efficiency of radio observation during an aperture synthesis.

INTRODUCTION

The quality characteristics (efficiency indicators) of surface observation radars are largely determined by the specific tasks of radio observation. Based on these tasks, three main modes of SAR operation can be selected [1]:

- surface mapping, i.e. obtaining a two-dimensional plan of radio brightness contrasts, allowing obtaining data on the state of the surface when solving numerous problems of cartography, planetology, ecology, oceanography, the study of natural resources, agriculture, etc.;
- detection of radio-brightness targets against the background of average low-contrast reflections;
- obtaining detailed radar images ("portraying") of particular objects under observation.

The most versatile characteristics of radar image quality are used in estimating the efficiency of radio mapping. The practice of using SAR and similar tools in these tasks has identified the following main qualitative indicators in this mode [2]-[4]:

- the surface resolution δ_g;
- the contrast (radio brightness, dynamic) sensitivity δ_d;
- the dynamic range of reproduced radio brightnesses z_d;
- the swath width to the side of the SAR carrier flight route ΔL.

Resolution δ_g and contrast sensitivity δ_d are interrelated parameters that characterize the distinguishability of radar image elements [5]. In this case, contrast sensitivity δ_d is usually understood as the minimum ratio of signal intensities from the two elements (expressed, as a rule, in logarithmic units), at which this difference can be established with the required reliability. The dynamic range of reproduced radio brightnesses z_d characterizes the degree of interburst interferences of the signals reflected by the resolvable surface elements, and can be defined as the limiting ratio of the signal intensities at which the possibility of their separate observation remains. The swath width ΔL is limited by the objective laws of space-time observation of periodic coherent signals and also depends on the requirements for the resolution and contrast sensitivity.

Depending on the specific type of the observed surface (for example, a mountain range or an ocean area), the contrast sensitivity and dynamic range of the reproduced radio brightnesses can affect the final efficiency of radio observation in different ways, but the resolution and swath width in all the cases of radio mapping are the most important parameters.

When detecting radio brightness targets, the main quality indicators remain the usual radar characteristics – the probability of correct detection and the probability of false alarms [6]. The use of a synthesized aperture to solve this problem ensures the achievement of the required angular resolution. In this case, the dynamic range of the reproduced radio brightnesses is of a particular importance, since the effective scattering surfaces (ESS) of the detected targets can differ significantly.

Obtaining detailed radar images of the observed objects is most closely related to the task of achieving the limiting resolution [7], [8]. To the greatest extent adequate to this mode of SAR are, apparently, the efficiency indicators involved in the pattern recognition technique [9], [10]. However, as most of the cases of this technique application demonstrate, using such indicators may be a rather complex practice due to the object classification uncertainty. It should be noted that the problem of pattern recognition also arises in some other cases of SAR employment – when identifying low-contrast scenes of a characteristic type, identifying topographic and radar maps of the area, etc.

The variety of practically important quality characteristics of radar images and the conditions of radio observation [11] that determine them make it reasonable to introduce a single indicator allowing at least a qualitative estimation of the influence of various factors on the potential efficiency of radar obsevation, regardless of the method of signal processing. As such an indicator, the amount of information contained in the reflected signal regarding the state of the observed object can be taken.

In this study, a comparative estimation of the efficiency of different methods of maintaining radio observation or the same methods but under the different conditions is carried out based on the information-theoretic methods in terms of indicators characterizing the amount of information received about the state of the object under observation [12]-[14]. The subsequent presentation assumes that the size of the synthesized aperture is independent of the length of the irradiated surface area. This corresponds to the conditions of the so-called "sliding spotlight mode", when the SAR directional pattern is forcibly oriented to the selected surface area during the entire observation time [15]. It is also supposed to use digital processing of SAR signals and obtain a radar image in the form of a radio brightness "mosaic" [16]. In this case, the size of the mosaic element is defined as the resolution. It means that the choice of the resolution element should be made based on the requirements to other quality indicators of the radar image. Thus, when mapping low-contrast surfaces (for example, marine water areas), resolution is understood as the size of the surface at which the required contrast sensitivity is achieved.

The generalized radar image quality indicator deals with resolution and/or contrast sensitivity and can be termed as a resolution volume. The objective factors limiting the achievable value of this indicator include, first of all:

- the random nature of the signal reflected by the resolution element, which causes flickering of the radio brightness (the so-called "speckle noise") and depends, in turn, on the scattering surface properties and their stationarity;
- the energy characteristics of the radio channel (signal-to-noise ratio).

Outside of these factors, the concept of a limiting resolution is meaningless. Based on the general conclusions of the statistical theory of resolution, one can assume that, in the absence of interfering influences, separate observation of the signals with arbitrarily close parameters is principally possible (the so-called "super-resolution" effect) [17], [18].

The practical presentation of the quality indicators close to the potential ones can be achieved as a result of an application of the processing methods arising from the resolution theory approaches and taking into account a priori statistical characteristics of the scattering properties of the observed object. In this case, the signal reflected by the resolution element should be considered as a random process with the specified (with varying degrees of certainty) statistical characteristics [19]. One of such characteristics the normalized autocorrelation signal function should be, in any case.

Obviously, the larger is the correlation interval of the reflected signal, the more efficient is the coherent accumulation, i.e. the longer is the synthesized aperture. Therefore, when estimating the maximum achievable resolution, it is of a particular importance to establish the autocorrelation function of the reflected signal based on the use of an adequate statistical model of the observed object.

CORRELATION FUNCTION OF THE REFLECTED SIGNAL

The observed surface is a two-dimensional distributed radar target. However, the patterns of the reflected signal formation by the surface elements located along the flight route of the SAR carrier are of greatest interest, since it is these patterns that determine the capabilities of the synthesized aperture. Therefore, in what follows, a one-dimensional pattern of a reflection from the band parallel to the sub-satellite wake is to be considered.

Fig. 1 schematically shows the implementation of the relief section and explains the designations adopted in what follows. The irradiating wave is assumed to be flat (unfocused synthesis conditions), the angle γ corresponds to the direction of arrival of the sensing signal and, in the following relations, is a variable that determines the current angular position of the SAR carrier during the sensing.

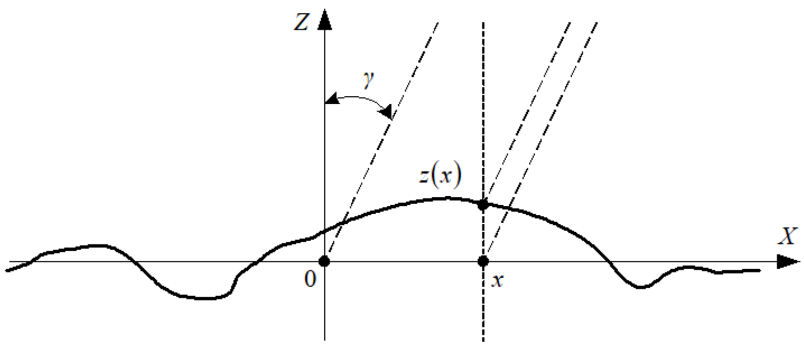

FIGURE 1. The relief section realization.

When recording a reflected wave, it is considered possible to use the principles of physical optics. In this case, the surface point with coordinate x creates a reflected signal in the direction of the carrier with a phase shift with respect to the irradiating signal (minus the constant value) [20]:

$$\varphi(x) = -4\pi\left(x\sin\gamma + z(x)\cos\gamma\right)/\lambda\,,$$

where λ is the wavelength of the irradiating signal.

Surface element bounded by the coordinates $\left(x_i + \Delta x/2, x_i - \Delta x/2\right)$ generates a reflected signal

$$S_i\left(t;\gamma;x_i\right) = S(t)\varepsilon\left(\gamma;x_i\right),$$

where $S(t)$ is the complex modulating function of the irradiating wave;

$$\varepsilon\left(\gamma;x_i\right) = \int_{x_i-\Delta x/2}^{x_i+\Delta x/2} \exp\left[j4\pi\left(x\sin\gamma + z(x)\cos\gamma\right)/\lambda\right]\mathrm{d}x =$$
$$= \exp\left[j4\pi x_i\left(\sin\gamma_1 + \sin\gamma_2\right)/\lambda\right]\int_{-\Delta x/2}^{\Delta x/2} \exp\left[j4\pi\left(x\sin\gamma + z\left(x+x_i\right)\cos\gamma\right)/\lambda\right]\mathrm{d}x\,. \tag{1}$$

The random function $\varepsilon\left(\gamma, x_i\right)$ is the one that determines the statistical characteristics of the signal reflected by the *i*-th element of the surface. The equation (1) does not take into account the non-uniformity of the irradiating field strength along the surface sections with different slopes. In particular, the shading effect is not accounted for.

The correlation function $R_\varepsilon\left(\gamma_1,\gamma_2;x_i\right) = \overline{\varepsilon\left(\gamma_1;x_i\right)\varepsilon^*\left(\gamma_2;x_i\right)}$ is of the form:

$$R_\varepsilon(\gamma_1,\gamma_2;x_i)\approx \exp[j4\pi x_i(\gamma_1-\gamma_2)/\lambda]\int\int_{-\Delta x/2}^{\Delta x/2}\overline{\exp[j4\pi(x_1\sin\gamma_1-x_2\sin\gamma_2)/\lambda]\times}$$

$$\overline{\times\exp\left[j4\pi\left(z(x_1+x_i)\cos\gamma_1+z(x_2+x_i)\cos\gamma_2\right)/\lambda\right]}\mathrm{d}x_1\mathrm{d}x_2=$$

$$=\exp[j4\pi x_i(\gamma_1-\gamma_2)/\lambda]\int\int_{-\Delta x/2}^{\Delta x/2}\exp[j4\pi(x_1\sin\gamma_1-x_2\sin\gamma_2)/\lambda]\times \tag{2}$$

$$\times\exp\left[-(4\pi\sigma_z/\lambda)^2\left(\cos^2\gamma_1+\cos^2\gamma_2-3r_0(x_1-x_2)\cos\gamma_1\cos\gamma_2\right)/2\right]\mathrm{d}x_1\mathrm{d}x_2 .$$

Here σ_z^2 is the dispersion of the normal random function describing the cross section of the relief $z(x)$, $r_0(x_2-x_1)$ is the normalized correlation function of $z(x)$, and the overline and the symbol "*" mean the operations of statistical averaging and complex conjugation, respectively.

This sets the nature of the irregularities of the reflecting surface or the configuration of the complex observed object. Further transformations (when passing to the integration variable $u=4\pi x/\lambda$) make it possible to obtain:

$$R_\varepsilon(\gamma_1,\gamma_2;x_i)=k\exp[\,ju_i(\gamma_1-\gamma_2)\,]\int_0^{\Delta u}\exp\left[-\sigma^2\left(\cos^2\gamma_1+\cos^2\gamma_2-2r_0(u)\cos\gamma_1\cos\gamma_2\right)/2\,\right]\times$$

$$\times[\,\sin((\sin\gamma_1-\sin\gamma_2)(\Delta u-u)/2)\cos((\sin\gamma_1+\sin\gamma_2)u/2)/(\sin\gamma_1-\sin\gamma_2)\,]\mathrm{d}u , \tag{3}$$

where k is the constant and $u_i=4\pi x_i/\lambda$, $\Delta u=4\pi\Delta x/\lambda$, $\sigma^2=(4\pi\sigma_z/\lambda)^2$ are the normalized parameters of the reflecting element.

The form of the function $R_\varepsilon(\gamma,\gamma+\delta\gamma;x)$, where $\gamma=\gamma_2$, $\delta\gamma=\gamma_1-\gamma_2$, shows in which sector of the sensing angles neighboring γ the correlation of the reflected signals is preserved, i.e. it determines the practically achievable angular size of the synthesized aperture.

If the correlation function of irregularities $z(x)$ is written as

$$R_\varepsilon(x_1-x_2)=\sigma_z^2\exp\left[-(x_1-x_2)^2/\rho_z^2\right],$$

where ρ_z can be taken as the correlation interval of the level of irregularities, then

$$r_0(u)=\exp\left(-u^2/\rho^2\right),\qquad \rho=4\pi\rho_z/\lambda .$$

The correlation function (3) can be represented as

$$R_\varepsilon(\gamma,\delta\gamma;u_i)=k\exp(ju_i\delta\gamma)r_\varepsilon(\gamma,\delta\gamma), \tag{4}$$

where the exponential factor in front of the integral determines the regular law of the signal phase change when this signal is reflected by the *i*-th element (a Doppler shift during the SAR carrier motion), so that the actual correlation properties of the reflected signal depend on the integral

$$r_\varepsilon(\gamma,\delta\gamma)=\int_0^{\Delta u}\exp\left[-\sigma^2\left(\cos^2\gamma+\cos^2(\gamma+\delta\gamma)-2r_0(u)\cos\gamma\cos(\gamma+\delta\gamma)\right)/2\right]\times$$

$$\times[\sin((\sin\gamma-\sin(\gamma+\delta\gamma))(\Delta u-u)/2)\cos((\sin\gamma+\sin(\gamma+\delta\gamma))u/2)/(\sin\gamma-\sin(\gamma+\delta\gamma))]\mathrm{d}u . \tag{5}$$

The form of the function (5) is determined by the parameters of the irregularities σ, ρ and the size of the reflecting element Δu. When $\delta\gamma$, the function (5) characterizes the backscattering coefficient in the direction γ:

$$r_\varepsilon(\gamma)=k_0\int_0^{\Delta u}\exp\left[-\sigma^2(1-2r_0(u))\cos^2\gamma\right](\Delta u-u)\cos(u\sin\gamma)\mathrm{d}u . \tag{6}$$

The formula (6) qualitatively reflects the "useful" effect of changing the average slope of the surface element and its structure in creating radio-brightness contrasts (in addition to the Fresnel reflection coefficient).

When $\sigma_z/\Delta x\le 1$, $\rho_z/\Delta x\le 1$ (the case of the rough surface), in the area $\gamma,\delta\gamma\le 1$ for the function (5) one can take:

$$r_\varepsilon(\gamma,\delta\gamma)\approx k_1\sin(\delta\gamma\Delta u/2)/\delta\gamma=k_2\,\mathrm{sinc}(\delta\gamma\Delta u/2),\qquad \mathrm{sinc}(u)=\sin(u)/u , \tag{7}$$

so that the correlation function of the reflected signal depends only on the length of the resolution element Δx and the wavelength.

However, when the sizes of surface irregularities are commensurate with Δx or greater ($\sigma_z/\Delta x > 1$, $\rho_z/\Delta x > 1$), the form of the function $r_\varepsilon(\gamma, \delta\gamma)$ changes significantly. Fig. 2 shows the results of calculating the normalized functions $r_\varepsilon(\gamma, \delta\gamma)$ (5) for $\gamma = 0.5$, $\Delta x/\lambda = 10$, $\rho_z/\Delta x = 2$ at three values $\sigma_z/\Delta x = 1$; 2.5 and 5.

A significant narrowing of the angular interval of the correlation of the reflected signal with an increase in the size of the irregularities can be interpreted as a consequence of the motion of the bright points of the surface over the observation interval, which violates the coherence of the reflections. This means that in these cases the artificial aperture cannot, in principle, be unlimited, and, consequently, the limiting resolution is limited.

In Fig. 3, the same effect is illustrated by the dependence of the width of the normalized function $r_\varepsilon(\gamma, \delta\gamma)$ on the length of the element Δx at the specific values $\lambda = 0.1$ m, $\sigma_z = 5$ m, $\rho_z = 5$ m and $\gamma = 0.5$ rad (Fig. 3a) or $\gamma = 1$ rad (Fig. 3b). The scale along the axes is logarithmic. It can be seen from the graphs that the correlation interval stops increasing at $\Delta x < 1$ m ($\gamma = 0.5$ rad) and $\Delta x < 3$ m ($\gamma = 1$ rad).

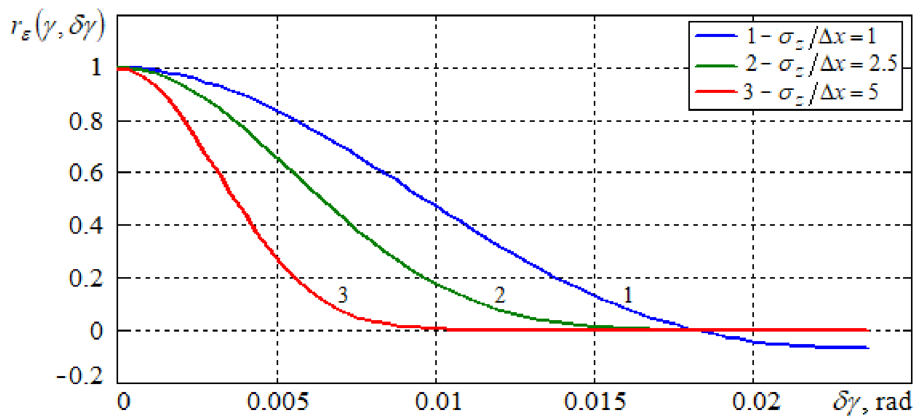

FIGURE 2. The correlation function of the reflected signal for the different values of the surface roughness parameter $\sigma_z/\Delta x$).

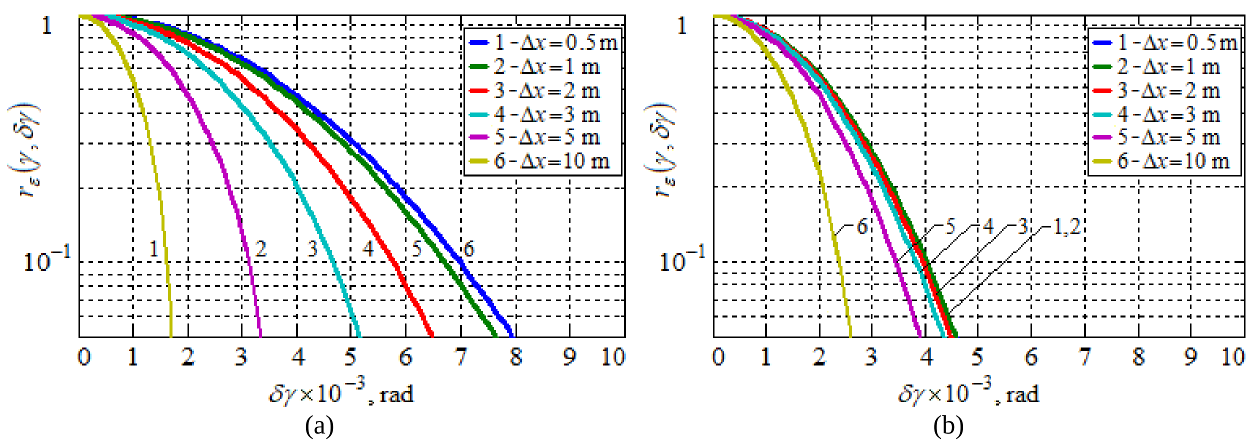

FIGURE 3. The correlation function of the reflected signal for the different lengths of the resolution element Δx when $\gamma = 0.5$ rad (a) and $\gamma = 1$ rad (b).

In general, a qualitative analysis of the relation (5) allows us to conclude that the real resolution of SAR is limited by the characteristic size of surface irregularities or structural elements of a complex observed object. A detailed consideration of the characteristics of radio observation under these conditions presents significant difficulties and is practically of little interest. Therefore, in the further study, observation areas are considered that have a rough surface and allow using the relation (7) to describe the correlation function of the reflected signal. The general expression for the normalized correlation function of the reflected signal, which will be used below, taking into account (4), has the form:

$$r_\varepsilon(\delta\gamma) = \operatorname{sinc}(\delta\gamma\Delta u/2)\exp(ju_i\delta\gamma), \tag{8}$$

where $\delta\gamma = \gamma_1 - \gamma_2$, $\Delta u = 4\pi\Delta x/\lambda$, $u_i = 4\pi x_i/\lambda$.

INFORMATION CHARACTERISTICS OF THE REFLECTED SIGNAL

In accordance with the main task of SAR, the state of the viewing surface should be characterized by the values ξ_i of radio brightness (specific radar cross section) of the resolution elements in the irradiation zone, considered as random variables. In this case, the random state vector $\boldsymbol{\xi}$ is displayed by a random sequence y_k of the complex samples of the received signal **y**. The amount of information $I(\mathbf{y},\boldsymbol{\xi})$ contained in the random vector **y** relative to the vector $\boldsymbol{\xi}$ can be taken as a measure of the potential efficiency of radio observation.

The mutual amount of information contained by the ensemble of random vectors **y**, $\boldsymbol{\xi}$ is determined by the formula [21]:

$$I(\mathbf{y},\boldsymbol{\xi}) = \int w(\mathbf{y},\boldsymbol{\xi})\log\frac{w(\mathbf{y},\boldsymbol{\xi})}{w(\mathbf{y})w(\boldsymbol{\xi})}\mathrm{d}\mathbf{y}\mathrm{d}\boldsymbol{\xi}. \tag{9}$$

In (9), $w(\mathbf{y})$, $w(\boldsymbol{\xi})$ are the partial (marginal) distributions of the probability density of the corresponding vectors, while $w(\mathbf{y},\boldsymbol{\xi})$ is their joint distribution.

Using the Bayes formula, the expression can be rewritten as follows

$$I(\mathbf{y},\boldsymbol{\xi}) = \int w(\boldsymbol{\xi})w(\mathbf{y}|\boldsymbol{\xi})\log\frac{w(\mathbf{y}|\boldsymbol{\xi})}{w(\mathbf{y})}\mathrm{d}\mathbf{y}\mathrm{d}\boldsymbol{\xi}, \tag{10}$$

where $w(\mathbf{y}|\boldsymbol{\xi})$ is the conditional distribution of the samples y_k for the specified values of ξ_i.

The physical principles of the reflected signal formation make it possible to establish the distributions $w(\boldsymbol{\xi}), w(\mathbf{y})$, $w(\mathbf{y}|\boldsymbol{\xi})$. The distribution $w(\boldsymbol{\xi})$ should be specified by choosing a statistical model of the reflecting surface. It is possible, for example, to consider the radio brightness of the resolution elements as the independent random variables with the same partial distributions $w(\xi_i)$.

The signal reflected by each element is a random function of the sensing angle γ (or of the time of the carrier motion) with the given normalized correlation function (8). The value ξ_i determines the partial signal dispersion. Thus, the correlation matrix of the total signal samples has the elements $R_{z\,kl} = \sum_i \xi_i r_i(\gamma_k - \gamma_l)$, where γ_k, γ_l are the discrete values of the sensing angles during the aperture synthesis.

The elements of the correlation matrix of the partial distribution $w(\mathbf{y})$ of the signal samples **y** are $R_{y\,kl} = \sum_i \bar{\xi} r_i(\gamma_k - \gamma_l)$, where $\bar{\xi}$ is the mathematical expectation of ξ_i (average background level).

If one considers the amount of information $I(\mathbf{y},\xi_n)$ relative to the value ξ_n of the element of the number *n*, then the elements of the correlation matrix of the conditional distribution $w(\mathbf{y}|\xi_n)$ take the form:

$$R_{n\,kl}(\xi_n) = \xi_n r_n(\gamma_k - \gamma_l) + \sum_i \bar{\xi} r_i(\gamma_k - \gamma_l).$$

Simultaneously,

$$I(\mathbf{y},\xi_n) = \int w(\xi_n)w(\mathbf{y}|\xi_n)\log\frac{w(\mathbf{y}|\xi_n)}{w(\mathbf{y})}\mathrm{d}\mathbf{y}\mathrm{d}\xi_n. \tag{11}$$

With a sufficiently large number of resolution elements in the observation area, it is permissible to consider the distribution of the signal samples as normal. It can be shown [22] that in this case

$$I(\mathbf{y},\xi_n) = \frac{1}{2}\int_0^\infty w(\xi_n)\log\frac{\det\mathbf{R}_y}{\det\mathbf{R}_n(\xi_n)}\mathrm{d}\xi_n, \tag{12}$$

where the sign det denotes the determinant of the corresponding correlation matrix, and the logarithm is taken to the base 2. In this case, the value $I(\mathbf{y},\xi_n)$ is calculated in binary units of information.

In further calculations, two distribution laws [23] of the logarithm of ξ ($\zeta = \ln \xi$) are considered:

– the binary one with the equiprobable levels

$$w(\zeta) = [\,\delta(\zeta - \zeta_0) - \delta(\zeta + \zeta_0)\,]/2\,, \tag{13}$$

– normal with the dispersion σ_ζ^2

$$w(\zeta) = \exp\left(-\zeta^2/2\sigma_\zeta^2\right)/\sigma_\zeta\sqrt{2\pi}\,. \tag{14}$$

At the same time

$$I(\mathbf{y},\zeta) = \frac{1}{2}\int_{-\infty}^{\infty} w(\zeta)\log\frac{\det\mathbf{R}_y}{\det\mathbf{R}_n(\exp(\zeta))}\mathrm{d}\zeta\,. \tag{15}$$

Entropy at a binary distribution is $E = 1$ bit, which allows comparing the absolute value with it. The log-normal distribution does not provide such an opportunity (because in this case entropy is $E = \infty$), however, it should be considered closer to the real conditions.

In the following calculation examples, a sequence of N signal samples with a given sensing angular interval $\mathrm{d}\gamma$ (i.e., the synthesized aperture angular size $\Gamma = (N-1)\mathrm{d}\gamma$) is used. The number of resolution elements M is specified for each of the cases. The amount of information is calculated relative to the central element $U_n = 0$.

In Fig. 4, one can see the dependence of $I(\mathbf{y},\zeta)$ on the value of σ for the log-normal distribution of radio brightness (14). The number of samples is $N = 25$, the number of the elements is $M = 3$, the element size is $\Delta x/\lambda = 10\ldots21$ (curves 1-6), $\mathrm{d}\gamma = 0.01$ rad. And Fig. 5 shows the similar dependence of the amount of information on $\Delta x/\lambda$ at $\sigma = 1.3\ldots3.9$ dB (curves 1-7).

Joint consideration of the diagrams allows tracing the relationship between the resolution and the contrast sensitivity, the measure of which is the value of σ. The same amount of information can be achieved at different resolutions by changing the requirements for the contrast sensitivity. Thus, the value $I(\mathbf{y},\zeta)$ marked by dotted line in Fig. 4 is achieved at both $\Delta x/\lambda = 13$, $\sigma_\zeta = 2.5$ dB and $\Delta x/\lambda = 10$, $\sigma_\zeta = 3.5$ dB.

The diagram in Fig. 6 corresponds to the binary distribution (13) and demonstrates the change in the amount of information for high values of ζ_0. The diagram parameters are: $\Delta x/\lambda = 10$, $\mathrm{d}\gamma = 0.0025$ rad, $M = 41$, $N = 25$. It can be seen from this diagram that at $\zeta_0 > 10$ dB the amount of information stops changing, which indicates that the limit of the dynamic range has been reached, when strong interfering signals begin to mask the useful signal. By changing the specified observation conditions, it is possible to estimate the achievable dynamic range of potentially reproducible radio brightnesses.

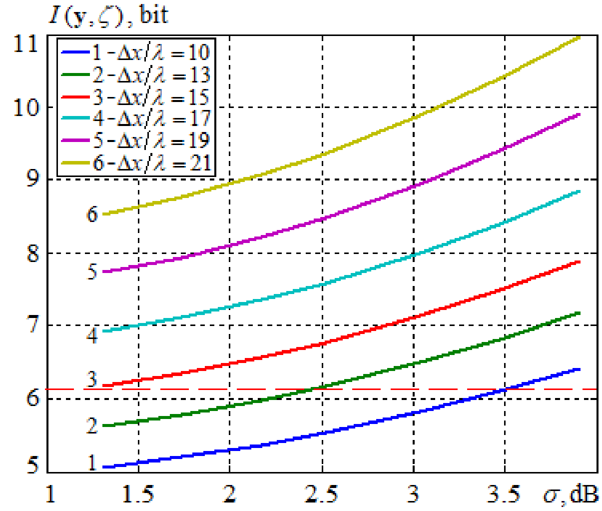

FIGURE 4. The dependence of the amount of information on the contrast sensitivity.

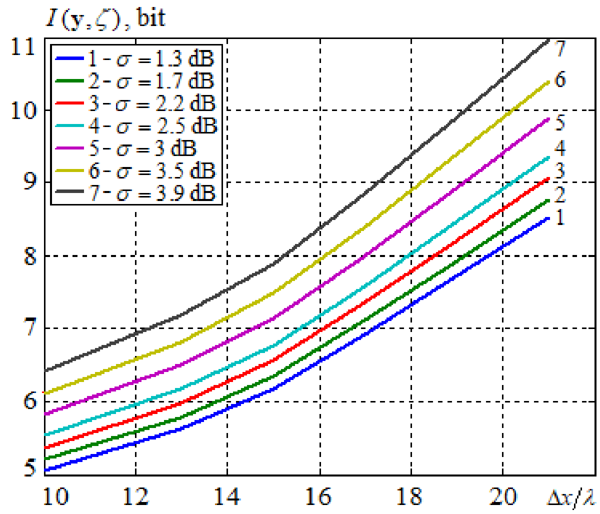

FIGURE 5. The dependence of the amount of information on the resolution.

The amount of information as an indicator of efficiency makes it possible to examine the effect of a recurrent interference on the quality of observation results. In Fig. 7, the values of $I(\mathbf{y},\zeta)$ for the binary distribution (13) at $\zeta_0 = 9$ dB is displayed. The number of the resolution elements M in the irradiation zone varies from 19 to 41. The elements are attached in pairs on both sides of the observation area. The resolution element size is $\Delta x/\lambda = 10$, the angular interval between the sensings is $\mathrm{d}\gamma = 0.0025$ rad, the number of the signal samples is $N = 25$. In accordance with (8), the recurrent interference is created by the element for which $U_i\delta\gamma = 2\pi$ or $\delta\gamma x_i/\lambda = 0.5$. In this case, the interference for the central element is generated by the 20-th side element ($M = 41$).

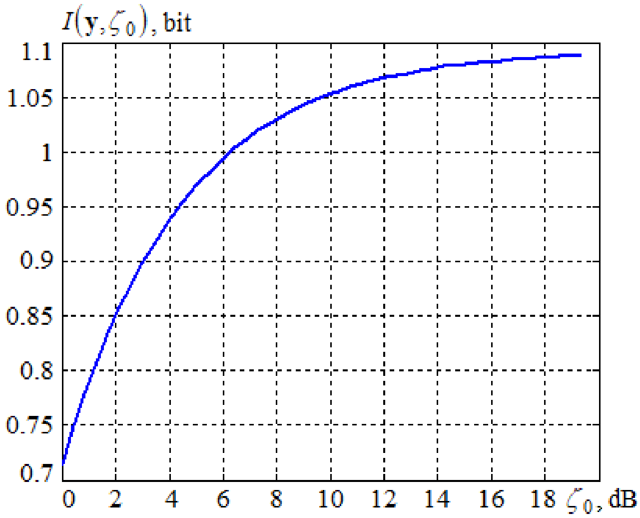

FIGURE 6. The change in the amount of information at large radio brightness values of the resolution elements.

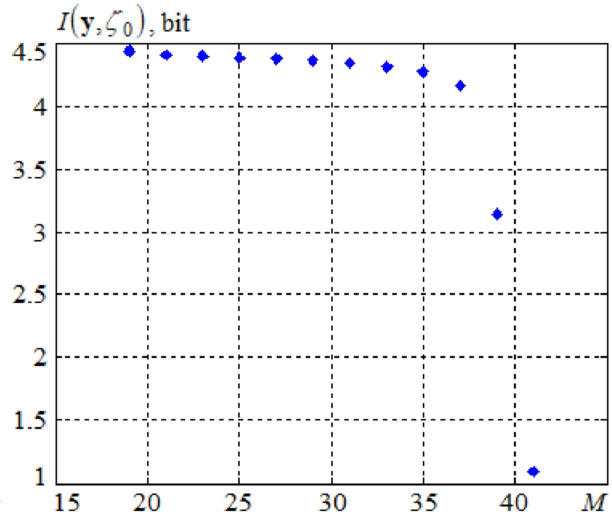

FIGURE 7. The influence of the recurrent interference on the quality of the observation results.

As it follows from Fig. 7, a sharp drop in the amount of information occurs at $M = 41$, thus reflecting the presence of the recurrent noise. Besides, a partial drop due to the interference produced by the 19-th side element ($M = 39$) is also detected.

CONCLUSION

A comparative estimation of the efficiency of the different radio observation methods during the aperture synthesizing or of the same methods but under the varied conditions can be performed based on the information-theoretic methods in terms of the indicators characterizing the amount of information received about the state of the observed object. Although, as absolute characteristics, such indicators, as a rule, are not used due to the complexity of their practical interpretation, a qualitative study of the information characteristics makes it possible to identify the relationship between such indicators of a potential efficiency as the resolution and the contrast sensitivity in the specific radio observation conditions.

If one considers the amount of information as a measure of the reliability of distinguishing between the two levels of radio brightness of the resolution elements for their given ratio, then a qualitative study further allows specifying the amount of information as a measure of the efficiency of a radio observation during the aperture synthesis. A similar characteristic is also used in other approaches to estimating the radio observation efficiency by SAR. In this case, as a measure of the reliability of the observation, one can consider, for example, the probability of distinguishing between the two levels of radio brightness. The amount of information as such a measure has the merit of being a generally accepted measure of the efficiency for many radio communication systems.

The results of the study can be used while designing the advanced tools of a remote radio surface watch.

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