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STUDY ON POTENTIAL APPLICATION OF BRIGHTNESS TEMPERATURE MODELS IN PASSIVE REMOTE SENSING

In the modern science and practice of remote sensing of any surface, including various types of land cover, radio systems are widely used. Due to low energy consumption and high stealth, the most promising direction of technical tools for remote sensing is the development of passive remote sensing systems. To estimate the specific parameters of the surface, information on the relation between the signals of the thermal radiation and these parameters is needed. Therefore, it is relevant to study and analyze the existing types of such relations that connect the brightness temperature and the parameters of the Earth's surfaces; this is the ***subject matter*** *of the study in this paper. The* ***goal*** *of this study is to analyze existing relation models and study the conditions of their application in terms of operating frequencies, geometric characteristics, type of surface coverage (with vegetation, without vegetation, etc.), as well as the method of obtaining mathematical relations (electrodynamic models or empirical models). Due to the large number of different types of earth surface coverings and different types of surface models, in order to simplify remote sensing tasks for passive systems, as well as to improve the results of modeling or experiments, the following* ***tasks*** *are formulated: to study and classify existing models of the relation between surface parameters and brightness temperature, and to calculate and analyze the potential accuracy of estimating surface parameters by passive remote sensing systems. The following* ***results*** *were obtained: the impact of the atmosphere on the surface's brightness temperature, described by the electrodynamic flat model, for the operating frequencies 75–110 GHz of the radiometer was analyzed. The impact of the atmosphere on the brightness temperature appears at sighting angles greater than 50° at horizontal polarization and greater than 80° at vertical polarization. According to the results, it can be said that the estimation accuracy of the imaginary part of the complex permittivity decreases with an operating wavelength decrease, and the estimation accuracy of the real part is the opposite.* ***Conclusions****. The results of simulation modeling show that for radiometers with the above-mentioned operating frequencies, it is possible to estimate the real permittivity or only the real component separately in the case of describing the surface with a complex permittivity parameter. It is recommended that the study be conducted at vertical and horizontal polarizations, without and with the impact of the atmosphere. To estimate the surface conductivity (the imaginary part of the complex permittivity of a surface), systems with lower operating frequencies are required. Thus, this study presents an analysis of existing models, calculates the potential accuracy of parameters estimation when using these models, and provides recommendations for practical experiments or modeling.*

Keywords: *brightness temperature; passive remote sensing; surface model; permittivity; conductivity.*

1. Introduction

Motivation. Solving the problems of monitoring the earth's surface state in modern science and practice, considering the constant climate change, is relevant and sometimes even necessary. Moreover, all modern studies, including studies of soil moisture [1, 2], use remote sensing methods and appropriate radiosystems to solve such problems.

As part of such studies, the creation and analysis of a passive radar (radiometer), which is planned to be launched on the university nanosatellite KhAI-1KA, is interesting from both practical and scientific points of view. The study in this paper is based on its characteristics, which allows us to determine the theoretically possible capabilities of estimating surface parameters using such a passive system.

State of the Art. Remote sensing, in the broadest sense, means obtaining information about the Earth's surface and objects located on it or in its interior using various non-contact methods [3]. When organizing and using remote sensing data, the following tasks should be solved: development of models of mathematical connections between surface parameters and backscattering characteristics, development of an observation equation, development of optimal processing algorithms and analysis of estimates' accuracy [4, 5]. Moreover, the choice of the optimal model for surface description and the optimal conditions for conducting the experiment is the key to the effectiveness of such an experiment and the interpretation of its results [6, 7].

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Currently, both active and passive radio systems are used for remote sensing [8]. Each of them has its advantages and disadvantages; therefore, both types of systems are most often on modern carriers.

An analysis from open sources shows that, due to their advantages, passive systems are often used to solve various problems (both theoretical and practical), in particular, to restore the parameters of the studied surface or to analyze the results of practical experiments [9, 10]. At the same time, the accuracy and suitability of the obtained results depend on the fit of the chosen surface description model to the real conditions of the studied surface [11]. Currently, there are difficulties in choosing optimal models of brightness temperatures. Therefore, this topic was chosen for the presented study: to analyze existing models, compare models' data provided by the authors, and research potential accuracy characteristics.

Objective. In this study, we consider systems for processing the self-radiation of surfaces and mathematical models for recording the brightness temperature as a function of surface parameters. This study develops recommendations for modeling and practical experiments and simplify the solution of remote sensing problems.

This article considers a passive system being developed at National Aerospace University "Kharkiv Aviation Institute" with specific operating parameters (operating frequency band from 75 GHz to 110 GHz). For this system, models of the connection between surface parameters and brightness temperature are selected, and mathematical modeling is performed to obtain the potentially possible accuracy of these parameter estimations.

To achieve the stated goals of the work, it was necessary to solve and complete tasks such as collecting information from open sources on existing models of surface description for active and passive remote sensing (section 2), describing and analyzing use cases and limitations for selected models (section 2, Table 1), analyzing modern radiometric systems to determine the conditions for conducting experimental studies and determining appropriate models for surface description (section 3), constructing the brightness temperature dependencies as a function of sighting angles (section 4), calculating potential accuracies of estimation of surface parameters according to the selected conditions and models and plotting the dependencies of estimation variances on sighting angles for horizontal and vertical polarization (section 5), calculating and analyzing potential accuracy dependencies as a function of wavelengths (section 5, Fig. 5), and formulating recommendations on the conditions for conducting research (section 7).

2. Analysis of Existing Models

The most mathematically and physically accurate relation between surface parameters and radiation characteristics is determined by electrodynamic models [12, 13]. Such models can be used to describe a water surface in complete calm (flat surface model), an asphalt, concrete, or arable land surface (microroughness surface model), a desert or water surface with varying levels of swell (large-scale and two-scale models), and other types of surfaces [13]. Despite the electrodynamic accuracy of such models, they do not always represent all the parameters of real earth surfaces; therefore, the problem of creating more practical empirical or regression models has arisen. Empirical models are mainly created for the remote sensing of a specific type of earth surface or for a specific experiment. Among such models are, e.g., the foam surface model [14, 15], the $\tau-\omega$ model [16], and the Q_p model [17].

Multiparametric measurements in passive sensing systems allow us to estimate not only the parameters of the underlying surface but also those of the atmospheric layer between this surface and the receiving antenna. To achieve this, the mathematical relation between the surface parameters and the radiated field must include the appropriate characteristics of this atmosphere layer. Such studies can be performed, e.g., using a flat surface model with the atmosphere impact [12, 18] and various models for estimating moisture reserves [19, 20]. For the above-mentioned electrodynamic and empirical models, a comparative analysis was performed on the basis of operating frequencies and usage restrictions. The results of the analysis are shown in Table 1. There are no frequency restrictions on the use of electrodynamic models, but there are strict requirements for the ratio of the operating frequency (wavelength λ) and the geometric parameters of the surface: the root mean square height of roughness σ_h (or their spatial height $h(x, y)$), radii of curvature of roughness $R_к$, etc. Empirical models, as mentioned earlier, are created for specific experimental studies; therefore, they work correctly only in limited frequency ranges and for a certain type of surface.

Thus, the process of selecting a model to describe the surface under study is a rather complicated and important operation that must be performed before each practical experiment. In addition, knowledge of the relation between surface radiation and its parameters is necessary to solve the inverse problem of estimating surface parameters from the self-radiation received by the radio system.

3. Modern radiometers

The main advantages of passive-type radio systems (stealth and energy efficiency) are the basis for the ongoing development of this area. In particular, in accordance with the Law of Ukraine "On Space Activity" and the "National Target Scientific and Technical Space Program of Ukraine for 2021-2025" [21, 22], National Aerospace University "KhAI" is conducting a study on the topic "Ultra-wideband microwave passive radar for the university nanosatellite KhAI-1KA". The project aims to design and manufacture a wideband microwave passive radar (radiometer), which is planned to be launched on the university nanosatellite KhAI-1KA. According to the problem statement, the proposed radiometer has an operating frequency band from 75 GHz to 110 GHz (wavelength 2.7 mm – 4 mm). This frequency range is used in this study to analyze the possibility of using different self-radiation models to solve the problems of surface estimation by passive radio systems.

4. Brightness temperature study

For the operating frequencies of the radiometer of 5 – 110 GHz (wavelength 2.7 – 4 mm), a comparative analysis of the atmosphere's influence on the surface's brightness temperature described by the flat model was performed.

Radio-brightness temperature of the thermal radiation of a flat surface

$$T_{ЯВ(Г)} = (1-\left|\dot{K}_{fB(Г)}\right|^2)T_0 , \qquad (1)$$

where $\dot{K}_{fB(Г)}$ is Fresnel coefficients;

Table 1

Comparative analysis of the models

№	Model name	Frequency (f)	Wavelength (λ)	Applicable for
1	Flat model	–	–	$h(x,y)=0$, $\sigma_h \approx 0$
2	Flat (taking into account the atmosphere) model	–	–	$h(x,y)=0$, $\sigma_h \approx 0$
3	Small-scale model	–	–	$\lvert h(x,y)\rvert \ll \lambda$, $\partial h(x,y)/\partial x \ll 1$, $\partial h(x,y)/\partial y \ll 1$, $\sigma_h \le \lambda/20$
4	Large-scale model	–	–	$R_{кх} \gg \lambda$, $R_{ку} \gg \lambda$, $\sigma_h \ge \lambda$
5	Two-scale model	–	–	$\sigma_{h1} \ge \lambda$, $\sigma_{h2} \ll \lambda$
6	Model of the surface with foam	9.3 – 34 GHz	8.8 mm – 3.2 cm	For sea surface with foam (excluding illumination), considering wind speed
7	$\tau-\omega$ model	4 – 8.8 GHz	3.4 – 7.5 cm	Vegetation is an evenly absorbing and backscattering layer above the soil surface.
8	Q_p model	6.9 – 36.5 GHz	8.3 mm – 4.3 cm	Surface without vegetation
9	Regression model	22.2 – 37.5 GHz	0.8 – 1.35 cm	Estimation of the moisture content of a cloudless atmosphere
10	"Meteor" regression model	37.5 GHz	0.8 cm	Estimation of the moisture content of the atmosphere and clouds at a sighting angle $\theta = 30^\circ$
11	"Nimbus 5" model	31.25 GHz, 22.22 GHz	$\lambda_1 = 0.96$ cm, $\lambda_2 = 1.35$ cm	To estimate the moisture content of the atmosphere and clouds during nadir viewing, $\theta = 0^\circ$
12	"Seasat" model	37.05 GHz, 20.98 GHz, 17.96 GHz, 10.71 GHz, 6.593 GHz	$\lambda_1 = 0.81$ cm, $\lambda_2 = 1.43$ cm, $\lambda_3 = 1.67$ cm, $\lambda_4 = 2.8$ cm, $\lambda_5 = 4.55$ cm	To determine the velocity of near-water winds $v_П < 7$ m/s, the thermodynamic temperature T_0 [K], atmosphere moisture content Q [g/cm^2], and clouds moisture content W [mg/cm^2]

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$$\dot{K}_{f\Gamma} = \frac{\cos\theta - \sqrt{\dot{\varepsilon} - \sin^2\theta}}{\cos\theta + \sqrt{\dot{\varepsilon} - \sin^2\theta}},$$
$$\dot{K}_{fB} = \frac{\dot{\varepsilon}\cos\theta - \sqrt{\dot{\varepsilon} - \sin^2\theta}}{\dot{\varepsilon}\cos\theta + \sqrt{\dot{\varepsilon} - \sin^2\theta}}, \quad (2)$$

$\dot{\varepsilon}$ – complex permittivity of the environment, $\dot{\varepsilon} = \varepsilon - j \cdot 60 \cdot \lambda \cdot g$ (λ – wavelength, g – conductivity of the environment); θ – sensing angle; T_0 – thermodynamic surface temperature.

The brightness temperature of a flat surface, taking into account the illumination by the atmosphere, can be written as follows [12, 13]

$$T_{ЯКВ(\Gamma)} = \chi_{B(\Gamma)}(\dot{\varepsilon},\theta)K(h_0,\theta)T_0 + \left|\dot{K}_{fB(\Gamma)}(\dot{\varepsilon},\theta)\right|^2 K(h_0,\theta)T_{ЯА}(\theta) + T_A\left[1 - K(h_0,\theta)\right], \quad (3)$$

where $\chi_{B(\Gamma)}(\dot{\varepsilon},\theta) = (1 - \left|\dot{K}_{fB(\Gamma)}(\varepsilon,\theta)\right|^2)$ – surface emissivity; $T_{ЯА}(\theta)$ – radio-brightness temperature of the total atmospheric radiation reflected from the surface in the θ direction; T_A – average temperature of the atmosphere (about 30° lower than the temperature of the atmosphere near the Earth).

$$T_{ЯА}(\theta) = T_A\left[1 - e^{\frac{-1}{\cos\theta}(\chi_{ko}z_k + \chi_{вo}z_в)}\right],$$

$$K(h_0,\theta) = \exp\left\{-\frac{1}{\cos\theta}(\chi_{ko}z_k + \chi_{вo}z_в)\right\},$$

where z_k, $z_в$ are characteristic heights of absorption by oxygen and water vapor, ($z_k = 5.3$, $z_в = 2.1$ km); χ_{ko}, $\chi_{вo}$ are absorption coefficients for oxygen and water vapor near the earth's surface ($\chi_{ko} = 0.0018$, $\chi_{вo} = 0.002$).

Figs. 1 and 2 show the dependence of the brightness temperature on the sighting angle without and with the impact of the atmosphere at the horizontal $Th(\theta)$, $Tha(\theta)$ and vertical $Tv(\theta)$, $Tva(\theta)$ polarizations. Initial parameters: frequency 90 GHz, thermodynamic temperature 300 K. Surface type: water (relative permittivity $\varepsilon = 70$, conductivity $g = 5$ S/m) [12].

5. Potential Accuracy Study

As mentioned earlier, one of the tasks that should be considered when organizing an experiment and using remote sensing data is to analyze the accuracy characteristics of the estimation. Such an analysis can be performed using the Fisher information matrix [13]. Such a study makes it possible to determine the conditions that provide minimal errors in surface parameter measurement depending on polarization, sighting angles, and other parameters.

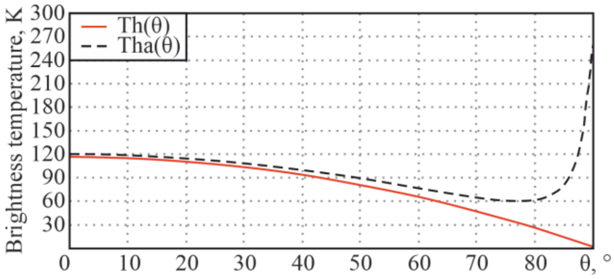

Fig. 1. Brightness temperature dependencies on the sighting angle without and with the impact of the atmosphere upon the horizontal polarization

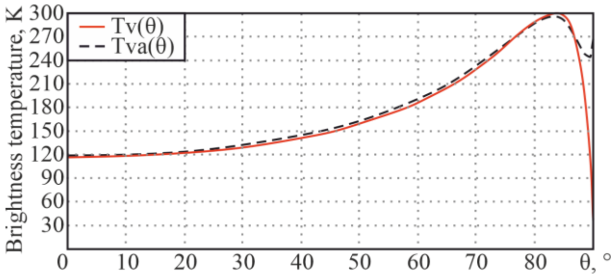

Fig. 2. Brightness temperature dependence on the sighting angle without and with impact of the atmosphere for vertical polarization

Let's consider a case where it is necessary to estimate the maximum measurement errors of the surface caused by the electrophysical properties using a radiometer with a single antenna. In the simplest case, when measuring one parameter in one receiving channel, the maximum error variance (lower bound) is determined as follows

$$\sigma_\lambda^2 = \frac{2}{T\Delta f}\left[\frac{T_Я(\theta,f,\lambda)}{\partial T_Я(\theta,f,\lambda)/\partial\lambda}\right]^2,$$

where $\frac{2}{T\Delta f}$ is parameter that considers the observation time T and the bandwidth Δf; f – operating frequency; λ – estimated parameter.

Below are graphs of the dependence of the variance of the estimation of the complex permittivity real component of the studied surface on the sighting angles θ without and with the influence of the atmosphere for the received radiation at horizontal $\sigma\varepsilon h(\theta)$, $\sigma\varepsilon ha(\theta)$ (Fig. 3, a) and vertical $\sigma\varepsilon v(\theta)$, $\sigma\varepsilon va(\theta)$ (Fig. 3, b) polarizations. Parameters are as follows: operating frequency 90 GHz, thermodynamic temperature 300 K, $\frac{2}{T\Delta f} = 10^{-6}$. Surface type: water (relative permittivity $\varepsilon = 70$, conductivity $g = 5$ S/m).

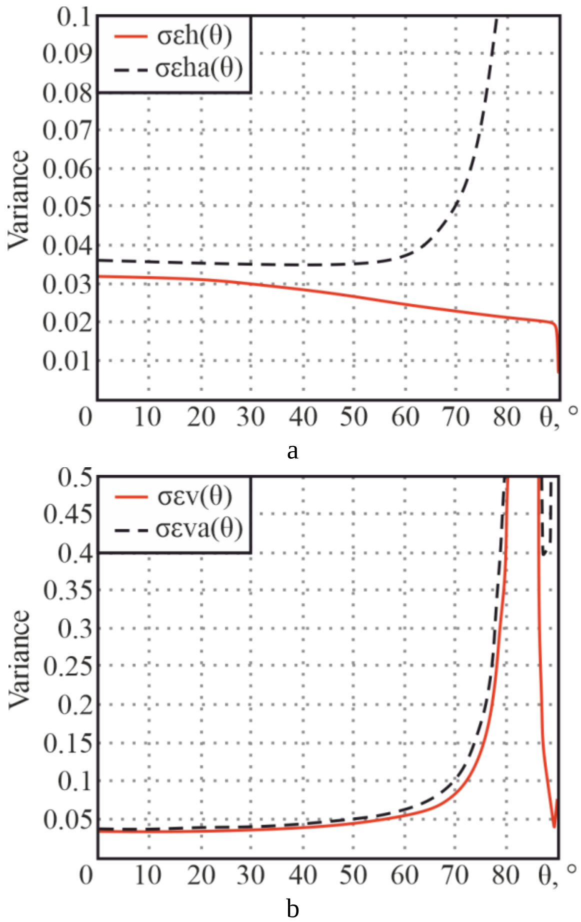

Fig. 3. Variances of the estimation of the complex permittivity real component upon horizontal (a) and vertical (b) polarizations

For a visual representation of estimate quality, graphs of potential estimation errors in percentage are presented below. The true value of the estimated parameter is taken as one hundred percent, and the graphs show the dependence of the error (in percent) on the sighting angle without and with the impact of the atmosphere for the horizontal $p\varepsilon h(\theta)$, $p\varepsilon ha(\theta)$, and vertical $p\varepsilon v(\theta)$, $p\varepsilon va(\theta)$ polarization (Figs. 4, a and 4, b).

For two channels receiving oscillations with vertical and horizontal polarizations, and two unknown parameters, the boundary error variances of the measurement parameters λ_1 and λ_2 can be obtained by the expression

$$\sigma^2_{\lambda_{1(2)}} = \frac{2}{T\Delta f}\frac{\left(\frac{\partial T_{ЯВ}}{\partial\lambda_{2(1)}}\right)^2 T^2_{ЯГ} + \left(\frac{\partial T_{ЯГ}}{\partial\lambda_{2(1)}}\right)^2 T^2_{ЯВ}}{\left(\frac{\partial T_{ЯВ}}{\partial\lambda_2}\cdot\frac{\partial T_{ЯГ}}{\partial\lambda_1} - \frac{\partial T_{ЯВ}}{\partial\lambda_1}\cdot\frac{\partial T_{ЯГ}}{\partial\lambda_2}\right)^2},$$

where $T_{ЯВ}$, $T_{ЯГ}$ – brightness temperature at vertical and horizontal polarization, respectively.

When simultaneously receiving radiation with horizontal and vertical polarizations (two-channel measurements), the unknown parameter λ_1 can be considered to be the real component of the studied surface complex permittivity ε, and the second parameter λ_2 is the conductivity of the surface g.

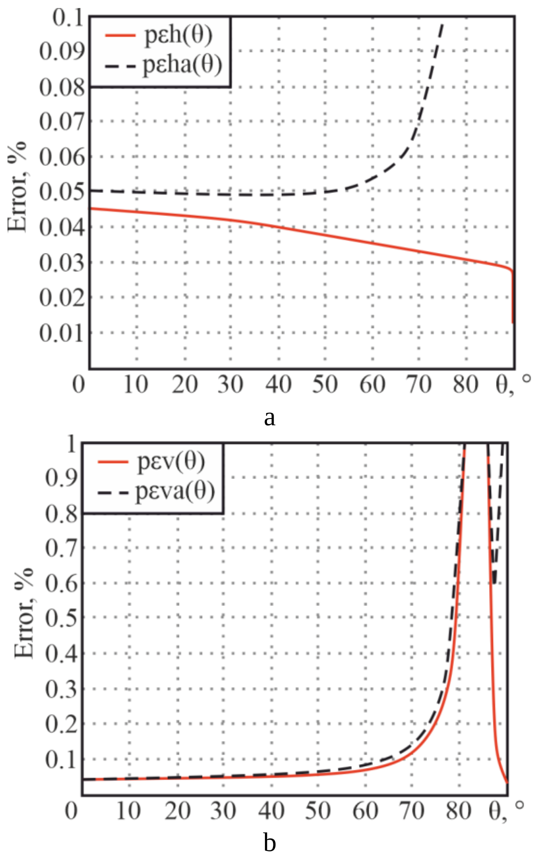

Fig. 4. Error percentage in estimating the real component of complex permittivity at the horizontal (a) and vertical (b) polarizations

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In this study, the calculations were performed on the basis of the following conditions: operating frequency 90 GHz, thermodynamic temperature 300 K, $\frac{2}{T\Delta f} = 10^{-6}$. Surface type: water (relative permittivity $\varepsilon = 70$, conductivity $g = 5$ S/m). The accuracy of estimation of the real component of the complex permittivity ε is highest at sighting angles θ from 0 to 60 degrees at both polarizations. However, the estimation of the conductivity of the surface g does not provide an acceptable estimation accuracy in any of the abovementioned estimation methods. To solve this problem, it was proposed estimating the imaginary part of the complex permittivity in general, without separating the conductivity g. In other words, to represent the complex permittivity in the form of $\dot{\varepsilon} = \varepsilon - j \cdot 60 \cdot \lambda \cdot g = \varepsilon r - j \cdot \varepsilon i$. This approach provides a much better, but still insufficient estimation accuracy.

The low accuracy of the imaginary part estimation of the complex permittivity at this frequency can be explained by the frequency dependence of the imaginary part of the complex permittivity.

The dependence of the complex permittivity modulus on the wavelength is shown in Fig. 5 ($\varepsilon = 70$, $g = 5$).

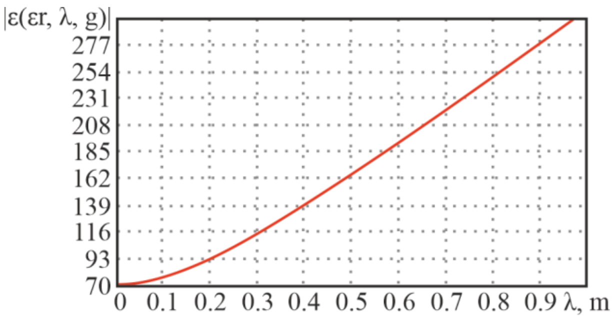


Fig. 5. Dependence of complex permittivity modulus on the wavelength

The variances of the real component estimation of the complex permittivity ε as a function of wavelength at $\theta = 30^{\circ}$ at horizontal $\sigma\varepsilon h(\lambda)$, $\sigma\varepsilon ha(\lambda)$ and vertical $\sigma\varepsilon v(\lambda)$, $\sigma\varepsilon va(\lambda)$ polarization are shown in Figs. 6, a and 6, b. Variances of the conductivity estimate g as a function of wavelength at $\theta = 30^{\circ}$ for horizontal $\sigma gh(\lambda)$, $\sigma gha(\lambda)$ and vertical polarization are shown in Figs. 7, a and 7, b.

6. Discussion

The following can be drawn from the performed modeling. At horizontal polarization, the brightness temperature (without considering the impact of the atmosphere) decreases as the sighting angle increases (see Fig. 1). At vertical polarization, it increases (see Fig. 2).

Considering the impact of the atmosphere leads to an increase in the brightness temperature at sighting angles greater than 50° for horizontal polarization and angles greater than 80° for vertical polarization (see Figs. 1, 2). For the studied device with the specified operating frequencies, the real permittivity of the surface can be a parameter with high estimation accuracy; at a given value of 70, the error is less than 0.1 over a wide frequency range (see Figs. 3, 4).

These dependencies show that the estimating accuracy of the imaginary part of the complex permittivity decreases as the operating wavelength decreases, and the estimating accuracy of the real part of the complex permittivity, on the contrary, increases (see Fig. 5).

Our study on the dependence of the potential accuracy of estimating the surface parameters shows that the estimating accuracy of the complex permittivity real part increases at wavelengths near 0.5 m (see Fig. 6) at both polarizations. The conductivity estimation accuracy increases with wavelength (see Fig. 7) at both polarizations.

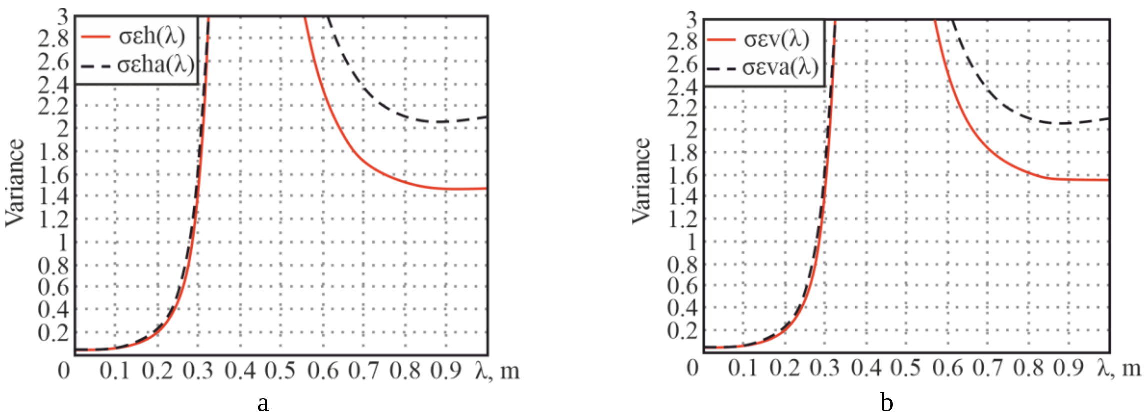
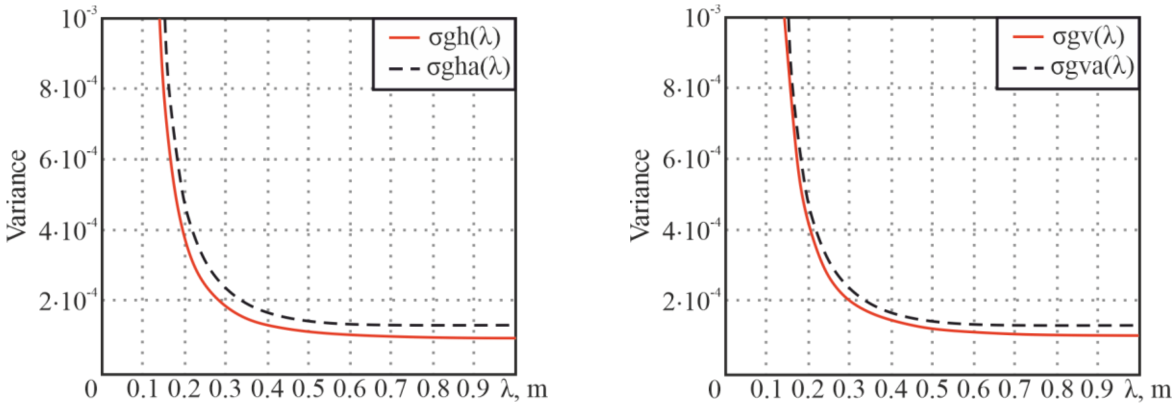


Fig. 6. Variances of the estimation of the real component of the complex permittivity at the horizontal (a) and vertical (b) polarizations



a b

Fig. 7. Variances of conductivity estimated at horizontal (a) and vertical (b) polarizations

The atmosphere impact on the estimation accuracy becomes noticeable at wavelengths above 0.6 m (see Figs. 6 and 7).

7. Conclusions

This study is carried out for a radiometer with operating frequencies of 75 - 110 GHz (wavelength 2.7 – 4 mm). The examined empirical models of brightness temperature work correctly at lower frequencies, and as an electrodynamic model, the flat surface model can be applied. To fulfill the condition of using a small-scale surface ($\sigma_h \le \frac{\lambda}{20}$) and operating wavelengths of 2.7 – 4 mm, the root mean square height of the surface roughness should be less than 0.135 – 0.2 mm.

According to the proposed model, the impact of the atmosphere on the brightness temperature becomes apparent at sighting angles greater than 50° for horizontal polarization and angles greater than 80° for vertical polarization.

The variance of the estimate of the complex permittivity real component increases with increasing wavelength, whereas the variance of the estimate of the conductivity decreases. Therefore, for radiometers with the mentioned operating frequencies, it is possible to estimate the real permittivity or the real component separately if the surface is described by a permittivity complex parameter. Moreover, the variances of the estimates of the real permittivity, considering the atmosphere, at horizontal polarization increase sharply at sighting angles over 60°. To estimate the surface conductivity (the imaginary part of the complex permittivity of a surface), devices with lower operating frequencies are required. Moreover, the real permittivity of the surface can be used as the estimated parameter, and it is recommended that the study be conducted at vertical and horizontal polarizations, without and with the impact of the atmosphere.

Future research directions. For further studies, we recommend expanding the research for modern remote sensing devices with other operating frequency ranges, as well as for other models of surface description. Further studies also imply practical measurements and recalculations of radio-brightness measured data into complex permittivity.

The above mentioned are planned to be presented in future publications of the authors.

Contribution of authors: conceptualization – **Valerii Volosyuk**, **Kseniya Nezhalskaya;** simulation – **Kseniya Nezhalskaya**, **G. Cherepnin**; validation – **Valerii Volosyuk, Kostiantyn Bilousov**; analysis of results, visualization – **Kseniya Nezhalskaya**, **Denys Kolesnikov**; writing original draft – **Kseniya Nezhalskaya**; writing-review and editing – **Denys Kolesnikov, Glib Cherepnin**.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, author ship or otherwise, that could affect the research and its results presented in this paper.

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Data availability

The manuscript has no associated data.

Use of Artificial Intelligence

The authors confirm that they did not use artificial intelligence methods while creating the presented work.

All authors have read and agreed to the published version of this manuscript.

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ДОСЛІДЖЕННЯ ПОТЕНЦІЙНИХ МОЖЛИВОСТЕЙ ВИКОРИСТАННЯ МОДЕЛЕЙ ЯСКРАВІСНОЇ ТЕМПЕРАТУРИ ПРИ ПАСИВНОМУ ДИСТАНЦІЙНОМУ ЗОНДУВАННІ

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У сучасній науці та практиці для дистанційного дослідження будь-яких поверхонь, в тому числі й різних типів покривів земної поверхні, широко використовують радіотехнічні засоби. Завдяки малим енергетичним затратам та великій скритності найбільш перспективним напрямком розвитку технічних засобів для дистанційних досліджень є розвиток пасивних систем дистанційного зондування. При цьому для оцінювання конкретних параметрів досліджуваної поверхні необхідна інформація щодо зв'язку сигналів власного теплового випромінювання, які приймаються радіометричною системою, з цими параметрами. Саме тому актуальним є дослідження та аналіз існуючих типів таких зв'язків, моделей поверхонь, які пов'язують яскравісну температуру та параметри земних площин, що і є **предметом** дослідження в представленій роботі. **Метою** роботи є аналіз існуючих моделей зв'язку, вивчення умов їх застосування за робочими частотами, за геометричними характеристиками, за типом покриття поверхонь (з рослинністю, без рослинності і т.і.), а також за способом отримання математичних зв'язків (електродинамічні моделі або емпіричні моделі). У зв'язку з великою кількістю різних типів покриттів земної поверхні та різних типів моделей поверхонь, для спрощення вирішення задачі дистанційного зондування пасивними системами, а також покращення результатів виконання моделювання або реальних експериментів, в даній роботі сформульоване таке **завдання:** вивчення та класифікація існуючих моделей зв'язку параметрів поверхонь з яскравісною температурою, розрахунок та аналіз потенційної точності оцінювання параметрів поверхні досліджуваної пасивними засобами дистанційного зондування. Отримані такі **результати**. Проаналізовано вплив атмосфери на яскравісну температуру поверхні, що описана електродинамічною плоскою моделлю, для робочих частот радіометра 75-110 ГГц. Вплив атмосфери на яскравісну температуру з'являється при кутах візування більших за 50^{o} на горизонтальній поляризації та кутах більших за 80^{o} на вертикальній поляризації. За результатами дослідження потенційної точності оцінювання можна сказати, що точність оцінювання уявної частини комплексної діелектричної проникності зменшується при зменшенні довжини робочої хвилі, а точність оцінок дійсної частини комплексної діелектричної проникності – навпаки. **Висновки**. У результаті імітаційного моделювання показано, що для радіометрів із вказаними вище робочими частотами можливе оцінювання дійсної діелектричної проникності або окремо тільки дійсної компоненти у випадку опису поверхні комплексним параметром проникності. Дослідження рекомендується проводити на вертикальній та горизонтальній поляризаціях, без урахування та з урахуванням впливу атмосфери. Для оцінки провідності поверхні (уявної частини комплексної діелектричної проникності поверхні) необхідні пристрої з меншими робочими частотами. Таким чином, в роботі представлений аналіз існуючих моделей, виконані розрахунки потенційної точності оцінювання параметрів при використанні цих моделей, надано рекомендації до проведення практичних експериментів або моделювання.

Ключові слова: яскравісна температура; пасивне дистанційне зондування; діелектрична проникність; провідність.

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