AEROSPACE SYSTEMS FOR MONITORING AND CONTROL

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METHOD OF EVALUATION OF THE ELECTRIC FIELD LEVEL OF DANGEROUS SIGNALS TO GNSS RECEIVERS

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Abstract

Purpose: *It is necessary to develop and test a method for estimating the dangerous signals level to GNSS receivers in order to make a decision on the possibility of fulfilling the target function of the GNSS radio receiver under the influence of interference and to solve the navigation problem.* ***Method:*** *the approach is based on the analysis of the electromagnetic environment, the statistical criteria for optimal detection and instrumental measurements.* ***Results:*** *the article uses the basis of normative documents on the application of GNSS to propose a method for estimating the state of the electromagnetic environment at the location of the GNSS radio receiver in order to make a decision on the possibility of performing the target function by the radio receiver of navigation signals. The proposed method was tested at the National Aviation University.*
Discussion: *the method is proposed for a tactical assessment of the electromagnetic situation at the location of the GNSS radio receiver and making a decision on whether the target function can be performed by this radio receiver.*

Keywords: dangerous signals level; integrity of navigation data; navigation; navigational task; power flux density; protection ratio; target function

1. Introduction

In conditions of intensive development of telecommunication systems, the electromagnetic fields created by them negatively influence the equipment of GNSS consumers. Thus exclusive attention is paid to monitoring and monitoring the integrity, accuracy, availability of signals in space in the navigation segment of network satellite systems,.

ICAO Standards and Recommendations on GNSS emphasize that states that use GNSS systems are responsible for ensuring that the required characteristics are met in the area of responsibility.

In this regard, the assessment of the level of dangerous signals is an urgent task to ensure the target function of GNSS receivers.

The level of a dangerous signal is understood as the value (in terms of power) of the electric field signal at which the GNSS receiver ceases to fulfill the target function.

The target function of the GNSS radio receiver is to determine the location, speed, time and / or spatial orientation of its carrier using satellite radio navigation system signals. It can also be said that the target function of the GNSS radio receiver is a solution to the navigational task that is accurately defined for GNSS.

2. Analysis of the research and publications

The GNSS noise immunity issues have received considerable attention from the very beginning of its creation, which is not weakening at the present time. The typical requirements for noise immunity of satellite navigation aero receivers are reflected in [1-4].

One effective way to increase flight safety and reduce the risk of accidents is to determine the availability of satellite navigation systems under interference influence [5].

3. Research task

The task of the research is to develop and test a method for estimating the level of dangerous signals to GNSS receivers, in order to be able to provide their target function.

4. Results and Discussion

In the absence of statistical data necessary for the implementation of a probabilistic approach to the assessment of the quality of electromagnetic environment created by the summation of electronic means from groups B and C [6-8], the hypotheses are not considered as appropriate scenarios. The action of the electric field Ei of each emitter at the point of location of the receiving antenna of system A is determined by the ratio:

$$E_i = \frac{13\sqrt{W_i G_i}}{r_i} V_i \ , \quad (1)$$

where W_i – the power at the antenna input of the i-th source of field, kW; G_i – the radiation source antenna gain multiplier, r_i – distance from source antenna to signal receiver antenna, km; V_i – the multiplier of the wave weakening at its propagation. At the same time, the total power W occurring in the receiving antenna under the influence of the number of lagged interferences is determined by the expression [6-8]:

$$W = 6{,}33 \times 10^3 G \sum_{i=1}^{B+C} \frac{W_i G_i \lambda_i^2}{r_i^2} V_i \quad (2),$$

where G – the receiving antenna gain multiplier, λ_i – wave length, caused by i-m radiation (m), G_i – the radiation source antenna gain multiplier.

Expression (2) contains constructive parameters of the interference transmitter. In the real environment, it is possible to assume only its power, therefore it is expedient to use the parameter, which includes the parameters of the transmitter of interference, such parameter may be the power flux density of the electric field at the location of the antenna of the GNSS receiver.

The power flux density of the electric field (the power passing through the surface element perpendicular to the direction of energy of the electromagnetic wave is divided into the area of this element) is shown in the expression[9]:

$$dS = \sum_{i=1}^{B+C} \frac{W_i G_{\text{апрм}}}{40\pi D^2}, \quad (3)$$

where dS – the power flux density of the electric field at the observation point (mW / cm2), W – interference transmitter power (W), $G_{\text{апрм}}$ – antenna gain at times, D – distance from antenna receiver (m).

The expressions (1), (2), (3) can be used with a small number of radiators. But it is advisable to rank the level of interference at the position of the receptor and analyze the "duel situations." The information obtained can be used for purposeful electromagnetic environment quality management activities, bearing in mind that the radio propagation environment is linear.

Therefore, to assess the level of the hazard signal of receiver interference source, depending on the integrity of the GNSS data, the following method can be proposed:

1. To obtain the value of the "signal / interference" protection ratio Q (expression 12) [6], it is necessary to choose the probability of realization of the target function of the GNSS receiver P (Ts | Hi). This may be the value of the GNSS data integrity. Where Q is such a minimal addition to the GNSS signal at the receptor input of the system, in which the system performs its functions with a quality that is no worse than the given one.

2. Using formula 12 [6], calculate the value of the "signal / interference" protection ratio Q.

3. Calculate the desired value of the power of the useful GNSS signal under conditions of interference.

4. Calculate the power flux density of the electric field on the plane of the antenna of the receiver GNSS at the power, obtained in paragraph 3.

5. Using expression 3, calculate the dependence of power flux density of the electric field on the distance at the probable constant power of the source of the jamming, on which it is possible to perform the target function of the GNSS receiver (see Fig. 2).

6. Using the measuring receiver, measure the power of the electric field and draw conclusions about the position of the GNSS receiver at this point for solving the navigation problem.

For example, let us apply the abovementioned method to decide on the possibility of category I landing in the airport area (See Fig. 1.20 p. 41 [10]).

Firstly, let us determine the protective ratio Q at the input of the GNSS receiver by expression (12) [6], where as $P(Ц_A|H_i)$ we shall take the value of the GNSS data integrity, for the hypothesis H_7 (See Fig. 1.20 p. 41 [10]) for this category $(1-1{,}94\times10^{-9})$= 0.99999999806 = $P(Ц_A|H_i)$. From expression (12) [6] we shall obtain Q in dB:

$$Q = 10\lg\left(\frac{P(Ц_a \mid H_7)}{1-P(Ц_a \mid H_7)}\right) = 87{,}12 \text{ dB}.$$

The calculated protective ratio Q will be 87.12 dB, that is, the real signal level at the input of the GNSS receiver should be (-164,5+87,12) = -77,38 $дБ_{Вт}$.

Let us calculate the density of the power flux on the antenna of the GNSS receiver TOKO DAK1575MS50T with sizes 2,5×2,5 sm, area 6,25 cm2 (See Fig.1)

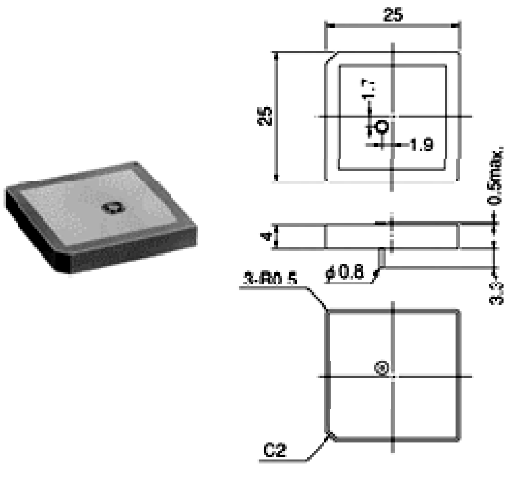

Fig. 1. GNSS receiver antenna TOKO DAK1575MS50T

$$dS = \frac{10^{-\frac{77{,}38}{10}}}{6{,}25},$$

which, by calculation, will equal dS=2,925e-9 mW/cm^2.

We shall calculate and construct a graph of the dependence of the power flux density of the electric field on the distance from the constant power of the source of interference and the integrity of the GPS GNSS data 0.99999999806 according to expression (3), where W is the interference power 1, 10 and 100 W, G_a is the GNSS receiving antenna gain multiplier 7dB, for the distance D from 0 to 100 km. the calculations result can be seen on Fig. 2.

On the graph we shall construct a line of calculated boundary density of the power flux of the electric field dS, the density of the power flux of the interference electric field, on the GNSS receiver antenna, which is equal to 2.925e-9 mW / cm2.

We shall let perpendiculares fall on the axis of the distance in the points of intersection of the line dS with the curves of the power flow density.

The area to the right of the perpendicular to the distance axis and below the power curve of the interference is the area in which the GNSS receiver will perform a navigation task with a probability no worse than the given one. The shaded graphics area represents interference power of 10 watts.

Using the measuring receiver (see Fig. 3), let us measure the power of the electric field at the location of the GNSS receiver, calculate the power flow density, determine the measured point on the graph, and decide on the possibility of solving the navigation task.

The measured power transferred to the power flux density of the electric field is dS = 2.6102 × 10-9 mW / cm2. The measured power flux density of the electric field is in the shaded area, which means that the interference power of 1 W, 10 W, 100 W will have no negative effect on the work of the GNSS receiver.

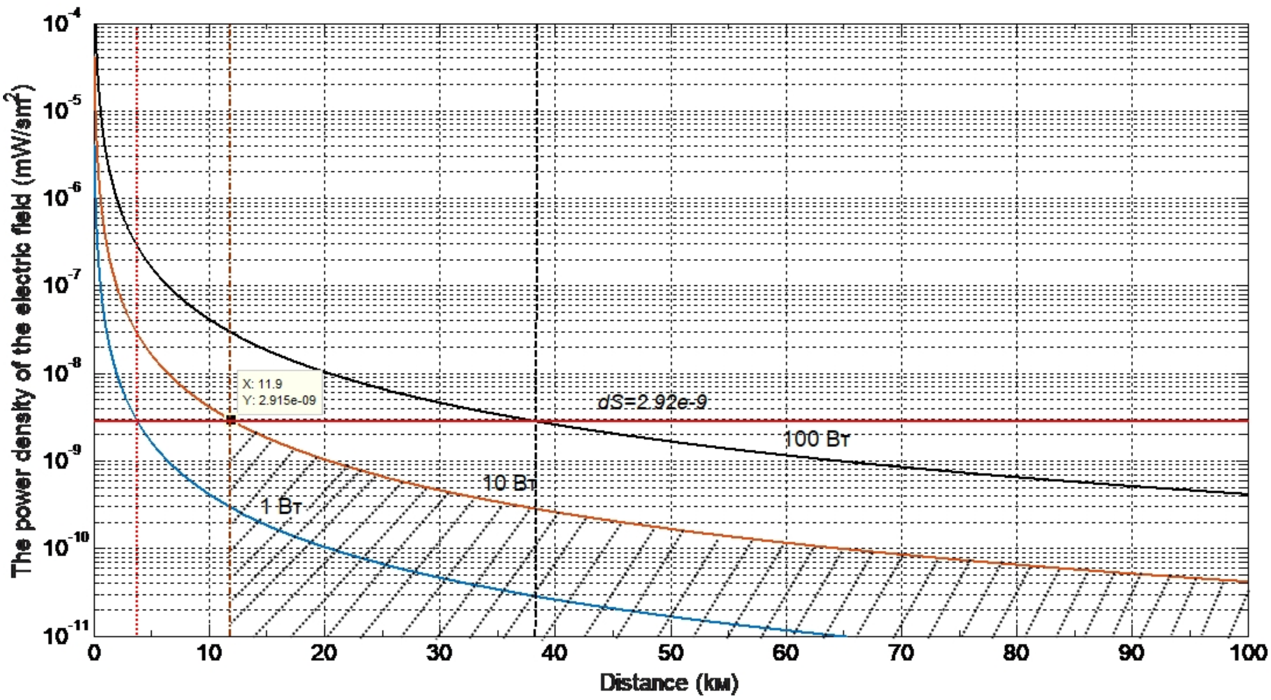

Fig . 2. The dependence of the power flux density of the electric field on the distance from the constant power of the source of interference and the integrity of the GPS GNSS data 0.99999999806

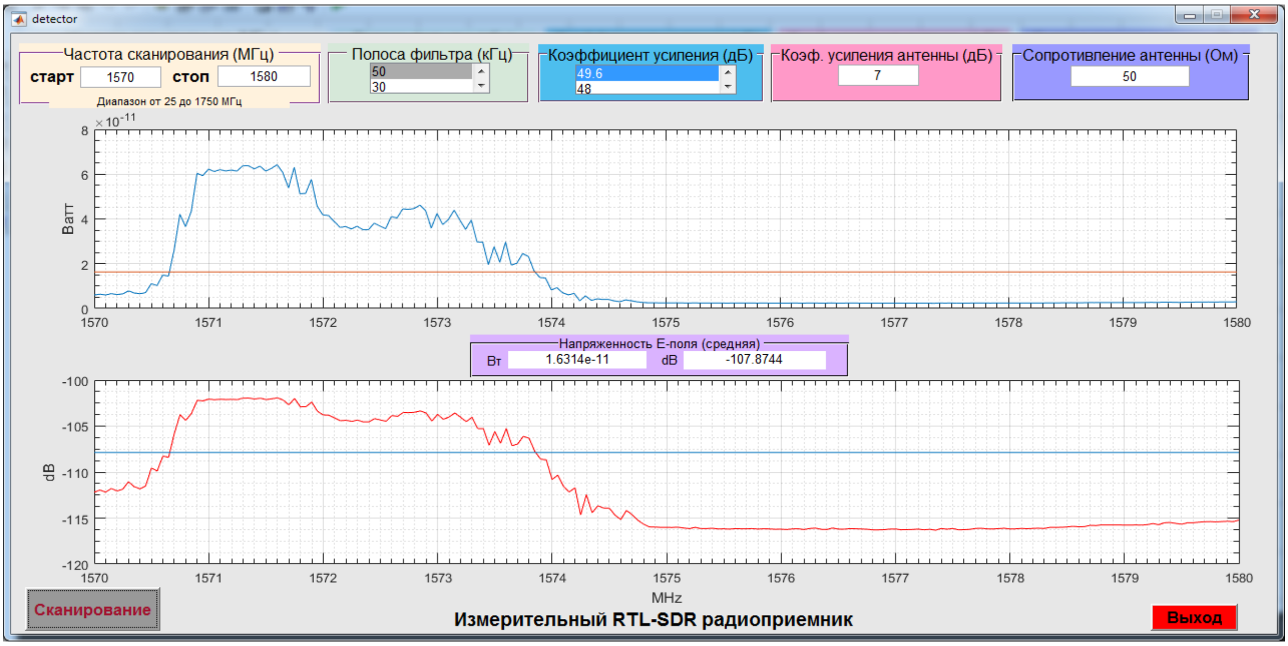

Fig. 3. An example of measuring the power of an electric field at the location of the GNSS receiver

5. Conclusions

The article uses the basis of normative documents on the application of GNSS to propose a method for estimating the state of the electromagnetic environment at the location of the GNSS radio receiver in order to make a decision on the possibility of performing the target function by the radio receiver of navigation signals. The proposed method was tested at the National Aviation University.

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Метод оцінки рівня електричного поля небезпечних сигналів приймачам GNSS

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Мета: Для прийняття рішення про можливість виконання цільової функції радіоприймачем системи ГНСС під впливом перешкод необхідно розробити і апробувати метод оцінки рівня небезпечних сигналів приймачів ГНСС, для можливості вирішення навігаційного завдання. **Метод**: підхід базується на аналізі електромагнітної обстановки, статистичних критеріях оптимального виявлення і інструментальних вимірах. **Результати**: в роботі на основі нормативних документів щодо застосування ГНСС, запропонований метод оцінки стану електромагнітної обстановки в точці розташування радіоприймача ГНСС для прийняття рішення про можливість виконання цільової функції радіоприймачем навігаційних сигналів. Запропонований метод пройшов апробацію в Національному авіаційному університеті. **Обговорення**: метод пропонується для тактичної оцінки електромагнітної обстановки в точці розташування радіоприймача ГНСС і прийняття рішення про можливість виконання цільової функції цим радіоприймачем.

Ключові слова: захисне відношення; навігація; навігаційне завдання; рівень небезпечних сигналів; цілісність навігаційних даних; цільова функція; щільність потоку потужності

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Метод оценки уровня электрического поля опасных сигналов приемникам GNSS

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Цель: Для принятия решения о возможности выполнения целевой функции радиоприемником системы ГНСС под воздействием помех необходимо разработать и апробировать метод оценки уровня опасных сигналов приемникам ГНСС, для возможности решения навигационной задачи. **Метод:** подход базируется на анализе электромагнитной обстановки, статистических критериях оптимального обнаружения и инструментальных измерениях. **Результаты:** в работе на основе нормативных документов по применению ГНСС, предложен метод оценки состояния электромагнитной обстановки в точке расположения радиоприемника ГНСС для принятия решения о возможности выполнения целевой функции радиоприемником навигационных сигналов. Предложенный метод прошел апробацию в Национальном авиационном университете. **Обсуждение:** метод предлагается для тактической оценки электромагнитной обстановки в точке расположения радиоприемника ГНСС и принятия решения о возможности выполнения целевой функции этим радиоприемником.

Ключевые слова: защитное отношение; навигация; навигационная задача; плотность потока мощности; уровень опасных сигналов; целевая функция; целостность навигационных данных

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