The Application of GIS and Diversity Combining in Designing of Wireless Communication Systems in the Presence of Fading

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Abstract: - In this paper, the application of Geographic Information System (GIS) in designing of wireless communication systems with diversity combining in the presence of Rice fading will be presented. The application of these solutions in designing of wireless telecommunications systems simplifies it, makes the time required for its configuration shorter and gives better economic effects. The obtained gain which has been made using diversity techniques is shown in some figures.

Key-Words: - Diversity Technique, Equal Gain Combining (EGC), Geographic Information System (GIS), Rice fading

1 Introduction

One of the most extensive application of Geographic Information System (GIS) is in telecommunications, particularly in the planning, installation and maintenance of telecommunication systems. The development of a broad and publicly available GIS has long been one of the strategic interests of the developed countries due to the impact that such a system can have on the development of society as a whole. Therefore, there are many investments, continually investigation and working on improving the existing system.

There are numerous software tools which deal with calculation of range of wireless communication systems. Some of them are less and some are more specialized.

These systems can be used in designing of wireless and mobile telecommunication systems, radar networks, and radio-relay links with important savings in time, human and material resources because the most of network design works is the computer's work, and there are not going outside.

Fundamental obstruction in wireless telecommunication systems is fading. The fading is changing of signal envelope at the receiver. It may be fast or slow fading. Fast fading is caused by multiple signal propagation paths. Fast fading can be modelled by Rice, Rayleigh, Nakagami-*m*, Nakagami-*q*, Weibull, Hoyt or other probability density functions [1].

The slow fading is caused by the effect of shadows. This fading is modelled usually by log-normal or gamma distribution. The most often way to mitigate fading influence on system performance is diversity technique [2]-[5]. The application of GIS in designing of wireless communication systems with Selection Combining (SC combining) in the presence of Rice fading is presented in [6]. In this paper, the application of GIS and Equal Gain Combining (EGC) will be considered.

2 Mathematical Problem Formulation

In this paper, a transformation of the two random variables with Rice distribution and its applications in wireless digital communication systems will be considered. The two random variables with Rice distribution are transformed into a random variable. A new random variable is equal to the sum of two random variables with Rice distribution. The probability density and joint probability density of this random variable and its first derivative are determined.

This random variable is obtained as the signal at the output of the EGC combiner with two inputs that are used to reduce the impact of fading on system performance [7, 8].

The Rice fading appears at the entrances of the combiner. The system error probability and the outage duration can be determined by using these probability density functions [9]-[11].

The signal envelope in wireless communication systems has often Rice probability density. When there is a direct component of the waves with more scattered components that are resulting in the refusal, refraction, scattering and bending of electromagnetic waves they can be described with Rice distribution [12]. It can be shown, by the application of the central limit theorem, that the probability density of equivalent signal envelope at the receiver is Rice. This kind of fading occurs in a variety of satellite telecommunication systems, radio relay for telecommunication systems with micro- and macro-diversity system and so on.

Let x_1 and x_2 be two Rice non-identical and non-correlated random variables. Their probability density functions are:

$$p_{x_i}\left(x_i\right)=\frac{x_i}{\sigma_i^2}\mathrm{e}^{-\frac{x_i^2+A_i^2}{2\sigma_i^2}} I_0\left(\frac{A_i\cdot x_i}{\sigma_i^2}\right), \qquad x_i\geq 0 \tag{1}$$

i=1, 2. By series expansion of the Bessel function it is obtained:

$$p_{x_i}\left(x_i\right)=\frac{x_i}{\sigma_i^2}\mathrm{e}^{-\frac{x_i^2+A_i^2}{2\sigma_i^2}}\sum_{i_i=0}^{\infty}\left(\frac{A_i}{2\sigma_i^2}\right)^{2i_i}\frac{1}{i_i!}x_i^{2i_i}=$$

$$=\frac{x_i}{\sigma_i^2}\mathrm{e}^{-\frac{x_i^2+A_i^2}{2\sigma_i^2}}\sum_{i_i=0}^{\infty}f_1\left(A_i,\sigma_i,i_i\right)x_i^{2i_i}=$$

$$=a_i x_i\,\mathrm{e}^{-\alpha_i x_i^2}\sum_{i_i=0}^{\infty}f_1\left(A_i,\sigma_i,i_i\right)x_i^{2i_i} \tag{2}$$

The cumulative probability densities are:

$$F_{x_i}\left(x_i\right)=\int_0^{x_i}p_{x_i}(t)dt=\int_0^{x_i}a_i t\,\mathrm{e}^{-\alpha_i t^2}\sum_{i_i=0}^{\infty}f_1\left(A_i,\sigma_i,i_i\right)t^{2i_i}dt=$$

$$=a_i\sum_{i_i=0}^{\infty}f_1\left(A_i,\sigma_i,i_i\right)\int_0^{x_i}t^{2i_i+1}\mathrm{e}^{-\alpha_i t^2}dt=$$

$$=a_i\sum_{i_i=0}^{\infty}f_1\left(A_i,\sigma_i,i_i\right)\frac{1}{2}\frac{1}{\alpha_i^{i_i}}\gamma\left(i_i,\alpha_i x_i^2\right) \tag{3}$$

First, the sum of two Rice distributed random variables will be considered. The probability density of the sum of two Rice random variable is equal to the convolution's integral of the probability density of individual summands. The cumulative probability density of the sum of two independent random variables, Rice distributed, is obtained by the integration of the probability density of the sum of two independent random variables, Rice distributed. The characteristic function of the sum of two independent Rice distributed random variables is equal to the product of two characteristic functions of Rice distributed adders. The moments of Rice's sum of two random variables can be expressed depending on the individual moments of Rice distributed adders. The central moments of random variables can be expressed according to the ordinary moments of the same random variable.

Let:

$$x=x_1+x_2 \tag{4}$$

Then,

$$x_1=x-x_2 \tag{5}$$

Probability density function of x is:

$$p_x(x)=\int_0^x p_{x_1}(x-x_2)\cdot p_{x_2}(x_2)\cdot dx_2 \tag{6}$$

$$p_x\left(x\right)=\frac{x_i}{\sigma_i^2}\mathrm{e}^{-\frac{x_i^2+A_i^2}{2\sigma_i^2}} I_0\left(\frac{A_i\cdot x_i}{\sigma_i^2}\right), \qquad x_i\geq 0 \tag{7}$$

$$p_x(x)=\int_0^x a_1\left(x-x_2\right)e^{-\alpha_1(x-x_2)^2}\cdot\sum_{i_1=0}^{\infty}f_1\left(A_1,\sigma_1,i_1\right)\cdot$$
$$\cdot\left(x-x_2\right)\cdot a_2\cdot x_2\cdot e^{-\alpha_2 x_2^2}\cdot\sum_{i_2=0}^{\infty}f_1\left(A_2,\sigma_2,i_2\right)\cdot x_2^{2i_2}\cdot dx_2 \tag{8}$$

$$p_x(x)=\int_0^x a_1\left(x-x_2\right)\cdot\sum_{k_1=0}^{\infty}\frac{\left(-\alpha_1\right)^{k_1}}{k_1!}\cdot\left(x-x_2\right)^{2k_1}\cdot\sum_{i_1=0}^{\infty}f_1\left(A_1,\sigma_1,i_1\right)\cdot$$
$$\cdot\left(x-x_2\right)^{2i_1}\cdot a_2\cdot x_2\cdot e^{-\alpha_2 x_2^2}\cdot\sum_{i_2=0}^{\infty}f_1\left(A_2,\sigma_2,i_2\right)\cdot x_2^{2i_2}\cdot dx_2 \tag{9}$$

$$p_x(x)=\int_0^x dx_2\cdot a_1\cdot\sum_{k_1=0}^{\infty}\frac{\left(-\alpha_1\right)^{k_1}}{k_1!}\cdot\sum_{i_1=0}^{\infty}f_1\left(A_1,\sigma_1,i_1\right)\cdot$$
$$\cdot\left(x-x_2\right)^{2i_1+2k_1+1}\cdot a_2\cdot x_2\cdot e^{-\alpha_2 x_2^2}\cdot\sum_{i_2=0}^{\infty}f_1\left(A_2,\sigma_2,i_2\right)\cdot x_2^{2i_2} \tag{10}$$

$$p_x(x)=\int_0^x dx_2\cdot a_1\cdot\sum_{k_1=0}^{\infty}\frac{\left(-\alpha_1\right)^{k_1}}{k_1!}\cdot\sum_{i_1=0}^{\infty}f_1\left(A_1,\sigma_1,i_1\right)\cdot$$
$$\cdot\sum_{k=0}^{\infty}\binom{2i_1+2k_1+1}{k_2}\cdot\left(-1\right)^{k_2}\cdot x_2^{k_2}\cdot x^{2i_1+2k_1+1-k_2}\cdot$$
$$\cdot a_2\cdot x_2\cdot e^{-\alpha_2\cdot x_2^2}\cdot\sum_{i_2=0}^{\infty}f_1\left(A_2,\sigma_2,i_2\right)\cdot x_2^{2i_2} \tag{11}$$

The statistical characteristics of the signal envelope at the output of dual EGC combiner can be calculated by using this probability density obtained by the sum of two Rice distributed random variables. Hence, the independent and nonidentical Rice fading is appeared at the input of EGC combiner.

Now, the cumulative probability density of the combiner output signal, the characteristic function of the combiner output signal, the moments of the EGC combiner output signal, the error probability for coherent and noncoherent system, that uses a diversity technique to reduce the impact of Rice fading on system performance and the system outage probability, can be determined.

The characteristic function of the sum $x=x_1+x_2$ is:

$$M_x(s) = M_{x_1}(s)\cdot M_{x_2}(s) \tag{12}$$

$$M_x(s) = \frac{a_1}{2}\cdot\sum_{k_1=0}^{\infty}\frac{s^{k_1}}{k_1!}\cdot\sum_{i_1=0}^{\infty} f_1(A_1,\sigma_1,i_1)\cdot \cdot\frac{1}{\alpha_1^{i_1+\frac{k_1}{2}}}\cdot\Gamma\left(i_1+\frac{k_1}{2}\right)\cdot\frac{a_2}{2}\cdot\sum_{k_2=0}^{\infty}\frac{s^{k_2}}{k_2!}\cdot \cdot\sum_{i_2=0}^{\infty} f_1(A_2,\sigma_2,i_2)\cdot\frac{1}{\alpha_2^{i_2+\frac{k_2}{2}}}\cdot\Gamma\left(i_2+\frac{k_2}{2}\right) \tag{13}$$

In this way, we can determine the characteristic function of the sum of two Rice distributed random variables. This is very important for diversity systems using EGC combiner. For this combiner the signal at the output is equal to the sum of the signal from its input. In this way one can determine the characteristic function of the signal at the output of dual EGC combiner in the presence of Rice fading. It can be calculated the system error probability and the system outage probability by using this characteristic function.

The moments are significant: the mean value of the random variable. Because of this, let calculate the moments of Rice distributed random variables.

The moment of the n-th order of x_1 is:

$$m_{n_{x_1}} = \overline{x_1^n} = \int_0^{\infty} x_1^n\cdot p_{x_1}(x_1)\cdot dx_1 \tag{14}$$

$$m_{n_{x_1}} = \int_0^{\infty} x_1^n\cdot a_1\cdot x_1\cdot e^{-\alpha_1\cdot x_1}\cdot dx_1 \tag{15}$$

$$m_{n_{x_1}} = a_1\cdot\sum_{i_1=0}^{\infty} f_1(A_1,\sigma_1,i_1)\cdot\int_0^{\infty} x_1^{n+1+2\cdot i_1}\cdot e^{-\alpha_1\cdot x_1}\cdot dx_1 \tag{16}$$

$$m_{n_{x_1}} = \frac{a_1}{2}\cdot\sum_{i_1=0}^{\infty} f_1(A_1,\sigma_1,i_1)\cdot\frac{1}{\alpha_1^{i_1+\frac{n}{2}}}\cdot\Gamma(i_1+\frac{n}{2}) \tag{17}$$

The mean value of x_1 is:

$$\overline{x_1} = \frac{a_1}{2}\cdot\sum_{i_1=0}^{\infty} f_1(A_1,\sigma_1,i_1)\cdot\frac{1}{\alpha_1^{i_1+\frac{1}{2}}}\cdot\Gamma(i_1+\frac{1}{2}) \tag{18}$$

The root mean square value of x_1 is:

$$\overline{x_1^2} = \frac{a_1}{2}\cdot\sum_{i_1=0}^{\infty} f_1(A_1,\sigma_1,i_1)\cdot\frac{1}{\alpha_1^{i_1+1}}\cdot\Gamma(i_1+1) \tag{19}$$

The variance is:

$$\overline{\sigma_{x_1}^2} = \overline{x_1^2} - (\overline{x_1})^2 \tag{20}$$

The moment of the n-th order of x_2 is:

$$\overline{x_2^n} = \frac{a_2}{2}\cdot\sum_{i_2=0}^{\infty} f_1(A_2,\sigma_2,i_2)\cdot\frac{1}{\alpha_2^{i_2+\frac{n}{2}}}\cdot\Gamma(i_2+\frac{n}{2}) \tag{21}$$

The mean value of x_2 is:

$$\overline{x_2} = \frac{a_2}{2}\cdot\sum_{i_2=0}^{\infty} f_1(A_2,\sigma_2,i_2)\cdot\frac{1}{\alpha_2^{i_2+\frac{1}{2}}}\cdot\Gamma(i_2+\frac{1}{2}) \tag{22}$$

The root mean square value of x_2 is:

$$\overline{x_2^2} = \frac{a_2}{2}\cdot\sum_{i_2=0}^{\infty} f_1(A_2,\sigma_2,i_2)\cdot\frac{1}{\alpha_2^{i_2+1}}\cdot\Gamma(i_2+1) \tag{23}$$

The variance of x_2 is:

$$\sigma_{x_2}^2 = \overline{x_2^2} - \overline{x_2}^2 \tag{24}$$

The moment of the n-th order of the sum $x = x_1 + x_2$ is:

$$\overline{x^n} = \overline{(x_1+x_2)^n} = \sum_{i=0}^{n}\binom{n}{i}\cdot\overline{x_1^{n-i}\cdot x_2^i} = \sum_{i=0}^{n}\binom{n}{i}\cdot\overline{x_1^{n-i}}\cdot\overline{x_2^i} \tag{25}$$

$$\overline{x^n} = \sum_{i=0}^{n}\binom{n}{i}\cdot\frac{a_1}{2}\cdot\sum_{i_1=0}^{\infty} f_1(A_1,\sigma_1,i_1)\cdot\frac{1}{\alpha_1^{i_1+\frac{n-i}{2}}}\cdot\Gamma\left(i_1+\frac{n-i}{2}\right)\cdot \cdot\frac{a_2}{2}\cdot\sum_{i_2=0}^{\infty} f_1(A_2,\sigma_2,i_2)\cdot\frac{1}{\alpha_2^{i_2+\frac{i}{2}}}\cdot\Gamma\left(i_2+\frac{i}{2}\right) \tag{26}$$

The moments of the sum of two random Rice distributed variables can be determined by using these formulas, where the moments of summands are known. This formula is obtained using a binomial form. In a similar way, we can determine the central moments. Moments are important parameters of a random process because the probability density of a random variable can be determined by using them. Then, the error probability of wireless telecommunications systems can be determined by using this probability density function. In this way, we can determine the power of EGC diversity system that is used to reduce the impact of Rice fading on system performance.

The joint probability density function of x_1 and $\dot{x}_1$ is:

$$p_{x_1\dot{x}_1}(x_1\dot{x}_1)=\frac{x_1}{\sigma_1^2}\cdot e^{-\frac{x_1^2+A_1^2}{2\cdot\sigma_1^2}}\cdot I_0(\frac{x_1\cdot A_1}{\sigma_1^2})\cdot\frac{1}{\sqrt{2\cdot\pi}\cdot\beta_1}\cdot e^{-\frac{\dot{x}_1^2}{2\cdot\beta_1^2}} \tag{27}$$

$$p_{x_1\dot{x}_1}(x_1\dot{x}_1)=\frac{\alpha_1}{\sqrt{2\cdot\pi}\cdot\beta_1}\cdot x_1\cdot e^{-\frac{\alpha_1\cdot x_1^2}{2\cdot\sigma_1^2}}\cdot\sum_{i_1=0}^{\infty}f_1(A_1,\alpha_1,i_1)\cdot x_1^{2\cdot i_1}\cdot e^{-\frac{\dot{x}_1^2}{2\cdot\beta_1^2}} \tag{28}$$

This is an expression for the joint probability density of the signal and its first derivative. Random process which is obtained as the first derivative of Rice random process is Gaussian random process. The mean value of obtained Gaussian random process is zero. The variance of this process is equal to:

$$2\pi f_m\Omega$$

where f_m is maximal frequency and Ω is biquadratic mean value of the signal.

Rice random process and derivative of Rice random processe are independent and these processes are in quadrature. The level crossing rate can be determined by using the joint probability density of the signal and its derivative. The level crossing rate is equal to the mean value of the first derivative of signal.

The joint probability density function of x_2 and $\dot{x}_2$ is:

$$p_{x_2\dot{x}_2}(x_2\dot{x}_2)=\frac{x_2^2}{\sigma_2^2}\cdot e^{-\frac{x_2^2+A_2^2}{2}}\cdot I_0(\frac{x_2\cdot A_2}{\sigma_2^2})\cdot\frac{1}{\sqrt{2\cdot\pi}\cdot\beta_1}\cdot e^{-\frac{\dot{x}_2^2}{2\cdot\beta_1^2}} \tag{29}$$

$$p_{x_2\dot{x}_2}(x_2\dot{x}_2)=\frac{a_2}{\sqrt{2\cdot\pi}\cdot\beta_2}\cdot x_2\cdot e^{-\alpha_2\cdot x_2^2-\frac{1}{2\cdot\beta_2^2}\cdot\dot{x}_2^2}\cdot\sum_{i_2=0}^{\infty}f_1(A_2,\sigma_2,i_2)\cdot x_2^{2\cdot i_2} \tag{30}$$

Let it be:

$$\begin{aligned}x&=x_1+x_2\\x_1&=x-x_2\\\dot{x}&=\dot{x}_1+\dot{x}_2\\\dot{x}_1&=\dot{x}-\dot{x}_2\end{aligned} \tag{31}$$

The conditional joint probability density of x and $\dot{x}$ is:

$$p_{x\dot{x}}(x\dot{x}\mid x_2\dot{x}_2)=|J|\cdot p_{x_1\dot{x}_1}(x-x_2,\dot{x}-\dot{x}_2) \tag{32}$$

where:

$$J=\begin{vmatrix}\frac{\partial x_1}{\partial x}&\frac{\partial x_1}{\partial\dot{x}}\\\frac{\partial\dot{x}_1}{\partial x}&\frac{\partial\dot{x}_1}{\partial\dot{x}}\end{vmatrix}=1 \tag{33}$$

By substituting and averaging it is obtained:

$$p_{x\dot{x}}(x\dot{x})=\int_0^x dx_2\int_0^{\dot{x}}d\dot{x}_2\cdot p_{x_1x_1}(x-x_2,\dot{x}-\dot{x}_2)\cdot p_{x_2x_2}(x_2\dot{x}_2)$$

$$p_{x\dot{x}}(x\dot{x})=\int_0^x dx_2\cdot\int_0^{\dot{x}}dx_2\cdot\frac{\alpha_1}{\sqrt{2}\cdot\pi\cdot\beta_1}\cdot(x-x_2)\cdot$$

$$\cdot e^{-\alpha_1(x-x_2)^2}\cdot e^{-\frac{1}{2\beta_1^2}(\dot{x}-\dot{x}_2)}\cdot\sum_{i_1=0}^{\infty}f_1(A_1,\sigma_1,i_1)\cdot(x-x_2)^{2i_1}\cdot$$

$$\frac{\alpha_2}{\sqrt{2}\cdot\pi\cdot\beta_2}\cdot x_2\cdot e^{-\alpha_2\cdot x_2^2}\cdot e^{-\frac{1}{2\beta_2^2}\dot{x}_2^2}\cdot\sum_{i_2=0}^{\infty}f_1(A_2,\sigma_2,i_2)\cdot x_2{}^{2i_2} \tag{33}$$

This is an expression of the joint probability density of the sum of two independent Rice random variables and its first derivative. Using this expression it can be determined the joint probability density of the signal and its derivative at the exit of EGC combiner with two inputs when there is a Rice fading. This combiner is used to reduce the effect of fast Rice fading on the system performance.

The average level crossing rate of the output signal, for the value which is equal to the threshold, can be calculated by this joint probability density.

One can determine the average outage duration,whichis an important parameter of the telecommunication system, can be determined from the quotient of the outage probability and level crossing rate.

3 Performances of Software Component for Calculation of Wireless Telecommunication Systems

3.1 System model

Below we will describe implemented software component including system architecture with key Use-Case Diagrams and other important UML diagrams. Since the system was developed using Rational Unified Process (RUP) methodology for software development [13], the system will be described, according to the RUP templates for system modeling, and "4+1" model system [14].

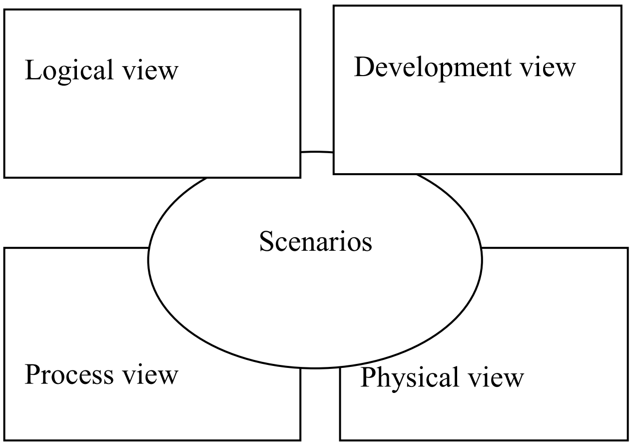

Fig.1 "4+1 view model"

This model presents, in fact, five different views of the system, with different aspects, which are intertwined:
1. User view of the system - a description of architecture, presented with series of use cases or scenarios, which describe the sequence of interactions between objects and processes. In essence, a user view of the system is a description of the functionality of the system and is used to identify the system architecture as well as its validation;
2. The logical architecture of the system - describes the most important classes in the system and their organization level;
3. Processing system architecture - describes the most important processes in the system and their organization;
4. Implementing the system model - describes the implementation of the software components;
5. The physical model of the system - describes the hardware used in the system.

3.2 User's view
User's view is presented with a series of use cases of the system organized into charts accidental use. User's view of the system is given by the diagram in Fig. 2. As one can see, there is one use case - the calculation of range of a wireless telecommunication channel.

The actors:
Beneficiary - A person who imports the necessary information on the receiver, transmitter, and telecommunications channel and start calculating the range and error probability of a wireless telecommunication channel and visualization of range of a wireless telecommunication channel.

The cases of use:
-The calculation of range of telecommunication channels

Short description of basic course:
1. The user, by click on the item "Signal range"; from the "Tools" menu opens dialog box for the calculation of-wireless telecommunications channel range.
2. The user initiates, by double-click on the map, marks drawing at the position of clicked point and display the dialog information about the coordinates and altitude of clicked point (when we use the "Choose of the transmitter position").
3. The user enters transmitter on dialogue for the calculation of wireless telecommunication channels range the relative height and emitted power (use of the case "Set transmitter parameters").
4. The user inputs parameter sets on the dialog for the calculation of wireless telecommunication channels range: the required SNR at the reception, presence/absence and species of diversity reception, noise factor and bandwidth (when we use the "Set of the receiver parameters").
5. The user enters the telecommunications channel parameters on dialogue for the calculation of wireless telecommunication channels range: modulation format for transmission and carrier frequency (use of the case "Setting telecommunication channel parameters").
6. The user, by click on the "Calculate" on dialogue for the calculation of wireless telecommunications channel range, initiates the calculation of the output data (the wireless telecommunications channel range and the error probability) for input parameters. As a result, output calculated data are displayed on the dialog box, and visual representation of the calculated data on the map (use of the case "Calculation of the range and the error probability").

4 Evaluation of Developed Software Component
Based on the above model a software component for the calculation of a wireless telecommunication system range is created. The advantages of using diversity techniques in the presence of Rice fading will be presented.

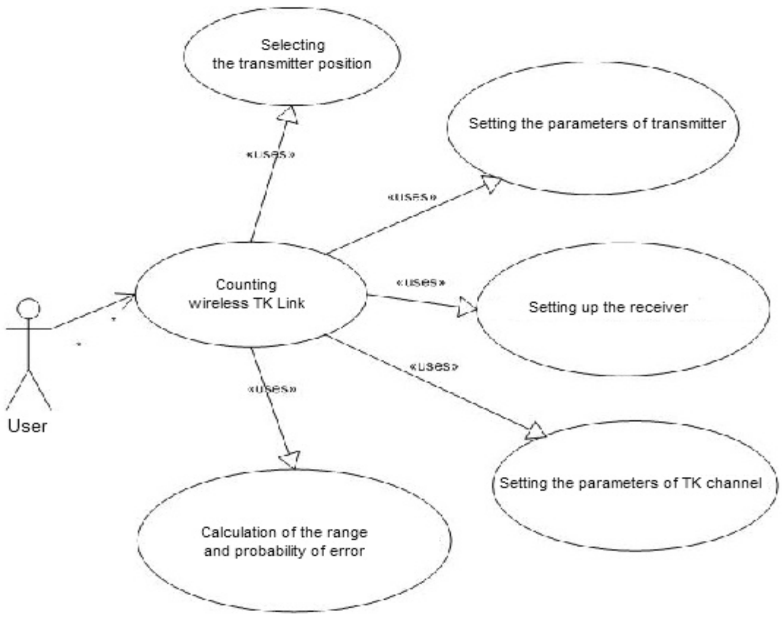

Fig.2. The user's view of the system

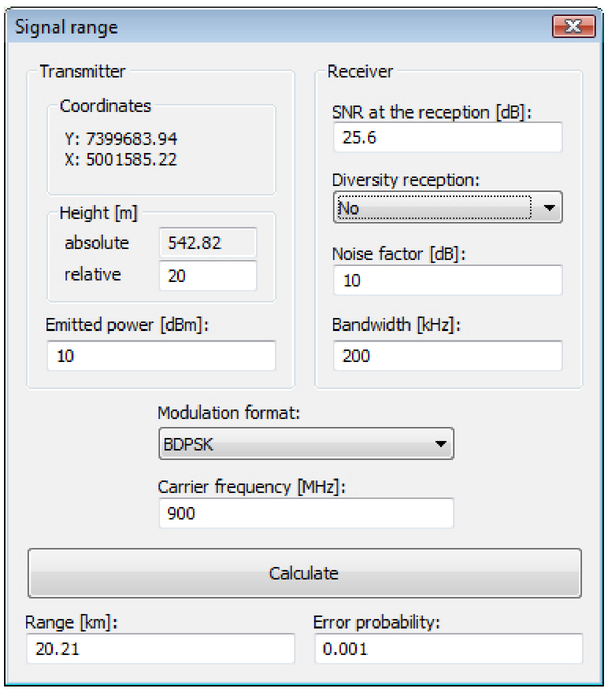

Fig.3. Initial screen

The practical part of this paper was realized through the implementation of the described software components and integration into the actual dedicated GIS. It is used then for the design of wireless telecommunications system in the presence of Rice fading. The product was developed for a known user, in order to achieve the necessary functionality, with the request that the system is optimal and requires the least engagement of resources.

Initial data entry screen is shown in Fig. 3. The transmitter parameters, such as the relative height, emitted power, carrier frequency [15], [16], are entered after determining the position of the transmitter by clicking on the GIS map (the system determines the transmitter coordinates). Also, the receiver parameters are entered into the first step: SNR (signal-to-noise ratio) at the reception, noise factor and bandwidth. As an important parameter, the information if diversity reception at the receiver is present is entered, the type of combining and the number of branches.

Transmitter coordinates are: Y=7399683.94 and X=5001585.22, absolute height [m]: 542.82 and relative height [m]: 20; emitted power [dBm]: 10; SNR at the receiver [dB]: 25.6, diversity reception: no, noise factor [dB]: 10, bandwidth [kHz]: 200, modulation format: BDPSK, carrier frequency [MHz]: 900; after calculating: range [km]: 20.21, the error probability: 0.001.

Basis on mathematical models that have been performed in previous Section, transmission without using diversity techniques and the using of EGC combining with two branches are shown here.

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Based on defined parameters and the required error probability, the system calculates the maximum range and the transmission with as little as possible error probability for the given distance between transmitter and receiver.

Also, based on a specified range and the desired error probability, it is possible to calculate the minimum of power needed at the transmitter.

The results obtained by modelling the signal transmission without the use of diversity techniques, as well as dual EGC combining are presented in Figs 4. and 5.

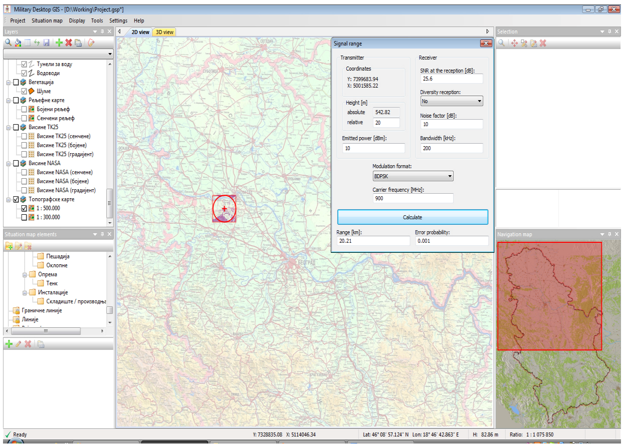

Fig. 4. The application of GIS in the design of wireless telecommunication systems in the presence of Rice fading without the use of diversity techniques (The error probability: 10^{-3}, SNR at the reception 25.6 dB, range: 20.21 km)

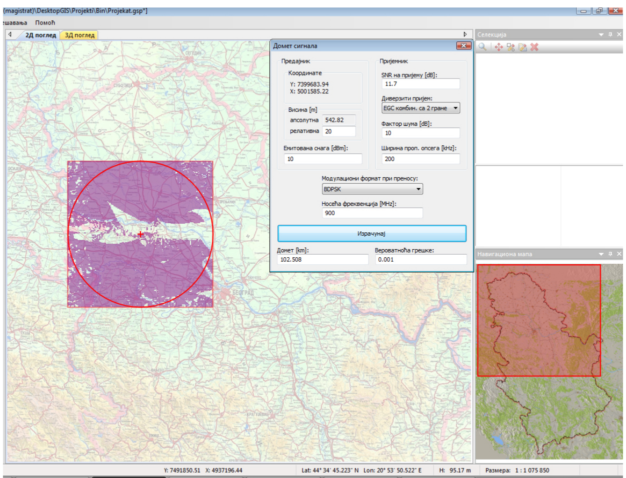

Fig. 5. The application of GIS in the design of wireless telecommunication systems in the presence of Rice fading and dual EGC diversity combining (The error probability: 10^{-3}, SNR at the receiver 11.7 dB, range: 102.508 km)

The application of GIS in designing of wireless telecommunication systems in the presence of Rician fading without the use of diversity techniques is presented in Fig. 4. When the error probability is 10^{-3} and SNR at the receiver is 25.6 dB, the range is 20.21 km.

The application of GIS in designing of wireless communication systems in the presence of Rice fading with EGC diversity combining with two branches, with the same error probability: 10^{-3} and when SNR at the reception is 11.7 dB, is shown in Fig. 5. It can be seen from this figure that the range was increased to 102.508 km with using of diversity technique.

Based on these results, it was shown that the integration of software components described in the existing special-purpose GIS, using diversity techniques and proper techniques of receiving, depending on the user's needs, can optimize the essential parameters of the transmitter and receiver. Developed software component that allows you to define and set the transmitter to the selected location, setting its parameters, calculate the line of sight, coverage and range of wireless signals in the presence of Rice fading with or without the use of diversity techniques. This is achieved by optimization of resources in the design and maintenance of wireless communication systems.

5 Conclusion

The results obtained in this paper can be used in wireless and mobile communication systems. The diversity technique with EGC combining is used to reduce the impact of fading. This type of combining and application of Geographic Information System are presented in this paper.

The distance between the transmitter and receiver can be increased without increasing the power of the transmitter in this way. Also, the transmission power for the same distance between the transmitter and receiver for the same power of noise, interference and fading can be reduced.

Based on these software components and the obtained results, the optimal telecommunication system can be designed. It is possible to achieve a greater distance between the receiver and transmitter for the same signal strength and the same signal quality by using this software. Also, it is possible to reduce the signal strength for the same range and same quality of connection, or the same power and same range to improve signal quality by reducing the error probability.

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Application of the proposed solutions in practice simplifies the design of wireless telecommunications systems, makes the time required for its configuration shorter and leads to considerable economic savings. This paper can be useful for institutions that deal with wireless transmission, mobile telecommunications, radar networks or radio-relay links.

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