Enhancing the Efficiency of Fixed Transmitters for Better Communication

Vladan Mihajlovic, Marko Kovacevic, Aleksandar Milosavljevic, and Dejan Rancic
Faculty of Electronic Engineering
at University of Niš
Aleksandra Medvedeva 14
18000 Niš, Serbia
{vladan.mihajlovic@elfak.ni.ac.rs} {marko.kovacevic@elfak.ni.ac.rs} {aleksandar.milosavljevic@elfak.ni.ac.rs} {dejan.rancic@elfak.ni.ac.rs}

ABSTRACT: *Fixed transmitters need to be used for better communication systems for which the correct location of the receivers need to be identified. High frequency and good range of coverage is required to achieve it. In this work we have used the field strength calculation system. We have applied the line rasterization method for producing terrain profile and to avoid arctangent function for angle calculation. We have used regular grid for producing terrain profiles. We have measured the field strength in each point which can identify the optimal point. This system ensures to understand the grid resolution and improve the accuracy and effectiveness. This method allows to find the grid as a transparent raster layer. We have used visual techniques to find alternative location for the receivers.*

Keywords: Field Strength Calculation, Dem, Terrain Profile, Optimal Location Search, Raster Visualization

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1. Introduction

Many different methods are designed to provide appropriate estimation of electromagnetic field strength for diverse application. The methods are developed to be adequate for particular frequency range, specific environment or particular distance range. In this paper we will consider the problem of searching for the location where to set the receiver to successfully gather the data from the sensor placed in the rural environment. The communication will be established using radio waves at high frequencies. The distance between transmitter and receiver is on the order of tens of kilometers.

The goal of this research is to develop method that will find appropriate location for the receiver inside the particular region for predefined position of the transmitter. The region of where the receiver should be placed can be rectangular or polygonal. The optimal receiver location should be the one where the field strength is maximal.

The first thing that must be considered in order to achieve this goal is developing the method for estimating field strength. There are various methods [1-3] that are accepted as good solutions for the problem. They describe the procedure of computing the field strength. The methods combine theoretical knowledge with the empirical results. ITU Recommendation P.1546 [1] is one of the one of the most frequently used methods which has good results in rural areas. It can estimate strength of the signal with high frequency range from 30MHz to 3000MHz and large distance range from 3km to 1000km. Therefore, this method is selected and implemented as a foundation for estimating field strength and finding optimal receiver point.

The recommendation uses more than dozen parameters as inputs. The most significant are: type of path, signal frequency, percentage of time, percentage of location, effective height of the transmitter, signal path length and clearance angle. The method is based on empirical measurement of the field strength for different combinations of the input parameters. In the general case, for the arbitrary input parameters, measurements are used as nominal values and the primary result is computed by interpolation. The final value is obtained by performing set of correction on the primary result. Our implementation load nominal values in main memory and use additional look up tables to provide efficient calculation of the field strength.

The accurate estimation requires data from the real terrain model and the can have great effect on the results. The recommendation uses this data indirectly throw following parameters: effective height of the transmitter and clearance angle. Both parameters need terrain profile for calculation. The performance of the field strength computing depends on efficiency of these tasks. The method presented in this paper efficiently extracts terrain profile from DEM data using well known techniques for segment rasterization. Clearance angle calculation is made faster by avoiding time consuming arctangent operation.

The recommendation estimates the field strength between two points. The goal to find appropriate location in particular area of interest must be done by applying the recommendation on selected set of points inside this area. Proposed system use set of points that form regular rectangular grid. The grid step can be chosen in order to achieve better accuracy of the calculation or speed up the computation. After that it is easy to find optimal solution.

Beside field strength calculation the system provide visualization of the calculation results. The field strength estimation is mapped to semitransparent bitmap and rendered on top of the map. This can helps in observing the correlation between the field strength and the terrain. Besides, visualization reveals alternative location for receiver which can be more appropriate considering other important criteria.

The research in this paper is presented in the following four sections. The next one addresses similar problems and solutions. The third explains developed methods in details. The fourth contain short overview of the implemented method characteristics. The last section presents the main advantages of the implemented solution.

2. Related Work

The problem of planning radio-communication network is not new. But, increasing computer power makes possible implementing it at ordinary Desktop PC. It is interesting for the companies that are involved in internet networks, telecommunication, radio communication and military domains. There are many different models that are used in practice for computing field strength, but there is small number of the software solutions available.

The Seamcat [4] is complex software that can be used for modeling communication systems. It implements several methods for calculating field strength among which is ITU-R P.1546 model. This system is relatively complex for common user and does not have real terrain model and visualization of the results on the map.

The systems that can calculate the field strength and provide visualization are not so common. Here, we will point out two software systems: MARSsys [5] and ICS telecom [6]. There is not much information about the methodology they use for calculating the field strength inside polygonal area, visualization and analysis of the results. The both systems can be used in wide spectrum of domains.

3. Field Strength Calculation and Visualization Methods

The goal of providing good connection between transmitter and receiver highly depends on many factors. The one of most important is finding convenient locations for them. There are three cases depending on the fact that transmitter and receiver can be fixed or not: transmitter is fixed, receiver is fixed and neither of them is fixed. In this paper, the focus is on the case where transmitter is on fixed position and the problem is to find appropriate location for receiver inside particular area of interest.

Solution for this problem is to estimate field strength inside the area and find the optimal location. It is implemented as a subsystem of one lager system Desktop GIS [7]. The subsystem consists of following five components: FieldStrengthCalculator, TerrainProfiler, PathProfiler, ReceiverAnalyser and FieldStrengthRenderer.

The first think is to choose a way to estimate the field strength at particular location. The basic theoretical model cannot be used because of many physical parameters, such as profile of terrain between, refraction, reflection, diffusion, weather conditions etc. The methods used in practice are combination of empirical results and the formulas that are used to add influence of mentioned factors.

These empirical methods can estimate field strength between the exact locations of transmitter and receiver. Estimating field strength for the whole area of interest demands selecting the set of locations for which the methods will be applied. The field strength is highly dependent on the terrain surrounding the receiver. The consequence is that relatively small change of the receiver position can highly affect the field strength. Therefore, the area of interest is represented with set of points in regular grid.

After calculation of the field strength in the area of interest it is easy to find optimal location. The problem is that optimal location sometimes can be at inaccessible location, which can depreciate value of the method result. Visualization of field strength estimation over the map is one solution to overcome this problem. Besides, it provides better insight of the field strength inside the area of interest.

3.1. Algorithm for Field Strength Prediction

The method for calculating electromagnetic field strength between two points, transmitter and receiver, depends on the application domain. In this paper, we consider the problem of calculating the field strength in rural areas, in order to gather the data from sensors. The communication network is well established in urban areas, and the sensors installed in this environment can be connected to network with relatively small effort. The FieldStrengthCalculator component represents implementation of the algorithm for field strength calculation based on International Telecommunication Union (ITU) recommendation P.1546-1.

The ITU-R P.1546-1 recommendation uses the result of conducted measurement as a foundation for field strength estimation. It has many input parameters. The most important are: type of path, the signal frequency, percentage of time, percentage of location, effective height of the transmitter, signal path length and clearance angle. The recommendation is based on conducted set of measurements for the several set of input parameters. The prediction of the field strength for arbitrary set of parameters is done by interpolation of the results of measurements and applying some kind of correction after that. Our algorithm for field strength prediction implements ITU-R P.1546-1 in full scope.

The recommendation contains set of curves representing the field strength in relation to distance between transmitter and receiver. Each curve is created for the particular set of parameters: type of path, signal frequency, percentage of time, percentage of location, effective height of the transmitter. Type of path can be solely land path, sea path or mixed path. The other parameters are numerical values and for the empirical measurement are cold nominal values. The curve represents the relationship in the continual domain. Therefore, it cannot be used by the algorithm as such. They are represented as set of linear segments approximating the curve. Using this approximation the measurement in recommendation are prepared in excel tables. Our algorithm load values from file in main memory to provide efficient calculation. This made possible simple change of empirical curves and in order to improve the accuracy.

The filed strength for particular input parameters is calculated using linear interpolation over two nearest nominal values for each parameter. Therefore the first step is to find the two nearest nominal values for each parameter. After that the interpolation is performed in well defined order: length of the signal path, effective transmitter antenna height, signal frequency and percentage of time. If the signal path is mixed, the calculation was done for the both path type and the field strength is calculated using predefined formula.

The recommendation use calculated field strength as a starting point for the correction to include other parameters: height of the receiver, properties of the signal path, terrain clearance and percentage of location. Our algorithm implements the recommendation exactly but uses the real data about the terrain.

3.2. Incorporating Terrain Data in Field Strength Prediction

The description of the ITU-R P.1546 recommendation reveals that information about the terrain is necessary to calculate field strength. The calculation uses only the altitudes on the terrain profile along the signal path between transmitter and receiver. The profile of the terrain is used in recommendation for calculating effective height of the transmitter, receiver clearance angle and transmitter clearance angle.

The component TerrainProfiler implements methods that process terrain data. It use terrain data is stored as DEM. DEM is regular grid of points with predefined cell size. The cell size can be chosen by user. This parameter can significantly affect the computation time. The component contains method that creates terrain profile along the path between transmitter and receiver. The method must be efficient because it will be called for each point inside the area of interest. This is achieved using method that is based on well known Bresenham's method [8] for line segment rasterization. The important difference is that our method must traverse each cell along the path. TerrainProfiler use created profile to easily calculate effective height of transmitter and efficiently compute clearance angles. To compute clearance, it is necessary to calculate the angle for each point on the terrain profile. Angle is computed using arctangent which is expensive operation. Our method use the fact that arctangent is continuously increasing function. Therefore, instead of comparing angles algorithm compares its tangents. The clearance angle calculation must also include earth curvature. To speed up the process precalculated look up table is used with earth curvature for set of equally distant points.

The component PathProfiler is responsible for determine the type of the signal path. The path can be land, sea or mixed, which depends whether the path traverse only land, only sea or both. The PathProfiler contains vector layer that represent the sea. It calculates intersection between the path and polygons of sea layer, creating the signal path profile for field strength calculation.

3.3. Analysis of Field Strength

Previously described components are enough to estimate field strength for the particular location of the receiver. But, the primary goal of this research is to provide mean to find optimal location for the receiver given the position of the transmitter.

The component ReceiverLoactionAnalyser is devoted to find optimal location. The component provide support for the three types of receiver area: set of points, rectangular area and polygonal area. Two rectangular and polygonal areas are represented with the regular grid of cell of equal size. Size of the cell can be defined externally to accommodate user needs. The method calculates the field strength estimation for each point. The ReceiverAnalyser sort calculated values easily and extract arbitrary number of the optimal receiver location.

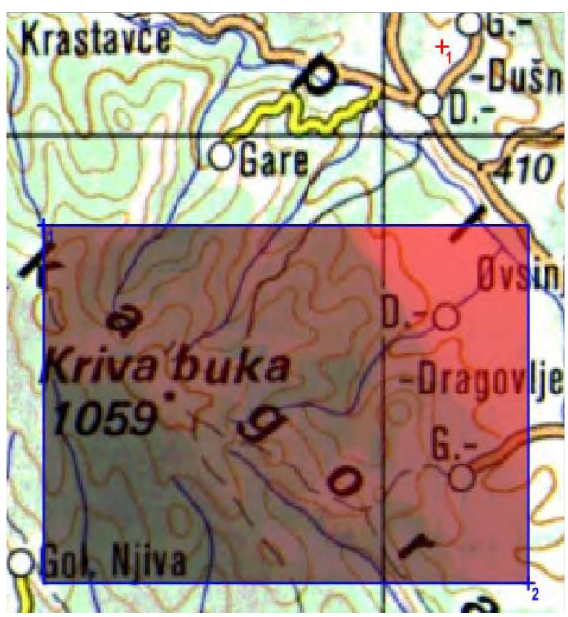

Figure 1. Visualization of the field strength intensity inside the rectangular area of interest

3.4. Visualization of Field Strength

Estimated field strength calculated for each point on the grid creates raster. The FieldStrengthRenderer provide visualization of the created raster (figure 1 and 2). It is performed using two color scale interpolation. First color is attached to maximal value of the field strength and the second is attached to minimal value. The component creates bitmap by transforming each field strength value to appropriate color using linear interpolation. The bitmap is rendered as one of the layers over the raster map. Bitmap is made semitransparent to enable anticipating the field strength and the location on the same time. The invalid values are made completely transparent. The component provides the feedback and display the field strength intensity at the mouse position.

4. Short Analysis of Methods Properties

Algorithm that finds the optimal location for the receiver over the particular area is not always sufficient. Sometimes optimal locations are not appropriate for installation of receiver that can be caused by number of reasons (e.g. inaccessible terrain, distant power supply etc.). Besides, it is common case that optimal location will be close to each other. In these situations visualization can reveal alternative location of receiver that could be considered. Even in the situation that the optimal location is appropriate, the alternatives can good enough but less expensive for installation.

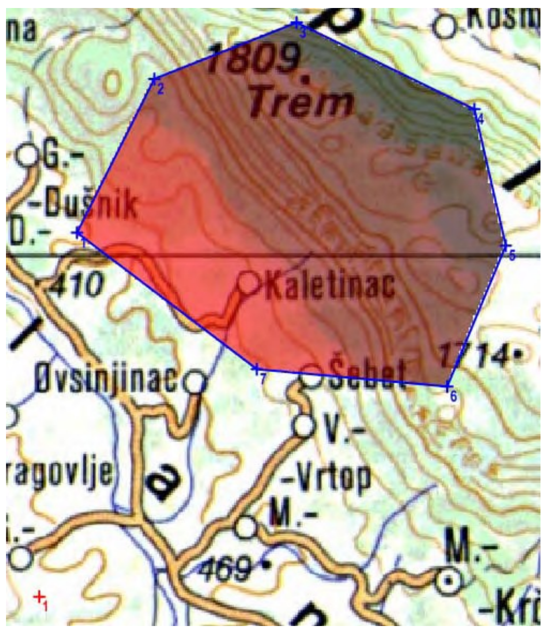

Figure 2. Visualization of the field strength intensity inside the polygonal area of interest

Besides the described techniques used to speed up the calculation of the field strength estimation, the whole process is time consuming. It can last from seconds to minutes on high performance desktop computers. It depends on several factors. The first is area in which method search for the optimal location of receiver. The processing time is directly proportional to the area of potential location. The second is the size of the grid cell used to represent the potential receiver's area. The processing time grow with the smaller cell size. The third is the cell size of the DEM grid. The less the cell size is the slower is field strength calculation. On the contrary with improving processing time the accuracy will decrease. It can be taught that the problem can be solved by using multiscale approach. First, analyze the field strength using large receiver size and finding promising areas, and iteratively reduce the cell size. But, this approach could omit some good locations because grid cell is represented with its center which can generate different terrain profile than points near it.

5. Conclusion

The system presented in this research is designed to find optimal location for the receiver inside the particular area and for fixed location of transmitter. The area is represented as a regular grid of points and the system calculate the field strength for each point of inside the area. The resolution of the grid can be defined by user making the system flexible. The smaller size of the grid will improve accuracy and the greater size will improve processing efficiency.

The developed system use ITU-R P.1546 recommendation for field strength estimating over real terrain altitudes. Field strength calculation is implemented to be very efficient, because it is called for each point of the area of interest. The two items are important to be considered in order to reduce processing time: terrain profile creating and clearance angle computing. Terrain profile is generated by rasterization algorithm based on highly efficient Bresenham's method. Implemented method uses comparison of tangent of clearance angles instead of real angles. This way it avoids arctangent function calculation and improve performance.

The system also provides visualization of the field strength inside the area of interest as a semitransparent raster layer. The visualization can reveals possible alternative locations for the receiver with satisfactory field strength intensity. These alternative locations can be more appropriate considering other important criteria necessary for recover installation and utilization. The next step could be to allow transmitter to be placed at arbitrary position and to use regular polar grid of points to represent the area of interest.

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