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ELECTROMAGNETIC WAVES DIFFRACTION ESTIMATION FOR MICROWAVE LINE-OF-SIGHT LINKS USING OPEN-SOURCE DIGITAL SURFACE MAPS

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ОЦІНКА ДИФРАКЦІЇ ЕЛЕКТРОМАГНІТНИХ ХВИЛЬ ДЛЯ РАДІОРЕЛЕЙНИХ ЛІНІЙ З ВИКОРИСТАННЯМ ЦИФРОВИХ МАП ПОВЕРХНІ, ОТРИМАНИХ З ВІДКРИТИХ ДЖЕРЕЛ

Розглянуто можливість використання растрових картографічних шарів, отриманих з відкритих джерел, для розрахунку факторів поширення радіохвиль. Аналіз зосереджено на оцінці дифракції електромагнітних хвиль на елементах земної поверхні як одного з ключових факторів, що впливають на енергетичний бюджет радіолінії. Розглянуто алгоритм розрахунку профіля радіолінії на основі растрового картографічного шару.

Microwave line-of-sight (LoS) communication links are essential for high-capacity wireless networks. However, signal propagation in such systems is affected by obstacles that cause diffraction, leading to signal attenuation and degradation [1]. Accurate diffraction analysis is crucial for optimal link design, and Digital Surface Maps (DSMs) have become an essential tool in this process.

DSMs provide high-resolution raster data representing terrain and built structures, which allows to model the exact propagation environment. By integrating DSMs into Geographic Information Systems (GIS), diffraction calculations can be performed with greater accuracy, ensuring that potential obstructions are identified and mitigated.

In this paper, using open-source DSMs is considered for diffraction estimation as a part of the design of line-of-sight microwave links. The International Telecommunication Union (ITU) provides several diffraction models suitable for microwave link planning. The most used of them include the following approaches:

– Knife-Edge Diffraction Model [2] is a simple yet effective method assuming a sharp-edged obstacle. While useful for basic calculations, it does not account for complex terrain variations.

– Multiple Knife-Edge Model [2] extends the single knife-edge approach to multiple obstacles, offering improved accuracy in mountainous or urban environments.

– Deygout Method [2] uses an iterative approach that estimates diffraction loss over multiple obstacles by identifying a dominant edge and computing successive diffraction effects.

– Bullington Method [2] is a simplified model that approximates multiple obstacles as a single equivalent obstruction, reducing computational complexity.

By using DSMs, it is possible to automate the selection of relevant diffraction models and optimize antenna location to minimize signal degradation. Modern GIS tools integrate DSM data with ITU-compliant algorithms, improving reliability and efficiency in microwave network planning. The combination of high-resolution DSMs and advanced diffraction models significantly enhances the accuracy of LoS assessments, reducing deployment costs and ensuring robust communication links.

The procedure of power budget estimation of a LoS link requires generation a surface profile showing the surface heights over the signal path [3]. A DSM is a raster digital map layer, which contains values of surface height over the reference level for each raster pixel, which can be used for building a profile for a microwave link. Fig. 1 shows the fragment of a DSM, used for modelling the signal path for a microwave LoS link.

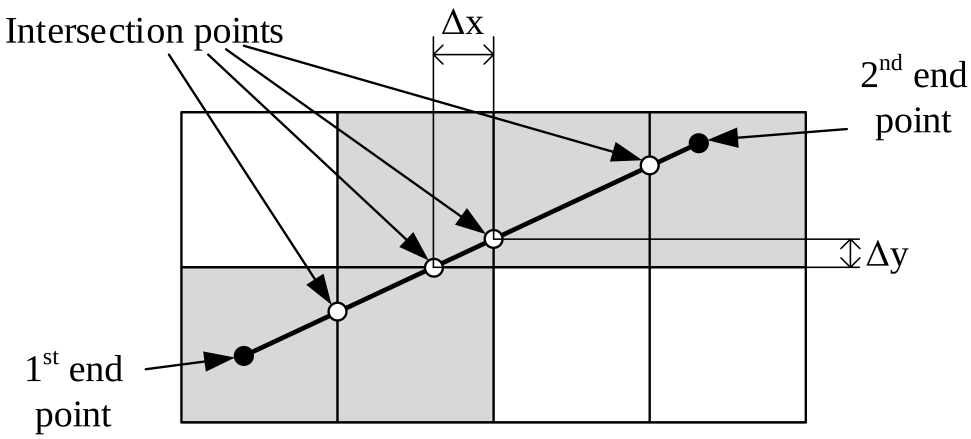

Fig. 1. Building a surface profile for a microwave LoS link.

The algorithm for building a profile includes the following steps:

– Building the line between the end points of the microwave link and calculation of the intersection points (see Fig. 1).

– Checking if the Δx and Δy (see Fig. 1) exceed the pre-defined threshold.

– Basing on the number of the intersection points, calculation of the number of pixels along the link path.

– Then, the profile as a dependence of surface height (Y axis in Fig. 2) versus distance from the 1st end point (X axis in Fig. 2) can be built. The points for X axis are taken as a uniform array consisting of the points (d_i, h_i), where d_i is the distance from the 1st end point of the link, and h_i is a surface height of this point. The distance values are calculated as follows: $d_i = i \cdot \frac{D}{N-1}$, where i is the point number, D is the distance between 1st end point and 2nd end point and N is the number of raster pixels along the path (shown as grey squares in Fig. 1).

– As a result, a link profile can be built (see Fig. 2).

For the calculations, open-source DSM can be used. In this work, the ALOS digital maps [4] were implemented. These maps have 30 x 20 m resolution and take into account not only the Earth elevation, but also the height of terrestrial objects, such as forests, buildings etc. A drawback of using the open-sours DSMs is absence of clutter layer, which makes it impossible to consider differences in electromagnetic wave propagation in different environment (for instance, concrete, wood etc.).

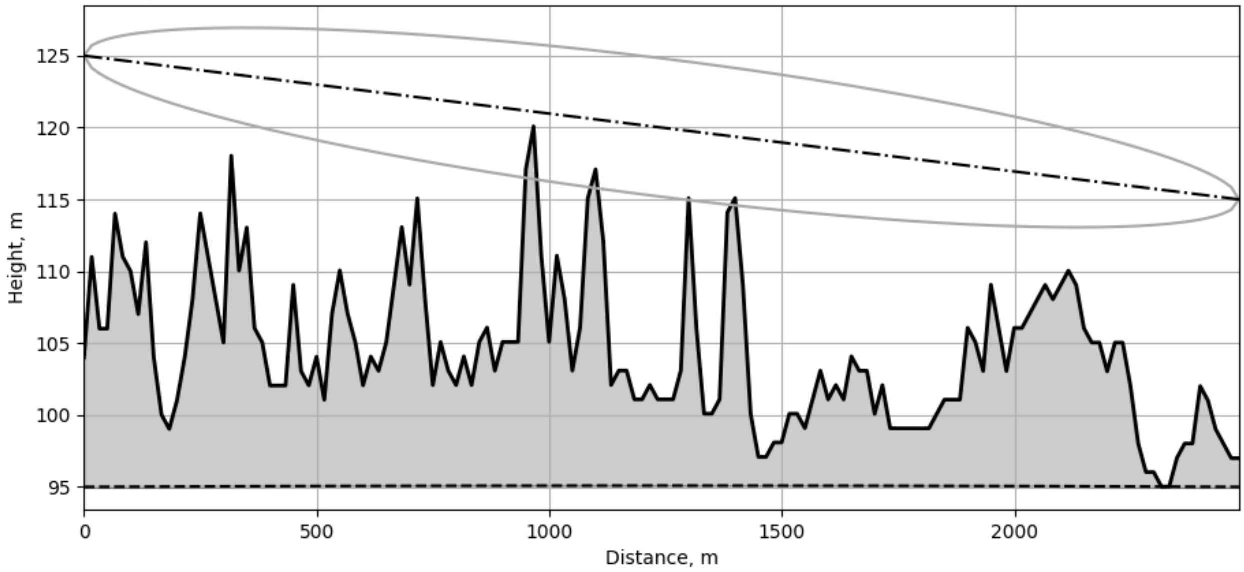

Fig. 2. Example of a microwave link profile.

To check the presented approach, Deygout method was used. The strength of this method is its ability to consider not only one or two obstacles along the wave path, but all obstacles that are essential for diffraction. As an example, for the link shown in Fig. 2, the value of power loss due to diffraction, calculated using Deygout method, is 8.9 dB. To provide the calculations, Python programming language was used, which makes the presented calculation approach independent from any commercial software.

It was shown that using ALOS DSMs and Deygout diffraction estimation approach allow to properly consider the diffraction along the signal propagation path in microwave LoS communication links. The calculations were performed for different types of terrain (rural and urban), different number of obstacles on the propagation path, various antenna heights. Good alignment with diffraction theory was observed for all combinations, which allows to consider the proposed approach reliable for the microwave LoS links planning and design.

References

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