

Modern and Optimized Planning Tool for Microwave Link Design

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Abstract— The microwave link planning tool described in this paper, named as Smart Link Planning Tool (SLPT), is a wireless communication planning tool for radio point-to-point communications, using microwave links (ML). This tool was firstly developed with the aim of helping telecommunication students, on their procedures to study and plan a ML and it was developed in a modern programming language, Java, to facilitate its continuous improvement and modernization on different platforms.

SLPT interacts with a geographic information system (GIS) and Google maps (GM), with a modern, intuitive and user-friendly interface which facilitates tasks such as the placement of the transmitter and receiver positions and the adequate number of repeaters along the path. It has the ability to show in real time the evolution of all calculations and the implications of the choices taken by the user towards optimization. The SLPT implements the latest standards and recommendations of the International Telecommunications Union (ITU), namely their radio counterpart (ITU-R), so the planned links obey these mandatory international regulations.

Keywords—Microwave Radio Links, Software Planning Tool, Geographic Information System, ITU-R, Google Maps.

I. INTRODUCTION

One of the major problems of engineering departments is the acquisition of data related to a certain city or cities, which is required for a proper planning of wireless networks.

This essentially corresponds to the geography of those cities, in which that planning is to be carried out. In most cases, this problem is solved by using digitalized maps, military maps, or even by directly collecting data of the target areas using teams of specialized technicians.

With this purpose, a few solutions emerged in the market to facilitate microwave link planning in engineering departments. Tools such as Motorola Broadband Planner, Mentum LinkPlanner and Pathloss, provided some paid solutions but they lacked both the flexibility of modern geographic information systems (GIS), relying on external sources for downloading updated geographical information, as well as the educational capabilities required for academic studies [1][2][3]. With this in mind, the SLPT tool was developed with the purpose of providing a more complete and flexible tool accessible to students and engineering departments. Integrating a cutting edge GIS, Google Maps (GM), allows the user to easily acquire the real geographical data necessary for correct planning without the need for constant mapping updates [4].

This tool provides the user with the capability to follow all steps necessary to implement a microwave link in a simple way, providing guided information regarding every option taken.

All planning results provided by this tool follow the latest International Telecommunications Union Radiocommunication (ITU-R) standards and recommendations [13].

This tool interacts with the user using detailed user friendly graphics and charts, which provide the necessary information to undertake correct design decisions.

This paper is organized in five sections: Introduction, Project Procedures, Google Maps Integration, Microwave Link Planning Tool and Conclusions.

II. PROJECT PROCEDURES

The SPLT was developed having in mind an easy and user-friendly interface, requiring a minimum of user interaction for a correct network planning and optimization.

The main operation of the SLPT can be described by three major functional blocks that mutually interact:

1. Inputs – Only a few and simple user inputs suffice to begin the correct planning of the desired network. Some typical input examples include the placement of the transmitter and receiver locations, one or more repeaters along the path, where required, the value of the earth correction factor (k_e), the carrier operation frequencies and so on [6];
2. Processing – This particular block of SLPT, corresponds to the processing system and implementation of mathematical operations corresponding to the models and ITU-R standards adopted, in accordance with the user criteria and choices;
3. Outputs – This is essentially a graphical interface to easily visualize the previously inserted values and options (Block 1) as well as the results outputted from this tool (Block 2), which can be presented using either graphics or tables to best suit the user needs of interpreting the inserted options. Therefore this is essential in the process of network planning optimization.

In order to perform a correct definition of the tool developed in Java, it was divided in two essential elements:

The GIS system embedded in a web page, which allows the user to survey the desired project location for the best possible choice terminal locations; The Planning Tool itself developed in Java, a modern and popular programming language with worldwide utilization and taught in many Universities.

III. GOOGLE MAPS INTEGRATION

The GIS used in this tool is GM due to its flexibility, reliability and range of capabilities provided by Google that facilitates user interaction and allows readily updated global maps (Fig.1). The interaction with the SLPT is performed through an Application Programming Interface (API) allowing the use of some of GM public services, such as the elevation service, required for retrieving the layout of the terrain.

That page contains a set of algorithms that were developed to allow the user to retrieve from GM accurate and essential data for the correct planning of a point-to-point microwave link. This data is essentially the antenna terminal coordinates, the link distance and a set of intermediate points between antennas or repeater terminals, containing the respective elevations that characterize the route between any two points (Fig.1). The number of points of this set can be chosen by the user between terminal stations, for example 256, which are then automatically taken equidistantly and stored in a file for further analysis and processing. A major advantage of the inclusion of GM in this tool is that we can now plan design any radio link anywhere in the globe without the need to obtain data from other maps which could eventually be unavailable. The process of data acquisition is divided in two steps, the Route selection and the GM data acquisition.

1. Route selection

The user simply needs to set a pair of markers, which will represent the terminal antennas. Then, the JavaServer Page (JSP) automatically draws a line between those two geographical positions, automatically providing all referred information, such as the distance and elevation of any intermediate points.

Since this is a point-to-point microwave link planning, the user has the possibility of inserting one or more repeaters, which are also represented as markers, as exemplified in Fig.1.

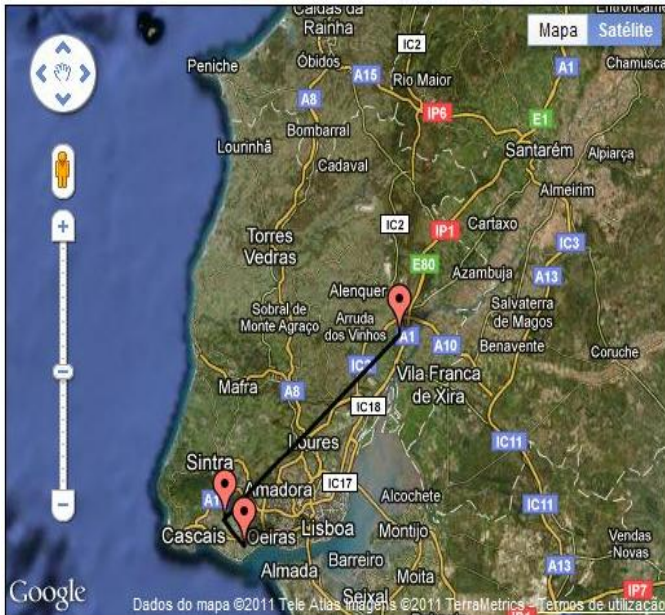


Fig.1 Route selection.

Subsequently the retrieved data is stored in a file named by the user.

2. GM data acquisition.

In order to obtain the necessary data from GM, we use a virtual server, GlassFish that is integrated in the Java Netbeans IDE (Integrated Development Environment) compiler, as shown in Fig. 2 [7], which then makes it available for the design [8].

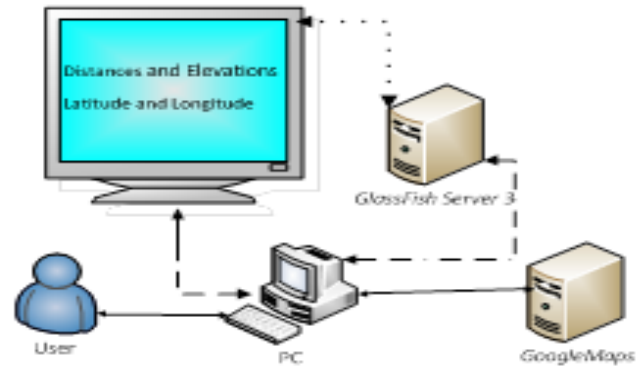


Fig. 2 Schematic representation of the SLPT interface with GM.

IV. SLPT DESCRIPTION

Starting with the initial link data obtained with the GIS, the SLPT initiates the planning and optimization of a point-to-point microwave link [9], for which the user has to take some actions or decisions that will influence the link's design and performance. Each action is usually required by the tool's user interface and SLPT only asks for a minimum of options or parameters that are needed to characterize to achieve an adequate planning. Whenever a parameter is changed, it will automatically influence the values of the following options and parameter results, so the user has the possibility to change the planning parameters at any time. This procedure allows an easy tuning and optimization of all required results, such as the Critical Margin (C_m) or the fulfillment of the ITU-R quality standards applicable to this type of links.

To facilitate the description of SLPT we have divided it into two major blocks, Link Budget and Link Quality, which functionalities and main options will now be described.

1. Link Budget

This is the first block that constitutes the SLPT tool, where the data entered by the user and the data retrieved by the GIS, provide the basis to initiate the planning of the point-to-point microwave link.

This block is subdivided into six smaller blocks with options that constitute the elements of signal propagation.

1) Data

This provides information on a given route, the corresponding coordinates (latitude, longitude and elevation) and the two highest elevations points or obstacles found in that route, which are displayed as shown in Fig. 3.

When there are repeaters or intermediate station in the link, the SLPT automatically detects their presence, giving information about their relative distance to the antenna transmitter.

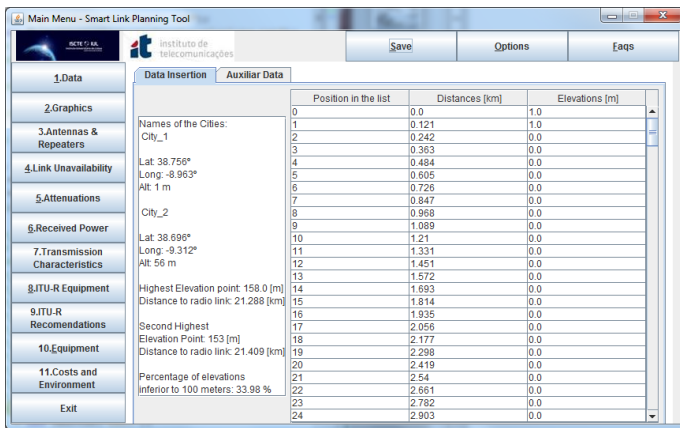


Fig. 3 SLPT main menu.

2) Antennas & Repeaters graphics

Through the introduction of simple inputs (antenna characteristics) the user has the possibility to visualize how the signal propagates along the first Fresnel ellipsoid. The masts of the antennas are shown in red. The larger ellipsoid represents the lowest carrier frequency used in the planning, while the smaller ellipsoid represents the higher carrier frequency, as shown in Fig. 4, whenever we choose to simultaneous evaluate the project for a certain range of frequencies.

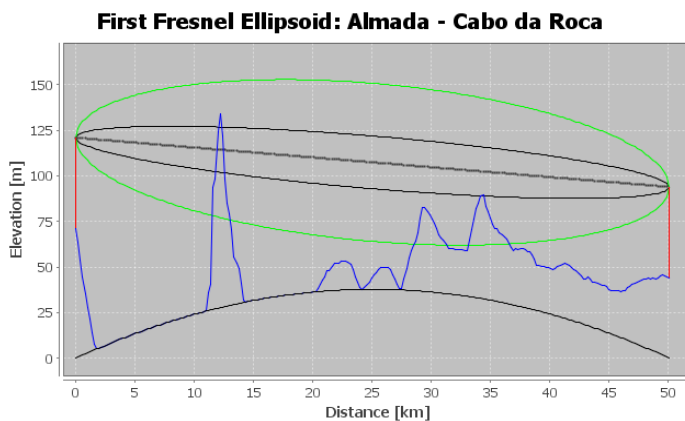


Fig. 4 Graphical representation of the first Fresnel ellipsoid.

A key feature of SLPT is its simple interface, which allows the user to change the majority of the required parameters with ease, for example to insert a repeater in the given route.

The SLPT also provides the user with a graphic representation of the repeater, as it can be seen in Fig. 5, where the repeater is represented in a blue line. In this example the repeater was placed on the highest point of that route.

Additional information is provided to the user with the introduction of a repeater, such as its gain and attenuations due to free space and obstacles.

3) Link Unavailability

The user defines the parameters which will limit this type of link, where the link becomes unavailable or too weak.

The parameters to consider are the rain, equipment and other sources (interference, auxiliary installations, and human activity) unavailability.

Repeater: Almada - Cabo da Roca

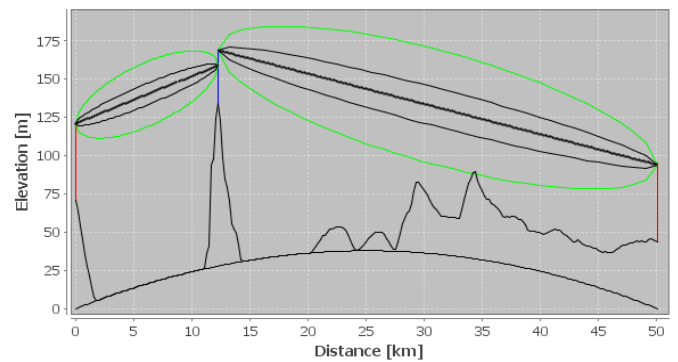


Fig. 5 – Fresnel ellipsoid with a repeater given by SLPT.

4) Attenuations

This option provides information related to some of the attenuations that influence this type of connection, such as the rain, atmospheric, hydro meteorites, free-space attenuation, etc.

5) Received Power

According to the initial parameter of transmission power, the SLPT informs the user of the values obtained for reception power. These results, take into account the values obtained in earlier options.

2. Link Quality

The Link Quality criteria, is where the user defines the type of modulation, transmission rate, channel band and the error ratio criteria's which will be added to the planning. These elements integrate the quality criteria that manage this type of link. Beyond these aspects, the SLPT provides information about the criteria's compliances, and how techniques like equalization and diversity mitigate certain effects, such as fading, that occurs in this type of transmission.

1) Transmission Characteristics

In accordance with the values previously obtained with the use of power plus the value of the various attenuations and respective modulated characteristics, it's showed by the SLPT the values of $\left(\frac{C}{N}\right)$ for a given microwave link considering that the following channel characteristic are essential to obtain an optimized design of a ML. These $\left(\frac{C}{N}\right)$ are:

- i. Rber;
- ii. berSESR;
- iii. berUnavailability.

These criteria are the residual ber ($[10^{-10}], [10^{-13}]$), ber Severely Errored Second Ratio (SESR) and ber Unavailability (10^{-13}).

The SLPT provides a graphical representation of signal-to-noise ratio $\left(\frac{C}{N}\right)$ obtained for each one of the bit error rate (ber) types that characterize this type of connection (Fig. 6) [6], [10].

The user is also informed about the best type of modulation to be used in planning, taking into account the three types of ber that characterized this type of planning (Fig.7) [12].

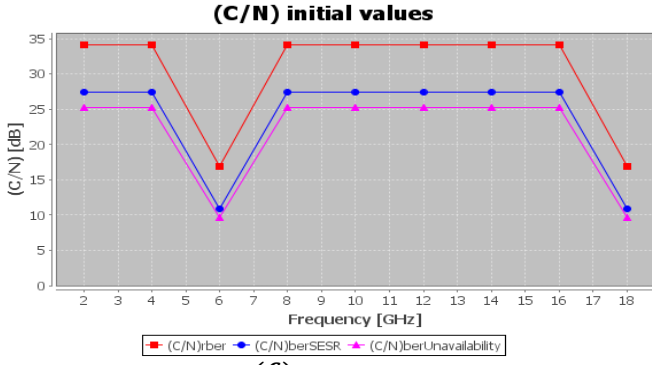


Fig. 6 Initial $\left(\frac{C}{N}\right)$ obtained by the SLPT.

| Modulation index (M) | Type of Modulation |
|----------------------|---------------------------|
| 64 | QAM |
| 64 | QAM |
| 4 | PSK or QAM -> best M: PSK |
| 64 | QAM |

Fig.7 - Type and index modulation.

The selection of the index and the type of modulation that is associated to the three different types of ber is carried out by an algorithm, which includes the execution of the inverse complementary error function (1), (2).

This function is characterized by implementing some mathematical complexity. [11]

$$erfc^{-1}(1-x) = erf^{-1}(x) \quad (1)$$

$$erf^{-1}(x) \approx sgn(x) \sqrt{\sqrt{\left(\frac{2}{\pi a} + \frac{\ln(1-x^2)}{2}\right)^2 - \frac{\ln(1-x^2)}{a}} - \left(\frac{2}{\pi a} + \frac{\ln(1-x^2)}{2}\right)} \quad (2)$$

With the use of some mathematical manipulation of the equations (1) and (2), it is possible to obtain $\left(\frac{C}{N}\right)$ for the type of modulation required for the planning, such as for a QAM modulation (3),(4),(5) or PSK(6),(7),(8)[6,13].

2) ITU-R Equipment

In this step, the user defines some of the equipment characteristics that will be used in planning, the MTTR (Mean Time to Repair) and MTBF (Mean Time Between Failures). Through these features the SLPT provides the user a device or set of equipment that best fits the giving planning parameters [6].

$$bber = \left(\frac{2}{\log_2 M}\right) \cdot \left(\frac{\sqrt{M}-1}{\sqrt{M}}\right) erfc\left(\frac{\sqrt{\frac{C}{N}}}{\sqrt{M-1}}\right) \quad (3)$$

$$\left(\frac{C}{N}\right)_{QAM[linear]} = 2 \left[\left(\sqrt{M}-1\right) \cdot erfc^{-1}\left(\frac{\log_2(M) \cdot bber}{2 \cdot (\sqrt{M}-1)}\right) \right]^2 \quad (4)$$

$$ber = \begin{cases} \frac{1}{2} \cdot erfc\left(\sqrt{\frac{C}{N}}\right), & \text{for } M = 2 \\ \left(1/\log_2(M)\right) \cdot erfc\left(\sin\left(\frac{\pi}{M}\right) \cdot \sqrt{\frac{C}{N}}\right), & \text{for } M \geq 4 \end{cases} \quad (5)$$

$$\left(\frac{C}{N}\right)_{PSK[linear]} = \begin{cases} erfc^{-1}(2 \times ber)^2, & \text{for } M = 2 \\ \left[\frac{erfc^{-1}(\log_2(M) \times ber)}{\sin\left(\frac{\pi}{M}\right)} \right]^2, & \text{for } M \geq 4 \end{cases} \quad (6)$$

3) ITU-R Clauses

As it was earlier mentioned, the SLPT integrates the standards and recommendations according to the ITU and the ITU-R, amongst them the fulfillment of four main clauses, the Severely Errored Second Ratio (SESR), Background Block Error Ratio (BBER), Errored Second Ratio (ESR) and rain.

If these standards are not met, the user always has the possibility of using two types of techniques that will facilitate their compliance. These techniques are equalization and diversity. These can be used individually or simultaneously if needed.

In order to be able to calculate each of these clauses, it is essential to obtain the selective margin (s_m) value, and two real margins (r_m) values, that are associated to these recommendations [6].

3.1) Adding equalization

With the introduction of equalization, the SLPT demonstrates the evolution that occurs in the planning, how this technique influences the quality of the s_m .

3.2) Adding diversity

Even though, with the introduction of equalization, sometimes the quality criteria's or ITU-R clauses are not fulfilled, it can be used another method or technique earlier mentioned, diversity. The user has the ability to define three types of diversity: Space Diversity; Frequency Diversity; Space and Frequency Diversity.

Similar to using equalization, the value of the selective margin improves by using diversity techniques.

3.3) Equalization and diversity

If the quality clauses have not been met, the user has the possibility of using simultaneously these two types of techniques, equalization and diversity. Due to this detail, the graphical representation of s_m is influenced with the use of both techniques, as can be seen in Fig. 8.

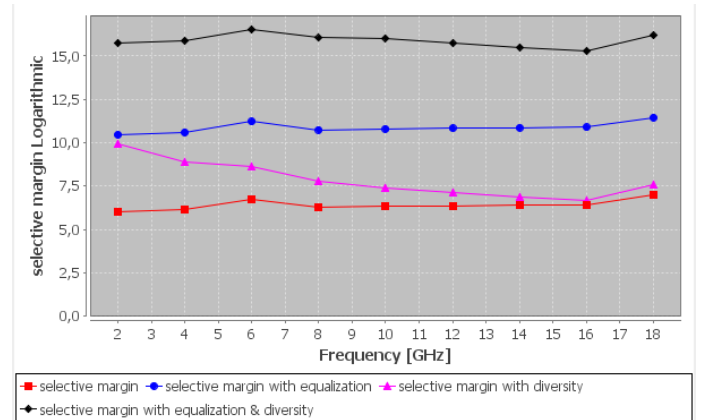


Fig. 8 Selective margin with equalization and diversity.

Thus, the SLPT provides the user with a constant view of the general behavior of the tool, how the results are influenced with the introduction of one these techniques.

The rain unavailability clause is presented in the same way as the other clauses through a column graph. However unlike the other graphics, its values are in dB units or log units (Fig. 10).

After calculating each one of these clauses, it is provided the Critical Margin (C_m) for a given microwave design.

4) ITU-R clauses

For each ITU-R clause (SESR, BBER, ESR) there's a dedicated bar graph with the results calculated previously. A special line is presented in the graphic determining which frequency below this value is able to fulfill the clause in question Fig. 9.

This value is obtained through the transmission debit that characterizes modulation used in this planning.

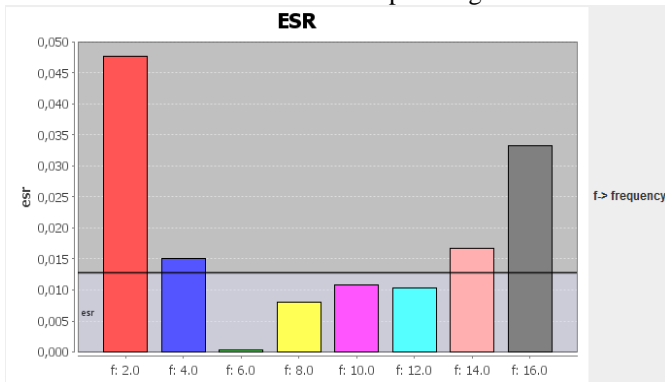


Fig. 9 ESR linear values, given by the SLPT.

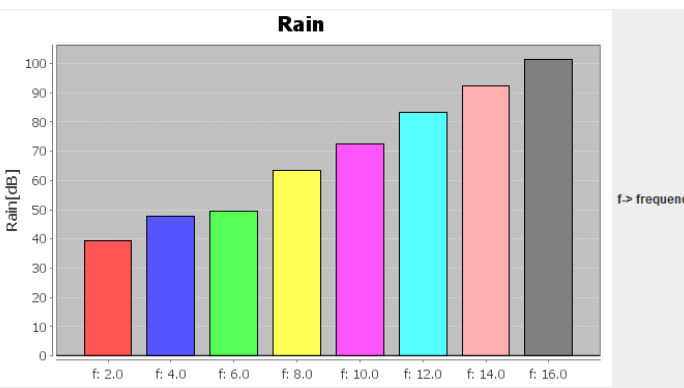


Fig. 10 Rain Unavailability values in dB units, given by the SLPT.

The SLPT performs a calculation for the best frequency to be used, according to the most appropriate value of C_m .

It's provided to the user additional information related ($\frac{C}{N}$) of the C_m , plus the respective index and type of modulation to be used in the correct planning (Fig. 11) [1].

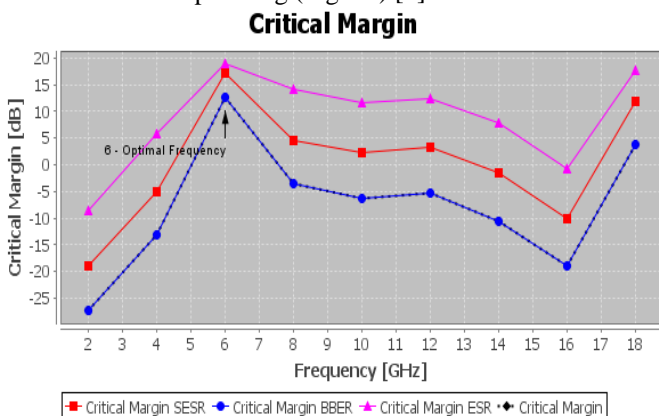


Fig. 11 Critical Margin supplied by SLPT.

V. CONCLUSIONS

This paper presents a new tool characterized by a simple and user-friendly interface, only requiring the introduction of a limited set of parameters to evaluate and optimize a given microwave link, while verifying the ITU-R standards. The tool outputs graphics and tables that further help on making their interpretation easy and intuitive.

This tool was developed in Java and interacts very easily with the GIS that includes Google Maps, which is the main source of input data for a given link. Furthermore, it allows an easy update of its functionalities, with the development of new tools as well as interaction with other products and applications.

This application's greatest advantage is the ability to combine academic and professional components in a single tool. This application provides information to students to understand how to plan a reliable microwave link, while providing professionals with a precise and powerful engineering tool.

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