Methodology Based on Recommendation ITU-R P.1546-4 for Prediction of Field-Strength in Mixed Path: Land-Freshwater

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Abstract — The latest versions of Recommendation ITU-R P.1546 contains considerations/corrections on propagation over mixed paths: land-sea. However, ITU recommends that paths over freshwater has to be considered all over land. This approach is acceptable for small portions of freshwater, but considering very large rivers or lakes such approach becomes poor. This paper proposes a methodology to correct the prediction of field-strength for mixed path over large portions of freshwater based on ITU-R P.1546-4. The implementation and validation of the methodology was done using data obtained from a measurement campaign carried out in Belém-PA (eastern Amazon, Brazil).

Keywords— Mixed paths, ITU-R P.1546-4; Empirical Propagation Model

I. INTRODUCTION

ITU-R P.1546-4 recommendation describes a method for point-to-area radio propagation predictions for terrestrial services in the frequency range 30 MHz to 3 000 MHz. It is intended for use on tropospheric radio paths over land paths, sea paths and/or mixed land-sea paths between 1-1000 km length for effective transmitting antenna heights less than 3000 m [1]. Since its third version (August 2005) [2], this recommendation allows mixed paths considering propagations zones over land and sea. The latest version [1] considers three types of paths over water: warm sea, cold sea and coastal regions, there is no consideration of freshwater (rivers and lakes). The most common accepted approach for mixed paths over freshwater is to treat totally over land [3], such consideration is acceptable only for small portions of freshwater, this consideration does not characterize the Amazon region that has rivers of expressive dimension.

This paper proposes a methodology for prediction of electric field for mixed paths on freshwater based on ITU-R P.1546-4. The implementation, comparison and validation of the proposed methodology was performed using data from a measurement campaign carried out in the metropolitan region of Belém-PA, having the characteristic of mixed path: urban and river. The data includes field-strength, power and delay profiles in UHF.

II. MEASUREMENT CAMPAIGN IN BÉLEM

A measurement campaign was carried out to acquire data on the quality of digital TV signal in the UHF band. The measurements occurred on 59 points in metropolitan region of Belém, including downtown and district Mosqueiro (Fig. 1). Points 1-14, located in Mosqueiro, present a mixed path crossing the Bay of Guajará (freshwater). Points 15-59 are located in Belém (land). The farthest point is located 47 km far from the transmitting antenna. The parameters obtained were: electric field-strength, received power, delay profiles, transmission frequency, distances Tx-Tr, and qualitative data on TV image quality.

For this study were selected data from one station located near downtown Belém. Its transmitting antenna is 100 m height. The antenna possess omnidirectional radiation pattern, 6 kW transmitter Toshiba thirty panel, 6 kW transmitter Toshiba thirty panel, gain of 11.10 dB, it operates in 521.143 MHz.

Figure 1. Measurement points in the metropolitan region of Belém.
III. RECOMMENDATION ITU-R P.1546 - 4

The ITU-R P.1546 aims to provide methodologies for planning coverage in the frequency range 30-3000 MHz and for distances between 1-1000 km. ITU-R P.1546 is applied to the percentages of time between 1% to 50% (time variability), effective height of transmitting antenna raging 10 m to 1200 m. It has corrections based on the terrain clearance angle, mixed paths, among other characteristics.

The determination of field-strength according to the recommendation ITU-R, is performed through the propagation curves, annex 2, 3 and 4 [2]. These curves are generated from data tabulated considering the terrain, transmitting antenna height, distance and time variability. If the case study has exactly the features covered in the tables, just check the associated field. But for not tabulated values one should be made interpolation or extrapolation assuming four parameters above. Therefore the recommendation provides four types of interpolation or extrapolation:

- Interpolation and extrapolation of field strength as a function of transmitting/base antenna height, \( h_i \);
- Interpolation of field strength as a function of distance;
- Interpolation and extrapolation of field strength as a function of frequency;
- Interpolation of field strength as a function of percentage time.

The recommendation provides a correction for effective height of the antenna, considering the path length and the topology of the terrain.

The latest version of the recommendation was increased of information including new parameters for the treatment of mixed path approved by the Regional Radiocommunication Conference RRC-06 only. In this fragment the recommendation proposes the estimation of average field-strength for the mixed path.

A. Considerations of Recommendation ITU-R P.1546-4 for mixed path

For the general case, the average field-strength \( E \) for mixed path considering portions of land, cold sea, warm sea or coastal regions is given by:

\[
E = (1 - A)E_{\text{land}}(d_{\text{total}}) + A \cdot E_{\text{sea}}(d_{\text{total}}) \quad (1)
\]

where:
- \( A \): interpolation factor given in annex 5 §8.1 [2];
- \( d_{\text{total}} \): length of total path;
- \( E_{\text{land}}(d_{\text{total}}) \): field strength for land path equal in length to the mixed path (dB(μV/m));
- \( E_{\text{sea}}(d_{\text{total}}) \): field strength for sea-and-coastal-land path equal in length to the mixed path;

The item c of § 8 considers the land path across several land regions and sea regions, as follows:

\[
E = (1 - A) \sum_{i=1}^{n_l} \frac{d_i E_{\text{land},i}}{d_{IT}} + A \cdot \sum_{j=1}^{n_s} \frac{d_j E_{\text{sea},i}}{d_{ST}} \quad (2)
\]

where:
- \( E_{\text{land},i} \): field strength (dB(μV/m)) for land path \( i \) equal in length to the mixed path, \( i = 1, \ldots, n_l; n_l \) is the number of land zones traversed;
- \( E_{\text{sea},j} \): field strength for sea-and-coastal-land path \( j \) equal in length to the mixed path, \( j = 1, \ldots, n_s; n_s \) is the number of sea-and-coastal-land zones traversed;
- \( d_i, d_j \): length of path in zones \( i, j \);
- \( d_{IT} = \sum_{i=1}^{n_l} d_i \): length of total land path;
- \( d_{ST} = \sum_{j=1}^{n_s} d_j \): length of total sea-and-coastal-land path;

The model considers information from all different types of propagation zones. That is, the model considers the influences of all paths. This is the main difference with respect to the model Dual Slope [4], which considers each part of the path (different pathways) independently.

B. Computation of the Interpolation factor \( A \)

The interpolation factor for mixed path applicable to all percentages of time is given by:

\[
A = A_0(F_{\text{sea}})^V \quad (3)
\]

where:
- \( A_0(F_{\text{sea}}) = 1 - (1 - F_{\text{sea}})^{2/3} \)

The fraction of path over sea \( F_{\text{sea}} \) given by:

\[
F_{\text{sea}} = \frac{d_{ST}}{d_T}
\]

\[
V = \max \left[ 1.0 ; \ 1.0 + \frac{\Delta}{40.0} \right]
\]

\[
\Delta = \sum_{n=1}^{N_s} E_{\text{sea}}(d_{T}) \frac{d_{sn}}{d_{ST}} - \sum_{m=1}^{M_l} E_{\text{land}}(d_{T}) \frac{d_{im}}{d_{IT}}
\]

where:
- \( N_s \): total number of sea zones and coastal land zones;
- \( n \): sea-path or coastal land-path zone number, \( n = 1, 2, \ldots, N_s \);
- \( M_l \): total number of land zones;
- \( m \): land-path zone number, \( m = 1, 2, \ldots, M_l \);
- \( d_{sn} \): distance traversed in sea or coastal land zone \( n \) (km);
- \( d_{im} \): distance traversed in land zone \( m \) (km).

IV. IMPLEMENTATION OF THE MODEL ITU-R P.1546-4 FOR THE CASE STUDY

Two cases were considered to analyze the field-strength for this study: i) Interpolations considering only land propagation zones; ii) Implementation of corrections for mixed paths.
A. Interpolations considering only land propagation zones

The four interpolations described in the recommendation were implemented using Matlab® software. The best interpolation performed was the interpolation of field-strength as a function of distance, according to the mean error and rms error (Fig. 2). It can be seen that the model results are very close to those measured in the urban area (up to 23 km). But it is seen that beyond 23 km the model begins to distance from the measured data. This is mainly because of changes in the characteristics of the path (bay and forest). The model underestimates points after the bay, exactly as observed in [3, 5].

Step 4: Admit a fictitious transmitting antenna with the mean field-strength \( E_M \), located in the boundary of the two propagations zones. This value is assigned to the first point of the second propagation zone;

Step 5: Return to step 2, considering now the next propagation zones.

In this sequence the information about the previous propagation zones is always kept to compute the electric field on the present propagation zone. However the information about further propagation zone is not considered. Differently from the methodology proposed, the recommendation considers all information about all propagations zones on each other.

VI. IMPLEMENTATION OF THE PROPOSED METHODOLOGY FOR THE CASE STUDY

A. Step 1: Identification of propagation zones

For the case studied the path was divided into three sections: 1) dense urban area (Belém), 2) Bay of Guajará (freshwater) 3) suburban area (Mosqueiro).

B. Step 2: Interpolation for the first propagation zone

The interpolation of field-strength as a function of distance was done only for the first propagation zone, points 15-49, Fig.3.

C. Step 3: Compute of \( E_M \)

The mean electric field was computed in IV B.

D. Step 4: Assigning the first point

By reverse interpolation of the data available in annex 5, it can be concluded that the fictitious transmitting antenna should be located at 8 km from the first point of the second zone. This is the approximate length of Bay of Guajará in the stretch considered. It is important to note that there are no measures of the second propagation zone. Thus for the case studied the fictitious point (antenna) is assigned to the third propagation zone.
E. Step 5: Interpolation with correction for the third propagation zone

The interpolation uses the points of Mosqueiro (third zone) with the correction of the first point (fictitious) with information related to the first zone, Fig. 4. Concluding the proposed methodology.

Figure 5 illustrates the methodology applied for the entire mixed path. It shows three distinct stretches: i) the first is all over land (dense urban area), with distances below 23 km; ii) the second is over freshwater (Bay of Guajará) with distances between 23-32 km; iii) the third is over land (suburban area). It can be seen that for all cases the proposed methodology follows the behavior of the measured data. It shows a good fit in the border points, 23 km and 32 km.

![Figure 4. Interpolation with correction of field-strength as a function of distance for the third propagation zone (Mosqueiro)](image1)

![Figure 5. Proposed methodology considering the entire mixed path (Belém-Bay of Guajará-Mosqueiro).](image2)

VII. COMPARISON BETWEEN ITU-R P.1546-4 RECOMMENDATION AND THE PROPOSED METHODOLOGY

Mean error (ME) and root mean square error (RMSE) were used to compare the proposed methodology with the best case of the recommendation of ITU-R P.1546-4, Table I. The comparison shows significantly lower errors for the proposed methodology. This confirms the good performance of the proposed methodology.

<table>
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<tr>
<th>MODEL</th>
<th>ME</th>
<th>RMSE</th>
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</thead>
<tbody>
<tr>
<td>ITU-R P.1546-4</td>
<td>4.1077</td>
<td>8.2596</td>
</tr>
<tr>
<td>Proposed Methodology</td>
<td>2.4483</td>
<td>2.9622</td>
</tr>
</tbody>
</table>

VIII. CONCLUSIONS

The ITU-R P.1546 recommendation has been modified and improved to correct several parameters, among which are the computations for electric field for mixed path. However, the prediction for mixed path is still insufficient.

This work proposes a methodology based on ITU-R P.1546-4 for prediction of field-strength for mixed path including freshwater region. The methodology was described and implemented in all the steps. Graphically it can be observed that the proposed method follows the behavior of the measured data. To validate the methodology, mean and rms error were calculated showing its good performance.

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REFERENCES


