Measurements of a CW signal in Brazil and Comparison with Prediction using ITU-R P.1546-1

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Abstract — **This paper compares the prediction given by ITU-R P.1546-1 to measurements obtained using a CW maintenance signal of a trunking system repeater operating at 856 MHz in the Brasília, capital of Brazil.**

Index Terms — **Land mobile radio, power measurements, prediction methods, mobile communication, UHF radio propagation.**

I. Introduction

Trunking systems used for critical communication applications allow public security agents, like the police and fireman, the ability to cooperate and coordinate efforts in the prevention of accidents, actions against catastrophes and public order maintenance. Deploying such a system requires a careful planning of sites structure to maximize the use of resources and to assure that the system availability in the covered region is acceptable.

In site planning it is necessary to use path loss models and prediction tools that incorporate the characteristics of a particular region in which the system will be deployed. This is achieved using terrain elevation databases in conjunction with the prediction tool to simulate the environment and determine the propagation path loss by a mathematical model.

This paper compares the prediction given by ITU-R P.1546-1 method [1] to measurements obtained using a CW maintenance signal of a trunking system repeater operating at 856 MHz in Brasília, capital of Brazil.

Measurement procedures are explained on the following topic. The third topic refers to the characteristics of Recommendation ITU-R P. 1546-1 and its methodology. The fourth topic presents the comparison between the measurements and the prediction given by ITU-R P.1546-1 and finally the conclusion of this paper.

II. Measurements

The measurements took place in the city of Brasília (Brazil) with the intention of studying a mobile environment.

Measurements were made using a regular compact automobile, an omni-directional antenna ASPD1894T (806-896 MHz, 3 dB gain), a power inverter (12VDC to 110VAC), a Garmin GPS 12 MAP receiver (with a RS-232 cable interface for external connection), an Agilent 4402B spectrum analyzer (using a GPIB-USB converter cable for external connection and control) and a notebook computer which controls the devices by a software developed in Agilent VEE Pro that consolidates the data obtained in a single output file.

The CW signal is generated at the frequency of 856.039 MHz with 100 W using a Motorola Quantar repeater. The signal is then passed thru a Sinclair Q4220 duplexer that delivers it to an omni-directional antenna RFS Penetrator (806-824/851-869 MHz, 8.14 dB gain).

The spectrum analyzer is set to zero span mode, single sweep mode, resolution bandwidth of 1 kHz and auto-calibration and internal pre-amplifier capabilities enabled. The sampling rate (number of points per sweep) depends on the distance of a stationary Rayleigh process for the given frequency, the intended vehicular speed, the confidence interval and the accuracy (accepted error). It must obey a minimum and a maximum distance between points to assure that the samples are not correlated and do characterize a stationary Rayleigh process. It was found that a distance up to 20 m for UHF [2-3] is necessary to assure this process. The minimum distance is related to the non correlation of samples taken which is a function of the wavelength. The non-correlation analysis is done by post-processing the signal, so there is no minimum speed required during the measurements. The relationship between these parameters is:

$$R_{Sample} = \frac{V_{Max} Q(I_c)^2}{D_{Rayleigh} \varepsilon^2} \tag{1}$$

where R_{Sample} is the sampling rate [points/s], V_{Max} is the maximum allowed mobile speed [m/s], $D_{Rayleigh}$ [m] is the distance where a stationary Rayleigh process for the working frequency is characterized, $Q(I_c)$ is the inverse complementary cumulative rayleigh distribution as a function of the confidence interval probability and ε is the accuracy (error) [dB].

A sweep is triggered by the GPS when data is send to the computer and has approximately 1 Hz. During this sampling second the points are taken in the first 800 ms as for the next 200 ms, they are used as a guard interval because of the uncertainty of the refresh rate of the GPS to send data. The structure of one sweep is depictured in Fig. 1.

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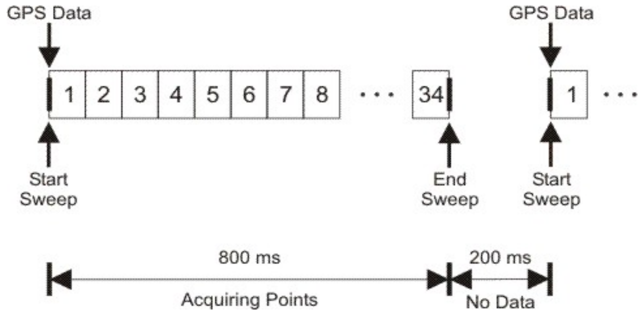

Fig. 1. Sweep Structure for frequency of 856.039 MHz, 90% confidence interval, 64 km/h top speed and 1.5 dB accuracy (34 points per sweep; 800 ms sweep duration).

In the spring of 2004 a measurement campaign was performed in the main roads of Brasília districts traveling over 400 km. The routes cover a great variety of terrain types including open areas, dense residential areas and mixed path (land-water) situations, among others. Selected measurement tracks plotted over a satellite image are presented in Fig.2.

Fig. 2. Measurement tracks (white) and base station (black triangle) shown over an IKONOS satellite image.

The output file obtained in the measurements is post processed in order to remove those points that are correlated and separate the fast and slow fading phenomena. This is a critical step in order to compare the measured results with the prediction that is given by ITU-R P.1546-1.

In order to remove those points that are correlated to each other, first the mean acceleration in 1 second (one sweep) is calculated. The spacing between two consecutive samples is determined using general acceleration and velocity equations by simple kinematics. The gap in the end of each sweep is also taken into account.

The minimum distance for adjacent samples to be uncorrelated is determined from the wavelength of the signal by 0.38λ at least [2-3].

After removing the invalid points from the measured data, a moving mean filter is used with a window of 22 meters so the short-term and long-term signal variations are separated. In Fig. 3 is presented a plot of the measured signal power in a 160m route and the resulting plot after the filter is used. Notice the presence of a line-of-sight multi-path component in the beginning of the route and the non-line-of-sight phenomena after approximately 50 m.

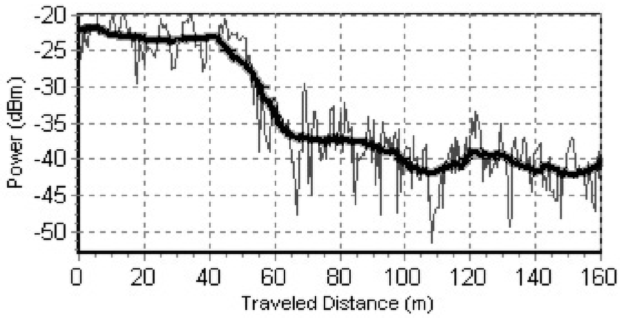

Fig. 3. Long-term (thick line) and short-term (thin line) separation over a 160 meters route.

III. Recommendation ITU-R P.1546-1 [1]

The ITU-R P.1546-1 is a recent point-to-area prediction method from the International Telecommunication Union for all broadcast and mobile services in the frequency range 30 MHz to 3000 MHz and for distances ranging from 1 km to 1000 km. This recommendation was developed to combine various methods into one unique method and to overcome limitations from older recommendations such as ITU-R P.370, P.529 and P.1146.

The P.1546 provides a set of curves that embraces a variety of variables, such as percentages of time exceeded (50%, 10% and 1%), frequencies (100 MHz, 600 MHz and 2000 MHz), path type (land, cold sea and warm sea), transmitting/base antenna height (1200 m, 600 m, 300 m, 150 m, 75 m, 37.5 m, 20 m and 10m), distances (1 km to 1000 km) and the receiving/mobile antenna which is equal to the representative height of ground cover. These curves where obtained based on measurements in temperate climates.

There are corrections to enhance the prediction accuracy of the method such as the terrain clearance angle correction, mixed-path, receiving/mobile antenna height, short urban-suburban correction and adjustment for different climatic regions.

A. Terrain Clearance Angle

The terrain clearance angle (TCA) improves the prediction accuracy by taking into account obstacles near the receiving antenna.

It is based on the transmitter and receiver height and the obstacles between them. It is a function of the heights and the angle between the horizontal and the line towards the transmitter that just clears all obstacles.

B. Mixed-Path

When propagation path is over both land and sea there is a correction based on ITU-R P.452 to correct the predicted field strength for a mixed-path. This is important to take into account since reflections from water surfaces are usually very strong.

C. Receiving/Mobile Antenna height

The field strength values given by the curves are for a reference receiving/mobile antenna at height *R* representative of the height of the ground cover surrounding it. The minimum height value is 10 m. Example of reference heights are 10 m for suburban areas, 20 m for urban areas and 30 m for dense urban areas.

A correction depending on the ground cover should be applied if the receiving/mobile antenna height is different from *R*.

D. Short Urban-Suburban Correction

If a path length is less than 15 km and the building heights are uniform over flat terrain, this correction should be added to reduce the field strength taking in account the building clutter effect.

E. Adjustment for Different Climatic Regions

Based on ITU-R P.453 that contains the global mapping of refractivity gradients in the lowest 65 m of the atmosphere, this correction should be used to correct ITU-R P. 1546 for any region in the world.

IV. Comparison between Measurements and ITU-R P.1546-1 Prediction Method

The measured power using the measurement method described earlier is shown over LANDSAT satellite image in Fig.4. The power measured in Fig.4. shows in light grey the higher power levels and in dark grey the lower power levels. The difference between each grade of gray represents a 10 dB variation of signal level.

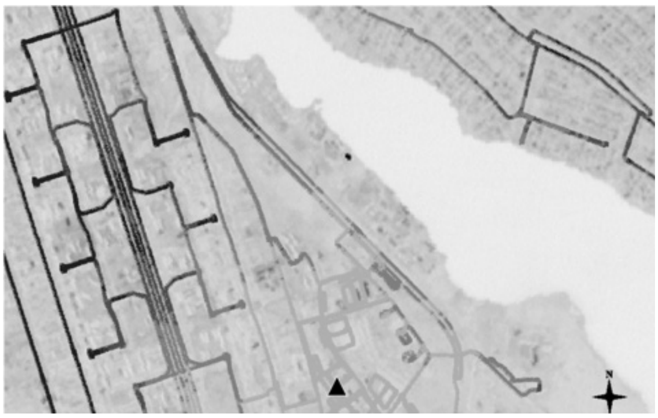

Fig. 4. Measured power over a color inverted LANDSAT satellite image.

The prediction was obtained using an ITU-R P.1546-1 implementation developed at the Federal University of Minas Gerais. The predicted power can be seen in Fig.5. The power is shown as the center points of a square of 200 m x 200 m as it is described in the recommendation and is graded in shades of red for higher power levels and blue for lower power levels. The difference between two shades represents a 10 dB variation of signal level just like the measured data. This allowed a quick preliminary comparison of the results.

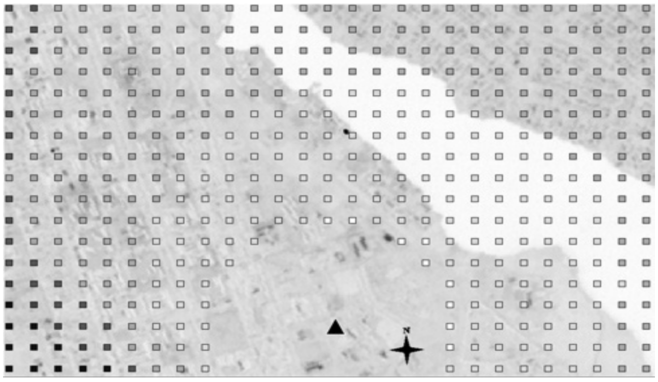

Fig. 5. Predicted power over a color inverted LANDSAT satellite image.

For comparing the results the difference between measured and predicted power was plotted over an inverted LANDSAT satellite image can be observed in Fig.6.

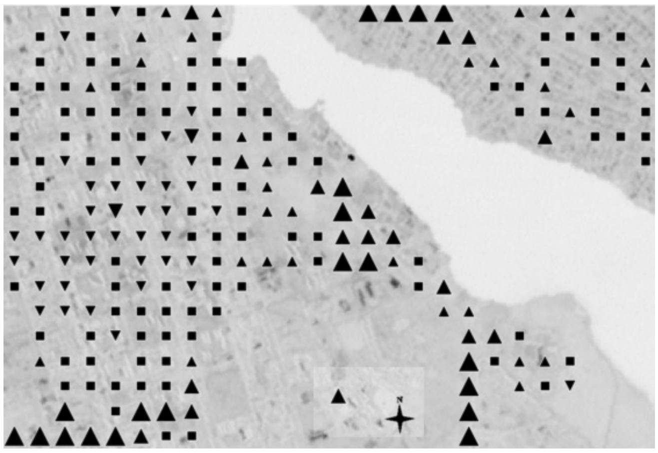

Fig. 6. Comparison between measured and predicted power over an inverted LANDSAT satellite image.

The squares represent regions where the difference between the predicted and the measured power is less than 5 dB. For differences bigger than 5 dB, the triangle pointing up refers to regions where the measured power is higher than the predicted and the triangle pointing down refers to regions where the measured power is lower than the predicted.

By the DEM (Digital Elevation Model) database it can be observed that higher elevations are in the southwest, intermediate elevations (near the Base Station elevation) crosses from northwest to southeast and the lowest elevations are in the northeast.

In the northwest area, several regions show a quite optimistic prediction. The main reason for this is because the topological and building heights data were not considered.

In the southwest area and other areas where the absolute receiver height is greater than absolute transmitter height the prediction was very pessimistic.

V. Conclusions

The DEM in Fig.6. shows that the antenna is placed in a hillside. By this situation it can be seen that the prediction for the northeast is better than the prediction for the southwest.

The ITU-R P 1546-1 is good for well behaved regions, but for anomalous situations as sometimes it can be faced when deploying cellular systems (when a antenna must be placed in a hole) it can return inconsistent results.

Future works includes corrections where the absolute receiver height is greater than absolute transmitter height and use of topological and building height data.

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