Path-Loss Model for UHF Bands IV and V

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Abstract — An empirical propagation model for UHF bands IV and V (450 to 1000 MHz) is presented. The model is a computational form of the data from the UIT-R (formerly CCIR) propagation curves for 50% locations, 50% of time. It is aimed to be used by practicing engineers and allows the estimation of median path loss, received power or electric field strength which is usually sufficient in many practical applications for outdoor communication systems.

Index Terms: Propagation models, outdoor propagation, path loss, statistical propagation models.

1. Introduction

The model presented here is a variation of a previous work [1] and was developed following similar procedures. It is actually a mathematical characterization of the UIT-R (formerly CCIR), propagation curves [3] for UHF bands IV and V (450 to 1000 MHz). The model allows for the estimation of the median value of path-loss as a function of frequency, distance and transmitting antenna height for a fixed receiving antenna height of 10 m. Originally, these curves were developed for use in the coverage prediction of broadcasting services in the VHF and UHF bands, and are frequency independent in the bands of interest, therefore they can also be used in other types of wide area communication systems in these bands. It must be emphasized that this model, as well as the original curves, is intended for the planning of broadcasting and mobile services, and not for use in point-to-point communication links for which more accurate methods must be used.

2. The Model

In the model, path loss is indirectly characterized by an attenuation factor, in this case, the exponent of distance, where for non-free space conditions, the equivalent received isotropic power at a distance \( d \) from the transmitter can be expressed as:

\[
P_{\text{iso}} = \frac{P_{\text{rad}} \left( \frac{\lambda}{4\pi} \right)^2}{d^n} \text{ watt} \tag{1}
\]

where \( P_{\text{rad}} \) is the effective isotropic radiated power, \( d \) the distance between transmitting and receiving antennas in meters and \( \lambda \) is the wavelength in meters. The value of \( n \) intrinsically embeds the effects of all propagation mechanisms: attenuation, diffraction, reflection, etc. The higher the effects of scattering mechanisms, the higher the value of \( n \). Path loss in dB is usually expressed as \( L = 10 \log \left( \frac{P_{\text{rad}}}{P_{\text{iso}}} \right) \), therefore, from (1), it can be calculated as:

\[
L = 10n \log_{10}(d) + L_0 \text{ dB} \tag{2}
\]

where \( d \) is in meters and \( L_0 \) the attenuation at 1 m in free space: \( L_0 = 20\log(4\pi/\lambda) \text{ dB} \). Model (2) has been used for indoor as well as outdoor communications, and several versions have been treated previously in the literature [4]-[5]. In the above expressions, no clear dependence of \( n \) with frequency, distance or antenna height appear evident. From the curves, it can be inferred that there is no dependence upon frequency, as well as from [6]. However, the dependence of \( n \) with distance and antenna height must be extracted from the curves. That is the aim of the model.
3. Dependence of the model with distance and transmitting antenna height

In order to establish the dependence of $n$ with distance and transmitting antenna height, field strength values were obtained from a set of CCIR for distances from 10 to 100 km, and for transmitting antenna heights from 37.5 up to 600 m. The curves assume a constant receiving antenna height of 10 m and corrections must be made for other heights. Even when field strength values from the curves are referred to an EIRP ($P_{rad}$ in (1)) of 1 kW, calculation of the isotropic received power is straightforward for any other value of $P_{rad}$ and the value of $n$ can be easily obtained from (1) as:

$$n = \frac{P_{rad} \text{ (dBw)} - P_{iso} \text{ (dBw)} - L_0}{10 \log_{10}(d)}$$

($3$)

$P_{iso}$ can be easily obtained from the field strength as:

$$P_{iso} = \frac{1}{480} \left( \frac{E \lambda}{\pi} \right)^2 \text{ watt}$$

(4)

where $E$ is the median field strength in V/m obtained from the CCIR curves, and $n$ is the median value of the exponent of distance. $P_{iso}$ must be calculated first, and then $n$, using (3).

4. The Model

Following the procedure described in the previous section, a set of values of $n$ for different distances and transmitting antenna heights was obtained. The best fit was found to be:

$$n = \sum_{i=0}^{4} \sum_{j=0}^{4} a_{ij} h^i d^j$$

(5)

which constitute the model whose coefficients are shown in Fig. 1.

All coefficients with the decimal places shown, must be used in implementing the model. Simpler, unidimensional models with less coefficients can also be derived for $n$ as a function of distance or transmitting antenna height alone.

5. Results

Results are shown in figure 2, compared with those obtained with the curves. The maximum deviation between the values of $n$ obtained from the curves, and those calculated with the model is of 1.3%.

![Fig 2. $n$ as a function of distance for constant Transmitting antenna height.](image)

6. Conclusions

A simple computational path loss model has been derived from the CCIR curves. Such curves were developed using measured values, taken in different geographical areas over different periods of time, and provide the median values of field strength for service at 50% of locations during 50% of the time. Therefore, they reflect reliable experimental data not derived from theoretical models. In the model, the exponent of distance is characterized as a function of distance and
transmitting antenna height. From this parameter, mean or median path loss, receiving power and field strength are easily obtained. Fitting of the model with CCIR curves is very good for distances between 10 and 100 km and antenna heights up to 600 m. Values are based on a receiving antenna height of 10 m, therefore corrections are necessary for other heights. The model does not require particular computational effort and is of simple application for practicing engineers who do not require a deeper knowledge of channel dynamics. The model is also independent of frequency and may be used for broadcasting applications as well as for outdoor communication systems.

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References:


