RECOMMENDATION ITU-R P.1791*

Propagation prediction methods for assessment of the impact of ultra-wideband devices

(Question ITU-R 211/3)

(2007)

Scope

This Recommendation provides methods valid for a frequency range from 1-10 GHz to calculate an ultra-wideband (UWB) path loss in indoor and outdoor operating environments for line-of-sight (LoS) and obstructed path categories and to assess the power received by a conventional narrow-band receiver from a UWB transmitter.

The ITU Radiocommunication Assembly,

considering

a) that ultra-wideband (UWB) technology is a rapidly emerging wireless technology;

b) that devices using UWB technology use multiple high data-rate streams and cover large bandwidth;

c) that knowledge of the propagation characteristics is essential for assessment of the impact of UWB devices;

d) that there is a need both for empirical (i.e. site-general) models and advice for interference assessment, and for deterministic (or site-specific) models for some detailed propagation predictions,

noting

a) that Recommendation ITU-R P.525 provides the calculation of attenuation in free space;

b) that Recommendation ITU-R P.528 provides propagation curves for aeronautical mobile and radionavigation services using the VHF, UHF and SHF bands;

c) that Recommendation ITU-R P.618 provides propagation data and prediction methods for Earth-space links;

d) that Recommendation ITU-R P.452 describes the procedure for the evaluation of microwave interference between stations on the surface of the Earth in the frequency range of about 0.7 GHz to 30 GHz;

e) that Recommendation ITU-R P.1238 provides guidance on indoor propagation over the frequency range 900 MHz to 100 GHz;

f) that Recommendation ITU-R P.1411 provides propagation methods for short paths in outdoor situations, in the frequency range from about 300 MHz to 100 GHz;

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* This Recommendation should be brought to the attention of Radiocommunication Study Group 1.

g) that Recommendation ITU-R P.1546 provides guidance on propagation for systems that operate over distances of 1 km and greater, and over the frequency range 30 MHz to 3 GHz;

h) that Recommendation ITU-R P.530 provides propagation data and prediction methods for the design of terrestrial line-of-sight (LoS) systems,

recommends

1 that the information and methods in Annex 1 should be used for calculating path losses of UWB devices between 1 GHz and 10 GHz;

2 that the information in Annex 2 should be used to assess the power received by a conventional narrow-band receiver from a UWB transmitter.

Annex 1

1 Introduction

The frequency dependence of the UWB LoS transmission loss actually results from the antenna characteristics. Therefore, the traditional path-loss model typically used for narrow-band signal propagation modelling is useful in computing the path loss experienced by UWB signals.

A considerable number of UWB propagation studies and experiments have been performed in a great variety of conditions, thus allowing the derivation of UWB propagation models and their parameters.

Both indoor and outdoor environments are foreseen for UWB devices. Detailed knowledge of the particular indoor site, including geometry, materials, furniture, etc. is required when performing propagation studies. In the case of outdoor propagation, information on buildings and trees is essential for propagation calculations. These factors usually result in multipath, which a UWB receiver is capable of resolving. Therefore, a UWB propagation model should capture both the path loss and multipath characteristics of the typical environment where UWB devices are expected to operate. Models that represent the propagation characteristics in the environment in a general manner are more suitable to achieve this goal. These models do not usually require a lot of input information by the user in order to carry out the calculations.

This Recommendation defines operating environments, path-loss categories, and provides methods for estimating UWB path loss in these conditions. It is to be used to determine the UWB link budget.

2 Physical operating environments

Environments described in this Recommendation are categorized solely from the radio propagation perspective. Two different environments are identified for indoor propagation and one for outdoor propagation. They are considered to be the most typical. Table 1 lists the three environments. Recognizing that there is a wide variety of environments within each category, it is not intended to model every possible case but to give propagation models that are representative of environments frequently encountered.

TABLE 1

Physical operating environments

Environment	Description
Indoor residential	Townhouse with domestic furniture, plasterboard and concrete walls
Indoor industrial	Office/laboratory (corridors, lecture rooms) with plaster/concrete walls and ceilings, plaster/concrete/parquet floors, furnished (metallic cabinets, desks, chairs, electronic instrumentation, etc.) and empty rooms
Outdoor	General and rural conditions including foliage and trees

3 Path categories

Analysing possible propagation situations between the UWB transmitter and receiver two different path categories can be identified: paths with a strong LoS component, and obstructed paths – non-line-of-sight (NLoS).

Because of obstacle or man-made blocking, an LoS situation seldom exists in indoor operating environments and the signal is received via multipath. Moreover, depending on the degree of receiver obstruction from the transmitter, additional path subcategories are considered in the indoor propagation environment: Soft-NLoS and Hard-NLoS. In the former case there is a standard obstacle or, at least, one plasterboard between the transmitter and the receiver. In the latter case the receiver is separated from the transmitter by a large number of obstacles or by, at least, one concrete wall.

4 Path-loss models and parameters

The path loss from the UWB transmitter to the UWB receiver can be estimated with either site-general or site-specific models. The use of transmission-loss models in indoor environments assumes that both the transmitter and the receiver are located inside the same building.

4.1 Site-general models

The models described in this section are considered to be site-general as they require little path or site information. The distance power-loss coefficients given below include an implicit allowance for transmission through walls and over and through obstacles, and for other loss mechanisms, like multipath, likely to be encountered in the UWB transmission channel. Site-specific models would have the option of explicitly accounting for the loss due to each obstacle instead of including it in the distance model.

The basic transmission loss $PL(d)$ experienced by UWB signals could be derived from the following model:

$$PL(d) = PL_0(d_0) + 10n\log\left(\frac{d}{d_0}\right) + X_\sigma \qquad \text{dB} \qquad (1)$$

where:

- $PL_0(d_0)$: basic transmission loss (dB) at the reference distance d_0 (where d_0 is typically equal to 1 m)
- d: separation distance (m) between the UWB transmitter and the receiver (where $d > 1$ m)

n: path-loss exponent

X_σ: log-normal shadow fading, i.e. a zero mean Gaussian random variable with standard deviation σ (dB).

If the basic transmission loss at the reference distance can be approximated by:

$$PL_0(d_0) = 20\log\left(\frac{4\pi d_0\sqrt{f_1 \cdot f_2}}{0.3}\right) \quad \text{dB} \qquad (2)$$

where f_1 (GHz) and f_2 (GHz) are the frequencies at the −10 dB edges of the UWB radiated spectrum.

The basic transmission loss will vary widely over the UWB bandwidth, and the overall system performance will depend on how this variation interacts with the antenna characteristics.

Typical parameters, based on various measurement results, are given in Table 2. They should be used for propagation distances up to 20 m. For propagation distances greater than 20 m the parameters corresponding to LoS and NLoS outdoor environment may provide an assessment of basic transmission loss between UWB transmitter and receiver. It should be noted also that LoS indoor propagation potentially results in multipath signal reinforcement indicating that other path-loss exponents in specific instances might apply.

TABLE 2

Parameters for basic transmission loss calculation

Environment	Path category	*n*	σ (dB)
Indoor residential	LoS Soft-NLoS Hard-NLoS	~ 1.7 3.5-5 ~ 7	1.5 2.7-4 4
Indoor industrial	LoS Soft-NLoS Hard-NLoS	~ 1.5 2.1-4 4-7.5	0.3-4 0.19-4 4-4.75
Outdoor	LoS NLoS	~ 2 3-4	– –

4.2 Site-specific models

Deterministic estimation of the path loss may be useful for detailed planning of UWB applications. Theoretical approaches for field-strength prediction based on the uniform theory of diffraction (UTD) are available. They require detailed information of the obstacle geometry and building structure (in the case of indoor environment) for the calculation of the field strength. Within such models the received waveform is modelled as a superposition of channel significant rays, taking into account the effects of the transmitter antenna, multipath propagation, and receiver antenna. The channel impulse response of a given ray takes into account not only the attenuation but also the dispersion due to interaction, and the receiver antenna impulse response in the arrival direction of this ray, respectively. The significant rays and their associated delays between the transmitter and receiver are to be determined by ray tracing. The channel transfer function associated with each ray is determined based on UTD. By including reflected and diffracted rays, the path-loss prediction accuracy is significantly improved.

Annex 2

To calculate the received power from a UWB transmitter into a conventional narrow-band receiver it is necessary to consider the bandwidth of the receiver. The effective radiated power to be considered is the UWB power spectral density integrated over the receiver bandwidth. In this case the received power can be calculated using conventional propagation models and the receiver antenna gain. ITU-R P Series Recommendations listed in *noting* a) through g) can be used within their ranges of applicability.