

■ White paper
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Mixed absorption-diffraction
propagation models for
wireless proximity networks

Jean-Philippe Noël
Emmanuel Grenier

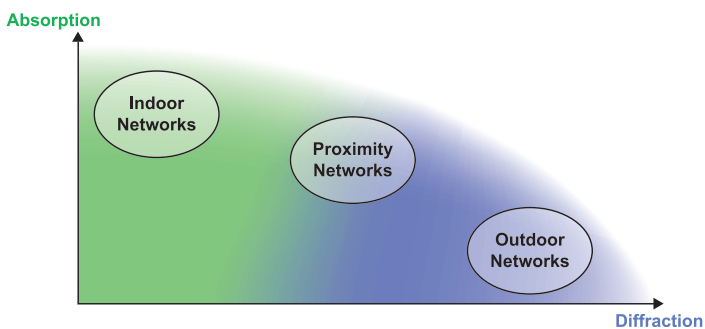


Context

Outdoor networks transmit signals which may be received indoor. When relatively low frequencies are used, for instance in broadcast, the diffraction is most of times considered as predominant compared to the absorption and the fact that the receiver is indoor is taken into account through an increase of the reception threshold (cf. Chester 97 Agreement for the coordination and planning of DVB-T).

On the other hand, for purely indoor networks, the standard approach is to neglect the diffraction and to focus on the absorption due to the materials crossed by the signal (cf. IMT-2000/ITU-1225).

With the emergence of the new proximity networks (WiFi, WiMax, DECT...), using outdoor base stations with indoor and outdoor subscribers at relatively high frequencies, the border between absorption and diffraction becomes much fuzzier, and there is a need to use mixed models, as illustrated on the figure below.



The purpose of this article is to explain briefly the principle of these mixed models and the way they can be used in ICS Telecom.

Diffraction models

The different models of buildings and terrain diffraction are based in ICS Telecom on standard recommendations (ITU-R 526, Deygout, Bullington...) and, for this reason, are not detailed here.

Absorption models

For purely indoor networks, ICS Telecom provides the capability, not detailed here, to work on the drawings of a given building and to specify in detail the material of each wall or partition.

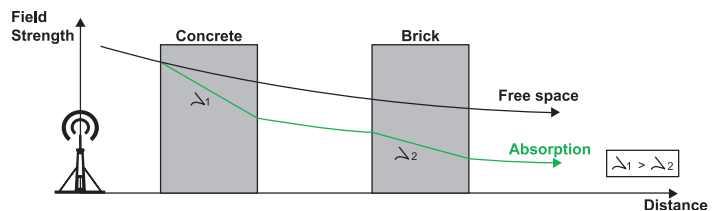
For proximity networks, the model of buildings absorption is based in ICS Telecom on three hypothesis :

- Each building is homogeneous, i.e. made of only one material
- The absorption attenuation, expressed in dB, is proportional to the length of the path crossed by the signal inside the building
- The coefficient of proportionality, also called absorption coefficient, is a characteristic of each material (concrete, glass, brick...)

The absorption attenuation can therefore be written as follows, where λ_i is the absorption coefficient of the i-th material and L_i is the length of the path crossed by the signal inside this material :

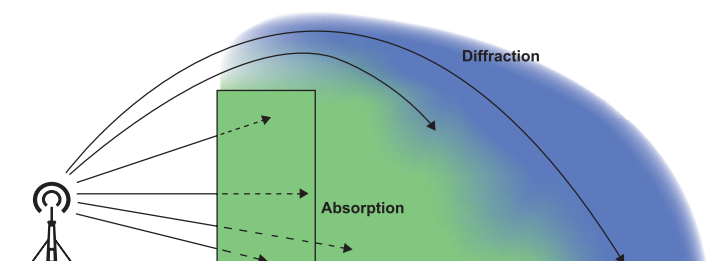
$$L_{\text{absorption}} \text{ (dB)} = \sum \lambda_i \times L_i \text{ (km)}$$

The figure below gives a qualitative view of this absorption model :



Mixed models

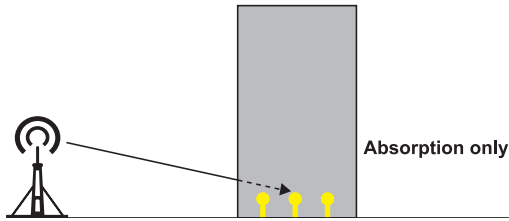
On the figure below, it is intuitively clear that the diffracted signal is not received inside the building and can be neglected just behind it. However, after a certain distance, the diffracted signal becomes predominant and the absorbed signal can be neglected.



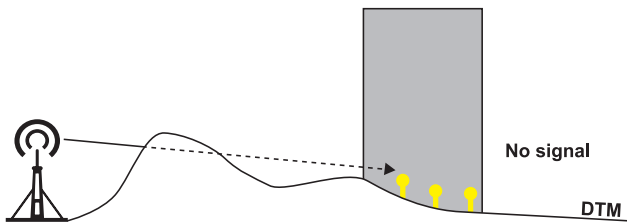


Therefore, the following rules are applied in ICS Telecom :

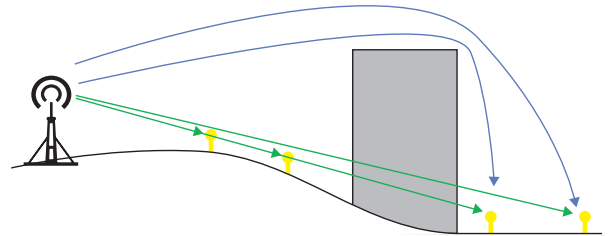
- Case 1.1 : the receiver is inside a building and the line of sight between the transmitter and the receiver is clean, only the absorbed signal is considered



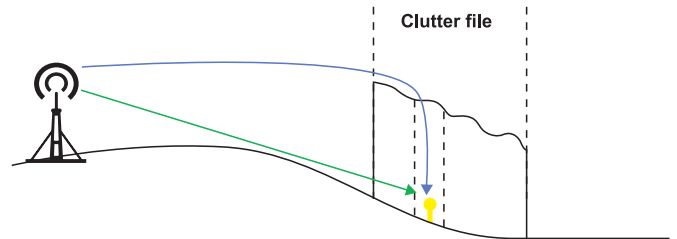
- Case 1.2 : the receiver is inside a building and the line of sight between the transmitter and the receiver is blocked, there is no signal



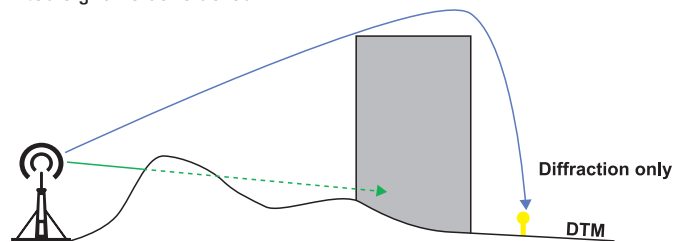
- Case 2.1 : the receiver is outside a building, the maximum of the absorbed and diffracted signals is considered



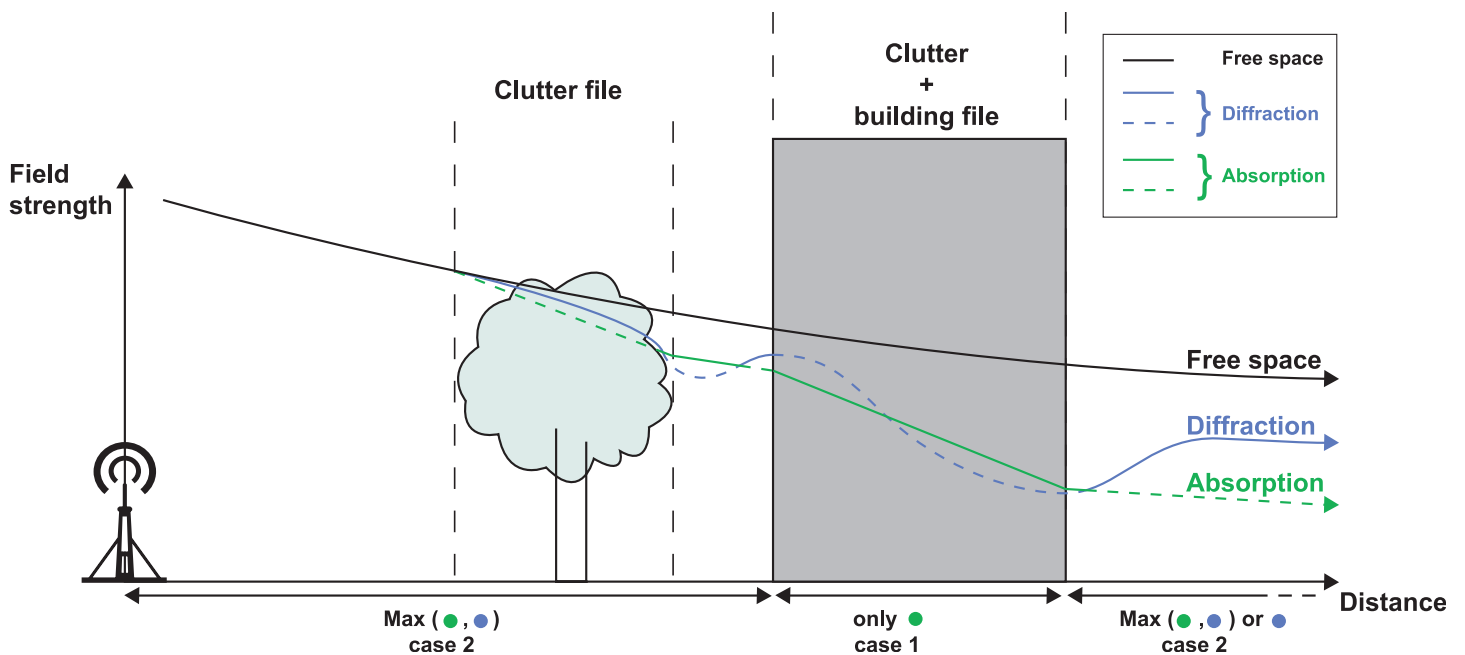
- Case 2.2 : the receiver is outside a building but within a clutter code such as vegetation, the maximum of the absorbed and diffracted signals is also considered



- Case 2.3 : the receiver is outside a building but the line of sight between the transmitter and the receiver is blocked, only the diffracted signal is considered



The figure below gives a qualitative view of such a mixed absorption-diffraction model





Required digital cartography

Four different cartographic layers are required :

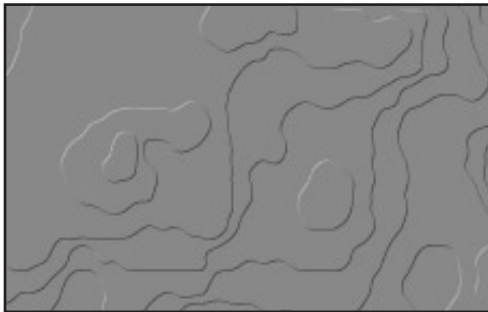
- The Digital Terrain Model (DTM)
- The ground occupancy layer (clutter)
- The image
- The building layer

In order to model properly the shape and the location of the buildings, a high resolution is required, ideally 1 or 2 meters. Such a high resolution cartographic dataset can be obtained thanks to a **stereo-restitution** process applied on couples of satellite or aerial photos.

The use of these different layers is briefly explained here and examples over the city of Paris are given.

The Digital Terrain Model (DTM)

This layer contains on each point the altitude of the ground above sea level, excluding the buildings heights. The data contained in this layer is used to compute the diffraction attenuation of the terrain.



The ground occupancy layer (clutter)

This layer describes the nature of the environment on each point of the area : streets, vegetation, water, building (up to 15 different sub-classes can be defined, depending on the material the building is made of) and free classes that are not predefined but can be set for particular calculations.

For the buildings classes, the data contained in this layer is used to determine which attenuation, i.e. which absorption coefficient, has to be applied. For the other classes (e.g. vegetation), it is used to determine the additional height to be applied for the calculation of diffraction.

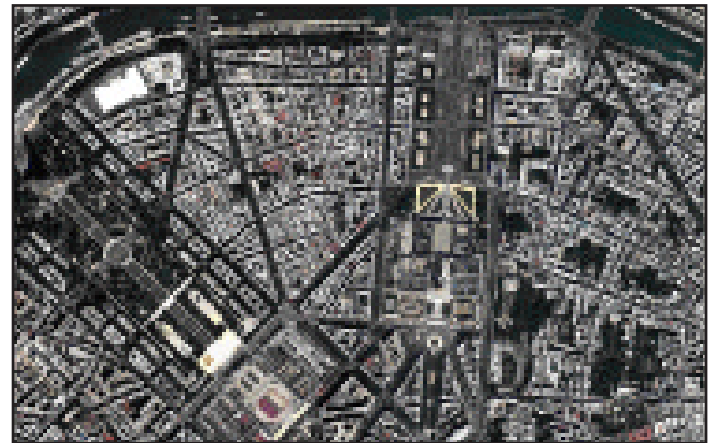
The absorption coefficients or the additional heights associated to each clutter class are not stored in the cartographic layer itself but defined by the user in the ICS Telecom project.



As on a given point, only one clutter value can be defined, it implicitly means that each building is homogeneous, i.e. made of only one material, on its whole height and on a ground surface equal to the resolution of the cartographic dataset. It must be noted that this hypothesis is never strictly satisfied, given the presence of windows on the facades and of air inside the buildings.

The image layer

The image is not used in the calculations, but is useful for printouts background and visual localisation.

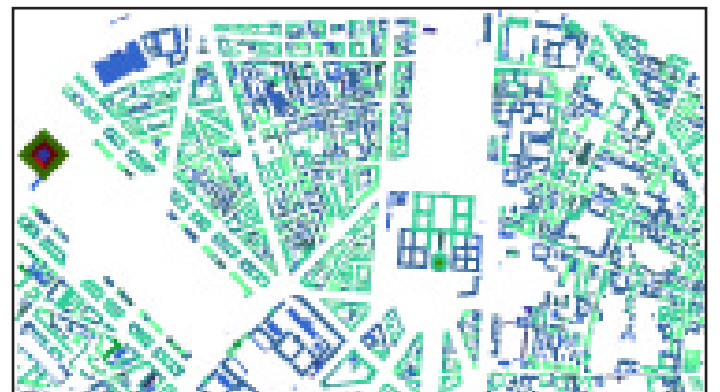


The building layer

This layer contains the description of each individual building, i.e. for each point of the terrain, the height of the roof above ground level, from 0 to 255 meters.

The data contained in this layer is first used to determine whether the receiver is inside a building or not, and then to determine which mode, absorption or diffraction, has to be applied. Basically, the receiver is considered inside a building if $H_{\text{Building}} > 0$ and $H_{\text{Building}} > H_{\text{Rx antenna}}$. In addition, in diffraction mode, the building heights are used to determine the diffraction due to the buildings.

It must be noted that if there is a building on a given point, this information is present in the clutter layer (one of the 15 building sub-classes), but also in the building layer (height above ground between 1 and 255m). Moreover, it is very likely that there will be a statistical relationship between the heights of the buildings and the materials they are made of. It is then clear that **there is a large correlation between the clutter and the building layers** (see figures below). It is therefore preferable to use the same cartographic sources to generate both layers, so that there is no incoherence between them.





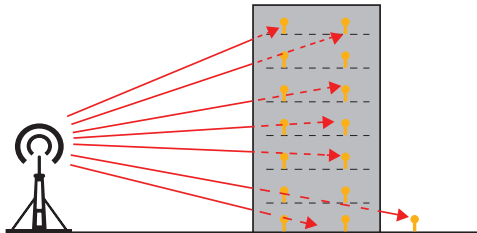
Determination of the absorption coefficients

In general, it is necessary to perform physical measurements on the terrain in order to adjust the absorption coefficients of each material.

The principle of the determination of these coefficients is the following :

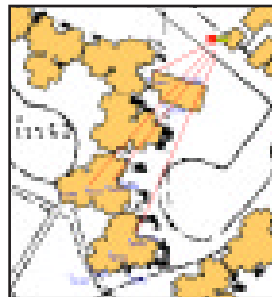
1 - Test points

- One or several test buildings, ideally with homogeneous facades, are selected in the neighbourhood of a known transmitter
- One or several test points are selected just behind each building
- Several test points are selected inside each building, nominally 2 test points per floor (see figure below)



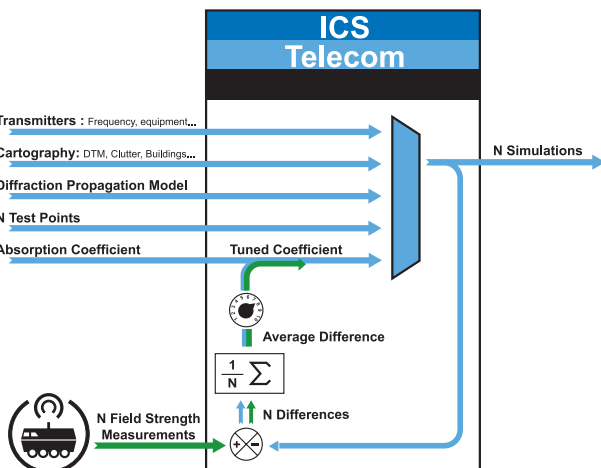
2 - Subscribers database

- In ICS Telecom, the user creates a subscribers database, with one subscriber on each test point (see figure across). The floor of the test point is specified in the subscriber antenna height.
- With the function *Subscribers/Point to point/All servers/Omni directional antenna*, the user can simulate the theoretical field strength received by each subscriber.



3 - Comparison measurements/simulations

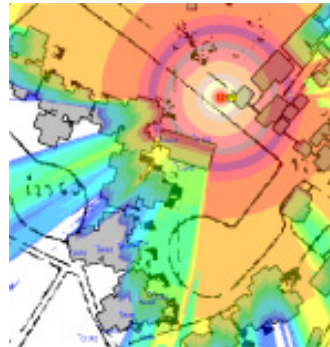
- The measurements are compared to the simulations on each test point
- The average of the differences is then computed on the whole set of test points. Depending on the sign of this average, the absorption coefficient must be manually increased or decreased by the user (see figure below)



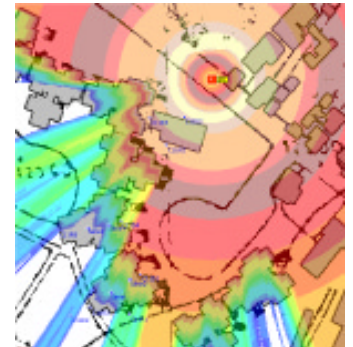
In addition, other measurements can be made in open areas in the neighbourhood of the transmitter, in order to validate on the one hand the technical parameters of the transmitters and on the other hand the diffraction model.

Coverage examples

The figures below gives examples of coverage calculation using a mixed absorption-diffraction propagation model.



Simulation at 1.5m above ground level



Simulation at 20m above ground level

Conclusion

All required cartographic inputs and simulation parameters can be introduced in ICS telecom to simulate the effects of absorption and diffraction due to the buildings. However, the user should keep in mind that is necessary to perform measurements on the terrain in order to obtain accurate and realistic values for the absorption coefficients.

ATDI SA

8, rue de l'Arcade - 75008 Paris - France
Tel. +33 (0)1 53 30 89 40 Fax. +33 (0)1 53 30 89 49
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