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OPTIMIZATION IN COMPUTATION TIME OF A RADIO COVERAGE PREDICTION FOR MICRO CELLULAR MOBILE SYSTEMS

Y.Pousset, R.Vauzelle, P.Combeau

University of Poitiers - IRCOM-SIC UMR CNRS n°6615. Bât. SP2MI, Téléport 2, Bd Pierre et Marie Curie, BP 30179, 86962 FUTUROSCOPE CHASSENEUIL Cedex, France

Phone : (33) 5.49.49.65.67, Fax : (33) 5.49.49.65.70

E-MAIL : pousset@sic.sp2mi.univ-poitiers.fr and vauzelle@sic.sp2mi.univ-poitiers.fr

Abstract:

This paper presents a method which optimises the computation time prediction of a radio coverage, whatever the propagation model used. The principle consists in reducing the number of application points of the propagation model in relation to a classical technique. The proposed method is based on a multi resolution analysis of measured signals carried out around 2 GHz, and on an electromagnetic analysis of the propagation environment. The performances of the method are evaluated in terms of reduction in computation time and of accuracy, in comparison with the classical technique.

1.Introduction:

Mobile cellular systems are based on a geographical distribution of base stations. Each transmitter provides a radio coverage that must be predicted with accuracy. The final aim is to enable a satisfying quality of communication everywhere. Generally, the coverage prediction is computed by a propagation model applied with a regular step in the area studied [1]. This method leads to a considerable computation time which might become unexploitable in complex geometrical environments.

They have already been some searches studying how to reduce that computation time. They consist in simplifying the propagation model used. The process presented in this article is complementary to them: it is independent of the model. This work has been developed in collaboration with the France Telecom Research and Development centre.

The principle, based on an hypothesis explained in the section 2, consists in reducing the number of application points of the propagation model and of optimising their location. Moreover, this optimisation must be obtained without deteriorate the

quality of the radio coverage prediction. This approach can be break down into two stages called “learning” and “application” stages which are developed in the section 3. In the section 4, we compare the performances of our method with those of the classical technique.

2.Hypothesis:

For the coverage prediction, where the fast fading is not considered, our method is based on the following hypothesis: *On a mobile route, the significant and slow fading of the received signal are due to changing of electromagnetic interactions combinations (reflection, diffraction and line of sight) undergone by the received waves.*

Thus for a geographical area, the set of points associated to a same combination of electromagnetic interactions leads to delimit a spatial region. Each region is characterised by a stationary received signal: the variation of the mean power is small. So, to go from one region to another amounts to consider a significant and slow variation of the received signal.

The Figure 1 illustrates this hypothesis on a schematic example. The electromagnetic wave propagation laws leads to different regions whose, each of them is characterised by a combination of electromagnetic interactions (Figure 1(a): (1) visibility, (2) visibility plus reflection, (3) diffraction). Considering the hypothesis, the received signal on the mobile route of the Figure 1(b) presents significant and slow variations at the points $\mathbf{P_1}$, $\mathbf{P_2}$. These points correspond to the limits of the different regions which are crossed by the mobile route.

This hypothesis is the base of the method presented in the next section to optimise the computation of a coverage prediction.

3.Method

Our method is split up into two stages: a “learning” stage which verifies the validity of the hypothesis and an “application” stage which provides the coverage prediction optimised in computation time.

3.1. Verification of the hypothesis: “Learning stage”

This stage necessitates two complementary analysis. The first one, heart of the optimised prediction, is an electromagnetic analysis software developed in the laboratory. It implements the wave propagation mechanisms which lead to the determination of a spatial cut out according to a transmitter located in a geographical area. The second one is a segmentation technique of signals based on the wavelets maxima. It allows to detect the behaviour changing of measured signals on a mobile route.

The search of a strong correlation between the results of these two tools leads to the verification of our hypothesis and constitutes the learning stage.

3.1.1. Electromagnetic analysis:

A micro cell configuration is defined by a transmitter height below the average height of roof tops. It is the reason why the electromagnetic study is based in the horizontal plan (2D_H).

The electromagnetic analysis software is founded on the search of the influence regions of the electromagnetic interactions.

For the line of sight and the reflection phenomena, the geometrical optic theory is applied. In an environment, the regions induced by these phenomena are delimited by the optic boundaries.

The diffraction phenomenon is more complex to delimit than the previous ones because the diffracted field due to an obstacle is present throughout the space.

Nevertheless, the amplitude of the diffracted waves decreases as the diffraction angle increases [3][4]. Therefore, the electromagnetic analysis takes into account a diffraction angle α which is the limit angle from this the amplitude of the diffracted wave is negligible in comparison with that of the line of sight. To calculate α, we consider firstly the diffraction loss A_{dB} for a perfectly conductive infinite half plane (Figure 2 a); its expression is given by **(1)** :

$$A_{dB}(v) = 10\log_{10}\left(\frac{P(v)}{P_0}\right) = 6{,}4 + 20\log_{10}((v^2+1)^{0,5} + v) \qquad \textbf{(1)} \qquad \text{for } v > -1$$

where :

P_0 is the received power without obstacle;

and $P(v)$ is the received power with the obstacle where $v = h\left[\frac{2}{\lambda}\left(\frac{1}{d_1} + \frac{1}{d_2}\right)\right]^{1/2}$.

The α angle is defined such that the diffraction loss $A_{dB}(v)$ is equal to -3dB (Figure 2 b). For this value, the magnitude of the wave in line of sight is equal to that of the diffracted wave. On this base, a study generalised to wedges and based on the UTD [4] has shown that, whatever the wedge angle, the length of link and the electrical nature of the wedge, α is roughly equal to one degree. Because, the α values are smaller than the geometrical parameters of the area studied, the diffraction phenomenon is considered only in the shadow zone in the electromagnetic analysis software.

To summarise, the electromagnetic analysis relies on the search of the optical boundaries and leads to a partition in regions based on the nature of the electromagnetic phenomena (diffraction, reflection, line of sight). A simple example of a partition is shown in the Figure 3 where the visualisation of each region is realised thanks to a grey scale. For the example given, with a maximum number of diffractions and reflections

equal to one, five regions exit. To generalise this example, we underline that the complexity of a spatial cut out is directly connected to the number of the different interactions.

3.1.2. Signal segmentation:

This technique is based on a multiscale analysis which allows the measured signal variations thought to significant to be detected; each scale corresponds to a particular frequency band.

The wavelet transform of a signal s(r), where r is the curvilinear abscissa, is defined by **(2)**:

$$W_e^1 s(r) = (e\frac{ds}{dt}) * \zeta_e(r) \quad \textbf{(2)}$$

where $\zeta_e(r)$ is the function which smoothes the signal s(r) at the scale *e*.

This relation indicates that $W_e^1 s(r)$ is the first derivative of the signal followed by a smoothing at scale *e*. The rapid variations of s(r) disappear progressively as the scale becomes high. Thus the extrema are due to the significant and slow variations of the signal [2].

In our problematic, this wavelet analysis identifies automatically the three significant intervals associated with the significant variations of the signal of the Figure 1(b).

3.1.3. Principle:

The objective of the electromagnetic analysis software is to give a partition which will lead to a coverage computation (§3.2). However, this calculation is built on the determination of the significant variations of received signals (§2). So, the partition must be constitute only by the regions which lead to the such variations. So for each region of the partition, it is necessary to define a hierarchy of the influence of the different electromagnetic interactions in order to determine the predominant

combinations, in terms of received energetic level. Thus for example, a region constituted by line of sight and reflected waves will be considered as a region in line of sight. On such considerations and after groupings of contiguous regions having the same characteristics, the significant partition of the Figure 3 (b) is obtained for the example of the Figure 3 (a).

Thus, the number of maximum diffraction and reflection taken into account in the electromagnetic analysis software must ensure that the limits of intervals detected by the "wavelet maxima" coincide with changing of regions. The search principle of these major interactions is described by the algorithm of the Figure 4.

After a statistical verification on several measured signals in different micro cellular environments such as the signal of the Figure 6 measured on the mobile route in the district of Paris presented in the Figure 5, the numbers of diffractions and reflections are equals to 4 and 0 respectively.

In view of the statistical validity of these numbers of interactions, they will be considered, whatever the micro cell environment studied, without apply the learning stage process. So, in the next section these values are used in the application stage to provide a satisfying coverage prediction.

3.2. Coverage prediction: "application stage"

To compute the radio coverage, it is necessary to apply a propagation model in each region of the spatial partition. To define the minimum number of application points per region, a rule has been considered. It relies on statistical results [5] on non-fade duration of measured signals : in 90% of the time, the signal magnitude is above to its local average value minus 10dB. Thus, it has been shown that, statistically, the minimum number of application points of the propagation model per region can be equal to two [6]. The average of these two estimated received powers provides a good estimation of

the average signal in the considered region. Concerning the location of these two points, it is around the barycentre of the region.

In an operational context, on an area defined by geographical data basis, the application stage consists in carrying out the spatial partition software with the correct number of diffractions and reflections provided by the learning stage. On the computed partition, a propagation model is applied in each region according to the previous rule. This procedure leads to the optimised coverage prediction.

4.Results:

The interest of our method is evaluated by comparing its coverage prediction to the one provided by the classical approach. The comparison is realised on the micro cellular environment of the Figure 5. The performances of the two approaches have been tested with the “microG” scalar propagation model applied during the deployment stage of some mobile networks [7]. The result of the prediction coverage zone due to our optimised method is presented on the figure 7.

For this example, the computation has been realised thank to a 1.6GHz Pentium computer. The classical computation of the coverage zone, with a constant spatial step equal to 5 meters, leads to a number of application points and a computation time equals to 30601 and 11 minutes respectively. Our optimised technique leads to a number of application points and a computation time equals to 3590 points and 1 minutes 8 seconds respectively. So, the comparison of these results shows that the reduction ratios in application points and computation time are equals to 88% and 9.7 respectively. Nevertheless, it is necessary to note that the previous reduction ratio in computation time must increase if we apply a 3D vectorial propagation model based on a ray tracing [8] or launching [9]. These models, although very accurate, have a computation time largely more important than this of the scalar propagation models. Thus, for a reduction

ratio in application points equal to 88.3% the computation time ratio considerably increases (near 50).

Moreover, such we can observe it on the cumulative functions of the figure 8(a) and (b), the optimisation time is obtained without a significant degradation of the accuracy. The Figure 8(a) shows that the classical and optimised repartition of the total losses are very closed. This result is confirmed by the repartition of the absolute deviation losses (Figure 8(b)). This representation indicates that for the probabilities equals to 0.5 and 0.9, the absolute deviation are equals to 1.46 dB and 5.53 dB respectively. These results are completely satisfying in an operational context because the operators require generally a standard deviation less than roughly 6dB.

5.Conclusion:

In conclusion, we have shown the interest of our optimised method of coverage prediction for micro cellular configurations. It provides a reduction factor of the computation time varying between 9 and 50 according to the propagation models used in comparison with the classical method. Moreover, this reduction is obtained without significant degradation of the accuracy.

The future works are dedicated to an extension of the presented method in vertical planes (2D_V) and in the combination of the 2D versions (2D_V and 2D_H) for a application in others types of configurations such as small and macro cells.

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References

[1] TAN S.Y. and TAN H.S. : “A microcellular communications propagation model based on the uniform theory of diffraction and multiple image theory”, IEEE Trans. On Antennas and propagation, Vol. 44, N°10, Oct. 1996.

[2] CARRE P., POUSSET Y., VAUZELLE R. and FERNANDEZ C.: “Segmentation of signals by wavelet maxima: application to the prediction of the radioelectric coverage zones”, Traitement du Signal et des Images 2001, Vol. 18,n°3.

[3] DEYGOUT J.: “Multiple knife-edge diffraction of microwaves”, IEEE Trans. on antennas and propagation, Vol. AP-14, N°4, July 1966.

[4] HOLM P.D.: “A new heuristic UTD diffraction coefficient for nonperfectly conducting wedges”, IEEE Trans. on antennas and propagation, Vol. 48, N°8, August 2000.

[5] PARSONS D.: “The Mobile Radio Propagation Channel”, Wiley-Pentech Publication, 1992.

[6] COMBEAU P., VAUZELLE R., AVENEAU L., POUSSET Y.: “An acceleration technical for the prediction of radioelectric coverage zone”, European Workshop on Integrated Radiocommunicated Systems, Angers, France, Mai 2002

[7] LAGRANGE X.: “Les réseaux radiomobiles”, Edition Hermes, 2001

[8] ESCARIEU F., POUSSET Y., VAUZELLE R., AVENEAU L.: “Outdoor and indoor channel characterization by a 3D simulation software”, PIMRC'2001, San-Diego, USA, September2001.

[9] KLOCH C., LIANG G., ANDERSEN J.B., PEDERSEN G.F., BERTONI H.L.: “Comparison of measured and predicted time dispersion and direction of arrival for multipath in a small cell environment”, IEEE Trans. on antennas and propagation, Vol. 49, N°9, August 2001.

Figure captions

Figure 1 : (a):Schematic studied area.

(b):Signal received on the route of (a).

Figure 2 : (a):Diffraction on a infinite half plane.

(b):Diffraction attenuation $J_{dB}(v)$ of (a).

Figure 3 : User interface of the spatial tool and visualisation of the regions produced by a building (for one diffraction, one reflection and theirs combinations).

(a): Before grouping.

(b): After grouping.

Figure 4: Algorithm of the learning stage on a mobile route.

Figure 5: Top view of a district of Paris.

Figure 6: Signal received on the mobile route of the Figure 5.

Figure 7: Radio coverage due to our optimised method, for 0 reflection and 4 diffractions, on the micro cellular configuration of the Figure 5.

Figure 8: Cumulative functions of: (a): The coverage zone losses:

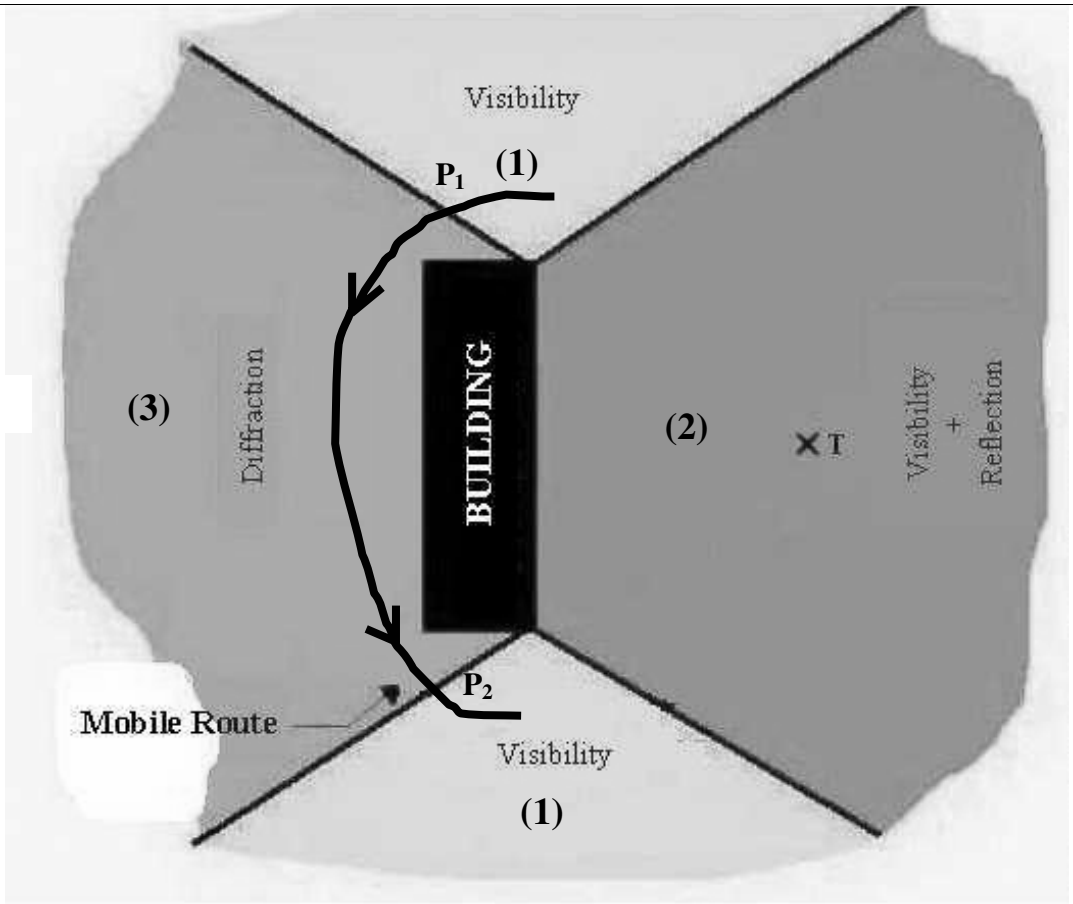
- Full line: Classical method.

-- Dotted line: Optimised method

(b): Absolute error losses between the classical and optimised methods.

Figure 1

(a)


Visibility
P1
(1)
(3)
Diffraction
BUILDING
(2)
T
Visibility
+
Reflection
P2
Mobile Route
Visibility
(1)

(b)

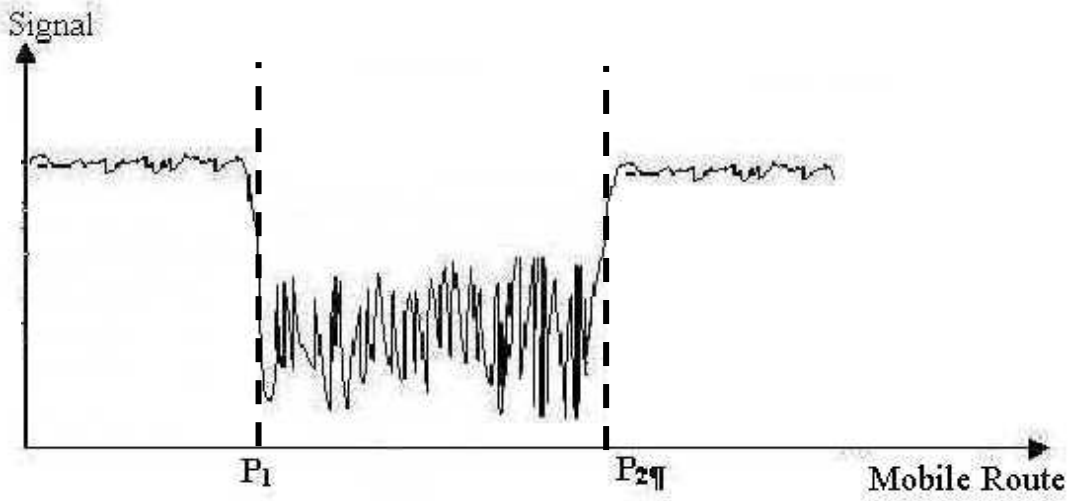
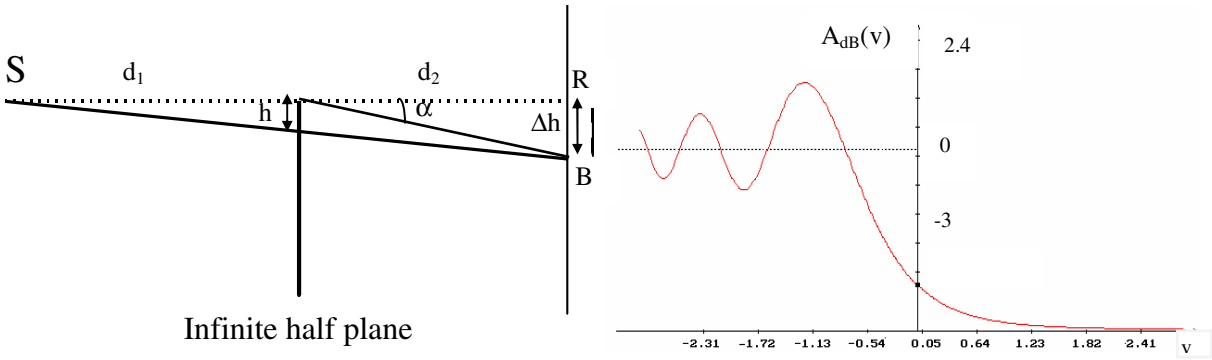
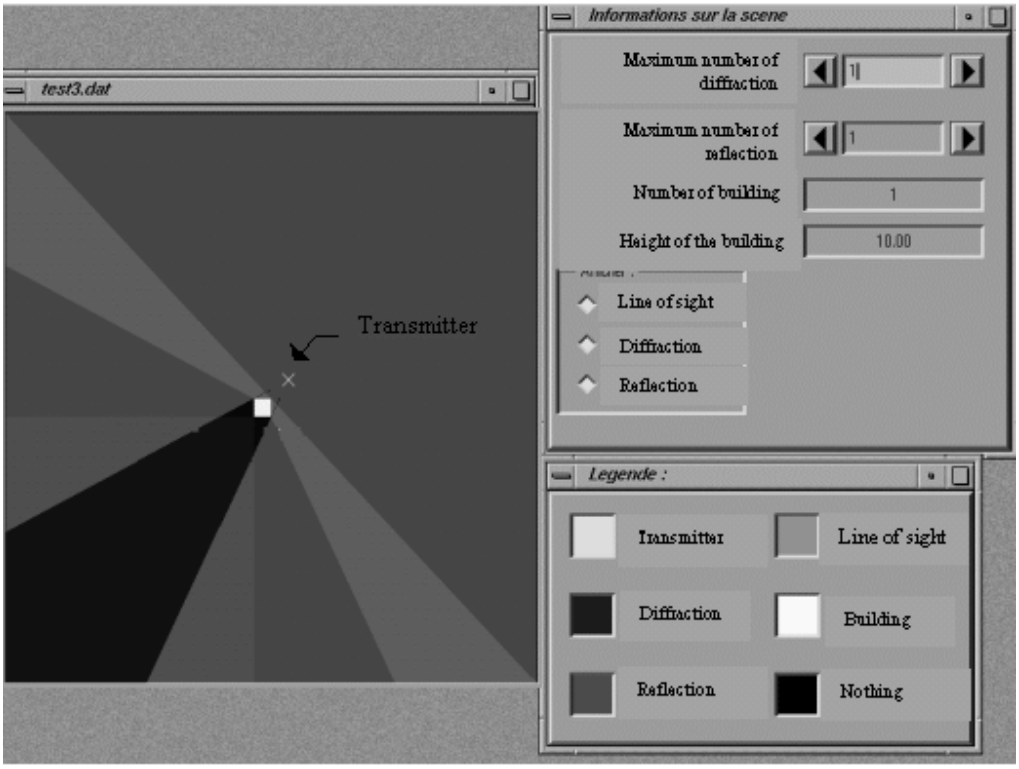

Signal
P1
P2¶
Mobile Route

Figure 2

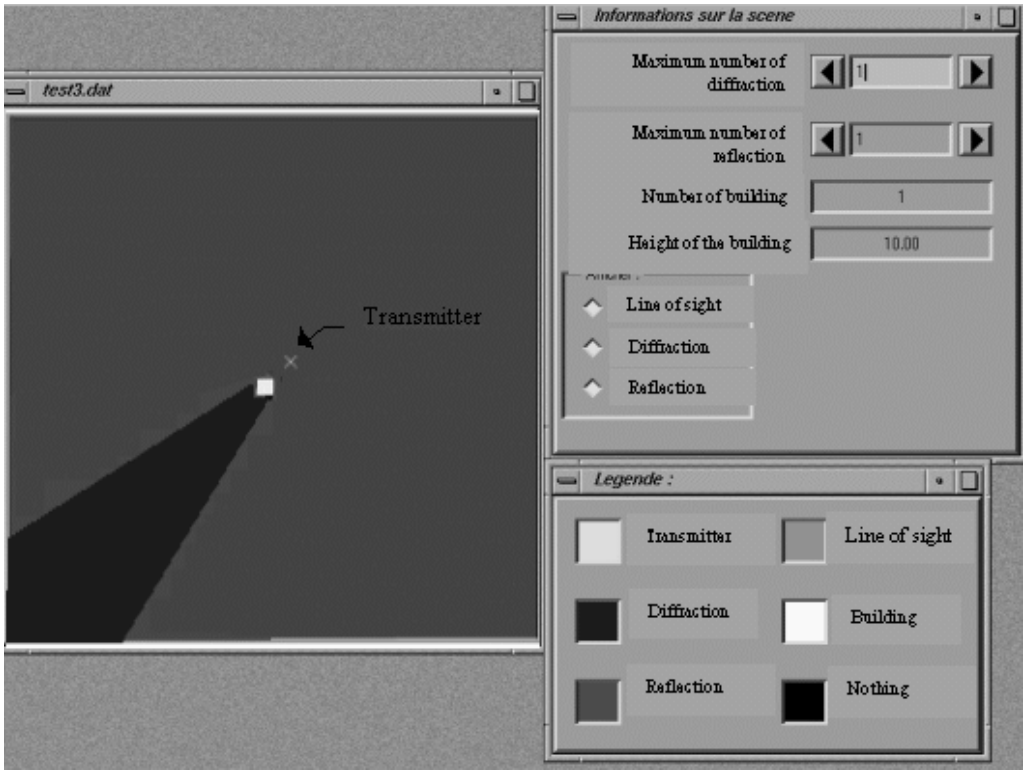

S
d1
d2
R
h
α
Δh
B
Infinite half plane
AdB(v)
2.4
0
-3
-2.31
-1.72
-1.13
-0.54
0.05
0.64
1.23
1.82
2.41
v

(a) (b)

Figure 3


test3.dat
Transmitter
Informations sur la scene
Maximum number of diffraction
1
Maximum number of reflection
1
Number of building
1
Height of the building
10.00
Line of sight
Diffraction
Reflection
Legende :
Transmitter
Line of sight
Diffraction
Building
Reflection
Nothing

(a)


test3.dat
Transmitter
Informations sur la scene
Maximum number of diffraction
1
Maximum number of reflection
1
Number of building
1
Height of the building
10.00
Line of sight
Diffraction
Reflection
Legende :
Transmitter
Line of sight
Diffraction
Building
Reflection
Nothing

(b)

Figure 4

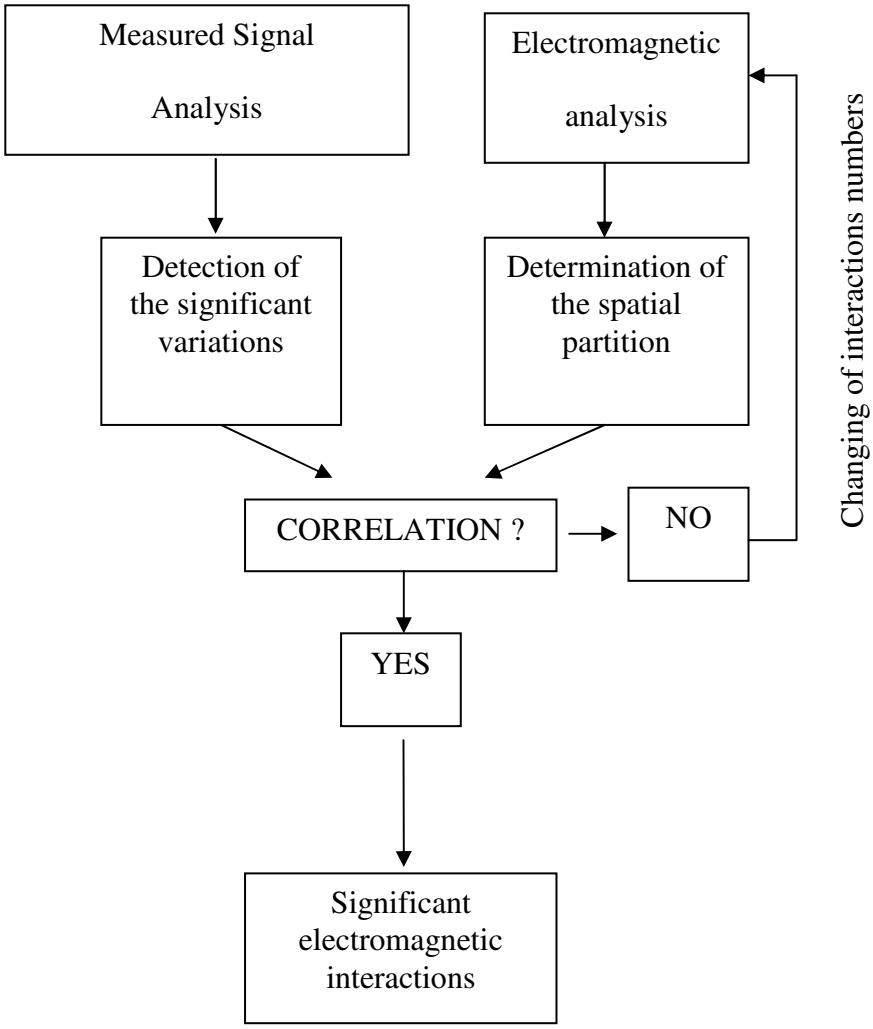

Measured Signal
Analysis
Electromagnetic
analysis
Detection of
the significant
variations
Determination of
the spatial
partition
CORRELATION ?
NO
YES
Significant
electromagnetic
interactions
Changing of interactions numbers

Figure 5

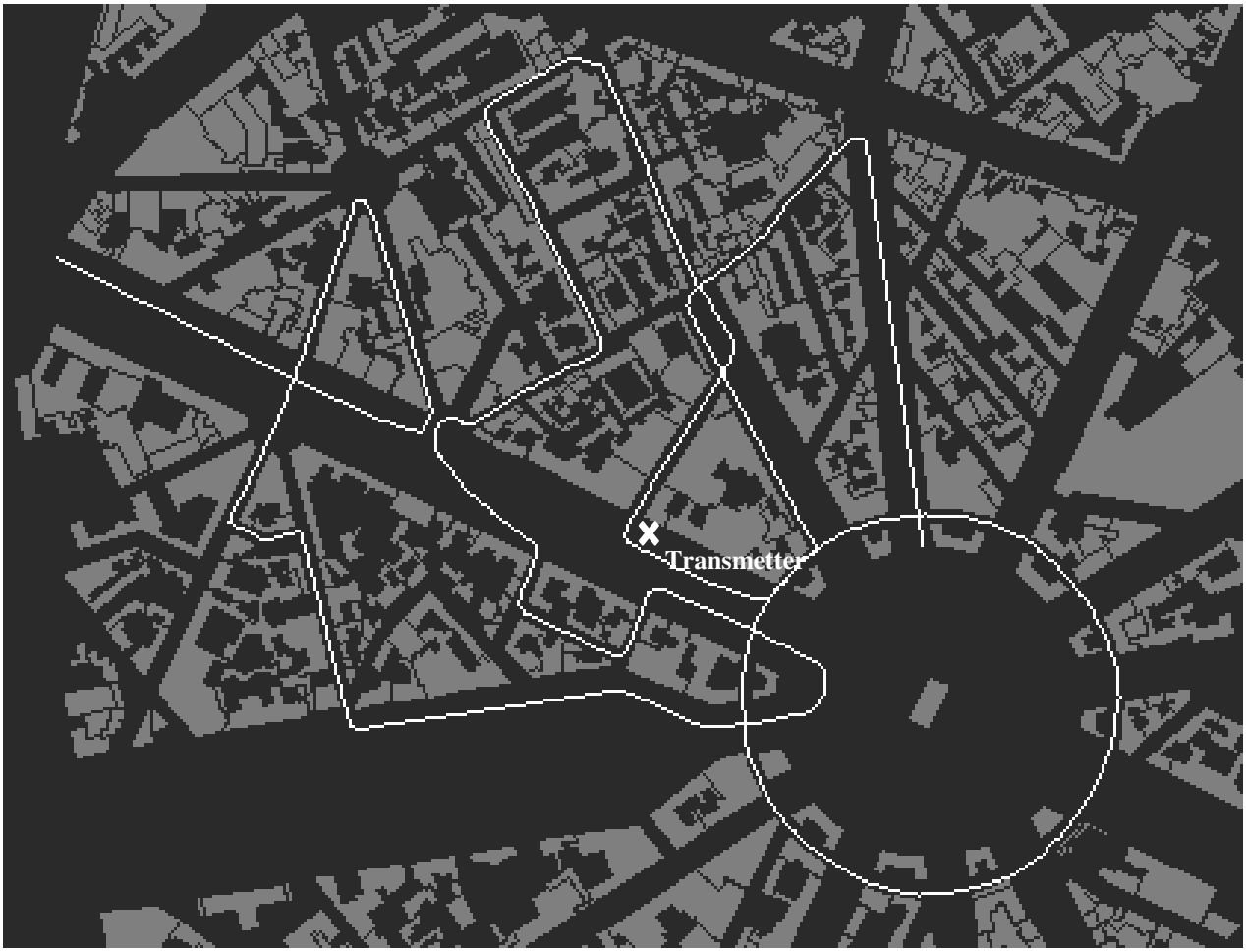


Figure 6

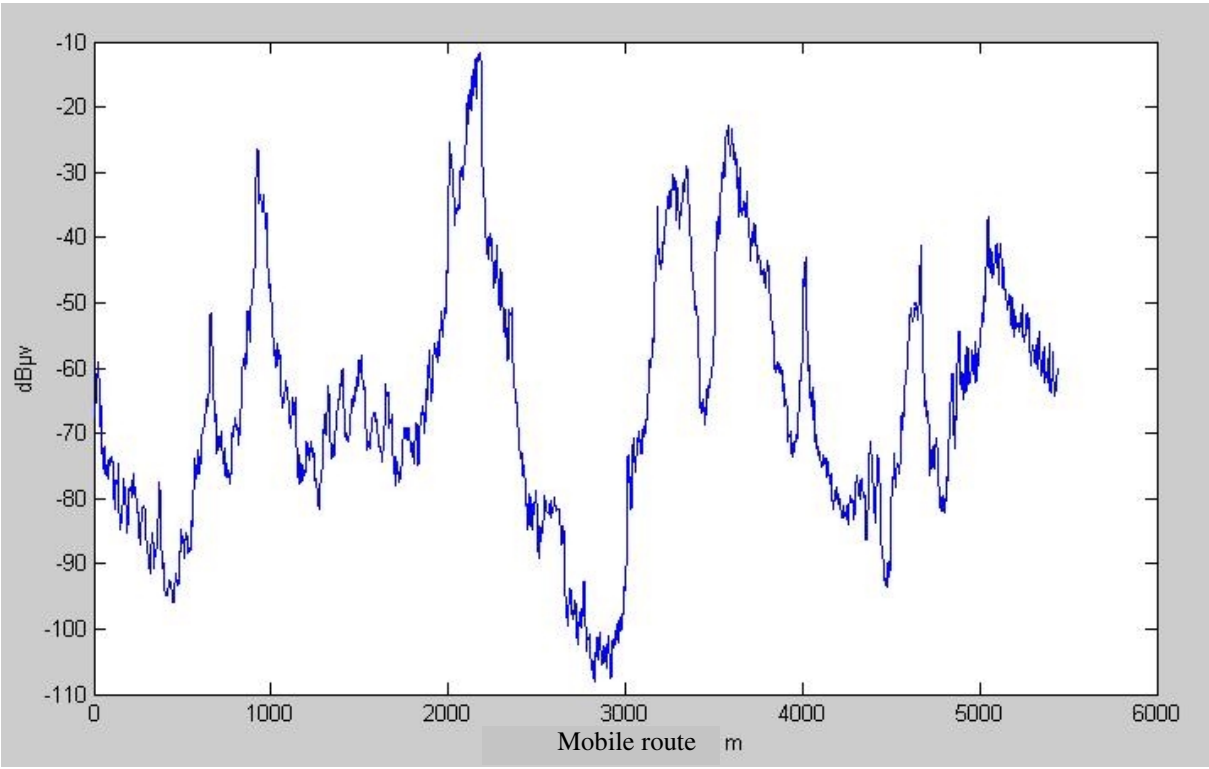

-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
dBμv
0
1000
2000
3000
4000
5000
6000
Mobile route m

Figure 7

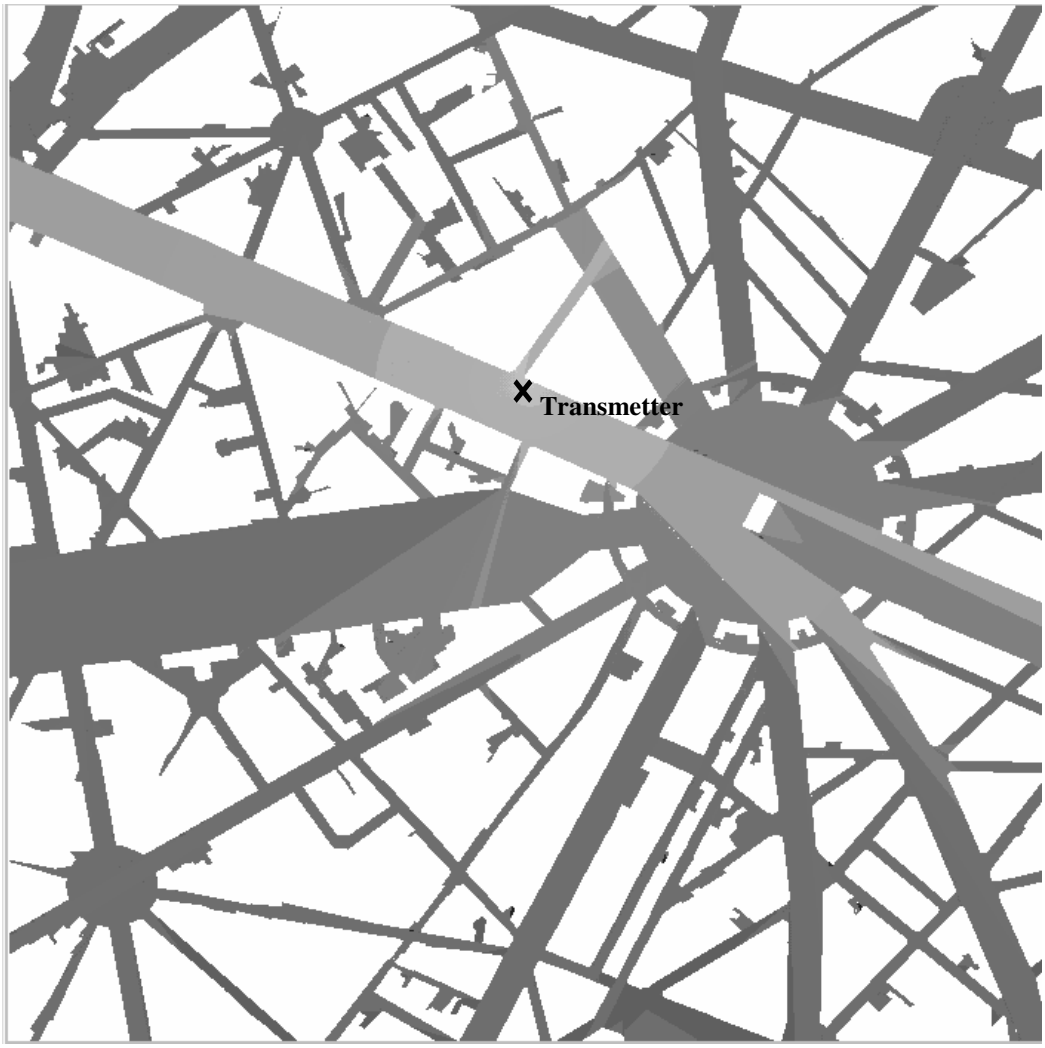
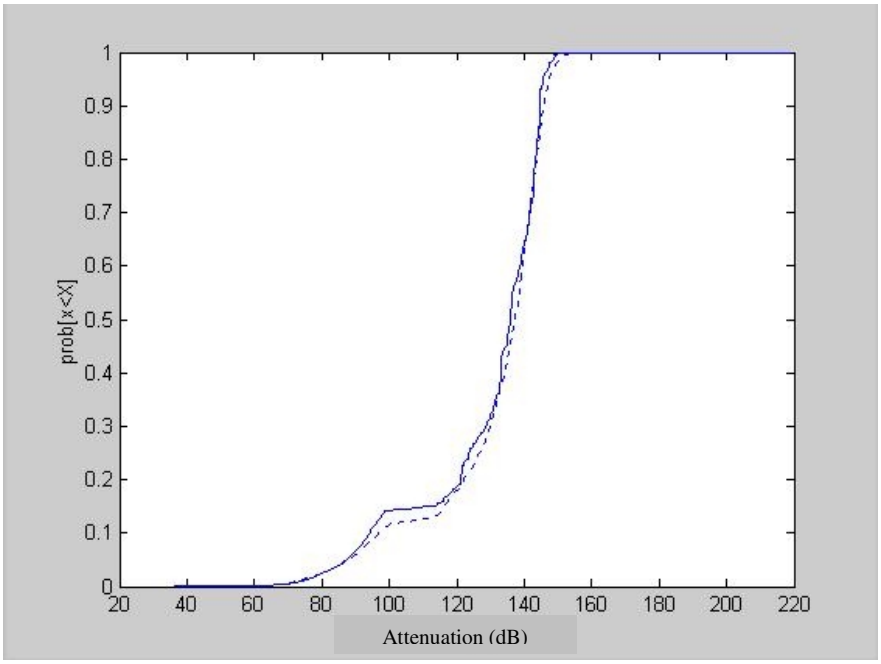
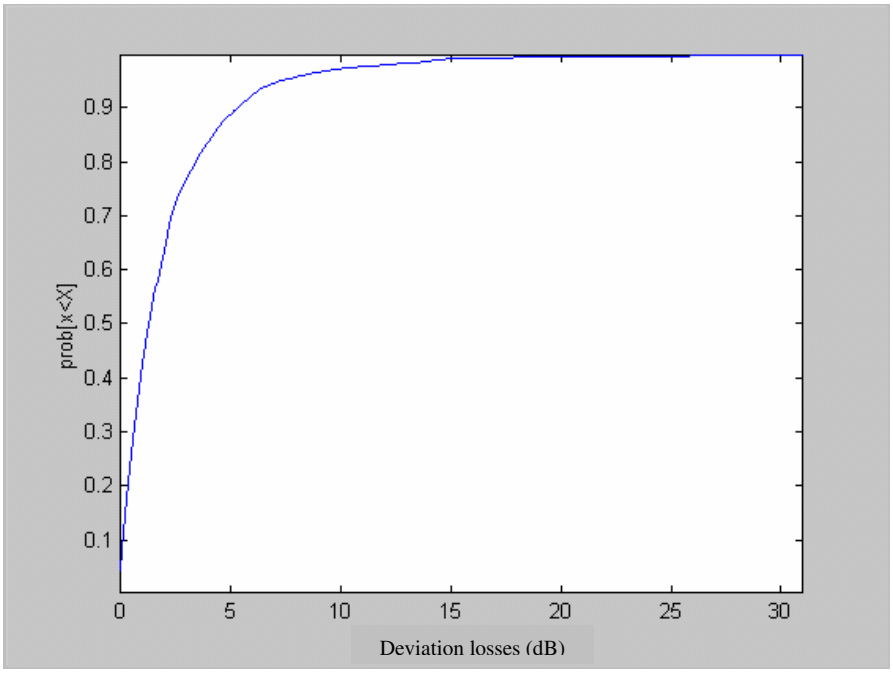


Figure 8

(a)



(b)