NOVEL APPROACH TO INDOOR PROPAGATION MODELLING

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Abstract

An indoor propagation prediction for personal communication systems is demanded for modern wireless services. There are two main general approaches for indoor propagation modelling: empirical and deterministic. Both of them have their advantages and disadvantages. Novel semi-deterministic approach to modelling of propagation of electromagnetic waves inside buildings, which combines both deterministic and empirical approaches is introduced. It is based on ray-launching technique, Monte Carlo method and statistics. The model is very fast and requires only easy to obtain inputs. The model is capable of wide-band parameters prediction as well. A description of the new approach together with first results of the model implementation and its evaluation by measurements are presented.

Keywords

personal wireless systems, indoor propagation, electromagnetic waves, modelling, Monte Carlo, ray launching, statistics

1. Introduction

For the design and maintenance of cellular networks of wireless personal communication services the knowledge of the signal propagation in different environments is required. Indoor propagation is one of the most complicated propagation topics based on the specific type of the building structure and used materials.

There are two main general approaches to the modelling: empirical and deterministic. In the beginning these techniques will be very briefly overviewed with their advantages and disadvantages. Then a new semi-deterministic approach will be introduced. The new model performance and comparison of its results with measurements will be discussed as well. A short outlook for the future work concludes the article.

2. Empirical models

The empirical models are based on very simple and straightforward formulas. The propagation loss between any point and transmitter can be expressed with a simple distance dependent equation, where empirical parameters obtained from measurements describe the environment. If we want to be more site-specific, we can add attenuation factors for each partition between transmitter and receiver.

The advantages of empirical approach: it is very fast, only simple input is needed and the formulas are very easy to apply, it can be even calculated by hand.

On the other hand the site-specific accuracy is poor especially for complicated interiors and building structures where supplementary measurement is necessary. For example the waveguiding effect in corridors is a problem. Also, the models are not able to predict wide band parameters such as delay spread and angle of arrival.

For more information on indoor propagation prediction using the empirical models see [2][3] or [4].

3. Deterministic models

On the opposite end of modeling approaches are the deterministic models, which try to follow physical principles of electromagnetic wave propagation. The most popular are ray tracing and ray launching. The are based on geometrical optics principles. In ray tracing all the rays between transmitter and receiver are found and their contributions added together. There are reflections, diffractions and penetrations along each ray, which must be calculated using electromagnetic theory. The ray launching is similar.

These models are very accurate, site-specific and they can predict also wide band parameters (time delay and angle spread), which are demanded for modern wireless systems.

On the other hand they are slow (or they are fast but need some pre-processing), they need precise input database with walls including the electrical parameters of used materials and the implementation code is pretty complicated.

Detailed description of these techniques can be found e.g. in [5].

4. Novel semi-deterministic model

In the new model the empirical and deterministic approaches are combined into a semi-deterministic model, which features:

- sufficient site-specific accuracy (agreement with measurements)
- fast computation (needed for software tools with complex iterative optimisation)
- simple, easy to obtain (it means inexpensive) input data.

4.1 Input data

The input for the new model is very simple. It is just the raster picture – bitmap of a studied floor plan and position, power and radiation pattern of a transmitter.

A uniform grid represents an analysed area where all partitions and obstacles fill appropriate elements. The element dimensions are predetermined by a wavelength (Fig. 1).

4.2 Algorithm

The main idea is based on a ray launching technique, Monte Carlo method and empirical statistics.

According to the transmitter antenna radiation pattern rays are launched in the grid using simple pixel graphics algorithm (Fig. 1). Each free element in the grid records the number of passed rays, which after sufficient number of launched rays predicts relative signal strengths in the location. The more rays are launched the more precise should be the prediction. The calibration measurement or calculation is then needed to get the actual signal strengths.

When a ray hits a filled element the elements in the neighborhood of the hit point are separated into a matrix called motif. The basic motifs are stored in motif database and play the key role of the algorithm (Fig. 2). The most similar motif (specific pattern in the grid) is found in the motif database. To each motif a probability function of ray behavior in a next step is assigned. It means next direction of the ray or its end - absorption in a material. This function should be properly tuned - by measurements for example. In fact the probability function is used in a form of distribution function, where according to the generated random number the angle is obtained (Fig. 3).

It can be seen that no complicated electromagnetic calculations of reflection or diffraction are used while all the effects including diffuse scattering are taken into account in the prediction at the same time.

It is obvious that the model is capable of wide band results. Recording length and angle of arrival of incoming ray in each pixel additional wide band parameters – time delay spread and angle spread – can be easily obtained.

4.3 Model performance

When running the algorithm the Fig. 4 show the results after 100, 1 000, 10 000 and 100 000 rays launched. If more than 100 000 rays are launched in this specific scenario the results stay almost the same. It means that no more rays are needed in this case.

The model is very fast. The last picture for 100 000 rays takes about 1 second to compute on an ordinary PC Pentium.

5. Model evaluation

For the first evaluation of the model results the data from narrow-band 900 MHz measurement campaign in Prague were used. This campaign and its results were fully described in [2].

The graphs in Fig 5. show a comparison between measurement and prediction in four different rooms., where measurement receiver was moving along line paths. The standard deviations are given in the graphs.

The first results show good agreement between measurements and prediction but much more measurements in different frequency bands must be accomplished to tune the motif database.

6. Conclusion

New semi-deterministic approach for indoor propagation modeling was introduced. The model is very fast, it require very easy input data - just a bitmap of a scanned blueprint for example - and first evaluation measurements show good accuracy.

Of course there is still a lot to do. The motif database must be enhanced and each motif tuned. More evaluation measurements in different frequency bands are needed. Intensive measurement campaign on 1900 MHz is prepared. The model is being implemented into a CAD software tool for complex design of indoor wireless cellular systems.

More general questions for the future are the possibility of expansion of the model principles into a third dimension using cubical 3D grid instead of 2D raster and usage of the model for outdoor scenarios.

References

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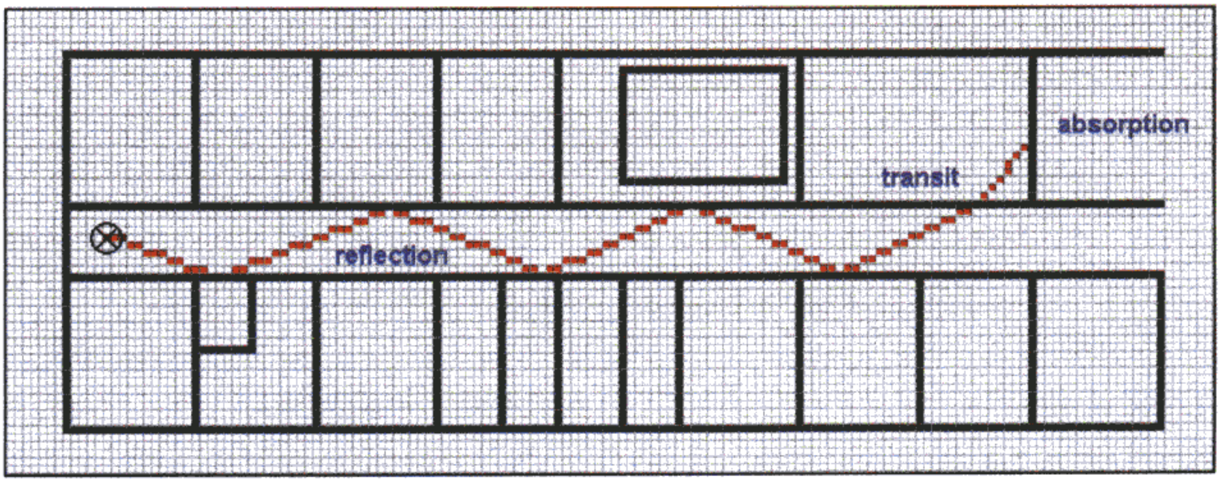

Fig. 1. Floor plan bitmap with one ray launched

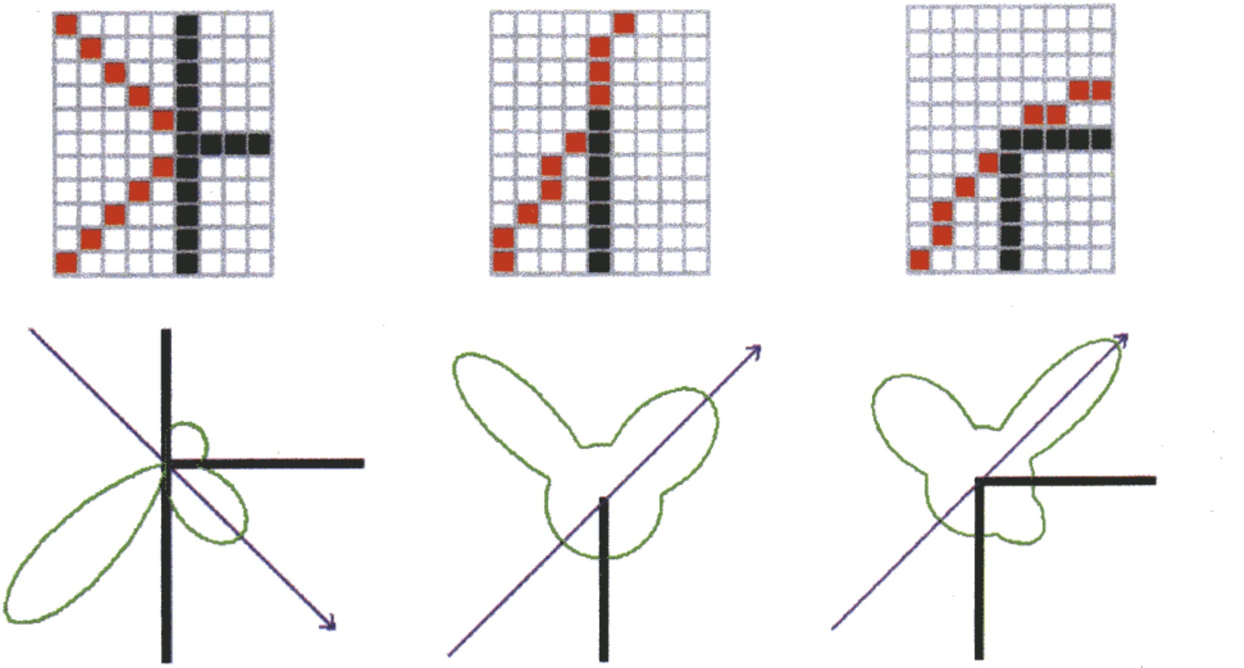

Fig. 2. Example of three basic motifs together with an incident ray and appropriate directional characteristics

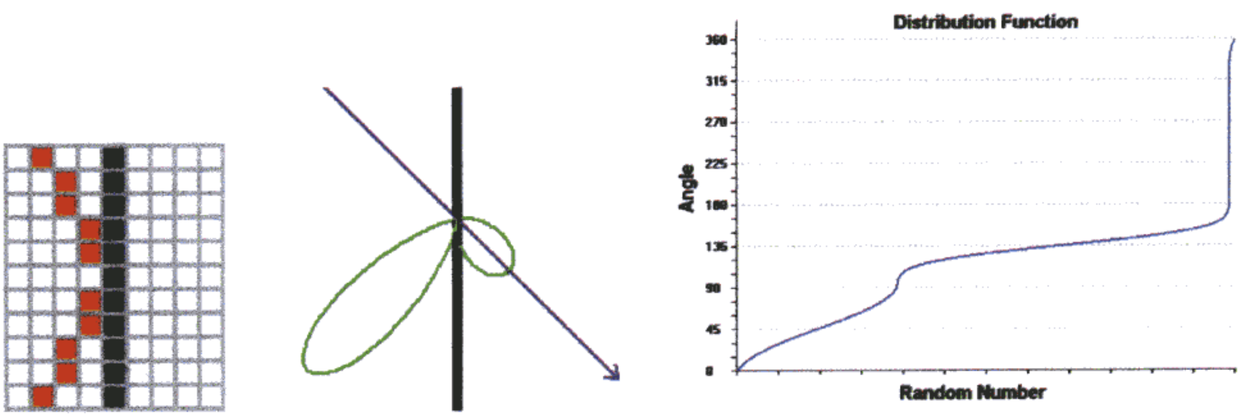

Fig. 3. Basic motif (straight wall) with an incident ray and probability function of the ray direction in the next step

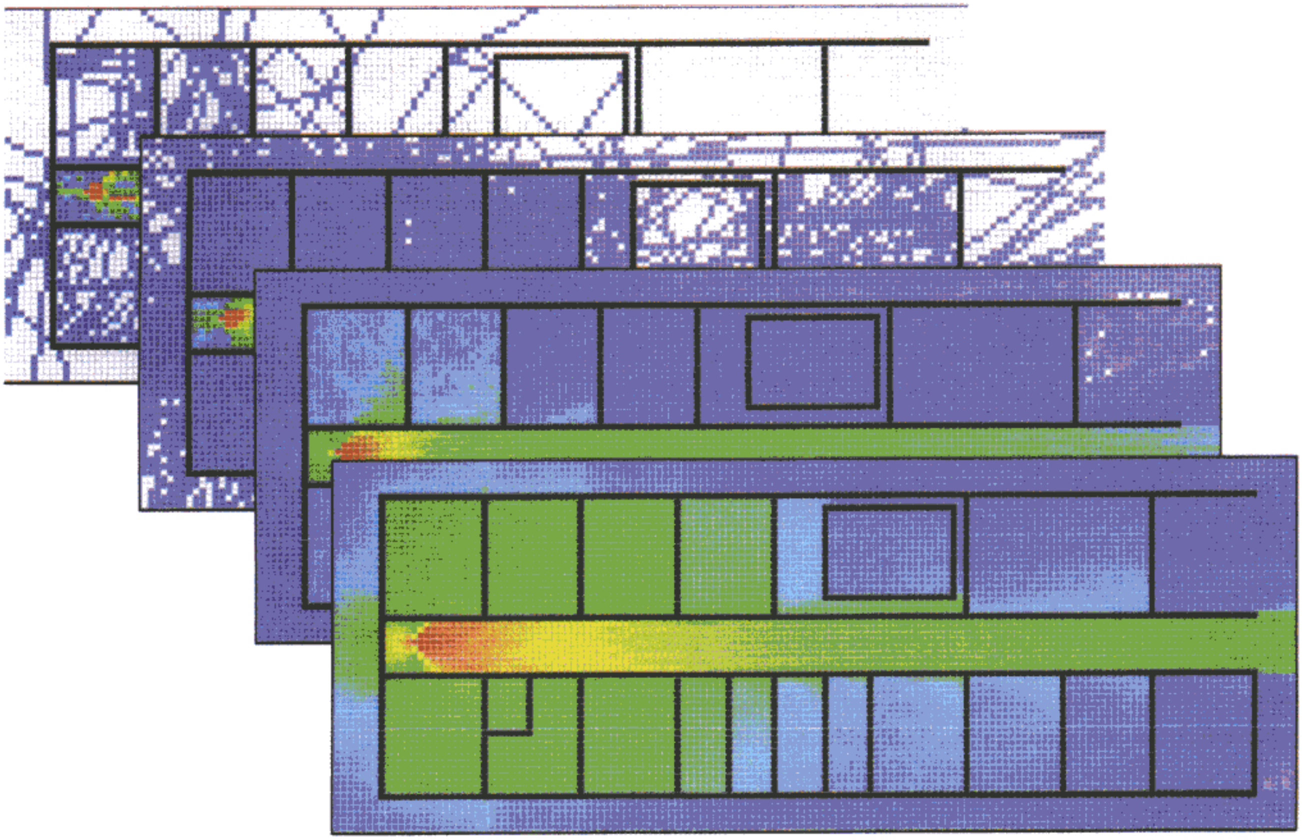

Fig. 4. The prediction results after 100, 1 000, 10 000 and 100 000 rays launched

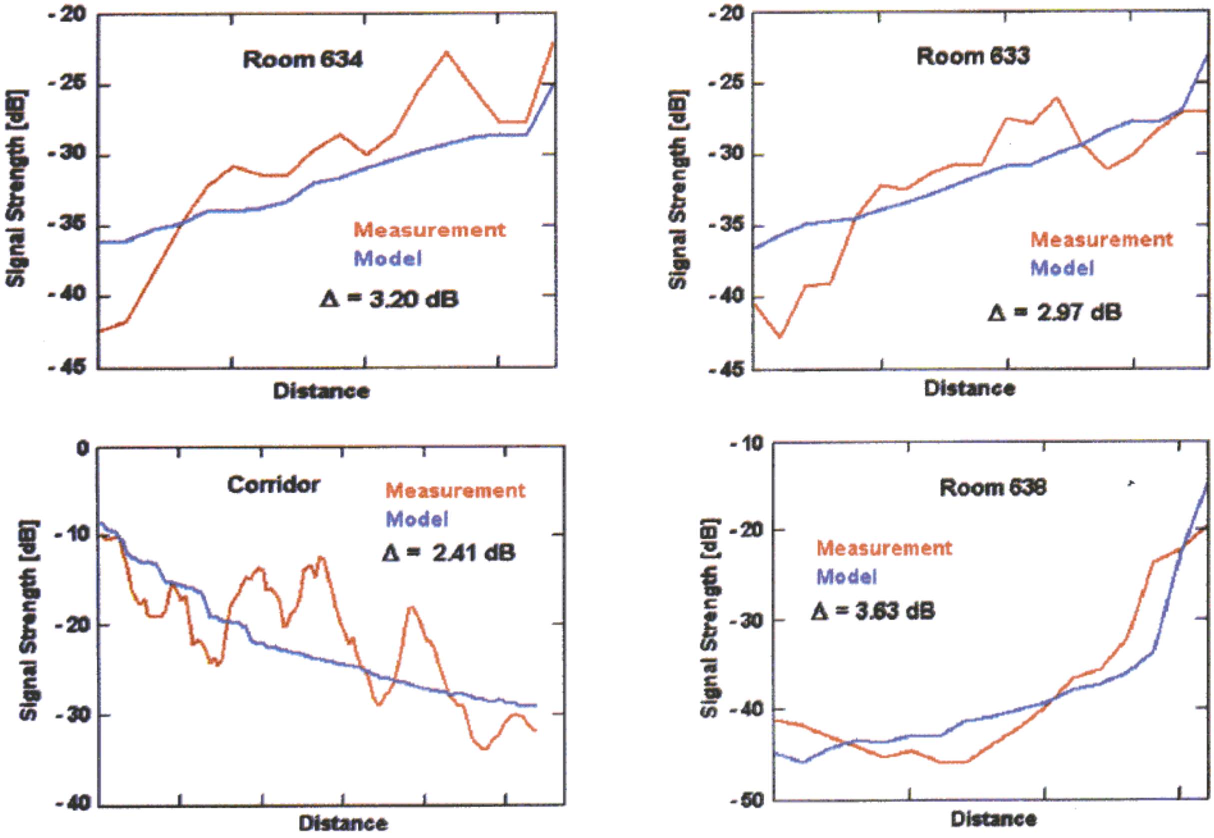

Fig. 5. Measurement vs. prediction in four different rooms

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