Plots of received signal at all of the 40 locations for for different frequencies and transmitted ray angle step of 1o and are shown in Fig. 5, Fig. 6 and Fig. 7. Simulation results for different frequencies do not vary in significant way, although these frequencies are close each other. It can be seen that simulation result and measured data differ no more than 3 dB. Note a special case when the receiver antenna is nearby the corner (location 35) when diffracted rays were supossed to be considered instead of line of sight and direct reflected rays.

Overall it can be concluded that the 2D Ray-tracing method can well be used for coverage prediction on small in-building areas taking advantage of its computational simplicity against 3D Ray-tracing methods.

7. REFERENCE

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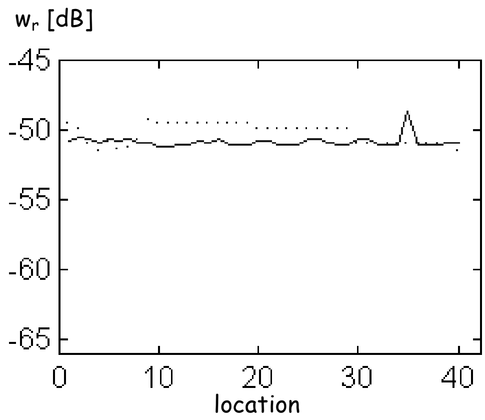

Fig. 5. Received power - 800 MHz - angle steps of 1o.

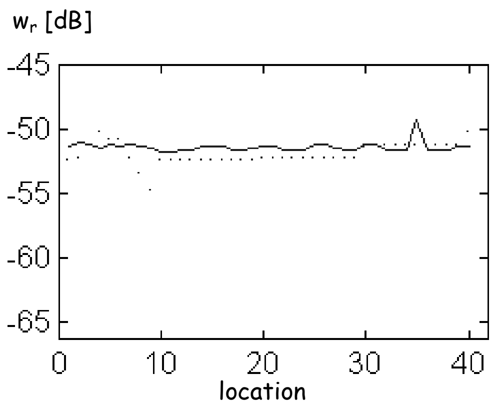

Fig. 5. Received power - 850 MHz - angle steps of 1o.

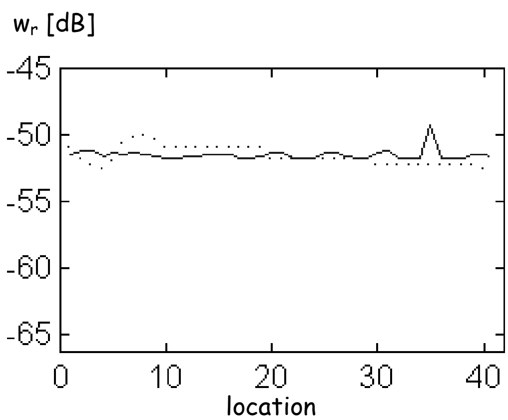

Fig. 5. Received power - 862 MHz - angle steps of 1o.

5. RESULTS AND CONCLUSION

Measurements were made by Paula M. Rodrígues in **Escuela Técnica Superior de Telecomunicaciones in University of Vigo, Spain**, under advisory of Professor M. G. Sanchez. The transmitter was at a fixed location in a room and measurements were taken with the receiver at 40 different locations with 5 cm from each other over a path. The receiver path was chosen to give different propagation conditions, such as line-of-sight, only-direct-rays and no-direct-rays. Simulations were carried out considering an omnidirectional antennas. No furniture were take into account.

The proposed algorithm was used for simulation of that environment described in Fig 4. Results of simulations for different frequencies and angle increment were plotted.

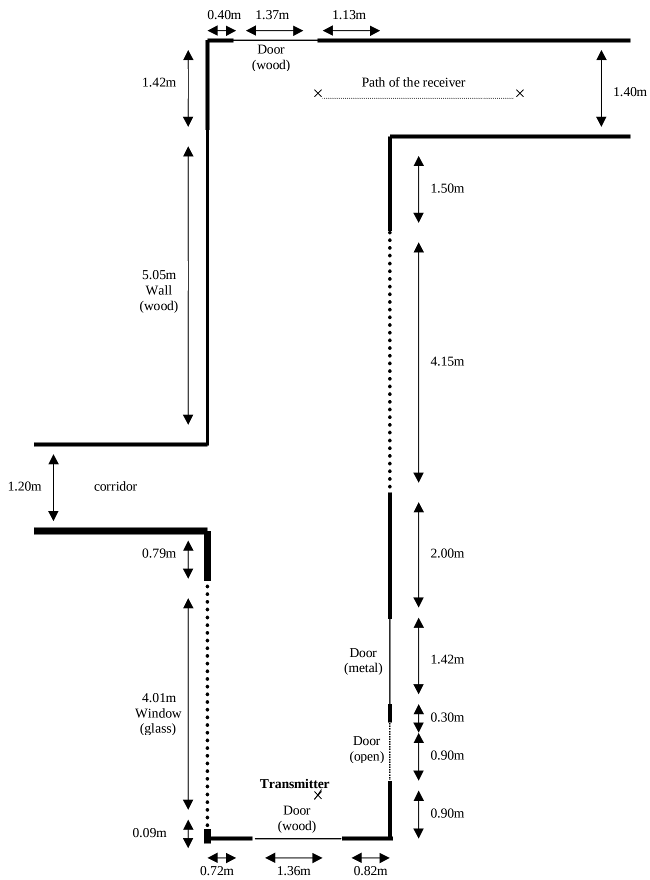

Fig. 4. Environment characteristics.

The transmission coefficient $\Theta_T(\theta)$ is defined by the ratio between crossing and incident electric fields and can be expressed by

$$\Theta_T(\theta)=\frac{\left(1-\Phi^2(\theta)\right).\exp\{-j(\upsilon-2\pi d/\lambda)\}}{1-\Phi^2(\theta).\exp(-j2\upsilon)} \quad (2)$$

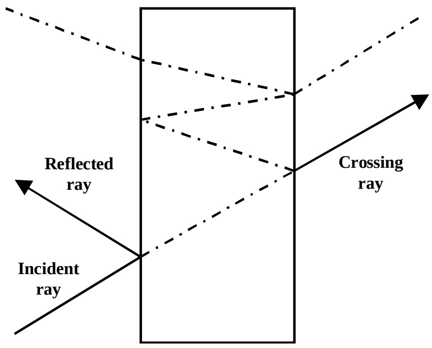

Fig. 3. Incident, reflected and crossing rays.

The reflection coefficient $\Theta_R(\theta)$ is defined by the ratio between reflected and incident electric fields and can be expressed by

$$\Theta_R(\theta)=\frac{1-\exp(-j2\upsilon)}{1-\Phi^2(\theta).\exp(-j2\upsilon)}.\Phi(\theta) \quad (3)$$

where $\upsilon=(2\pi d/\lambda).\sqrt{n^2-sin^2\theta}$, n represents the refraction characteristics of the material and

$$\Phi_V(\theta)=\frac{\cos\theta-\sqrt{n^2-sin^2\theta}}{\cos\theta+\sqrt{n^2-sin^2\theta}} \quad (4)$$

and

$$\Phi_H(\theta)=\frac{n^2\cos\theta-\sqrt{n^2-sin^2\theta}}{n^2\cos\theta+\sqrt{n^2-sin^2\theta}} \quad (5)$$

where $\Phi_V(\theta)$ and $\Phi_H(\theta)$ are the *Fresnel reflection coefficient* for vertical and horizontal polarization respectively.

Each transmitted ray is tracked until reaching either a receiver or an obstacle. In the first case the received power from this path is then calculated. In the other case it is considered the reflected ray. In this case it must be calculated the signal power and direction of the new ray.

This procedure is repeated until one of the following occurs:

- A receiver is reached;
- The signal power reaches a minimum along the path;
- The number of reflections in the path reaches a threshold previously set.

It is considered that a ray reaches a receiver when not only a direct ray reaches it, but also when a ray is in the vicinity of the receiver. This vicinity is shown in Fig 2.

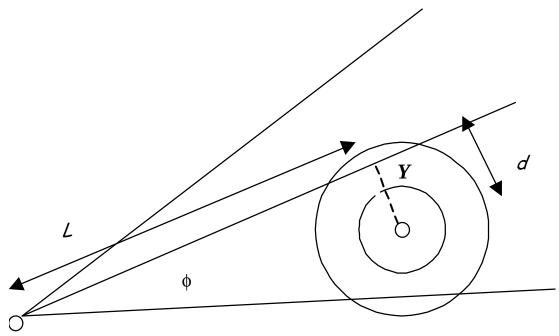

Fig. 2. Vicinity of the receiver.

Let d be the distance from the receiver and its projection *Y* on the ray path. Let *L* be the distance from the transmitter to *Y*. And let ϕ be the increment of the transmitted ray angle used on the algorithm. Each ray that crosses the circular region defined by radius $\phi L/2$ with center on the receiver location is considered to contribute to the received signal. This is the same that if $d<\phi L/2$ the ray contributes to the received signal.

4. PROPAGATION MODEL

The received signal power w_r is calculated from the well known *Friss formula* given by

$$w_r = w_t \cdot \left(\frac{\lambda}{4\pi d}\right)^2 \cdot \prod_n \Theta_T^2(\theta) . \prod_n \Theta_R^2(\theta) \tag{1}$$

where w_r is the transmitted power, λ is the transmitted wavelength, d was previously defined, $\Theta_T(\theta)$ and $\Theta_R(\theta)$ are the transmission and reflection coefficient, respectively, both dependent on the incident angle θ as shown in Fig. 3.

possible to avoid computing paths that do not exist due to the finite dimensions of the environment and reflected obstacle.

Fig. 1 shows three possibilities that must be considered for reflected rays. The path to receiver Rx1 is due to the reflection on the obstacle. This path id determined by the intersection between the transmitted ray and the obstacle and by considering that incident angle equals reflection angle.

The path to receiver Rx2 does not exist because the line from the image to Rx2 does not intercept the reflecting side of the obstacle although it crosses part of the obstacle. The receiver Rx3 does not receive a reflected ray either in this case. Note that Rx2 and Rx3 receive no direct reflected rays but can receive secondary reflected rays, with lower power.

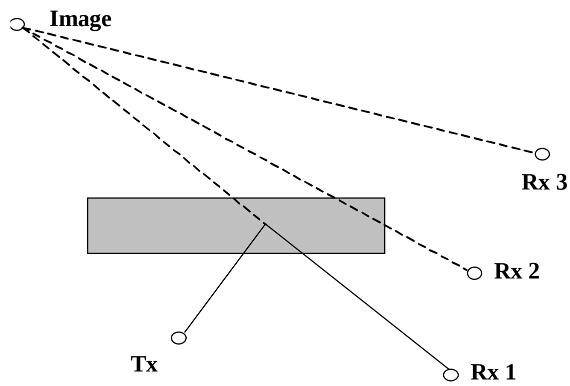

Fig. 1. Propagation radio paths - Ray-tracing.

Each possible path to the receiver must be considered, including line-of-sight and direct reflected rays; then repeat this procedure for the resulting images, until the last possibility of receiving a signal adequate for communication. These interactions can be limited by the number of reflections, by signal power along the path or even by signal power compared to mean received power already computed.

The diffraction effect can be treated using the same image technique, but it will not be considered in this work because the power contribution from diffracted rays is minimum.

3. THE RAY-TRACING ALGORITHM

The Ray-tracing method aims to represent the most significant signals reaching the receiver taking into account all possible paths. In this work it is considered an isotropic antenna and the algorithm is evaluated repeatedly for the range from 0o to 360o around the antenna. The angle increment can be set.

On the 2D Ray-Tracing for Within Propagation Prediction Model

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Abstract. The commercial success of indoor wireless communications services and networks has lead to several proposals on radio propagation modeling. This paper presents a comparison between indoor signal power prediction results and indoor measurements. It is shown how a 2D Ray-tracing model can be effective for small in-buildings coverage prediction.

1. INTRODUCTION

The increasing popularity of wireless networks for use within office environments has lead to several researches on radio propagation focused on indoor radio propagation [1-6]. The communication industry has a specific interest on the wireless services and networks.

Several measurements, statistical models and Ray-tracing algorithms were combined leading to several indoor radio channel models. The aim is to estimate the area within which the received signal power is adequate communication. In this work we compare 2D Ray-tracing results to measured data in order to analyze the effectiveness of this method.

2. THE RAY-TRACING METHOD

The Ray-tracing method is based evaluation of on reflection, diffraction and absorption of energy by means of geometry. Part a radio signal energy is reflected an part of it crosses any obstacle in radio path. Each one of these new rays origin others by intercepting other obstacles each, and successively. Hence, the paths of rays that reach the receptor is to be determined in order to estimate the received power.

Due to the complexity to model a dynamic environment by means of the Ray-tracing method, it seems to be more effective when base station site and environmental characteristics are well known. An alternative representation of the environment reduces the complexity by considering the transmitter image against the reflecting obstacle with transmitted power and polarization modified. Thence, it is