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# Prediction Modelling of Indoor Radio Propagation for the Pico-cellular Environment.

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**Abstract**

This synopsis presents an analytical method for the prediction of power delay profiles within a room environment. The model works directly on a 3-D description of a room. In this contribution a brief discussion of the model is presented together with both measured and modelled results for delay spread values, which are shown to be in good agreement. The model's output for narrowband signal strength values was found to be well represented by the usual theoretical distributions.

## 1 Introduction

Indoor radio propagation has been an active area of study in recent years, with several researchers reporting wideband impulse response measurements [1-3]. Such data is useful in predicting maximum allowable data rates due to intersymbol interference and in the exploration of such techniques as diversity and equalisation. It also of importance to consider the propagation behaviour in the pico-cellular environment given the significant interest presently being shown in Personal Communication Networks (PCNs) .

## 2 The Model

The channel impulse response is represented by multiple paths arriving at the receiver with real positive gains $\alpha_k$ , propagation delays $\tau_k$, and associated phase shifts $\Phi_k$. Thus the complex low pass channel impulse response is given by [1]:-

$$h(t) = \sum_{k=1}^{n} \alpha_k.exp(j\Phi_k).\delta(t - \tau_k) \quad (1)$$

where $\delta(t - \tau_k)$ is the *Dirac* function. It is common for researchers to discard the phase information and measure a power delay profile. This represents a purely real function of power with respect to time for an impulse sent across a channel and its equation is [1]:-

$$p(t) = \sum_{k=1}^{n} \alpha_k^2.\delta(t - \tau_k) \quad (2)$$

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The model presented here uses ray tracing to find the values of $\alpha_k$, $\tau_k$, and $\Phi_k$. The value of $\alpha_k$ is found by applying a square law for attenuation of field strength with distance and $\tau_k$ and $\Phi_k$ are calculated from the distance travelled and the speed of light. The inclusion of the phase information allows for the impulse responses to be calculated and hence narrowband modelling to be performed.

The ray tracing is done by an elegant analytical method, where the entire room plus receiver is reflected about a chosen wall. A line is then drawn between the reflected receiver and transmitter. If this line is intersected only by the reflecting wall then the line represents a valid path. The technique has been extended to include paths which have transmitted through walls. This algorithm can theoretically be extended to include any number of permutations of walls, here up to four reflections are considered.

The mathematics has been solved to find the variation of reflection coefficient for differing incident angles and wall materials, allowing the program to realistically simulate strong reflection and weak transmission for a ray with grazing incidence.

## 3 Wideband Modelling Results

A communications laboratory within the University of Bristol has been both modelled and measured (at a frequency of 1.7 GHz) in order that comparisons may be made. The room dimensions are shown in figure 1. This represents a simplification as the room contains windows, has equipment, and a constant movement of people. Impulse response files (see figure 2) were generated for many places around the room. This information was used to create power delay profiles and their resulting delay spread values [3]. Figure 3 demonstrates that there is a good agreement between the modelled and measured curves.

An FFT has been performed on an impulse response (see figure 4) to show the frequency spectrum of the channel. Because the method used here is deterministic the phase information is known and it is therfore possible to fully characterise the channel and show magnitude, phase, and group delay spectra. Work has been done by Nix and McGeehan [4] to simulate data transmission using MSK over such channels. This work indicates that for delay spread values found here diversity may be required for the implementation of systems to DECT standards. Further work concerning different environments has shown that with increased room size the delay spread increases.

## 4 Narrowband Modelling Results

The model has been used to generate impulse responses for a series of closely separated positions within a room environment. The impulse responses have been convolved with a CW signal and the resulting signal strengths calculated. The cumulative distribution of these results (see Figure 5) have been found to be well represented by a Rayleigh distribution for non LOS and Rician distribution for LOS scenarios.

## 5 Conclusions

A simple geometry based reflection model for the calculation of delay spread values has been shown to work well with measured results taken at the University of Bristol. The maximum and typical delay spreads have been found by both model and measurement to be largely determined by room size - the larger the room the greater the delay spread.

The narrowband characteristics have been modelled and found to agree well with the standard theory [5].

## 6 References


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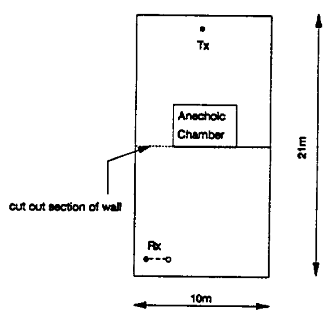


Figure 1 Dimensions of Communications Laboratory at the University of Bristol.

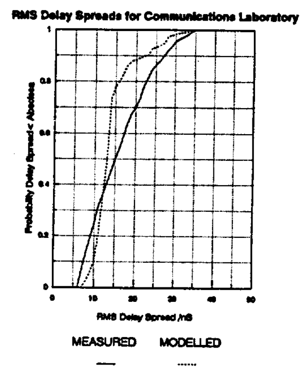


Figure 3

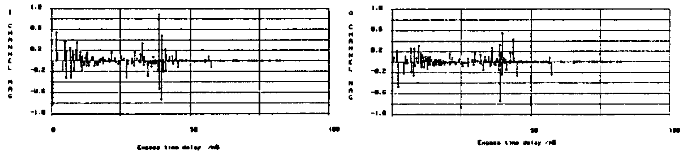


**Figure 2 Typical impulse response produced by model.**

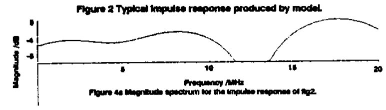


**Figure 4a Magnitude spectrum for the impulse response of fig2.**

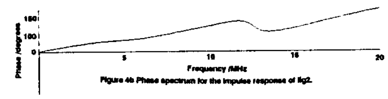


**Figure 4b Phase spectrum for the impulse response of fig2.**

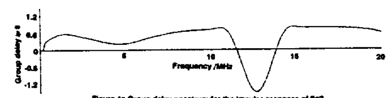


**Figure 4c Group delay spectrum for the impulse response of fig2.**

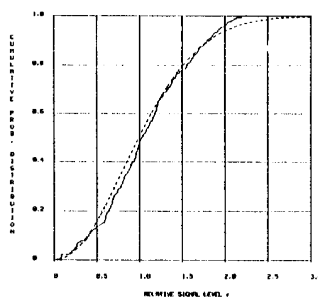


**Figure 5a Rayleigh fading statistics (non LOS case).**

Theoretical distribution — Output of computer simulation

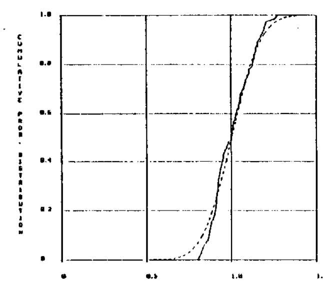


**Figure 5b Rician Fading statistics (LOS case).**

Theoretical distribution — Output of computer simulation