

Since f is a monotonically increasing function, $f'(u) > 0$, and the conditions for minimising E can be achieved by making

$$\frac{du}{dt} = -\frac{\partial E}{\partial x} \quad (5)$$

There is one more factor that has to be considered. This is the unbounded increase or decrease of u as x approaches 0 or 1. This problem can be eliminated by adding a fourth energy term E_4 , where

$$E_4 = \sum_{\text{all neurons}} \int_{1/2}^x f^{-1}(y) dy$$

For large values of λ , this term becomes unboundedly large as x approaches 0 or 1, but is otherwise insignificant. From eqn. 5, we can write

$$\begin{aligned} \frac{du_i^k}{dt} = & I - A' \sum_j n_j^k \\ & - B' \sum_j n_i^k c_j^k c_j^k \\ & - C' \sum_{m,n,j} \text{city_block_distance} [(i,j), (m,n)] \\ & \times \text{number_of_connections} (k,l) \\ & \times n_m^k c_n^k c_l^k - u_i^k \end{aligned}$$

A similar expression can be written for u_i^k .

We have now obtained the dynamics of the individual neurons. The outputs of all neurons are set to random values close to 0.5 (signifying that no particular decision regarding the placement has been made), and the network is allowed to evolve according to the dynamics derived above.

Results: The behaviour of the network was simulated on problems that with upto 36 modules. The results were compared to those obtained using the pairwise exchange method¹ for the same problems.

Table 1 shows that the neural network gives 10–15% smaller wavelength placements than those of the pairwise

Table 1 COMPARISON OF NEURAL NETWORK APPROACH WITH ADJACENT PAIRWISE EXCHANGE METHOD

Example	Grid size	Number of modules	Average wavelength in 10 attempts	
			Neural network	Pairwise exchange
1	4 × 4	16	553.2	609.1
2	5 × 5	25	1404.2	1573.8
3	6 × 6	36	2997.3	3418.3

exchange method. The major drawback is that the constants in the neural network method must be experimentally determined.

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EFFECTS OF TRAFFIC AND LOCAL MOVEMENTS ON MULTIPATH CHARACTERISTICS OF AN INDOOR RADIO CHANNEL

Indexing term: Radiowave propagation

The effects of local traffic around a transmitter and receiver and local movements of an antenna are studied by collecting and analysing multipath profiles at 910 MHz. The statistics of RMS delay spread and the received power in the multipath profiles are computed and compared for these experiments.

Introduction: Multipath propagation characteristics for indoor radio channels has recently attracted tremendous attention. There have been attempts to study the statistics of the multipath spread and to model the indoor radio channel.^{1–5} The effects of short time variations in the delay spread and power, caused by human traffic around a transmitter and receiver, has not yet been thoroughly investigated. Such variations are of importance in digital communication systems. Measurements taken to determine the short time changes in the RMS delay spread and the received power are reported. The variations are caused by local traffic close to the terminals and local movements of the terminals in the indoor radio channel. The issue of Doppler spread and the narrow-band received power caused by such local disturbances are addressed in Reference 6.

Measurements: The experimental set-up for the multipath propagation measurements involves the modulation of a 910 MHz signal by a train of 3 ns (3 dB width) pulses with 500 ns repetition period.² The stationary receiver includes a digital storage oscilloscope, coupled to a personal computer using the GPIB bus. The transmitter and receiver both use vertically polarised quarter-wave dipole antennas placed about 1.5 m above the floor level. The short time variations studied in this letter are each of 5 s duration. During these samples, 100 multipath profiles are stored in the digital oscilloscope, to be later transferred into the computer. The sampling rate of 20 samples/s is adequate to properly measure short time variations, because the Doppler spread of the indoor channel is less than 10 Hz.⁶

Since indoor radio communication behaves differently in line of sight (LOS) and obstructed LOS environments, experiments to induce short time variations in the channel were performed in both environments. The four sets of experiments conducted were

- Two persons walked briskly around the transmitter and the receiver in the LOS environment
- The transmitter antenna was rotated and moved manually by a person around a given location in the LOS environment
- Two persons walked briskly around the transmitter and the receiver, in an obstructed LOS environment
- The transmitter antenna was rotated and moved manually by a person around a given location in the obstructed LOS environment.

Care was taken to prohibit any other kind of activity or movement in the nearby vicinity when the profiles were being stored. For all four sets of data, the transmitter and the receiver were about 10 m apart. For the LOS experiments, both the transmitter and the receiver were located in a large electronics laboratory, comprising typical laboratory equipment on wooden benches such as oscilloscopes, voltmeters and power supplies. For the obstructed LOS experiments, the transmitter and the receiver were separated by two walls having windowed glass. The walls were made of plasterboard with metal studs.

Results and discussions: The parameters describing the channel characteristics, which are investigated in this letter, are the RMS delay spread and the total multipath power.^{1,5}

received in the entire band. These parameters were computed for each of the 100 profiles obtained, during the 5 s duration of every experiment.

Fig. 1a and b show the RMS delay spread and the received multipath power variation with time for experiment b. The

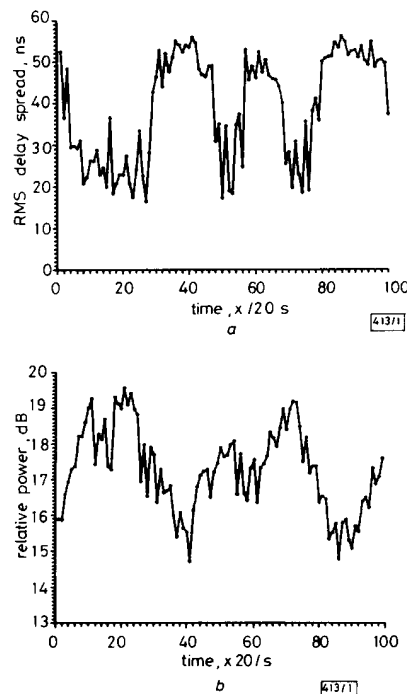


Fig. 1 Experiment B
a RMS delay spread
b Total multipath power

fluctuations in the multipath power were about 5 dB as the transmitter antenna was moved and rotated around the given location at 10 m. The RMS delay spread varied by about 40 ns. Fig. 1 shows that whenever the received multipath power is small, the RMS delay spread is large and vice-versa. This suggests a correlation between the RMS delay spread and the received multipath power. The Pearson's coefficient was used to measure this correlation. The computed correlation coefficient was found to be 0.4, for the LOS experiments a and b, and 0.2 for the obstructed LOS sets c and d.

Fig. 2 shows the complementary cumulative distributions of the RMS delay spread for the four sets of experiments. The variations in the RMS delay spread for the LOS experiments

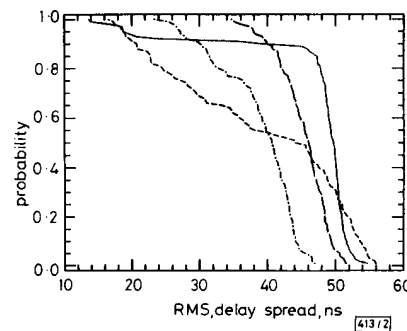


Fig. 2 Complementary CDFs of RMS delay spread
..... A
----- B
—— C
- · - · D

a and b, were about 40 ns. For the obstructed LOS experiments c and d they were about 20 ns. The standard deviations of the RMS delay spread for the LOS sets a and b were 9.2 and 12.8 ns, respectively. The obstructed LOS sets c and d have standard deviations 3.7 and 5.7 ns, respectively. The variations of the RMS delay spread in LOS environments is usually more than that in obstructed LOS environments.

Fig. 3 shows the cumulative distributions of the multipath power for the four sets of experiments. The range of fluctuations in the multipath power were about the same and less

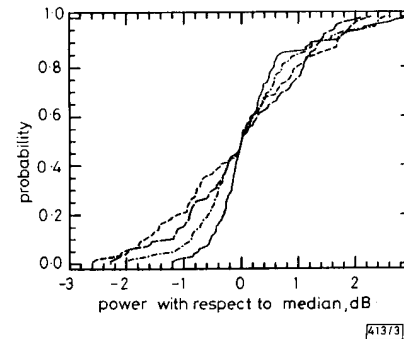


Fig. 3 CDFs of total multipath power received

..... A
----- B
—— C
- · - · D

than 5 dB for all the experiments. The standard deviations of fluctuations in multipath power for all the data sets were around 1 dB. The standard deviation for local movements of the terminal was usually higher than that for local traffic around the terminals.

The Rayleigh, Weibull and log-normal distributions were considered potential models for the received signal amplitudes collected from any data set. The parameters of these distributions were calculated¹ from the data obtained from any experiment. Fig. 4 shows the comparisons between the theoretical and the experimental distributions for experiment c, in the obstructed LOS environment. The horizontal axis is nor-

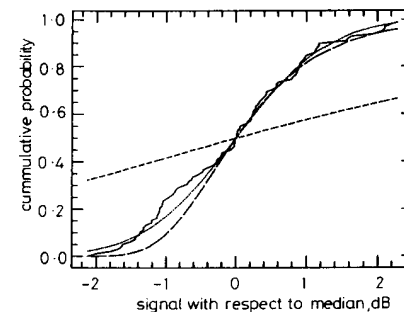


Fig. 4 CDF of received signal amplitudes
Experiment C

malised to the median value of the data in decibels. The Rayleigh distribution shows a poor fit to the data. Both the log-normal and the Weibull distributions provide closer fits with the log-normal distribution providing the closest fit. This conclusion was made for all the four experiments. For narrow band measurements fluctuations of power are usually much larger which results in a better fit for the Rayleigh distribution.⁶

Conclusions: Results of 910 MHz, pulsed multipath propagation experiments used to determine the effects of short time variations in the indoor radio channel were presented. Variations in the RMS delay spread in LOS environments were

found to be less than 40 ns. In obstructed LOS environments the variations were below 20 ns. The range of fluctuations in received multipath power during such short time variations was found to be less than 5 dB. The log-normal distribution was shown to be the best fit for the fluctuations in the received multipath power.

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COARSE-TO-FINE LEAST SQUARES STEREO MATCHING FOR 3-D RECONSTRUCTION

Indexing terms: Image processing, Least squares approximation, Mathematical techniques

Least squares methods have been used for 3-D reconstruction from digital stereo images. A preliminary estimate of the disparity of points to be matched in the two images is required for the convergence of the method. A new approach based on a Gaussian pyramid decomposition of the stereo images and application of the least squares method at each level of the pyramid is presented. Results obtained from digitised stereo images and 3-D reconstruction are reported.

Introduction: Least squares methods (LSM) are effective for the detection and recognition of corresponding points in two stereo images.¹⁻³ A good estimate of the disparity between matching points is necessary, where disparity represents the difference of the co-ordinates of the points in the left and right image and depends on the relief of the scene taken. In our approach LSM is applied in a coarse-to-fine analysis based on Gaussian pyramid decomposition of images, which permits a gradual approach to the correct matching.

Least squares method: The basic idea of the use of LSM as a correlation method consists in finding an optimal matching of two homologous areas in the stereo images by minimising the sum of the squares of the differences between grey levels in the two areas. As the images are different perspective views of the same scene, they differ both in geometry (because of the relief of the scene) and in radiometry (because of different exposures and different positions with respect to light sources). A geometric and a radiometric transformation are therefore considered.

Let (x_l, y_l) and (x_r, y_r) be the co-ordinates in the two windows of the left and the right image to be matched and let

$g_l(x_l, y_l)$ and $g_r(x_r, y_r)$ be the grey level values in the two windows. The geometric transformation used is an affine linear transformation, i.e.,

$$x_r = a_0 + a_1 x_l + a_2 y_l$$

$$y_r = b_0 + b_1 x_l + b_2 y_l$$

whereas a linear transformation has been used for the radiometric fitting, that is

$$T_R[g_r(x_r, y_r)] = h_0 + h_1 g_r(x_r, y_r)$$

Considering also that images are affected by noise (supposed additive) yields the transformation

$$g_l(x_l, y_l) + n_l(x_l, y_l) = T_R[g_r(x_r, y_r) + n_r(x_r, y_r)]$$

that is

$$\begin{aligned} v_l(x_l, y_l) &= n_l(x_l, y_l) - T_R[n_r(x_r, y_r)] \\ &= T_R[g_r(x_r, y_r)] - g_l(x_l, y_l) \end{aligned}$$

The parameters $h_0, h_1, a_0, a_1, a_2, b_0, b_1, b_2$ are to be chosen so that

$$\sum [v_l(x_l, y_l)]^2 = \text{minimum}$$

The problem of minimisation may be resolved with classical algorithms based on the partial derivatives of $v_l(x_l, y_l)$ with respect to the eight parameters.¹

Gaussian pyramids: For the coarse-to-fine stereo matching, Gaussian pyramid decomposition has been used.⁴

Let $g_0(i, j)$, $i, j = 0, 1, \dots, N-1$, with N a power of 2, be the original image, which may be considered as the level 0 of the pyramid. Level 1, $g_1(i, j)$, consists in a subsampled version of $g_0(i, j)$: in order to avoid aliasing effects, lowpass filtering is applied. In general level l may be obtained from level $l-1$ by

$$g_l(i, j) = \sum_{m=-2}^2 \sum_{n=-2}^2 w(m, n) g_{l-1}(2i+m, 2j+n)$$

where $w(m, n)$ are the weights of a low-pass filter, defined in a five-by-five kernel and assumed to be separable and symmetric.

Stereo matching: In our approach the estimate of the disparity at level 0 is reported at the top level K by successive divisions by 2. Applying the LMS algorithm at this level, a better approximation is obtained: this value is carried to the lower level multiplied by 2 and will be the new starting point for the LSM at level $K-1$. These operations are repeated until level 0 is reached. Automatic recognition of gross errors is obtained by means of the root mean square (RMS) of the residuals: only if this value lies below a certain threshold is the matching considered to be correct and spatial (3-D) co-ordinates may be found.

The main advantage of the use of Gaussian pyramid consists in having at the top level K information about the entire image. If δ is the distance from the initial estimate and the correct matching point at level 0, at level K this value will be reduced to $\delta/2^K$.

3-D reconstruction: In our experiments tridimensional reconstruction has been obtained from aerial photographs. The calibration of the pictures was given by the stereoplotter Galileo Digicart 40, from the terrain co-ordinates of some reference points. By knowing the co-ordinates of the optical focus on the two plates it is possible, through simple geometric relations, to calculate the terrain co-ordinates from the plate co-ordinates of matching points.

In Figs. 1a and b two fragments of the stereo photographs, digitised by two CCD cameras, are shown. They have a dimension of 512×512 pixels, corresponding to a resolution of about $15 \mu\text{m}$. A regular grid of 12×12 points, at a distance