RMS Delay Spread in Indoor LOS Environments at 5.2 GHz

J.T.E. McDonnell, T.P. Spiller, T.A. Wilkinson
Appliance Communications Solutions Department
HP Laboratories Bristol
HPL-98-63
April, 1998

E-mail: emcd@hplb.hpl.hp.com

Hiperlan,
indoor wireless,
delay spread

This Letter presents the results of measurement and analysis of the spatial distribution of rms delay spread (RDS) in indoor line-of-sight (LOS) conditions at 5.2GHz. Measurements and modelling show that the maximum RDS in a room is dependent on the dimensions of the room and the reflection coefficient of the walls. Furthermore, the RDS increases with radial distance from the transmitter up to a maximum value and plateaus at this maximum over a large part of the room.

RMS Delay Spread in Indoor LOS environments at 5.2 GHz

J.T.E. McDonnell, T. P. Spiller, T.A. Wilkinson

Hewlett-Packard Laboratories,
Filton Road, Stoke Gifford, Bristol. BS34 8QZ. U.K.

Email: emcd@hplb.hpl.hp.com

Indexing terms: HIPERLAN, U-NII, indoor wireless, delay spread

Abstract: Measurements and modelling of rms delay spread (RDS) in indoor line-of-sight (LOS) conditions at HIPERLAN/U-NII frequencies (5.2GHz) with omni-directional antennas show that the maximum RDS in a room is dependent on the dimensions of the room and the reflection coefficient of the walls. Furthermore, in a given room RDS increases with distance from the transmitter up to a maximum value and plateaus at this maximum over a large part of the room.

Introduction: Intersymbol interference brought about by propagation through a dispersive channel is a major problem in the design of high-speed wireless networks. The rms delay spread (RDS) [1] is a commonly used practical measure of the extent of time dispersion introduced by multipath channels. In turn, it has been found [2] that RDS is directly related to the minimum symbol length that can be used in order to avoid excessive intersymbol interference. The objective of this research was to investigate RDS and its relationship to the dimensions and material properties of the indoor LOS environment. A model for RDS in a bounded room was derived and this was tested against measurements conducted at 5.2 GHz in various residential properties and business premises. The results from modelling and measurements are in good agreement. Several new and important conclusions are presented from this study.

Measurement equipment: The sliding-correlator channel sounder that was used to measure RDS has been described elsewhere [3]. The transmitting and receiving antennas were quarter-wavelength monopole antennas with small square ground-planes that are omni-directional in the horizontal plane. At each measurement point between 10 and 14 separate measurements were taken and averaged to provide the recorded RDS.

Measurement sites: Measurements were conducted in rooms in six business and residential properties. Two representative examples of the rooms examined are described below. The window-less business meeting room (11.5m x 16.6m) has a floor made of carpet-covered square metal tiles that are suspended above a concrete sub-floor. All the wall surfaces have a cloth-covered metal facing and across all the suspended ceiling there is a fine wire mesh. The room was filled with metal-framed chairs arranged in an auditorium style. The residential room is 4.7m by 4.5m and is flanked on three sides by thick stone walls and by three large single-glazed windows on the other side. The floor is carpet-covered pine boards and the ceiling is plaster on laths. The room was conventionally furnished.

Measurement Results: Figures 1 and 2 show the results of delay spread measurements undertaken in the business and the residential rooms respectively. The spatial distribution of RDS suggests that RDS is constant with distance over much of the area of the room. This same spatial pattern of RDS with distance was observed in all the other rooms examined.

Modelling: The rms delay spread, τ_{RDS}, is given by the second moment of the impulse response [1]: $\tau_{RDS} = \left(\overline{\tau^2} - \bar{\tau}^2\right)^{\frac{1}{2}}$ where the average of the *k*-th power of propagation time is $\overline{\tau^k} \equiv K^{-1} \sum_i \tau_i^k P_i$. The normalization factor is the total received power: $K \equiv \sum_i P_i$, so the sums are over all paths from the transmitter to the receiver. Considering the radiation pattern of the transmitting and receiving antennas used, reflections from the walls rather than the floor and ceiling are the dominant components in the received signal and for this reason a two-dimensional ray-tracing model was applied. From the method of images it is easy to see that there are 4*N* possible paths which undergo *N* (*N* > 0) reflections. The rectangular room (with sides *a* and *b*) is centred on the origin in the *x*-*y* plane and the transmitter and receiver are placed at (x_t, y_t) and (x_r, y_r) respectively. The receiver and all its images lie at the points $\left((-1)^n x_r + na, (-1)^m y_r + mb\right)$ for integer *n* and *m*. The distance from the transmitter to an image is given by $d_{nm}^2 = ((-1)^n x_r + na - x_t)^2 + ((-1)^m y_r + mb - y_t)^2$ and the time taken for a ray to reach this image is thus $\tau_{nm} = c/d_{nm}$. A ray reaching the *nm*-th image undergoes $|n| + |m|$ reflections. With the reflected power reduced by a factor α at each reflection and assuming an inverse square-law fall-off, the power in the ray at the *nm*-th image is $P_{nm} = P\alpha^{|n|+|m|} d_{nm}^{-2}$ with the constant *P* (which does not affect the value of τ_{RDS}) set by the transmit power. To model a channel sounder with a short capture time, the sums can be truncated at an appropriate value of $N\ (|n| + |m|)$, or, more correctly, taken over all images with d_{nm} less than some appropriate distance. However, for a sounder which captures rays until they become negligible, the model calculation of τ_{RDS} sums over *n* and *m* until this holds (the actual cut-off values are then unimportant). Note that this simple model ignores interference between rays at different images and neglects any variation of α with angle of reflection. For a room of fixed shape and fixed α, a scaling of all wall lengths by a factor β results in an increase in τ_{RDS} by the same factor β. The dependence of τ_{RDS} on α is more involved, but can be evaluated numerically.

Figure 3 shows a model calculation of τ_{RDS} as a function of receiver position in the business meeting room described above. This used the actual room dimensions and a power reflection coefficient of $\alpha = 0.62$, corresponding to a voltage reflection coefficient of 0.79 per reflection. This value of reflection coefficient was judged to be suitable given the wall material of the room. For comparison, figure 1 is the measured RDS for the same room. It is seen that the results from modelling and measurement are in good agreement. It should be noted that if the transmitter is positioned in the centre of the modelled room then the RDS plateau becomes radially symmetric in the room.

Conclusion: Measurements and modelling of RDS at 5.2 GHz in LOS indoor scenarios have shown that it has a characteristic spatial distribution that increases with distance from the transmitter up to a maximum plateau value. This maximum value of RDS is determined by the dimensions of the room and the reflectivity of the enclosing walls.

REFERENCES

[1] Rappaport T.S., “Wireless Communications”, Prentice-Hall, New Jersey, pp.160, 1996.
[2] Chuang, Justin C-I., “The Effects of Time Delay Spread on Portable Radio Communications Channels with Digital Modulation”, IEEE J. Sel. Areas in Comms, sac-5, no. 5, pp. 879-889, June 1987.
[3] Hafezi, P., Wedge D., Beach M.A., Lawton M., “Propagation Measurements of the 5.2GHz Radio Band in Commercial and Domestic Environments”, PIMRC’96.

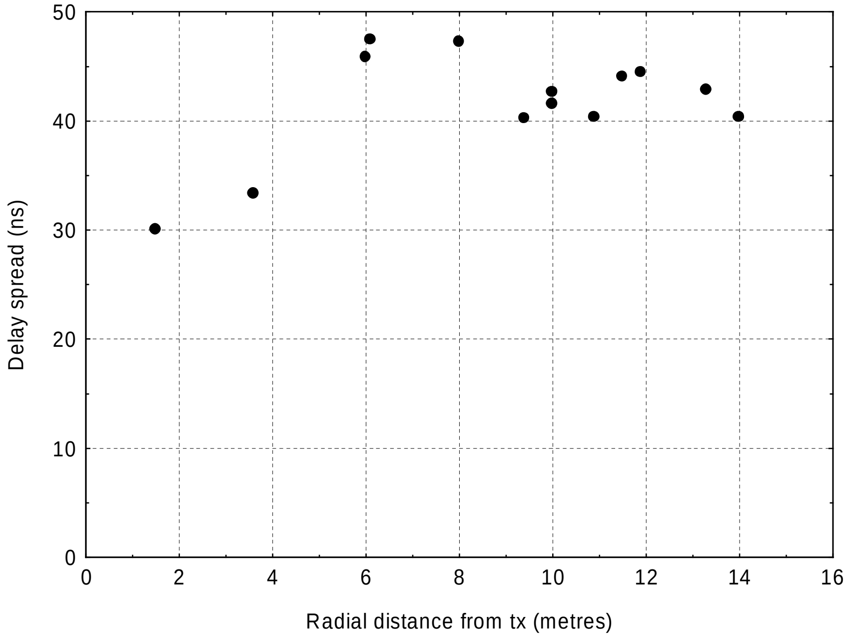

Figure 1: Measured LOS rms delay spreads in a ‘business’ room with the transmitter at $(x_t, y_t) = (3.8, -4.28)$ metres.

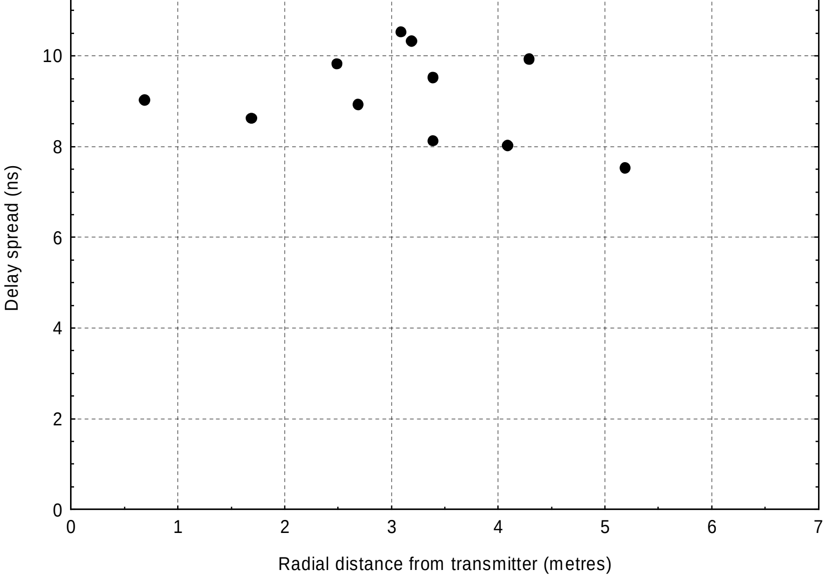

Figure 2: Measured LOS rms delay spreads in a residential room