CS698T
Wireless Networks: Principles and Practice

Topic 05
Fading, Multipath

Bhaskaran Raman,
Department of CSE, IIT Kanpur

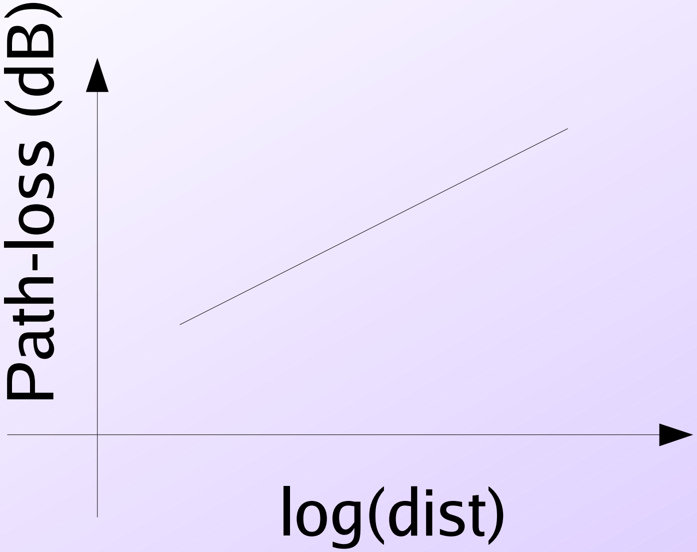
http://www.cse.iitk.ac.in/users/braman/courses/wless-spring2007/

Received Signal Strength

- It is a function of three components
  - Path loss
  - Long-term fading (slow)
  - Short-term fading (fast)

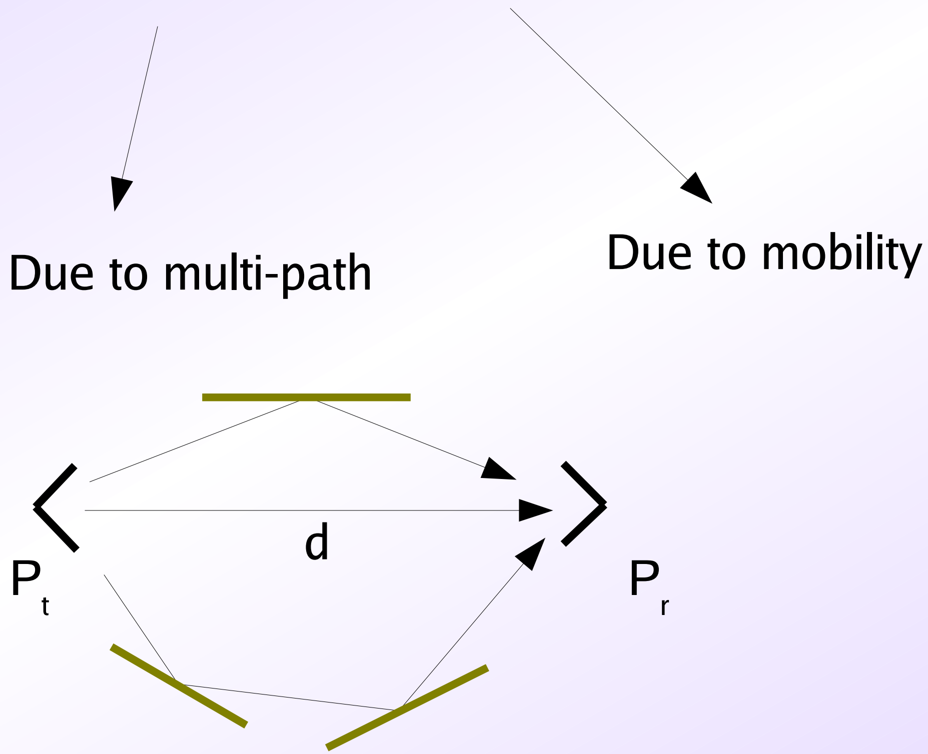
Path loss $\alpha\, d^{-\beta}$

β is in the range 3-4

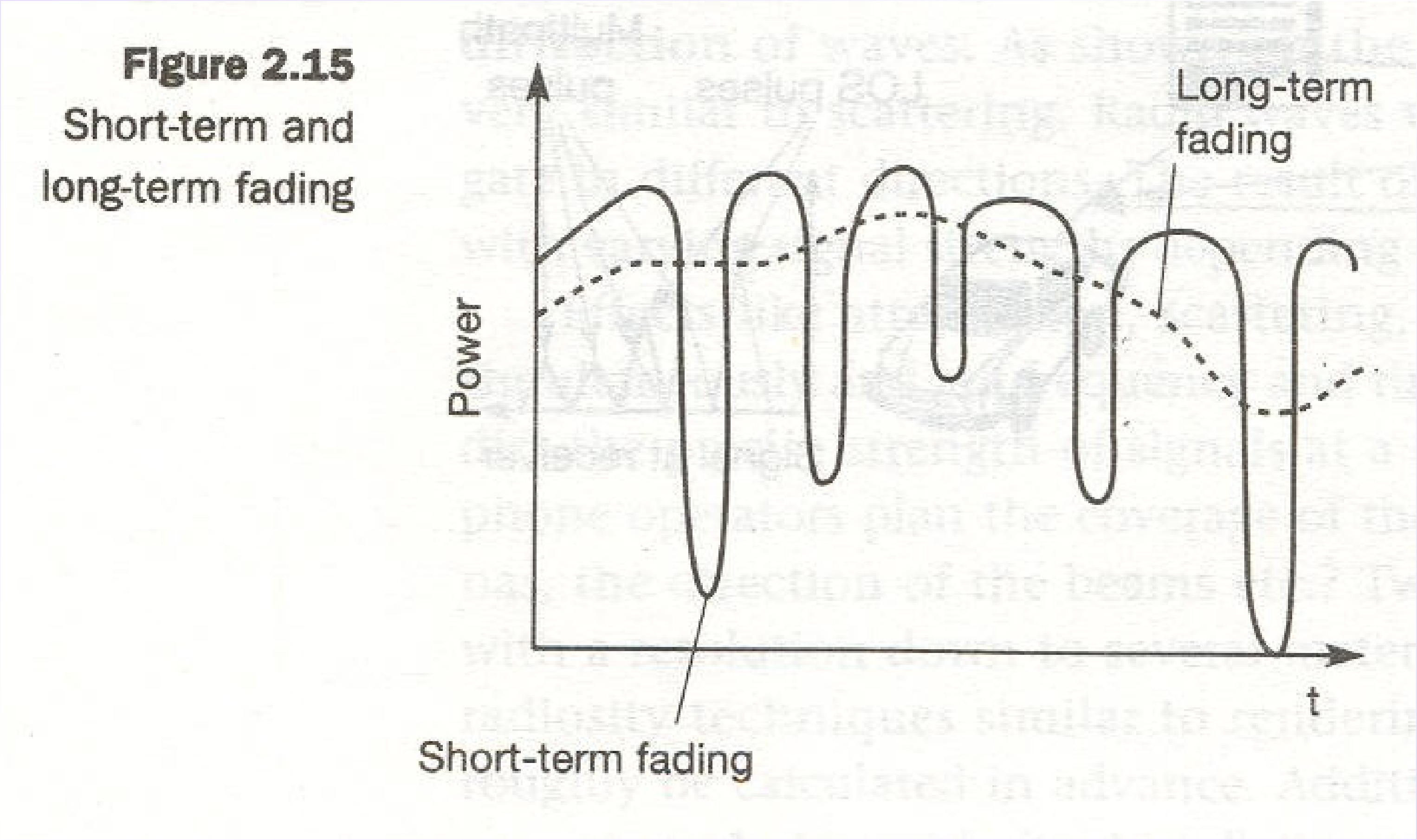


Fading and Multipath

Fading: the rapid variation of received signal strength over a small period of time

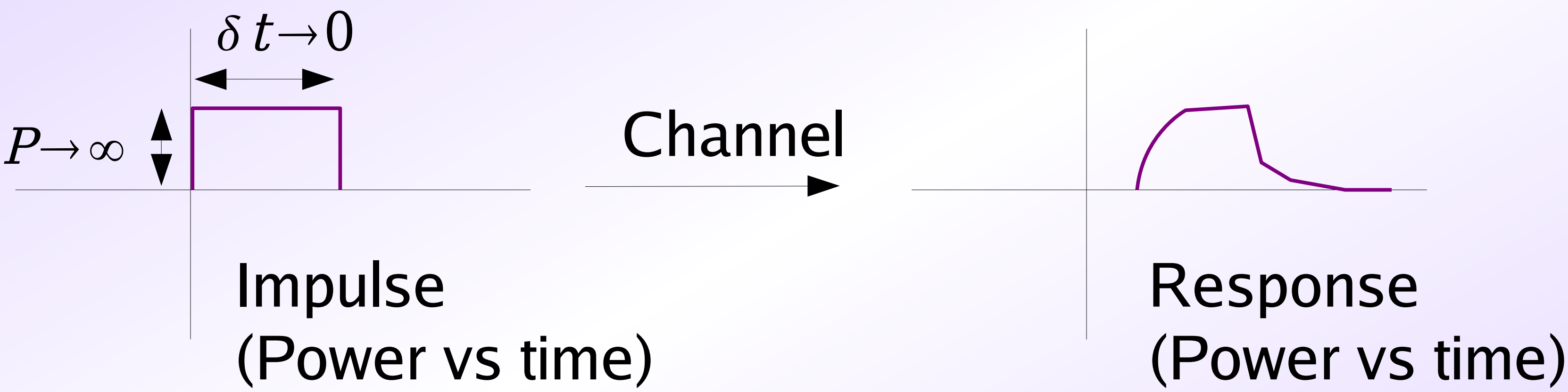


Short-term vs. Long-term Fading

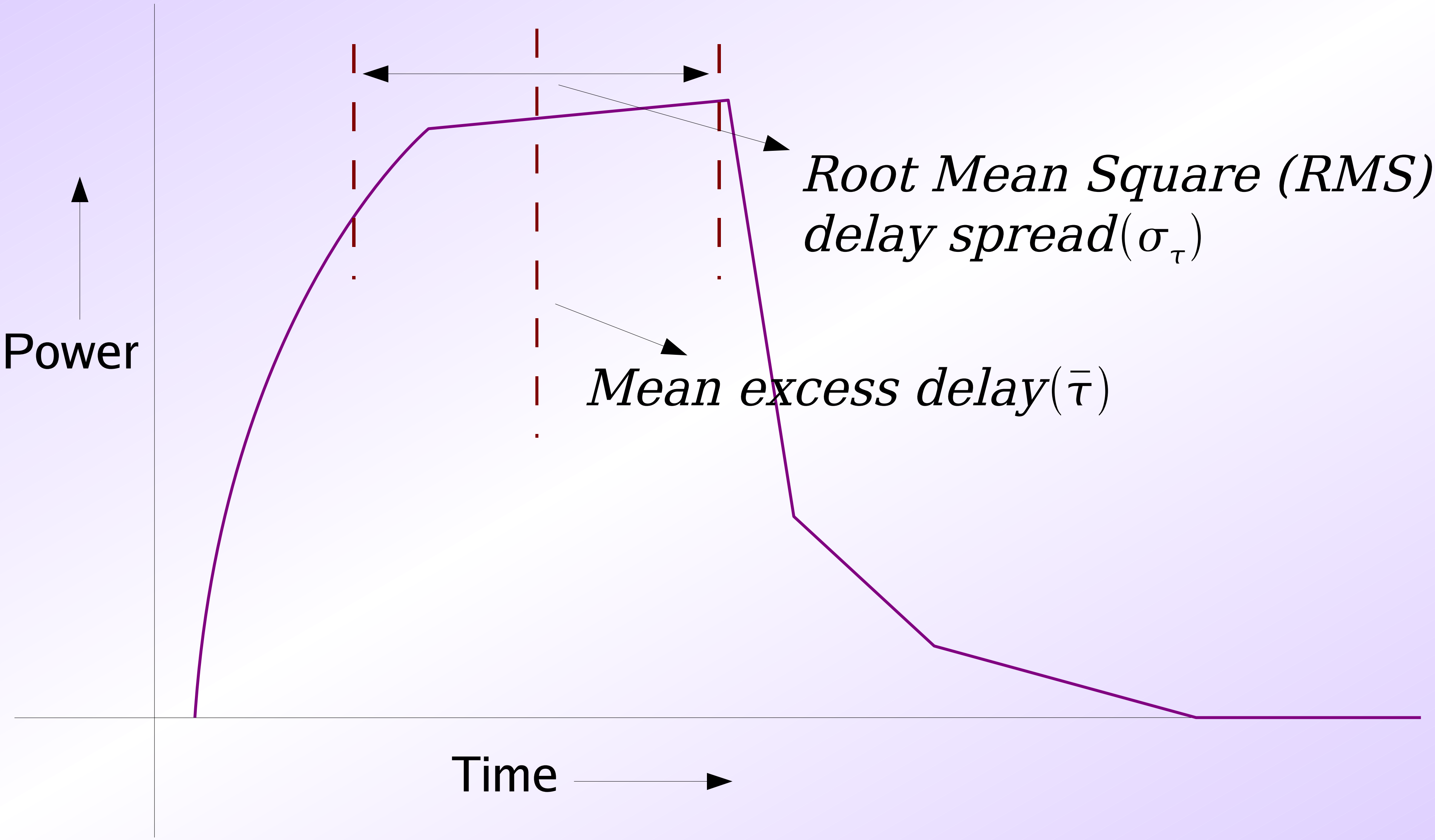


Source: Mobile Communications, Jochen Schiller

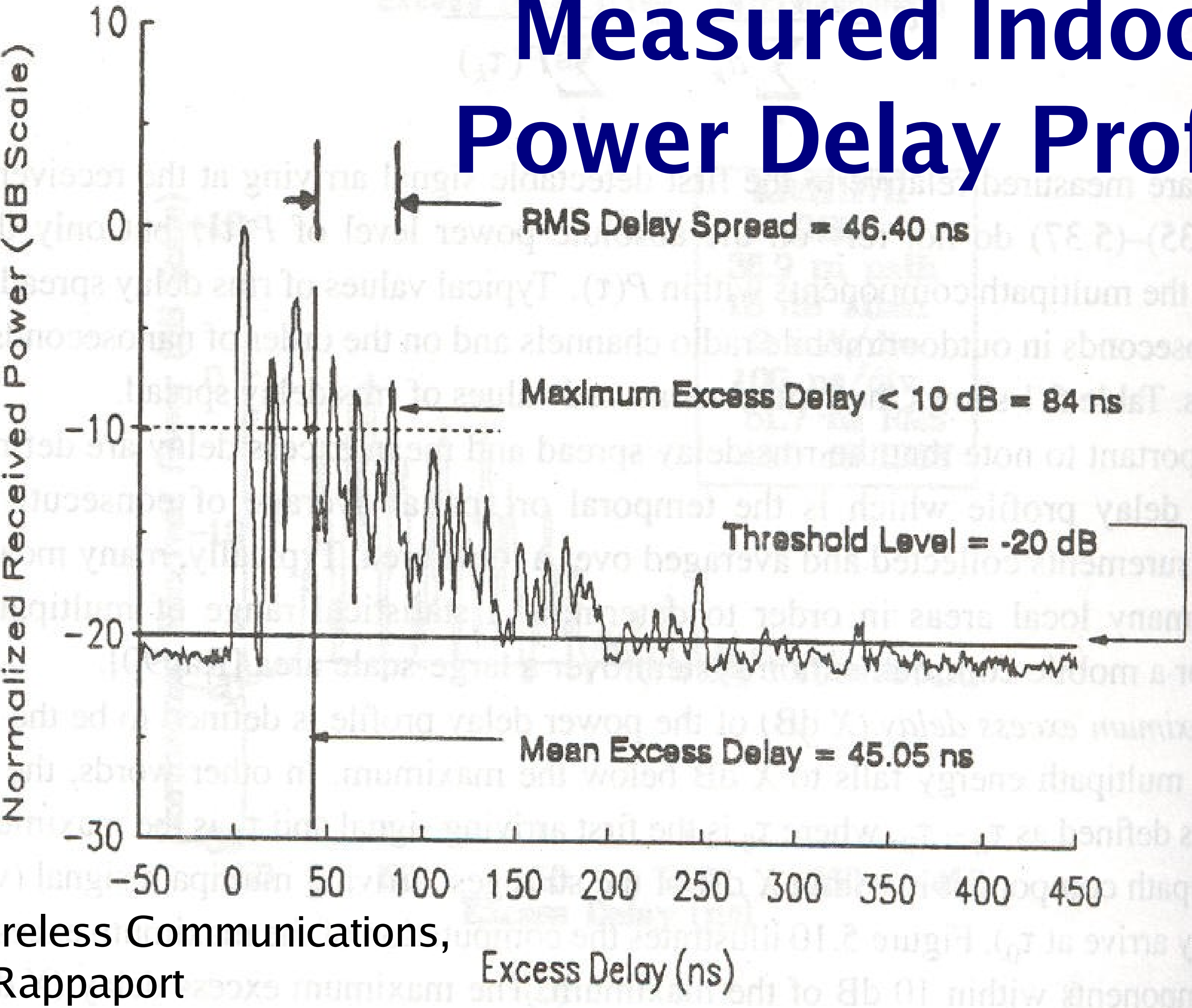
Channel Impulse Response



Power Delay Profile



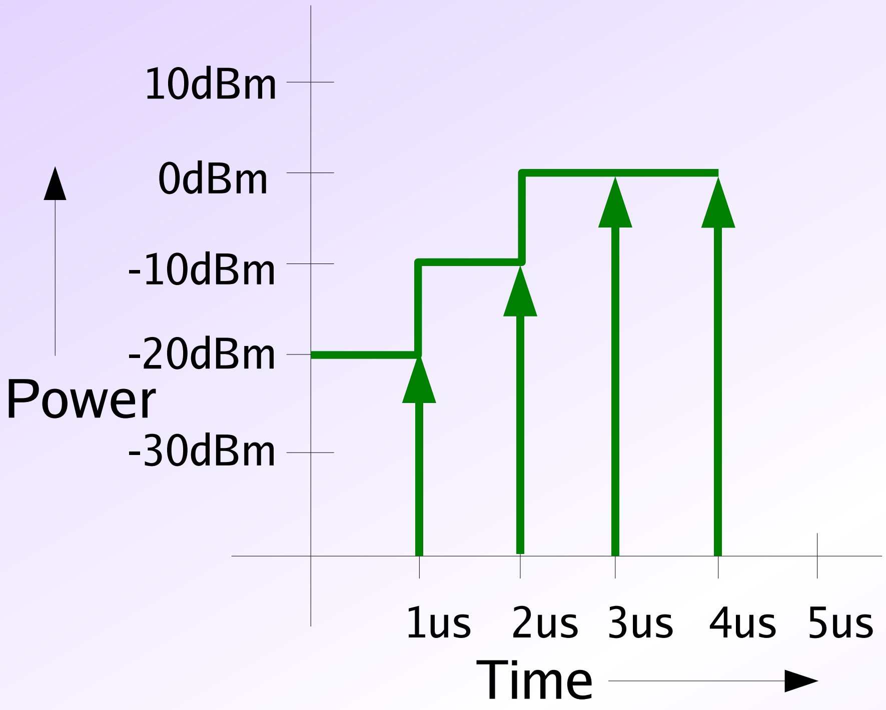
Measured Indoor Power Delay Profile



Source: Wireless Communications, Theodore Rappaport

Figure 5.10 Example of an indoor power delay profile; rms delay spread, mean excess delay, maximum excess delay (10 dB), and threshold level are shown.

An Example Calculation



$$\bar{\tau} = ? \qquad \sigma_\tau = ?$$

$$\bar{\tau} = \frac{(0.01 \times 0.5 + 0.1 \times 1.5 + 1 \times 2.5 + 1 \times 3.5)}{(0.01 + 0.1 + 1 + 1)}$$

$$\bar{\tau} = 2.92 \mu s$$

$$\bar{\tau^2} = \frac{(0.01 \times 0.5^2 + 0.1 \times 1.5^2 + 1 \times 2.5^2 + 1 \times 3.5^2)}{(0.01 + 0.1 + 1 + 1)}$$

$$\bar{\tau^2} = 8.88 \mu s^2$$

$$\sigma_\tau = \sqrt{8.88 - 2.92^2} = 0.59 \mu s$$

RMS Delay Spread Examples

Table 5.1 Typical Measured Values of RMS Delay Spread

Environment	Frequency (MHz)	RMS Delay Spread (σ_τ)	Notes	Reference
Urban	910	1300 ns avg. 600 ns st. dev. 3500 ns max.	New York City	[Cox75]
Urban	892	10–25 μs	Worst case San Francisco	[Rap90]
Suburban	910	200–310 ns	Averaged typical case	[Cox72]
Suburban	910	1960–2110 ns	Averaged extreme case	[Cox72]
Indoor	1500	10–50 ns 25 ns median	Office building	[Sal87]
Indoor	850	270 ns max.	Office building	[Dev90a]
Indoor	1900	70–94 ns avg. 1470 ns max.	Three San Francisco buildings	[Sei92a]

Source: Wireless Communications, Theodore Rappaport

Some Remarks

- RMS delay spread is a good measure of multi-path
  - Urban environments: 2-10 us
  - Indoors: 10-500 ns
- Symbol time: time to transmit a bit (0/1)
- Symbol time ~ RMS delay spread ==> Inter-Symbol Interference (ISI)
  - Equalization required
  - Generally, ISI results when
    - symbol time < 10 x RMS-delay-spread