2.4 LINK BUDGET DESIGN USING PATH LOSS MODELS

Radio propagation models can be derived by use of empirical methods: collect measurement, fit curves. And by use of analytical methods. Model the propagation mechanisms mathematically and derive equations for path loss.

1. Log Distance Path Loss Model

Empirical and analytical models show that received signal power decreases logarithmically with distance for both indoor and outdoor channels

The average large-scale path loss for an arbitrary T-R separation is expressed as a function of distance by using a path loss exponent n.

$$PL(d) \propto \left(\frac{d}{d_0}\right)^n$$

or

$$PL(\text{dB}) = PL(d_0) + 10n\log\left(\frac{d}{d_0}\right)$$

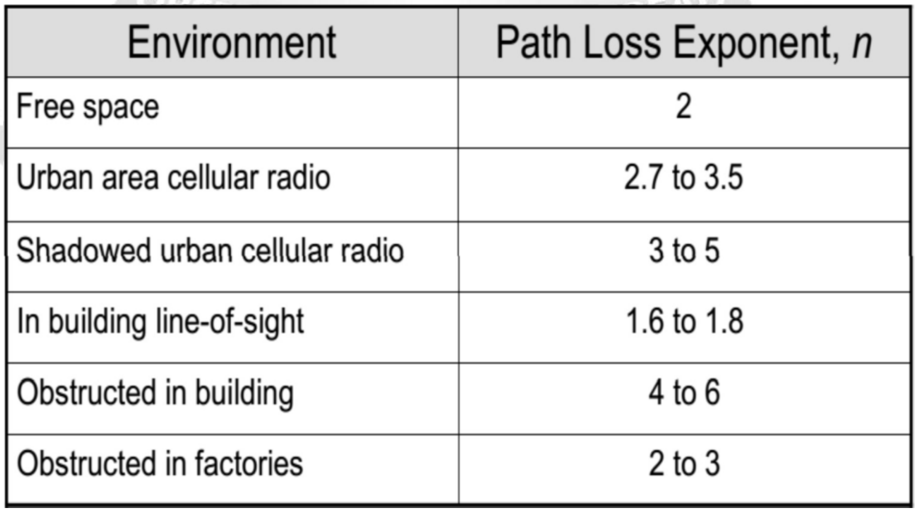
Path loss exponent **n** indicates the rate at which the path loss increases with distance.

The value of n depends on the propagation environment: for free space it is2.

When Obstructions are present it has a larger value.

Path Loss Exponent for Different Environments is shown in table1 below.

Table1: Path Loss Exponent



Environment	Path Loss Exponent, *n*
Free space	2
Urban area cellular radio	2.7 to 3.5
Shadowed urban cellular radio	3 to 5
In building line-of-sight	1.6 to 1.8
Obstructed in building	4 to 6
Obstructed in factories	2 to 3

Selection of free space reference distance

In large coverage cellular systems 1km reference distances are commonly used.

In microcellular systems, much smaller distances are used: such as100m or 1m.

The reference distance should always be in the far-field of the antenna so that near-field effects do not alter the reference path loss.

2. Log-Normal Shadowing

This method deals with measurements that are different than the predicted values obtained using the above equation.

Measurements show that for any value d, the path loss PL(d) at a particular location is random and distributed normally. That is

$$PL(d)[dB] = \overline{PL}(d) + X_\sigma = \overline{PL}(d_0) + 10n\log\left(\frac{d}{d_0}\right) + X_\sigma$$

And $P_r(d)[dBm] = P_t[dBm] - PL(d)[dB]$ (antenna gains included in PL(d).

where X_σ , is a zero-mean Gaussian distributed random variable (in dB) with standard deviation σ (also in dB).

The equation takes into account the shadowing affects due to cluttering on the propagation path.

It is used as the propagation model for log-normal shadowing environments.

The received power in log-normal shadowing environment is given by the following formula

$$P_r(d)[dBm] = P_t[dBm] - PL(d)[dB]]$$

The antenna gains are included in PL(d).

The log-normal distribution describes the random shadowing effects which occur over a large number of measurement locations which have the same T-R separation, but have different levels of clutter on the propagation path. This phenomenon is called log-normal shadowing.

SMALL SCALE FADING

• Describes the rapid fluctuations of the amplitude, phase of multipath delays of a radio signal over short period of time or travel distance

• Caused by interference between two or more versions of the transmitted signal which arrive at the receiver at slightly different times.

• These waves are called multipath waves and combine at the receiver antenna to give a resultant signal which can vary widely in amplitude and phase.

Effects of multipath

Rapid changes in the signal strength over small travel distances, or over small time intervals.
Random frequency modulation due to varying Doppler shifts on different multiple signals.
Time dispersion(echoes) caused by multipath propagation delays.

Multipath occurs because of: Reflections and Scattering.

At a receiver point, Radio waves generated from the same transmitted signal may come

- From different directions
- with different propagation delays
- with (possibly) different amplitudes (random)
- with (possibly) different phases (random)
- These multipath components combine vectorically at the receiver antenna and cause the total signal to fade or distort.

Factors Influencing Small Scale Fading

- **Multipath propagation**

• Presence of reflecting objects and scatterers cause multiple versions of the signal to arrive at the receiver

• With different amplitudes and time delays

• Causes the total signal at receiver to fade or distort

- **Speed of mobile**

• Cause Doppler shift at each multipath component

- Causes random frequency modulation
- Speed of surrounding objects
- Causes time-varying Doppler shift on the multipath components.

- **Transmission bandwidth of the channel**

The transmitted radio signal bandwidth and bandwidth of the multipath channel affect the received signal properties:

- If amplitude fluctuates or not
- If the signal is distorted or not.

Doppler Effect

- When a transmitter or receiver is moving, the frequency of the received signal changes, i.e. İt is different than the frequency of transmission. This is called Doppler Effect.
- The change in frequency is called Doppler Shift.
- It depends on the relative velocity of the receiver with respect to transmitter.

<u>Doppler Shift</u>

Consider a mobile moving at a constant velocity v, along a path segment having length d between points X and Y, while it receives signals from a remote source S, as illustrated in Figure1.2.

The difference in path lengths traveled by the wave from source S to the mobile at points X and Y is $\Delta l = d\cos\theta = P\Delta t\cos\theta$, . where Δt is the time required for the mobile to travel from X to Y, and $ is assumed to be the same at points X and Y since the source is assumed to be very far away.

The phase change in the received signal due to the difference in path lengths is therefore

$$\Delta\phi = \frac{2\pi\Delta l}{\lambda} = \frac{2\pi v\Delta t}{\lambda}\cos\theta$$

and hence the apparent change in frequency, or Doppler shift, is given by fd'
where

$$f_d = \frac{1}{2\pi}\cdot\frac{\Delta\phi}{\Delta t} = \frac{v}{\lambda}\cdot\cos\theta$$

The above equation relates the Doppler shift to the mobile velocity and the spatial angle between the direction of motion of the mobile and the direction of arrival of the wave.

It can be seen that if the mobile is moving toward the direction of arrival of the wave, the Doppler shift is positive (i.e., the apparent received frequency is increased), and if the mobile is moving away from the direction of arrival of the wave, the Doppler shift is negative.

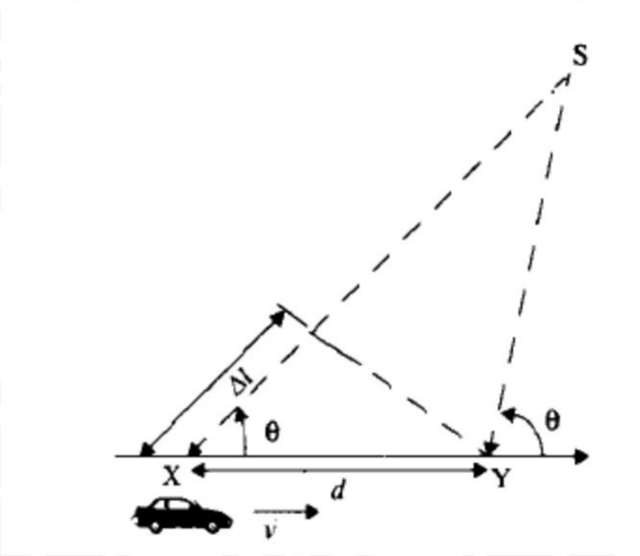


Fig 1.3.1: Doppler Shift

[Source : "Wireless communications "by Theodore S. Rappaport,Page-142]