Fading → characteristic of the wireless channel

Wireless Communication and Satellite Communication

Fading

- Wireless communication system consist of transmitter and a receiver.
- Signal takes multiple paths while travelling from transmitter to receiver
- Definition: The time variation of received signal power due to changes in transmission medium or paths is known as fading.

Types of Fading

T-R separation

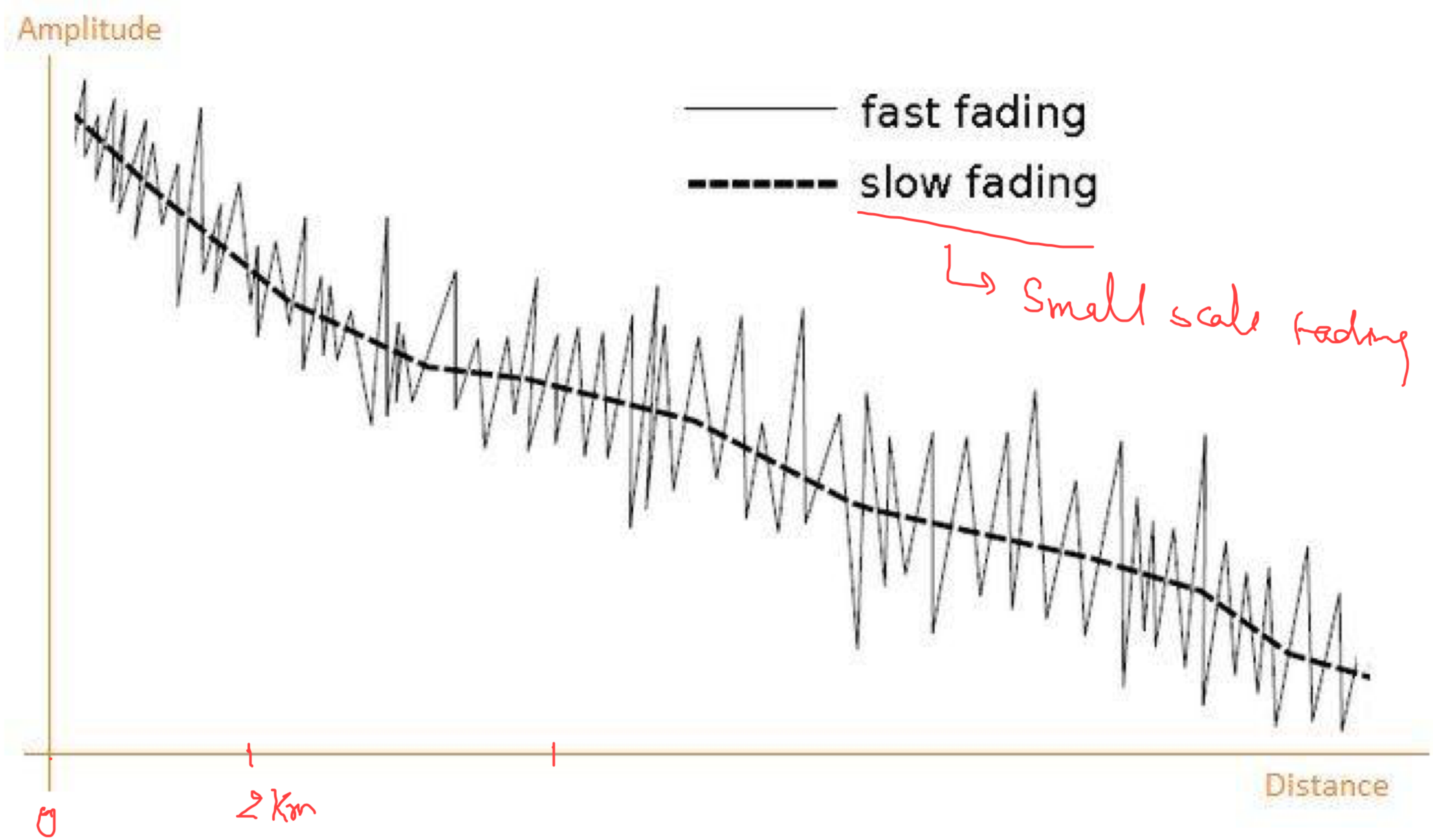
- Fading Types
  - Large Scale Fading
    - Path loss
    - Shadowing
  - Small Scale Fading
    - Multipath delay spread
      - Flat Fading
      - Frequency Selective Fading
    - Doppler Spread
      - Fast Fading
      - Slow Fading

couple of kilometers

signal fluctuates around a mean value.

we concentrate and examine the signal power over a few hundred m.

Fast Fading vs Slow Fading



(1) Free space

(ii) two-ray

Path Loss Models

There are two approaches for formulating a path loss model:

a) Analytical Approach: modelled using mathematical equations and assumptions

b) Empirical Approach: modelled by physical measurements and fitting a curve by considering all known and unknown parameters.

- It is equally important to validate a model in various environments with required frequency of transmission.

The path loss models also enables us to predict/ calculate the important transmission parameters such as SNR, Noise Floor, and capacity of the communication system.

Pure analytical approach path loss models are inaccurate because of many immature assumptions made to reduce the derivation complexity.

[illegible] → LOS → Gaussian

NLOS

Path Loss Models

This actually necessitates the modelling of a path loss model considering the practical scenarios into account.

Practical Path loss model estimation techniques:

(i) Log distance Path Loss Model

(ii) Log Normal Shadowing Model

$\rightarrow 0$

Log distance Path Loss Model

↳ extension of free space path loss model

- Average received signal power decreases lograithmically with distance whether in outdoor or indoor radio channel.
- 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

free space model

$$PL(dB) = 10\log\left(\frac{P_t}{P_r}\right) = -10\log\left(\frac{\lambda}{4\pi d}\right)^2$$

general Path loss equation w.r.t. T-R separation is given by;

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

→ Log distance path loss

or $$\boxed{\overline{PL}(d) = \overline{PL}(d_0) + 10n\log\left(\frac{d}{d_0}\right)}$$

Free space path loss

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

free $\rightarrow n = 2$

n → path loss exponent which indicate the rate at which the path loss increases with distance

d_0 → reference distance

d → T-R seperation distance

Log distance Path Loss Model

The value of n depends on the specific propagation environment.

Environment	Path Loss Exponent (n)
Free space	2
Urban area cellular radio	2.7 to 3.5
Shadowed urban cellular radio	3 to 5
Inside a building - line-of-sight	1.6 to 1.8
Obstructed in building	4 to 6
Obstructed in factory	2 to 3

Table 1: Path loss exponent for various environments

Log distance Path Loss Model

It is important to select a reference distance that is appropriate for the propagation environment.

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

In indoor/microcellular environment, much smaller distances such as 100 m or 1 m are used.

The reference path loss is always calculated using the free space path loss formula.

$PL(d_0)$

LogNormal shadowing model

Shadowing

Shadow fading

- It is common practice in radio communications that amplitude variation of a received radio signal is modelled as a product of path loss, shadow fading and small-scale fading.
- Several models exist for path loss, such as free space, two ray, including the variants of Okumura-Hata and Walfisch-Ikegami formulas.
- Likewise, numerous statistical models have been proposed for small- scale fading, most notably the Rayleigh, Rice and Nagakami-m probability laws.

Definition: It occurs when objects between the transmitter and receiver partially absorb the transmission power.

- The obstructing object may cause a random variation in the received signal power.
- The objects that cause the fading, may be large buildings or other structure.

Log Normal Shadowing Model

One downfall of the log-distance path loss model is that it does not account for shadowing effects that can be caused by varying degrees of clutter between the transmitter and receiver.

obstruction

The **log-normal shadowing model** attempts to compensate for this.

The log normal distribution describes the random shadowing effect which occurs over a large no. of measurement locations having same T-R separation but have diffrent levels of clutter on the propagation path.

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

$X_\sigma = 0$ log distance path loss mod.

X_σ → Shadowing

X_σ: Zero-mean gaussian distributed random variable with sd as σ

$$P_r(d) = 10\log\left[P_0(d_0)\right] + 10n\left(\frac{d_0}{d}\right) dBm + X_\sigma$$

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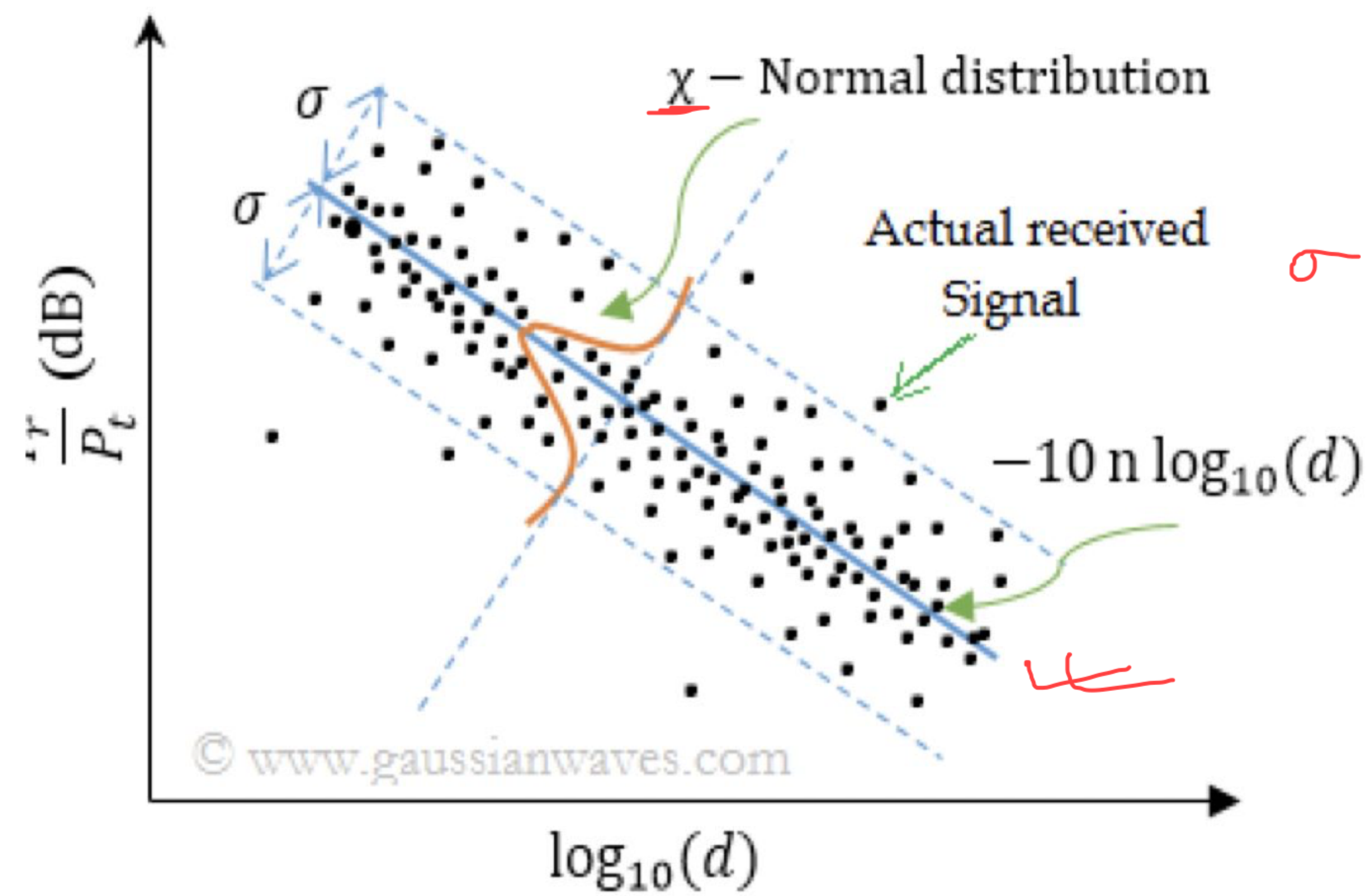
Log Normal Shadowing Model

- Usually, to model real environments, the shadowing effects can not be neglected.
- If the shadowing effect is neglected, then the path loss is simply a straight line.
- To add shadowing effects, a zero mean gaussian random variable with standard deviation σ is ~~added to~~ the equation.



σ → Sd

Log Normal Shadowing Model

- The actual path loss may still vary due to the the other factors.
- η The path loss exponent and the standard deviation of the random variable σ should be known precisely for a better modelling.
- PLE The Path Loss Exponent (PLE) table is for reference only. $P_L \alpha \left(\frac{d}{d_0}\right)^n$
- It may or may not fit the actual environment we are trying to model. PLE is an important parameter and it affects the system performance drastically.
- Usually PLE is considered to be known a-priori but mostly that is not the case.
- Care must be taken to estimate the PLE for the given environment before design & modeling.
- PLE estimation is done by equating the observed (empirical) values over several time instants to the established theoretical values. Refer state of the art literature for PLE estimation in large wireless networks.

Log Normal Shadowing Model

Q: Calculate the received power at a distance of 3km from the transmitter if the path loss exponent is 4. Assume the transmitting power 4W at 1800 MHz, a shadow effect of 10.5 dB, and the power at a reference distance(d0) of -32dBm. What is the allowable path loss?

n d

X_σ

100m

$P(d_0)$

Allowable path loss $= P_t - P_r$

$P_t \to 4W$

$P_r = 10\log[P_0(d_0)] + 10n\log\left(\frac{d_0}{d}\right) + X_\sigma$

$= -32 + 10 \times 4 \times \log\left(\frac{100}{3000}\right) + 10.5$

$= -32 + 10 \times 4 \times \log\left(\frac{1}{30}\right) + 10.5$

$= -80.5\ dBm$

P_t

$$P_t(\text{dBm}) = 10\log\left(\frac{4}{1\times10^{-3}}\right)$$

$$= 10\log(4\times10^{3})$$

$$= 10\log 4 + (\log 10^{3})\times 10$$

$$= 30 + 6.\underline{02}$$

$$= 36\ \text{dBm}$$

Allowable Path loss

$$= 36 - (-80.5)$$

$$\boxed{= 116.5\,\text{dB}}$$

Q: What is the seperation distance b/w the Tx and the Rx with an allowable path loss of 150 dB and shadow effect of 10 dB?

Path loss equation (in dB)

$$L_p = 133.2 + 43 \log d$$

↳ seperation distance in Km.

Solⁿ:

Allowable path loss = path loss + shadowing

$$\Rightarrow 150 = 133.2 + 43 \log d + 10 \text{ dB}$$

$$\Rightarrow d = 1.44 \text{ Km}$$

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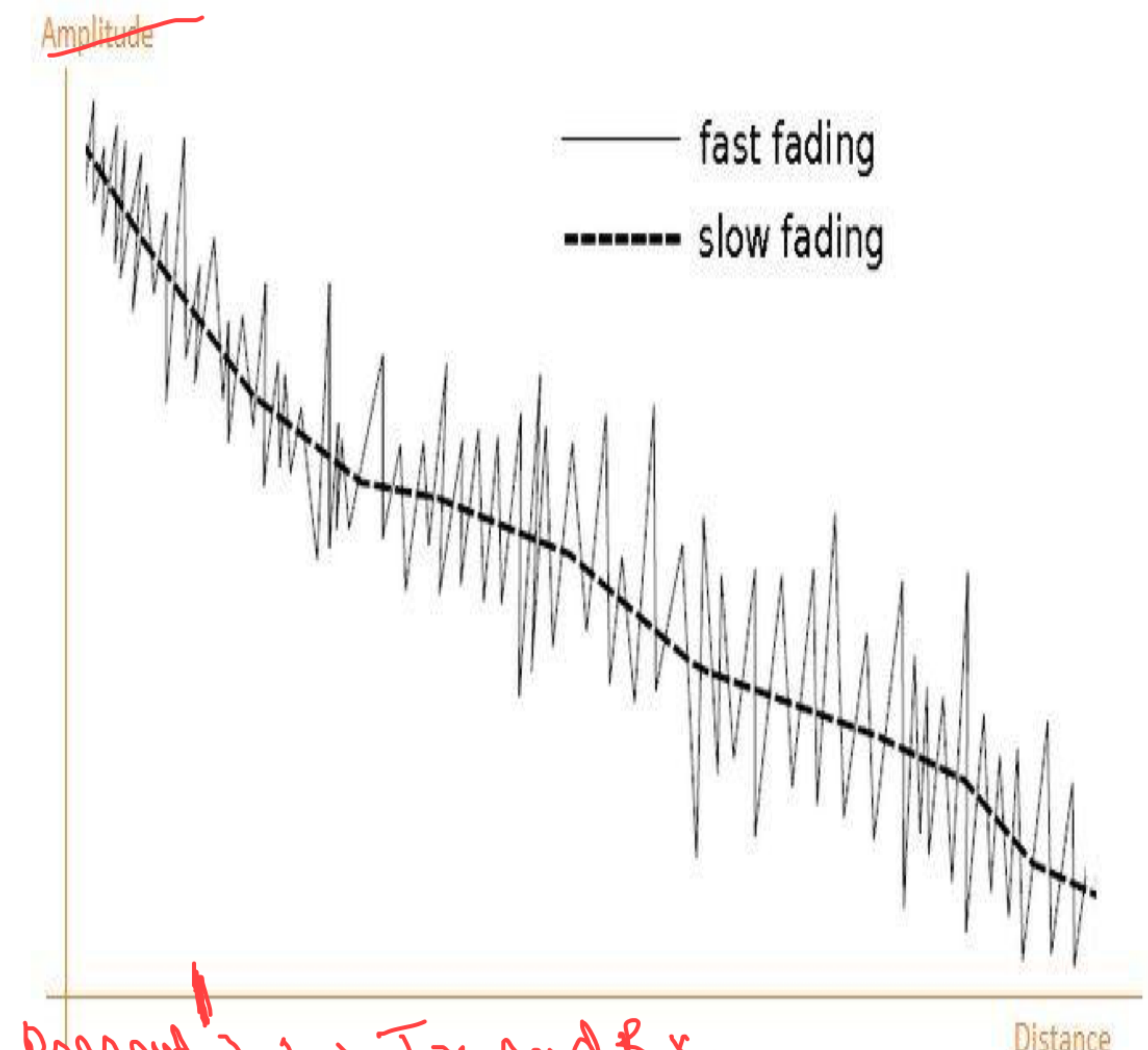
Small scale Fading

signal strength Z_0 Z_1 $Z_1 - Z_0$

Definition:

- It refers to the rapid fluctuation of amplitude of a radio signal over a short period of time or travel distance.



causes:

- caused by interference b/w two or more versions of the transmitted signals which arrives at the receiver at slightly different times.

effects:

As the result of signal combining, there will be change in amplitude and phase depending on:

- Distribution of intensity ✓ no of multipath component present b/w Tx and Rx.
- Relative propagation time ✓
- Bandwidth of the propagated signal ✓
  ↳ at what Bandwidth signals are getting propagated

Factors that influence Small Scale Fading

1. Multipath Propagation
2. Speed of mobile
3. Speed of Surrounding Objects
4. Transmission Bandwidth of the channel

- Path loss model allows you to calculate the mean signal attenuation.
- Fading/Shadow fading are used to calculate the variance of the attenuation