Propagation and fading

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Communication channels –

① Wired channel
- Stationary
- Predictable

② Wireless channel
- Random
- Typical to analyze
- Susceptible to noise, interference, other time varying channel impairments

Channel Models –

① Physical models – Considers exact profile of the propagation environment.
Modes of propagation considered: free space or LOS, reflection and diffraction.

② Statistical models – Takes an empirical approach. The model is developed on measuring propagation characteristics in a variety of environments. They are easy to describe and use then physical models.

Need for propagation models –

Propagation models can be used to determine
- Coverage area of a transmitter
- Transmit power requirement
- Battery lifetime
- Modulation and coding schemes required to improve the channel quality
- Maximum achievable channel capacity of the system.

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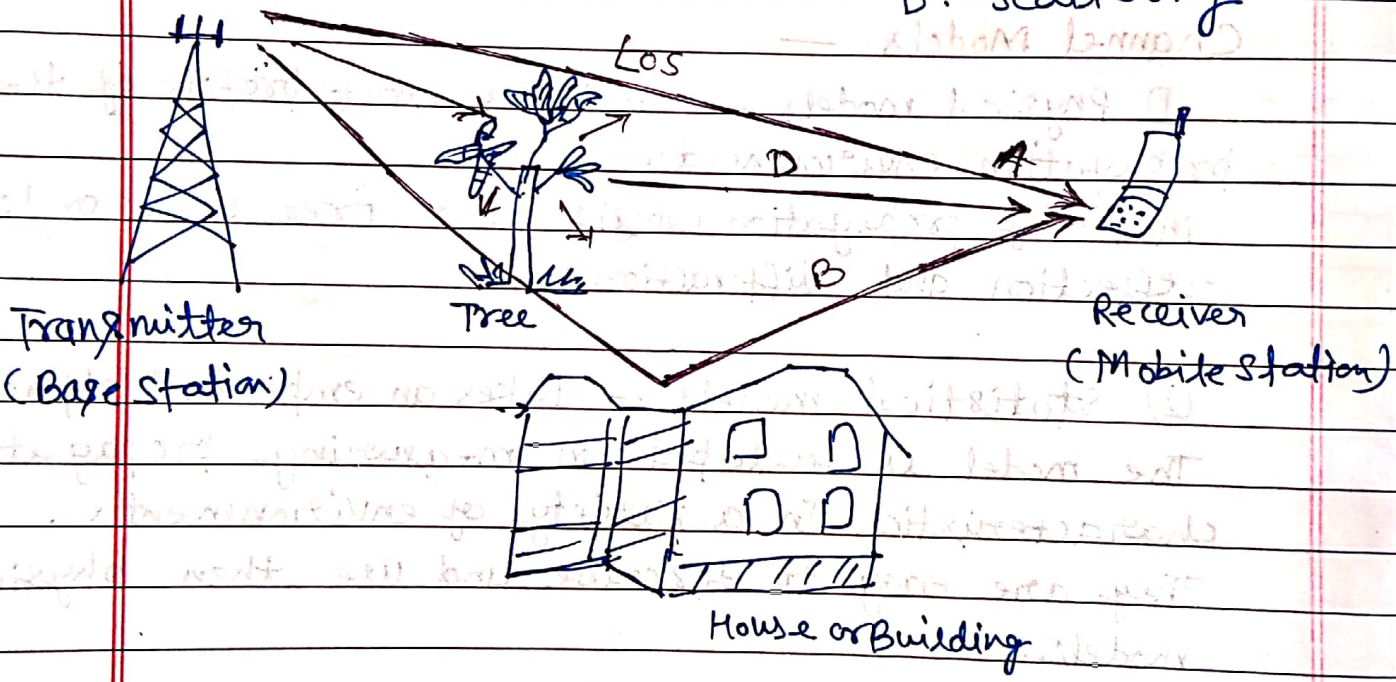
There are three basic attributes in radiowave propagation –

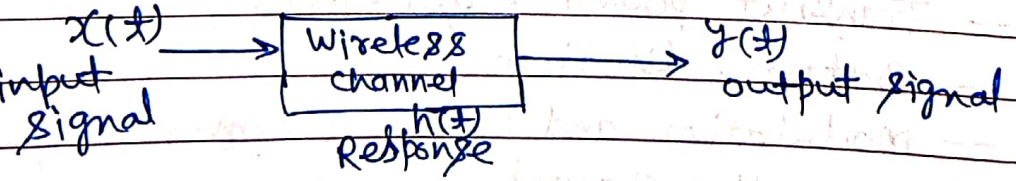
1. Reflection
2. Diffraction
3. Scattering

① ~~Reflection~~

A: Free space
B: Reflection
C: Diffraction
D: Scattering



→ At receiver multiple signal component so it is a multipath propagation Environment.



⇒ i^{th} path of wireless environment is characterized by
- Delay, τ_i
- Attenuation, a_i

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$a_i\ \delta(t-\tau_i)$

↳ impulse shifted by τ_i.

↳ attenuation

Multipath scenario –

1 —— a_1, τ_1 —— $a_1 \delta(t-\tau_1)$

2 —— a_2, τ_2 —— $a_2 \delta(t-\tau_2)$

⋮

L —— a_L, τ_L —— $a_L \delta(t-\tau_L)$

Multipath response = Sum of individual responses

$$h(t) = a_1 \delta(t-\tau_1) + a_2 \delta(t-\tau_2) + \cdots + a_L \delta(t-\tau_L)$$

$$h(t) = \sum_{i=1}^{L} a_i \delta(t-\tau_i)$$

impulse response of channel

Transmitted signal –

f_c → carrier frequency

$$s_p(t) = \mathrm{Re}\{ s(t)\, e^{j2\pi f_c t} \}$$

$s_p(t)$ ↓ Passband signal

$s(t)$ ↓ Complex baseband signal

$f_c \approx 900$ MHz GSM

1800, 2100, 2300 MHz

1st path — a_1, τ_1

$$\mathrm{Re}\{ a_1 s(t-\tau_1) e^{j2\pi f_c (t-\tau_1)} \}$$

ith path — a_i, τ_i

$$\mathrm{Re}\{ a_i s(t-\tau_i) e^{j2\pi f_c (t-\tau_i)} \}$$

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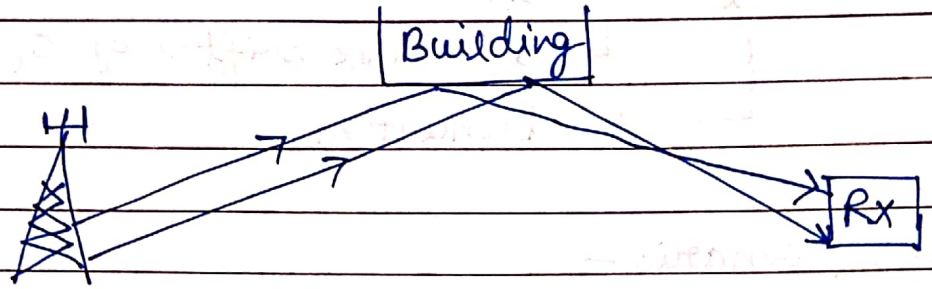
① Reflection —



→ when an electromagnetic wave travels from one medium to another medium (here, free space to building), reflection occurs.

→ Reflection occurs when wave impinges upon an obstruction much larger in size compared to the wavelength of the signal.

Ex:- Reflections from earth and buildings.

Perfect dielectric —
- Part of the energy is transmitted into the second medium and part of the energy is reflected back into the first medium
- no loss of energy in absorption

Perfect Conductor —
- All incident energy is reflected back into the first medium.
- no loss of energy

Note — The fraction that is reflected is described by the Fresnel equation and is dependent upon the incoming light's polarization and angle of incidence.

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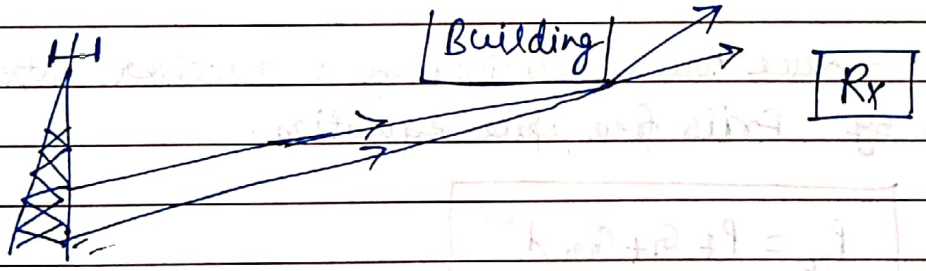
(2) ~~Diffraction~~ –

Reflection – occurs when the signal encounters a large solid surface, whose size is much larger than the wavelength of the signal, e.g., a solid wall

Diffraction – occurs when the signal encounters an edge or a corner, whose size is larger than the wavelength of the signal, eg. an edge of a wall.

Scattering – occurs when the signal encounters small objects of size smaller than the wavelength of the signal

(2) Diffraction –



→ Due to obstacle (here, a large building) or insulating material whose size is large, the direction of EM wave is deviated from its original direction & some of the energy are absorbed in the path is known as diffraction.

→ Due to absorption of energy, energy loss occurs.

(3) Scattering –

– Scattering occurs due to very small object
– when the EM wave propagate/meets on the sharp edge of any smaller size object, it spreads out in all direction and energy loss occurs. (Ex. Trees)

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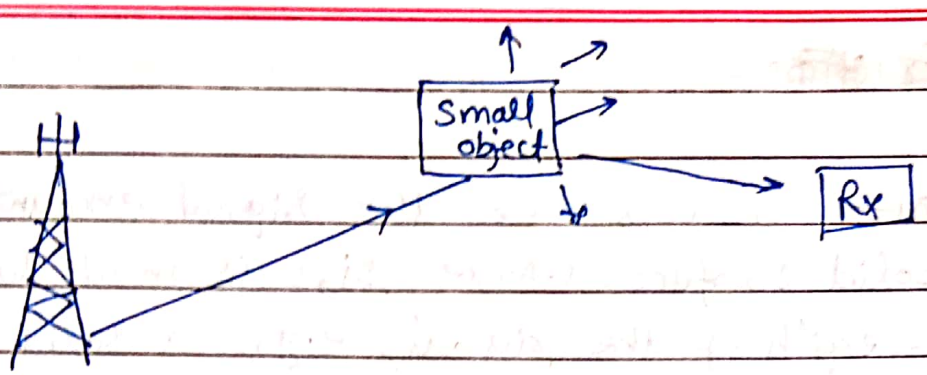

Free space propagation model —

→ Predict the received signal strength when transmitter and receiver have clear, unobstructed LOS (Line-of-sight) path between them.

Ex- Satellite communication, microwave LOS system.

→ The received power decays as a function of T-R seperation raised to some power.

→ Free space power received by a receiver antenna is given by Friis free space equation.

$$P_r = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2 L}$$

P_t → Transmitted power, P_r → Received power

G_t, G_r → Tx, Rx antenna gain ~~(dimensionless quantity)~~

d → distance between T-R in meters

L → System loss factor not related to propagation ($L \geq 1$)

$L=1$ indicates no loss in system hardware (we consider $L=1$ in our calculations)

$\lambda = c/f$ c → Speed of light ~~in meters/sec~~

f → Carrier frequency in Hz.

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$$P_r|_{dB} = 10\log P_t + 10\log G_t + 10\log G_r - 10\log(L_f)$$

$$L_f|_{dB} = 10\log\left(\frac{4\pi d}{\lambda}\right)^2$$

$$= 20\log\left(\frac{4\pi d}{\lambda}\right)$$

$\frac{P_t}{P_r} = \left(\frac{4\pi d}{\lambda}\right)^2 \frac{1}{G_t G_r}$

P_t/P_r → path loss

Neglecting gain of Antenna

loss, $P_t/P_r = \left(\frac{4\pi d}{\lambda}\right)^2$

Free space loss $= 20\log(4\pi d) - 20\log\lambda$

when no other loss is considered

$$L_f|_{dB} = 32.44 + 20\log d + 20\log f$$

where, d is in km (>1 km)

f is in MHz

Note –

① If frequency is doubled, then loss increases by an amount of 6dB.

② If distance is doubled then loss increases by an amount of 6 dB.

③ If both frequency and distance double, then loss increases by 12 dB.

$$\Rightarrow P_r = \frac{P_t G_t G_r \lambda^2}{(4\pi d)^2} = \frac{P_t G_t G_r}{L_f} \quad \because L_f = \left(\frac{4\pi d}{\lambda}\right)^2$$

path loss $\Rightarrow$ $\frac{P_t}{P_r} = \frac{L_f}{G_t G_r}$ $\Rightarrow$ free space attenuation (FSA)

If other losses are also present, then

$$P_r = \frac{P_t G_t G_r}{L_f L_o}$$

L_o → other losses

$P_t G_t$ = Effective isotropic radiated power (EIRP)

(Power after transmission or power at the surface of Antenna)

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What is Decibel (dB) —

→ A logarithmic unit used to describe a ratio between two values of a physical quantity (usually measured in units of power or intensity)

Ex: $P_1 = 100W$, $P_2 = 1W$

ratio of $P_1/P_2 = 10 \log\left(\frac{P_1}{P_2}\right)$ dB

$= 10 \log\left(\frac{100}{1}\right) = 20$ dB

→ dB unit is generally used to describe ratios of numbers with modest size

⇒ dBm :— indicates power ratio in dB with 1mW as the reference power.

Ex: Transmit power = 100W in dBm is

Transmit power (dBm) $= 10 \log\left(\frac{100W}{1mW}\right) = 10 \log\left(\frac{100 \times 10^3 mW}{1mW}\right)$

$= 10 \log(10^5) = 50$ dBm

Similarly,

1mW = 0dBm, 1W = 30dBm, 10W = 40dBm

100W = 50dBm, 10^6W = 90dBm

Q: If a transmitter produces 50W of power, express the transmit power in units of (a) dBm

(b) dBW

If 50W is applied to a unity gain antenna with a 900MHz carrier frequency, find the received power in dBm at a free

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space distance of 100 m from the antenna. what is P_r(10km)? assume unity gain for the receiver antenna.

Sol $P_t = 50W$, $f_c = 900MHz$

(a) Transmit power, $P_t(dBm) = 10\log\left(\frac{P_t(mW)}{1mW}\right)$

$= 10\log\left[\frac{50\times10^3\ mW}{1\ mW}\right]$

$= 47\ dBm$

(b) $P_t(dBW) = 10\log\left(\frac{P_t(W)}{1W}\right)$

$= 10\log\left[\frac{50}{1}\right] = 17\ dBW$

$\Rightarrow$ Received power, $P_r = \frac{P_t G_t G_r \lambda^2}{(4\pi d)^2 L}$

$\lambda = \frac{c}{f} = \frac{3\times10^8}{900\times10^6} = 0.33$

$P_r = \frac{50(1)(1)(1/3)^2}{(4\pi)^2(100)^2(1)}$

$= 3.5\times10^{-3}\ mW$

$P_r(dBm) = 10\log P_r(mW)$

$= 10\log(3.5\times10^{-3}\ mW) = -24.5\ dBm.$

$P_r(10km) = -64.5\ dBm$

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Losses / Attenuation due to reflection —
or
Ground Reflection (Two-Ray model) –

→ Based on geometric optics and it considers both the direct path and a ground reflected propagation path.

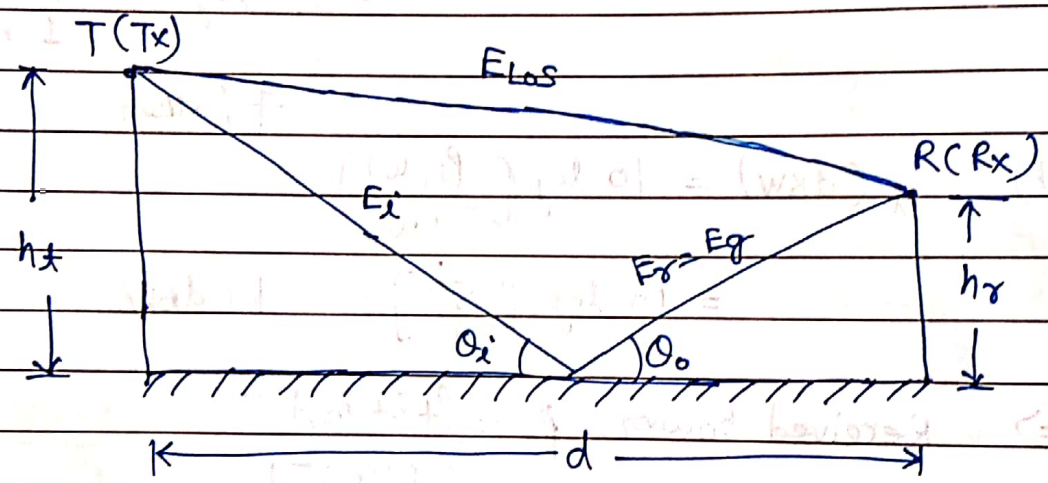

fig: Two-ray ground reflection model

→ Reasonably accurate for predicting the large scale signal strength over distances of several kilometers for mobile radio systems that use tall towers.

→ The total received E field,

$$E_{TOT} = E_{LOS} + E_g$$

(E_{LOS}: LOS component; E_g: Ground reflected component)

→ for large distance, $d \gg \sqrt{h_t h_r}$

$$P_r = P_t G_t G_r \frac{h_t^2 h_r^2}{d^4}$$

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→ The received power falls off with distance raised to the fourth power, or at a rate of 40 dB/decade.

→ This is much more rapid path loss than expected due to free space.

$$\text{Attenuation or Path loss} = \frac{P_t}{P_r} = \frac{d^4}{G_t G_r h_t^2 h_r^2}$$

$$\text{Path loss, } P_L(dB) = 40 \log d - [10 \log G_t + 10 \log G_r + 20 \log h_t + 20 \log h_r]$$

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Propagation Path-loss model—

→ Propagation path loss models are used to calculate transmisson power, frequency, antenna height, losses.

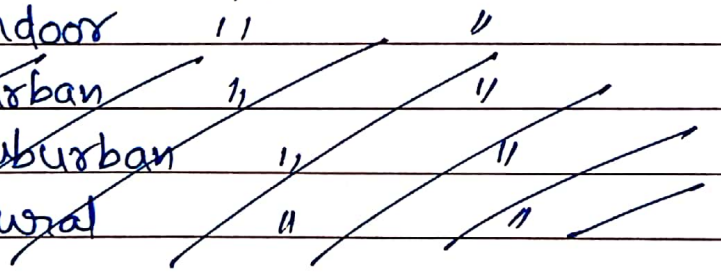
→ It also helps in predictions of interference, handoff optimization, power level adjustments, antenna placements.

→ Hence, propagation path loss model is used to design the mobile systems.

→ for different environment, different propagation models are used.

→ Some propagation path loss models are

1. outdoor propagation model
2. Indoor
3. Urban
4. Suburban
5. Rural



outdoor propagation model —

→ Radio transmission in a mobile communications system often take place over irregular terrain. The terrain profile of a particular area needs to be taken into account for estimating the path loss.

→ The terrain profile may vary from a simple curved earth profile to a highly mountainous profile.

→ The presence of trees, building, and other obstacles also must be taken into account.

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(i) Longley - Rice model
(ii) Durkin's model
(iii) Okumura model ✓
(iv) Hata model ✓
(v) PCS extension to hata model
(vi) Walfisch and Bertoni model
(vii) Wideband PCS microcell model

Okumura model –

→ Okumura's model is one of the most widely used models for signal prediction in urban areas.
→ frequencies in the range 150MHz to 1920MHz.
→ This model is applicable for distances 1Km to 100km and
→ It can be used for base station antenna heights ranging from 30m to 1000m.

→ This model is used in Europe and North America for Cellular system.
→ Okumura analyzed path-loss characteristics obtained from experimental data collected around Japan.

→ He obtained the average path loss curves for urban areas under several propagation path conditions.

→ Then he also applied several correction factors, such as antenna height, carrier frequency, diffraction loss due to mountains, sea or lake areas etc.

$$L_{50}(dB) = L_f + A_{mu}(f,d) - G(h_{te}) - G(h_{re}) - G_{AREA}$$

L_{50} → 50^{th} percentile (i.e. median) value of propagation path loss
L_f → free space propagation loss
A_{mu} → median attenuation relative to free space

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$G(h_{te})$ → Base station antenna height gain factor
$G(h_{re})$ → Mobile antenna height gain factor
G_{AREA} → Gain due to the type of Environment

→ Okumura's model is wholly based on measured data and does not provide any analytical explanation.

Hatta model →

→ The Hata model is an emperical formulation of the graphical path loss data provided by okumura and is valid from 150 MHz to 1500 MHz.

⇒

→ Hata presented the urban area propagation loss as a standard formula and supplied correction equations for application to other situations.

→ The standard formula for median path loss in urban area is given by

$$L_{50}(\text{urban})\ (dB) = 69.55 + 26.16 \log f_c - 13.82 \log h_{te} - a(h_{re}) + (44.9 - 6.55 \log h_{te}) \log d$$

where f_c is the frequency in MHz from 150MHz to 1500 MHz
h_{te} → effective transmitter (BS) antenna height (30m to 200m)
h_{re} → effective receiver (mobile) antenna height (in meters) (1m to 10m)

d → T-R separation distance in km
$a(h_{re})$ → correction factor for effective mobile antenna height which is a function of the size of the coverage area

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→ for a small to medium size city, the mobile antenna correction factor is given by,

$$a(h_{re}) = (1.1 \log f_c - 0.7) h_{re} - (1.56 \log f_c - 0.8) \text{ dB}$$

→ for a large city,

$$a(h_{re}) = 8.29 (\log 1.54 h_{re})^2 - 1.1 \text{ dB} \quad \text{for } f_c \leq 300 \text{ MHz}$$

$$a(h_{re}) = 3.2 (\log 11.75 h_{re})^2 - 4.97 \text{ dB} \quad \text{for } f_c \geq 300 \text{ MHz}$$

⇒ Path loss in suburban area,

$$L_{50}(dB) = L_{50}(\text{urban}) - 2[\log(f_c/28)]^2 - 5.4$$

→ Path loss in open rural areas,

$$L_{50}(dB) = L_{50}(\text{urban}) - 4.78 (\log f_c)^2 + 18.33 \log f_c - 40.94$$

→ Hata model is well suited for large cell mobile systems.

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① Partition losses (same floor)
② Partition losses between floor
③ Log-distance path loss model
④ Ericsson multiple breakpoint model
⑤ Attenuation factor model

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Indoor propagation model — (path loss within buildings)

→ The indoor radio channel differs from the traditional mobile radio channel in two aspects —
- The distances covered are much smaller
- The variability of the environment is much greater for a much smaller range of T-R seperation distances.

→ Propagation within buildings is strongly influenced by specific features such as the layout of the building, the construction materials and the building type.

→ Indoor radio propagation is dominated by the same mechanisms as outdoor: Reflection, diffraction and scattering. However, conditions are much more variable.

For example, signal levels vary greatly depending on whether interior doors are open or closed inside a building.

→ Antennas mounted at desk level in a partitioned office receive vastly different signals than those mounted on the ceiling.

→ In general, indoor channels may be classified either as line-of-sight (LOS) or obstructed (OBS), with varying degrees of clutter.

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Partition losses (same floor) —

→ Buildings have a wide variety of partitions and obstacles which from the internal and external structure.

→ Houses typically use a wood frame partition with plaster board to form internal walls and have wood or nonreinforced concrete between floors.

→ office buildings, have large open areas which are constructed by using moveable office partitions so that the space may be reconfigured easily and use metal reinforced concrete between floors.

→ Partitions that are formed as part of the building structure are called hard partitions.

→ Partitions that may be moved and which do not span to the ceiling are called soft partitions.

→ Partitions vary widely in their physical and electrical characteristics, making it difficult to apply general models to specific indoor installations.

→ Researchers have formed extensive data bases of losses for a great number of partitions.

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Partition losses between floors —

→ The losses between floors of a building are determined by the external dimensions and materials of the building, as well as the type of construction used to create the floors and the external surroundings.

→ Even the number of windows in a building and the presence of tinting (which attenuates radio energy) can impact the loss between floors.

→ The attenuation between one floor of the building is greater than the incremental attenuation caused by each additional floor.

→ After five or six floor separations, very little additional path loss is experienced.

Indoor path loss shown as,

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

(Path loss) ⇒ n → depends on the surroundings and building type

X_σ → normal random variable in dB having a standard deviation of σ dB.

d_0 → close in reference distance which is determined from measurements close to the transmitter

d → T-R separation distance

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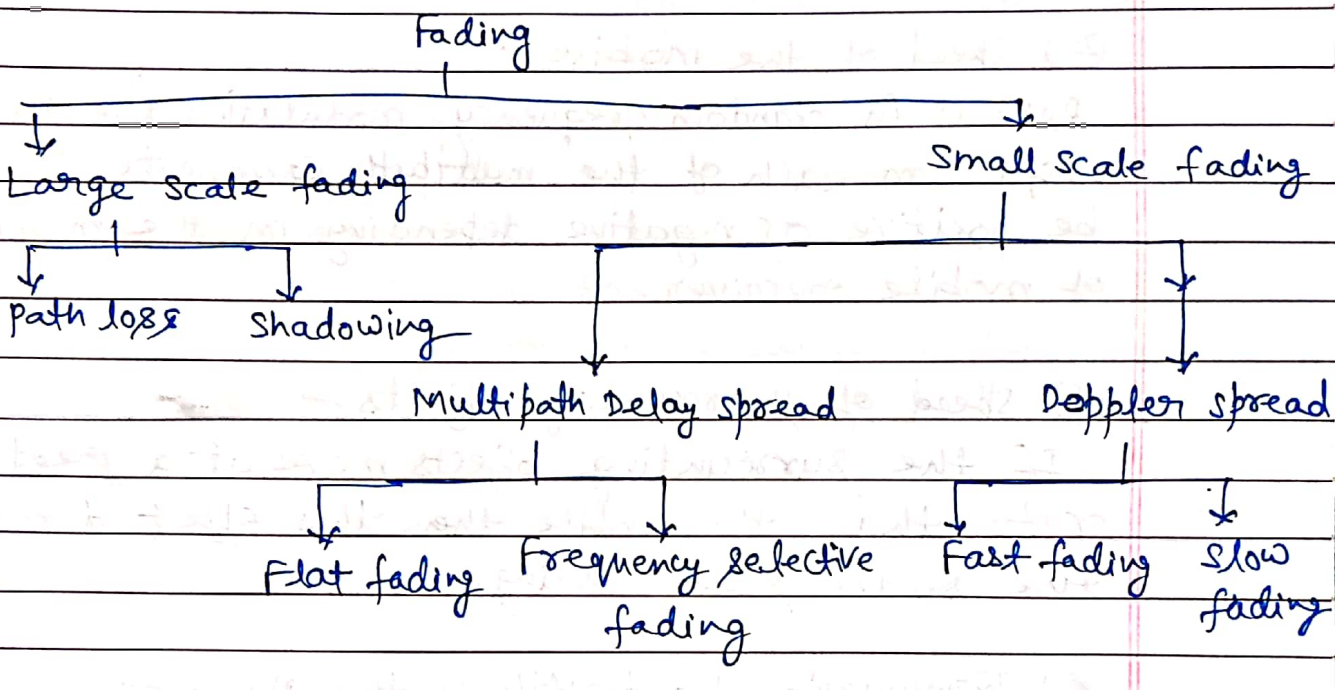
Fading —

The time variation of received signal power due to changes in transmission medium or paths is known as fading.



→ RF power spread over in the form of electromagnetic wave.

→ Receiver encounters with a number of RF waves, so there are number of delays in between Tx & Rx.

→ As path followed by all the received signals are not same, then the phase of those signals are also not same. Due to this change in path & phase, RF power may decrease and receiver does not get proper or any information as change in phase can add the signals or cancel the signals, this effect is known as fading.

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Factor influencing fading —

(1) Multipath propagation :- Multiple versions of the signal arrives at the receiver can cause signal smearing due to inter symbol interference.

(2) Speed of the mobile —
Results in random frequency modulation due to doppler shifts on each of the multipath components. It can be positive or negative depending on the movement of mobile receiver.

(3) Speed of surrounding objects —
If the surrounding objects move at a greater rate than the mobile then this effect dominates the small-scale fading.

(4) Transmission bandwidth of the signal —
→ The bandwidth of the multipath channel can be quantified by the coherence bandwidth.
→ The coherence bandwidth is a measure of the maximum frequency difference for which signals are still strongly correlated in amplitude.

Small scale fading —
Small scale fading or simply fading is used to describe the rapid fluctuations of the amplitude, phases or multipath delays of a radio signal over a short period of time or travel distance.

→ Characterize rapid fluctuations in the received signal strength over very short travel distance (a few wavelengths)

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→ Signal is the sum of many contributors coming from different directions. Thus phases of received signals are random and the sum behave like a noise (Rayleigh fading)

→ Received power may vary by as much as 3 or 4 orders of magnitude (30 or 40 dB)

Large scale fading —

Large scale fading is the result of signal attenuation due to signal propagation over large distances and diffraction around large objects in the propagation path.

→ Characterize signal strength for large T-R separation (Several hundreds or thousands of meters)

→ Compute local average received power by averaging signal measurements over a track of 5λ to 40λ.

→ Received signal decreases gradually

→. Useful for estimating the coverage area of transmitters.

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① Large scale fading

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(1) Path loss –

Path loss shows the relation of received power strength vs distance. Some models consider terrain profile to get the received power strength and also others consider frequency and distance but the height of antennas has large effect on path loss models.

Log-distance path loss model –

Both theoretical and measurement-based propagation models indicate that average received signal power decreases logarithmically with distance.

→ The average large-scale path loss for an arbitrary Tx-Rx seperation is expressed as,

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

or

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

where, n → path loss exponent
d_0 → close-in reference distance
d → Tx-Rx seperation distance

Environment	Path loss exponent, n
Free space	2
Urban area cellular radio	2.7 to 3.5
Shadowed urban area 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

→ for free space, $n=2$, and if obstructions are present $n>2$

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→ In large coverage cellular systems, 1 km reference distance are commonly used, whereas in microcellular systems, much smaller distances (such as 100 m or 1m) are used.

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(ii) Shadowing model — (Log-normal shadowing) - Shadowing is the effect that the received signal power fluctuates due to material blockes in the propagation path between sender and receiver. obstacle can lead to shadowing of one or several multipath components. Any wave which reached at the receiver through or around the material is greatly attenuated.

→ In free space and two ray models, the received power is a deterministic function of distance, but received power at certain distance is random variable due to shadowing effect. It can be modeled as gaussian random variable, which is added to the mean loss to account environmental influence at the sender and the receiver.

→ In this model, it is assumed that the mean received power decreases logarithmically. It is long term fading (large scale fading) and so called log normal shadowing.

So path loss is,

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

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

→ Rayleigh distribution fading model
→ Rice distribution fading model
} other model like Gaussian

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② Small Scale fading

Doppler shift — Due to relative motion between Tx & Rx, there is frequency shift occurs in the received signal which is known as doppler-shift.

→ If the receiver moves towards the transmitter, the resultant frequency = $f + f_m$

→ If the receiver moves away from the transmitter, the resultant frequency = $f - f_m$.

→ The maximum doppler shift, f_m is given as

$$f_m = \frac{v}{\lambda}$$

$$\boxed{f_m = \frac{v}{c/f}}$$

where, c = velocity of RF waves in free space

v = Velocity of moving vehical (i.e. Receiver)

f = frequency of carriers (i.e. used frequency)

Delay spread — The time between the reception of the first signal and the last echoed signal is called delay spread.

Time dispersion — Due to multipath propagation, doppler shift, scattering or reflection from objects, one frequency component changes into multiple frequency component and arrive at receiver with different time, is known as time dispersion.
and undergo different attenuation & dispersion.

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Frequency selective fading —
changing of one frequency component signal into multiple number of frequency components signals due to multipath propagation (dispersion) it's known as frequency dispersion and arriving of these multiple frequency component at receiver with different times is known as time dispersion.

Coherence bandwidth —
The frequency band over which attenuation remains constant and all frequency components behave identically then that frequencyband is known as coherence bandwidth ~~of the channel~~.

→ If coherence bandwidth, B_c of the channel is smaller than the signal modulation bandwidth (B_w), then time dispersion occurs and this time dispersion leads to ISI (Inter symbol interference)

ISI — when the energy of one symbol spills over into another symbol or when frequency component of Con symbols overlap with each other then it is known as ISI.

→ ISI increases bit error rate (BER)

Coherence time —
Time over which channel impulse response is constant, known coherence time or invarient.

→ The coherence time is inversely proportional to doppler ~~shift~~ spread.

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$$T_c = \frac{1}{2\pi f_m} = \frac{0.423}{f_m}$$

where, $f_m = \frac{v}{\lambda} = \frac{v}{c/f}$

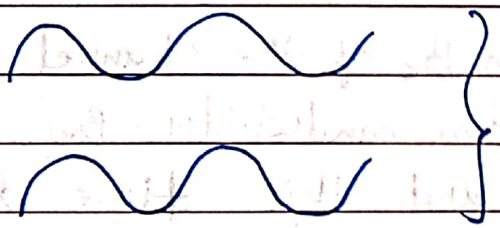
$v \rightarrow$ Velocity of moving vechicle

$f \rightarrow$ carrier frequency

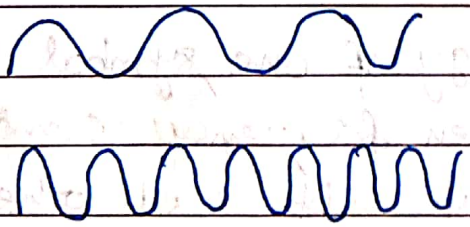
$c = 3 \times 10^8$ m/s

Coherence BW, $B_c = \frac{1}{2\pi \tau_d}$

where, $\tau_d \rightarrow$ rms delay spread in multipath delay by τ_d



Coherence i.e. must have same wavelength



Different wavelength

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Fading effects due to multipath time delay spread — Time dispersion due to multipath causes the transmitted signal to undergo either flat or frequency selective fading.

(Depends on propagation environment)

Small scale fading

(Based on multipath time delay spread)

Flat fading	Frequency selective fading
(i) → BW of signal < BW of channel	(i) → BW of signal > BW of channel
(ii) → Delay spread < symbol period	(ii) → Delay spread > Symbol period

→ ~~Due to multipath delay~~

Flat fading — The wireless channel is said to be flat fading if it has constant gain and linear phase response over a bandwidth which is greater than the bandwidth of the transmitted signal.

→ In this type of fading all the frequency components of the received signal fluctuate same proportions simultaneously, it is also known as non-selective fading.

Signal BW << Channel BW

Symbol period >> Delay spread

→ The effect of flat fading is seen as decrease in SNR. These flat fading channels are known as amplitude varying channels or narrowband channels.

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Frequency selective fading —

→ It affects different spectral components of a radio signal with different amplitudes. Hence the name selective fading.

Signal BW > Channel BW

symbol period < Delay spread

Small scale fading
(Based on doppler spread)

Fast fading	Slow fading
(i) High doppler spread	(i) Low doppler spread
(ii) Coherence time < Symbol period	(ii) Coherence time > Symbol period
(iii) Channel variation faster than baseband signal variations	(iii) Channel variation slower than baseband signal variations

Fast fading —

→ If the distance between Tx & Rx is less or Rx is in the coverage area of a Tx then suddenly there will be a distortion in the signals. This scenario is known as short term fading or fast fading
→ distance between Tx & Rx is about half of the wavelength

→ The phenomenon of fast fading is represented by rapid fluctuations of signal over small areas.

→ Fast fading occurs when channel impulse response changes very rapidly within the symbol duration.

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→ Fast fading is result of reflections of local objects and motion of objects relative to those objects.

→ Fast fading distorts the shape of baseband pulse.
→ This distortion is linear and create ISI. Adaptive equalization reduces ISI by removing linear distortion induced by channel.

Slow fading —
when Receiver moves away from transmitter or distance between Tx & Rx increases, the signal strength decreases slowly, this scenario is known as slow fading or long term fading.
i.e distance between Tx & Rx is in several kms.

→ Slow fading is result of shadowing of buildings, hills, mountains and other objects over the path.

→ Slow fading results in a loss of SNR. Error correction coding and receiver diversity techniques are used to overcome effects of slow fading.

Fast fading — Fast fading is a kind of fading occurring with small movements of a mobile or obstacle. Depending upon how rapidly the transmitted baseband signal changes as compared to the rate of change of the channel.
Slow fading — Slow fading is a kind of fading caused by larger obstructions within the propagation environment.

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Q: Calculate the received power at a distance of 3 km from the transmitter, if the path loss exponent n=4, Assume the transmitting power of 4 W at 1800 MHz, a shadow effect of 10.5 dB & the power at reference distance (d_o = 100 m) of −32 dBm.
What is the allowable path loss?

Sol: $d = 3\,km$, $n = 4$, $P_t = 4W$, $f = 1800\,MHz$,
$X_\sigma = 10.5\,dB$, $P_r(d_o) = -32\,dBm$,
$d_o = 100\,m$,
$P_r(d) = ?$

Allowable path loss $= P_t - P_r$

$P_t = 4W = 4000\,mW$
$= 10\log(4000) = 36.02\,dBm$

$P_r = P(d_o)\left(\frac{d_o}{d}\right)^n X_\sigma$

$P_r|_{dB} = 10\log P(d_o) + 10n\log\left(\frac{d_o}{d}\right) + 10\log X_\sigma$
$= -32 + 40\log\left(\frac{1}{30}\right) + 10.5$
$= -80.58\,dBm$

Allowable path loss $= P_t - P_r$
$= 36.02 - (-80.58)$
$= 116.6\,dBm$

Ans

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Q. Assume the speed of a vehicle is equal to 60 mph (88 ft/sec), carrier frequency, $f_c = 860$ MHz & rms delay spread $\tau = 2$ μsec.
Calculate coherence time & coherence Bandwidth at a coded symbol rate of 19.2 Kbps.
What kind of fading occurs?

Sol. $V = 60$ mph (88 ft/sec) 1 mile = 5280 ft

$f = 860$ MHz, $\tau_d = 2$ μsec

$$\lambda = \frac{c}{f} = \frac{3 \times 10^8}{860 \times 10^6} = 1.4442 \text{ ft}$$

maximum doppler shift, $f_m = \frac{V}{\lambda} = \frac{88}{1.1442} = 77$ Hz

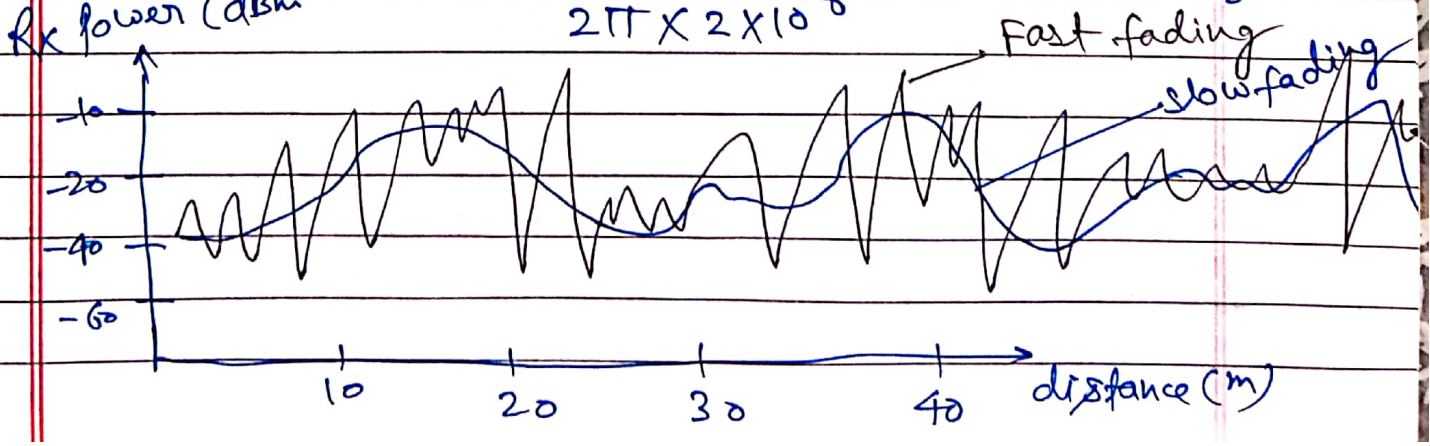
Coherence time, $T_c = \frac{1}{2\pi f_m} = 0.0021$ sec

symbol rate, $T_s = \frac{1}{19.2 \times 10^3} = 52$ μs

$T_c > T_s$ Slow fading

Coherence BW $= \frac{1}{2\pi \tau_d}$

$= \frac{1}{2\pi \times 2 \times 10^{-6}} = 79.56$ KHz



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