Large Scale Fading → Mean Signal Attenuation
→ Variations about mean

Affected by forests, billboards etc

Need to compute path loss as a function of distance → mean path loss (n th Power law)

Small Scale Fading (Rayleigh Fading) → due to motion between receiver & transmitter.

Affects signal amplitude & phase

Manifested in two ways:
- time spreading of signal (signal dispersion)
- time variant behaviour of channel

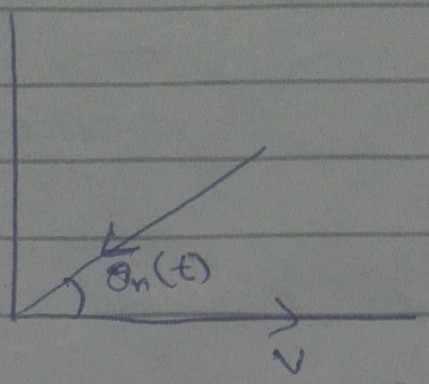
Channel is time-variant because propagation paths change due to motion b/w transmitter & receiver

if
— Many multipath,
— No line of sight components (non-fading components)
then
signal's envelope described by Rayleigh pdf.

Three ways that impact signal prop:
— Reflection
— Diffraction (shadowing)
— Scattering

Time Spread of signal → Time-delay domain desc
→ Frequency domain desc

Time Variance of the channel → Time-domain description
→ Doppler-Shift domain desc
→ fast & slow



$$f_{D,n}(t) = f_m \cos(\theta_n(t))$$

where

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

$$s(t) = Re\{u(t) \cdot e^{j2\pi f_c t}\}$$

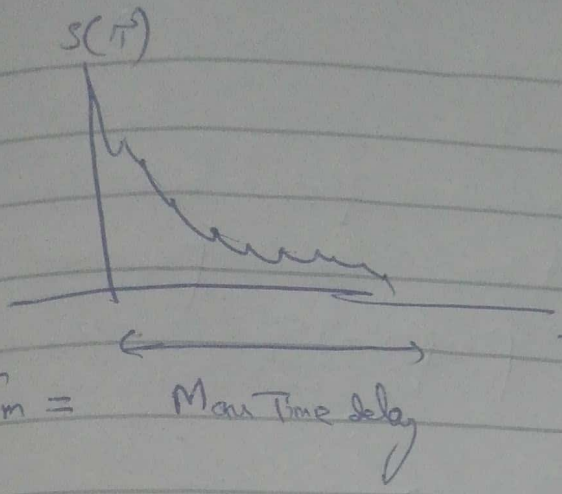
$$x(t) = Re\{r(t)\, e^{j2\pi f_c t}\}$$

where

$$r(t) = \sum_{n=1}^{N} \alpha_n(t)\, e^{-j2\pi\phi_n(t)}\, u(t - \tau_n(t))$$

where

$$\phi_n(t) = \left(f_c + f_{D,n}(t)\right)\tau_n(t) - f_{D,n}(t) \cdot t$$



$T_m > T_s$ → Frequency Selective (channel-induced ISI)

$T_m < T_s$ → Frequency non-selective

Channel Time Variant because path changes

Fast fading : channel fading characteristics change several time within symbol time, causing baseband pulse to be distorted

Mitigation :

Frequency Selective : equalization

equalization : make symbol energy back together into its original time.

Large Scale Fading:

Results in path loss which is reduction in power density as it propagates through space

$$L = 20 \log_{10}\left(\frac{4\pi d}{\lambda}\right) \text{ in dB}$$

$d = 2$ in free space
$d = 4$ for lossy environments

Small Scale Fading:

Also called Rayleigh Fading. Occurs when signal has multiple pathways to reach receiver.

Occurs in two ways
- Time Spreading of signal
- Time Variancy of channel.

Time Spreading of Signal:

At a single instant of time multiple delayed versions of the same signal arrives with different powers.

Two variants.

- Frequency Selective:

If max delay of the received signal exceeds symbol time hence having an effect of ISI.

- Frequency Non-Selective

No ISI. Need to improve SNR because of destructive interference.

Time Variance of Channel:

- Fast-fading: When channel coherence time is less than symbol time. Coherence time is the time in which channel behaves in a correlated way. Hence in fast-fading channel will change several times during a single symbol time. duration. which changes baseband symbol.

- Slow fading:
$T_0 > T_s$
Channel remains unchanged during single symbol time duration.

Mitigation Methods: (Frequency selective)

- For Frequency-selective:
Equalizers:
gathers symbol energy back to within symbol time duration.
Need to design a filter which when combined with channel give flat response.
Since channel is varying adaptive filter required.

- Decision Feedback Equalizer:
Predicts the ISI induced by current detected symbol on future received symbols.

- Max-Likelihood Seq. Estimation (MLSE)
Checks all possible data sequences and selects most probable in them.

— Rake receiver :
Uses a separate correlator for each multipath component.

Mitigation for Fast Fading :

— Add signal redundancy for increasing signal rate than fading rate.

— Error correcting codes. Reduces required SNR.

Mitigation for decreasing loss in SNR

— Time diversity :
Transmit signal on specified number of diff: time slots.

— Freq: diversity :
Transmit signal on specified numbers of diff: carriers.

— Spatial diversity :
Using multiple receivers.

— Polarization diversity.