FADING

- **Small Scale Fading**
- **Link Budget**

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Definition

- Refers to mathematical models for the distortion.
- Rapid fluctuation of the Amplitudes, Phases, or multipath delay of a radio signal.
- Caused by interference between two or more versions of transmitted signal.
- Called Multipath waves, combine at the receiver antenna to give resultant signal.
- It may also be caused by attenuation of a single signal.
- For Example: Stopping at traffic lights and hearing lot of static noises on radio.

Small Scale Fading

- Propagation models that characterize the rapid fluctuations of the received signal strength over very short travel distances (a few wavelength) or short time durations (on the order of seconds) are called Small-Scale Fading.

Small Scale Multipath Propagation

- Three most important effects are:
  - Rapid changes in signal strength over a small travel distance or time interval.
  - Random frequency modulation due to varying Doppler shifts on different multipath signal.
  - Time dispersion (echoes) caused by multipath propagation delays.

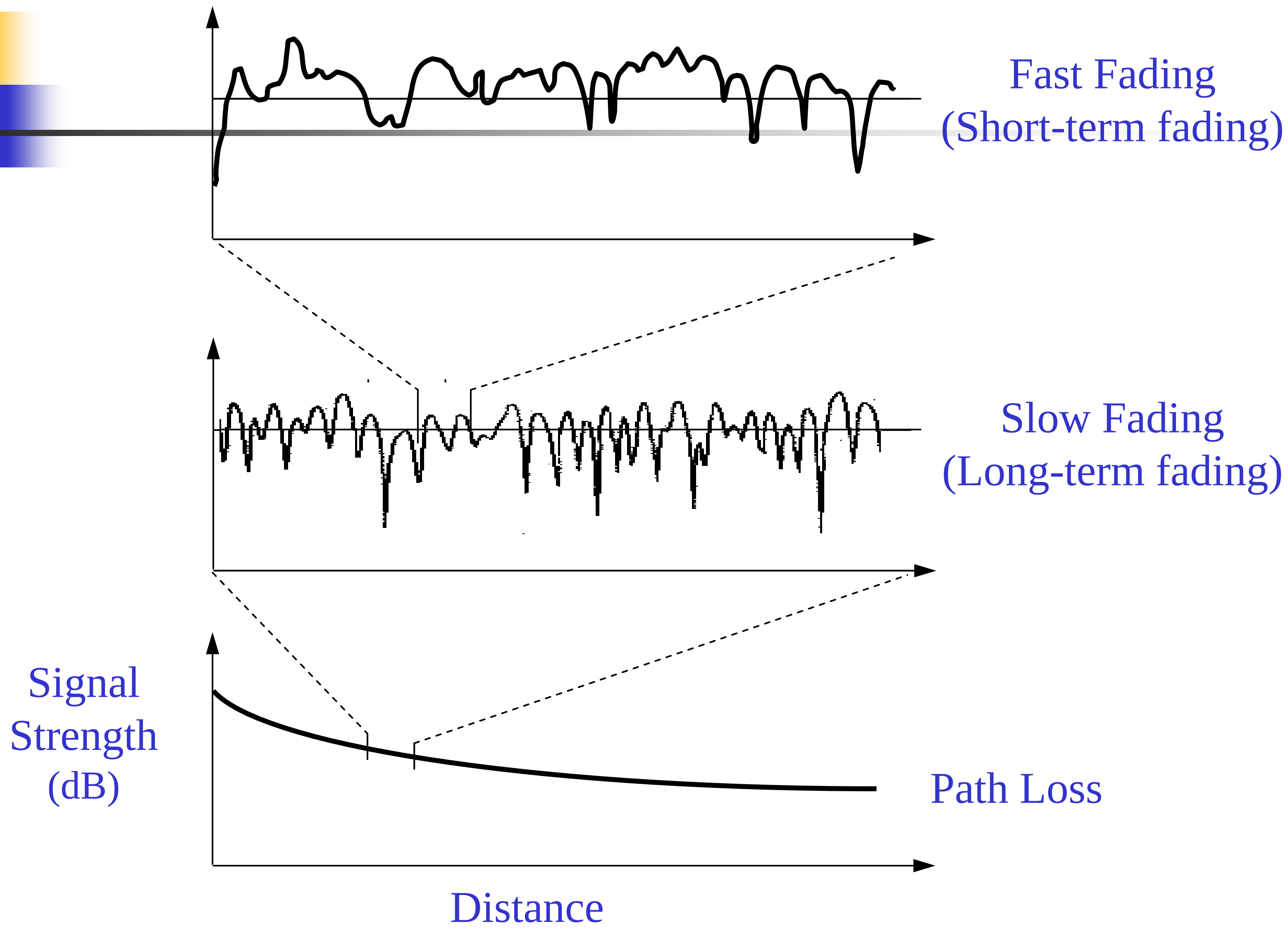
Factors Influencing

- Multipath propagation
  - Presence of reflecting objects.
  - Result in multiple version.
  - Fluctuations in signal strength.
- Speed of Mobile
  - Relative motion between the base station and the mobile.
  - Doppler shift will be positive or negative.
- Speed of surrounding objects.
  - Surrounding objects move at a greater rate than the mobile.
- Transmission bandwidth of the signal
  - If transmitted radio signal bandwidth is greater than the bandwidth of the multipath channel.

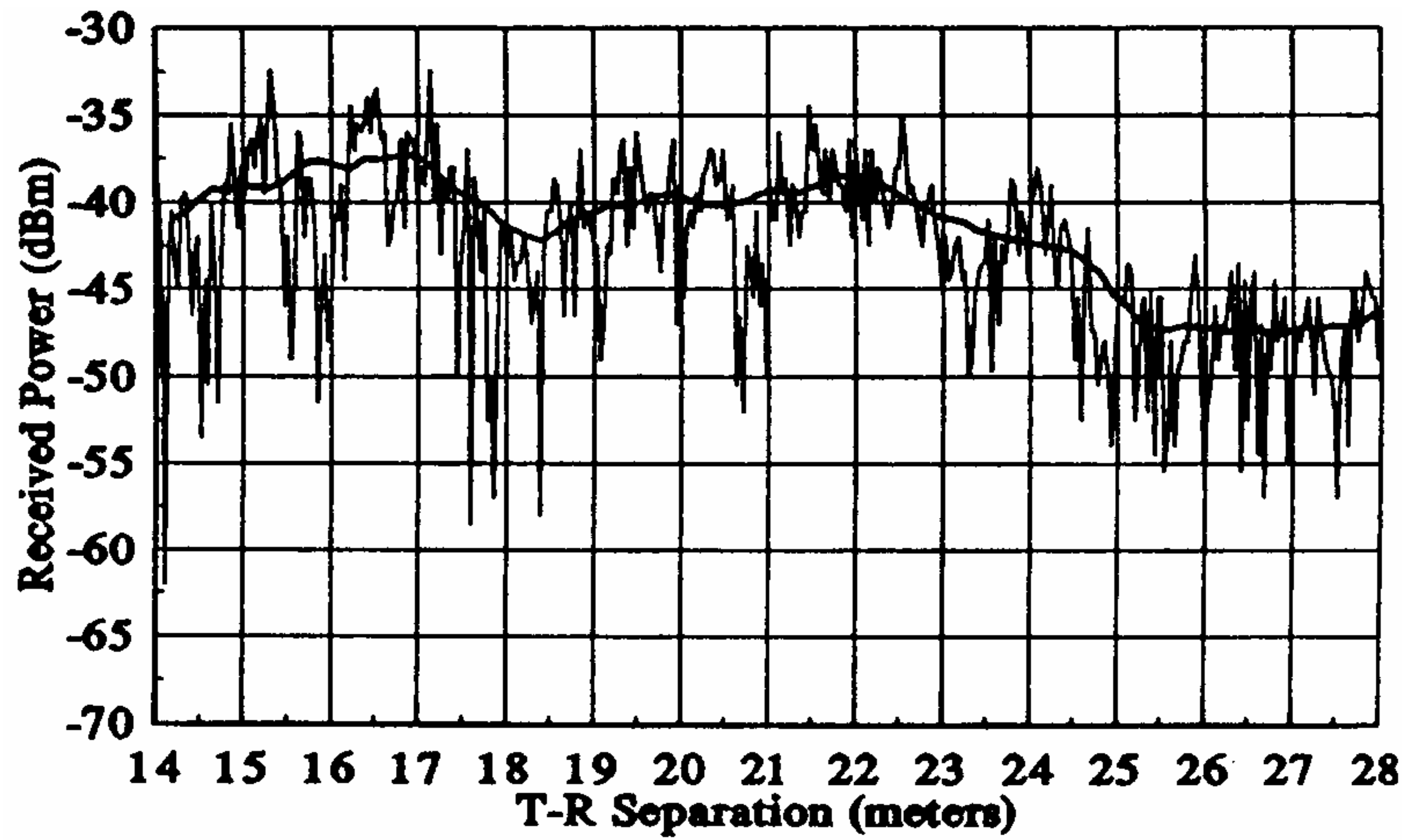
Large Scale Propagation

- Propagation models that predict the mean signal strength for an arbitrary transmitter-receiver separation distances are useful in estimating the radio coverage area of a transmitter and are called Large-Scale propagation.

Fading


Fast Fading
(Short-term fading)
Slow Fading
(Long-term fading)
Signal
Strength
(dB)
Path Loss
Distance

Small Scale and Large Scale Fading



Doppler Shift

- Doppler Effect: When a wave source and a receiver are moving towards each other, the frequency of the received signal will not be the same as the source.
  - When they are moving toward each other, the frequency of the received signal is higher than the source.
  - When they are opposing each other, the frequency decreases.

  Thus, the frequency of the received signal is

$$f_R = f_C - f_D$$

- where f_C is the frequency of source carrier,

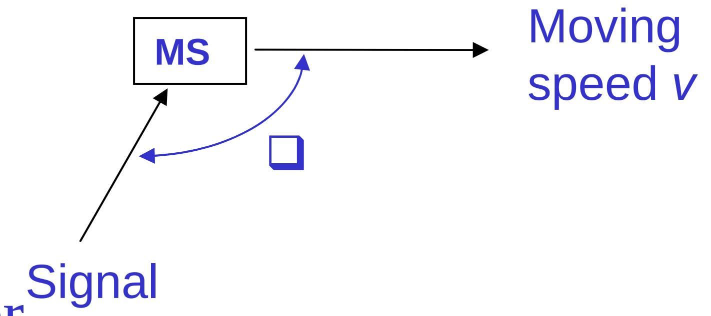
  f_D is the Doppler frequency.

- Doppler Shift in frequency:

$$f_D = \frac{v}{\lambda}\cos\theta$$

where v is the moving speed,

λ is the wavelength of carrier.



Doppler Shift

$$f_d = (v/\lambda)\ .\ \text{Cos}\ \theta$$

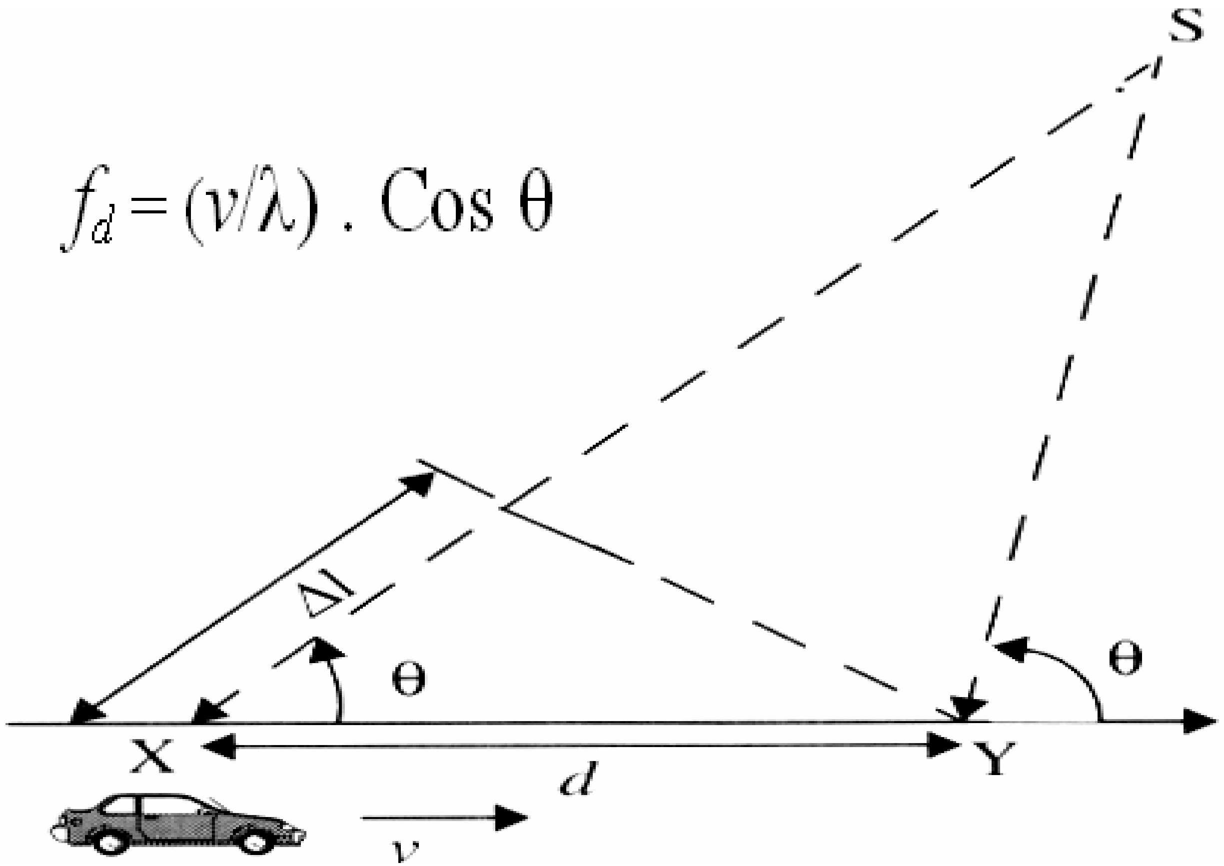


Illustration of Doppler effect.

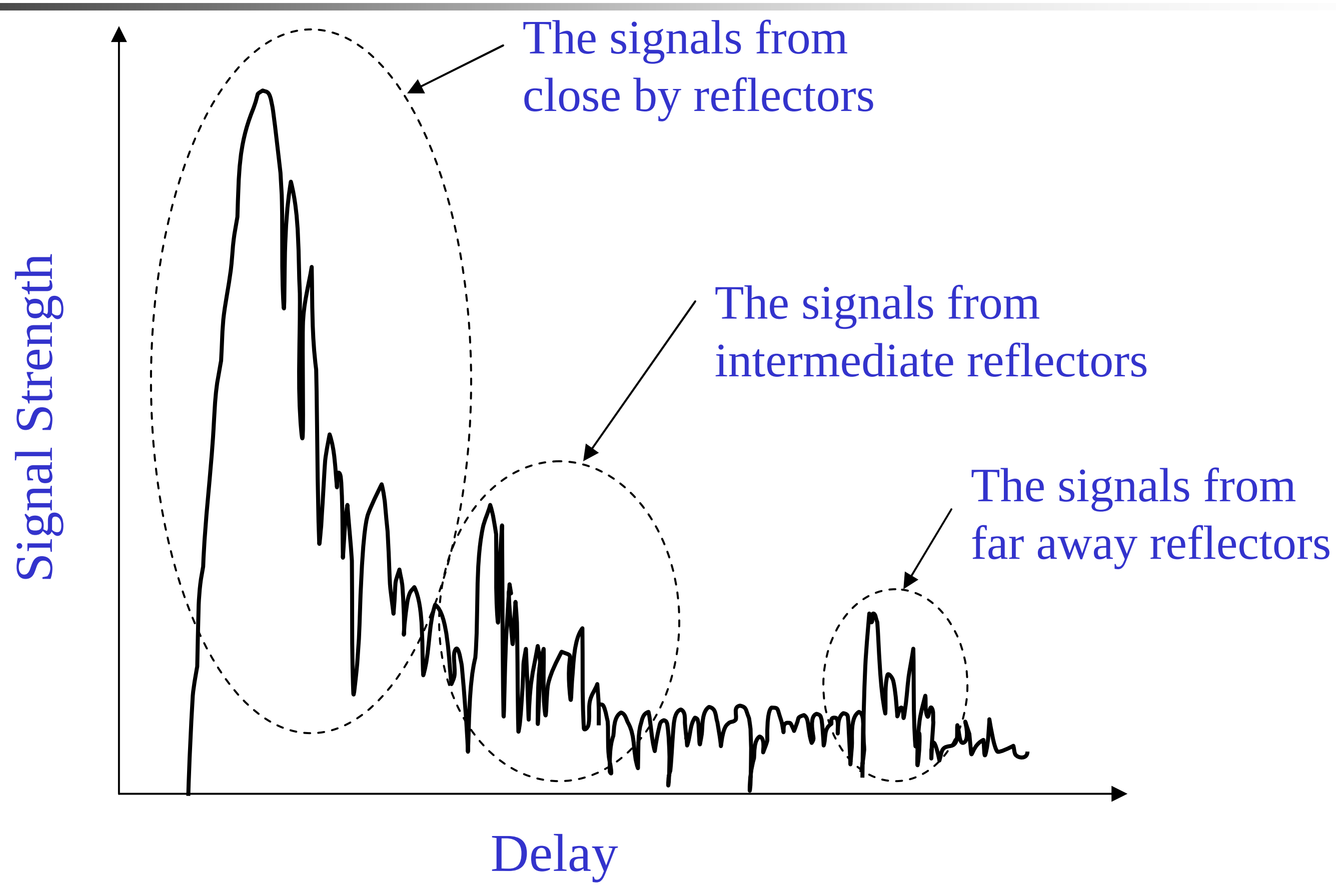
Numerical

- Consider a transmitter which radiates a sinusoidal carrier frequency of 1850 MHz. For a vehicle moving 60 mph, compute the received carrier frequency if the mobile is moving (a) directly toward the transmitter, (b) directly away from the transmitter, and (c) in a direction which is perpendicular to the direction of arrival of the transmitted signal.

Delay Spread

- When a signal propagates from a transmitter to a receiver, signal suffers one or more reflections.
- This forces signal to follow different paths.
- Each path has different path length, so the time of arrival for each path is different.
- This effect which spreads out the signal is called “Delay Spread”.

Delay Spread



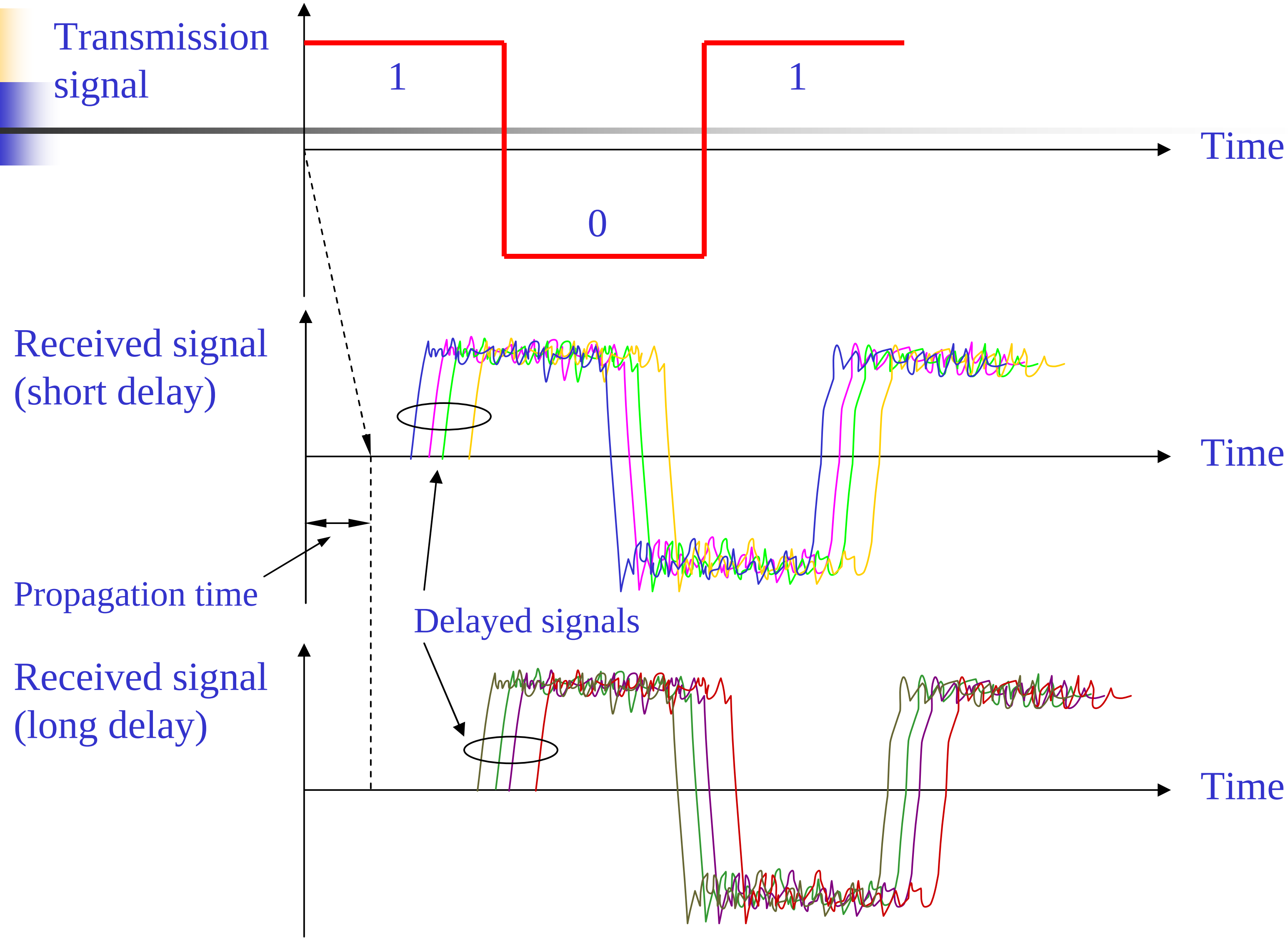
Intersymbol Interference (ISI)

- ISI means that consecutive symbols interfere with each other and it gets difficult on the receiver side to decide which actual symbol is detected (or actually, sent).
- Caused by time delayed multipath signals
- Has impact on burst error rate of channel
- Second multipath is delayed and is received during next symbol

$$R < \frac{1}{2\tau_d}$$

- For low bit-error-rate (BER)
- *R* (digital transmission rate) limited by delay spread τ_d.

Intersymbol Interference (ISI)



Time dispersion

- The introduction of digital transmission brings another problem: time dispersion.

- This also has its origin in reflections, but in contrast to multipath fading, the reflected signal comes from an object far away from the Rx– antenna, say in the order of kilometers.

- The time dispersion causes Inter Symbol Interference (ISI).

Types of Small Scale Fading

- Fading, experienced by signal propagation through Mobile radio channel.
- Depends on transmitted signal nature and characteristic of channel.
- Signal parameters:
  - Bandwidth
  - Symbol period
- Channel parameters:
  - rms delay spread
  - Doppler spread
- Types are:
  - Multipath delay spread (Time dispersion and Frequency selective fading)
  - Doppler spread (Frequency dispersion and Time selective fading)

Two Independent Fading Issues

Small-Scale Fading
(Based on multipath time delay spread)

Flat Fading

1. BW of signal < BW of channel
2. Delay spread < Symbol period

Frequency Selective Fading

1. BW of signal > BW of channel
2. Delay spread > Symbol period

Small-Scale Fading
(Based on Doppler spread)

Fast Fading

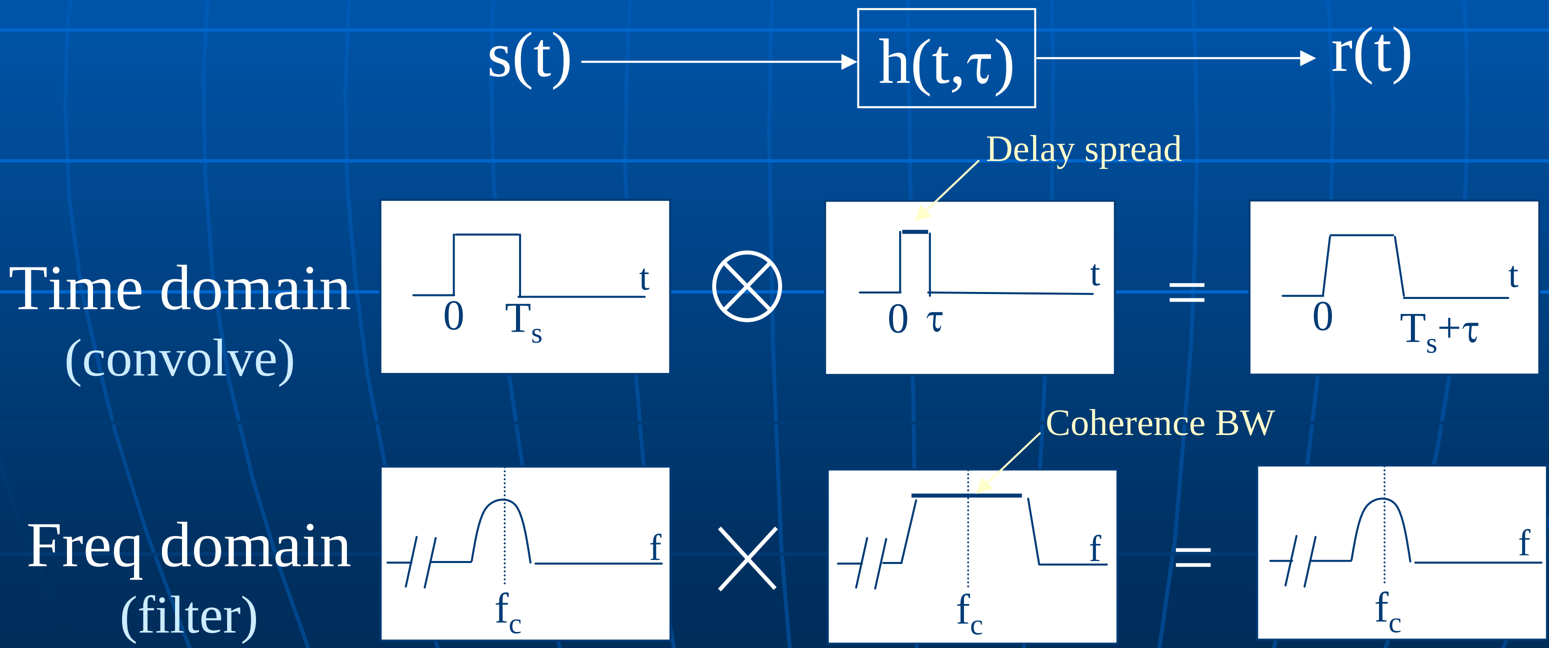
1. High Doppler spread
2. Coherence time < Symbol period
3. Channel variations faster than base-band signal variations

Slow Fading

1. Low Doppler spread
2. Coherence time > Symbol period
3. Channel variations slower than baseband signal variations

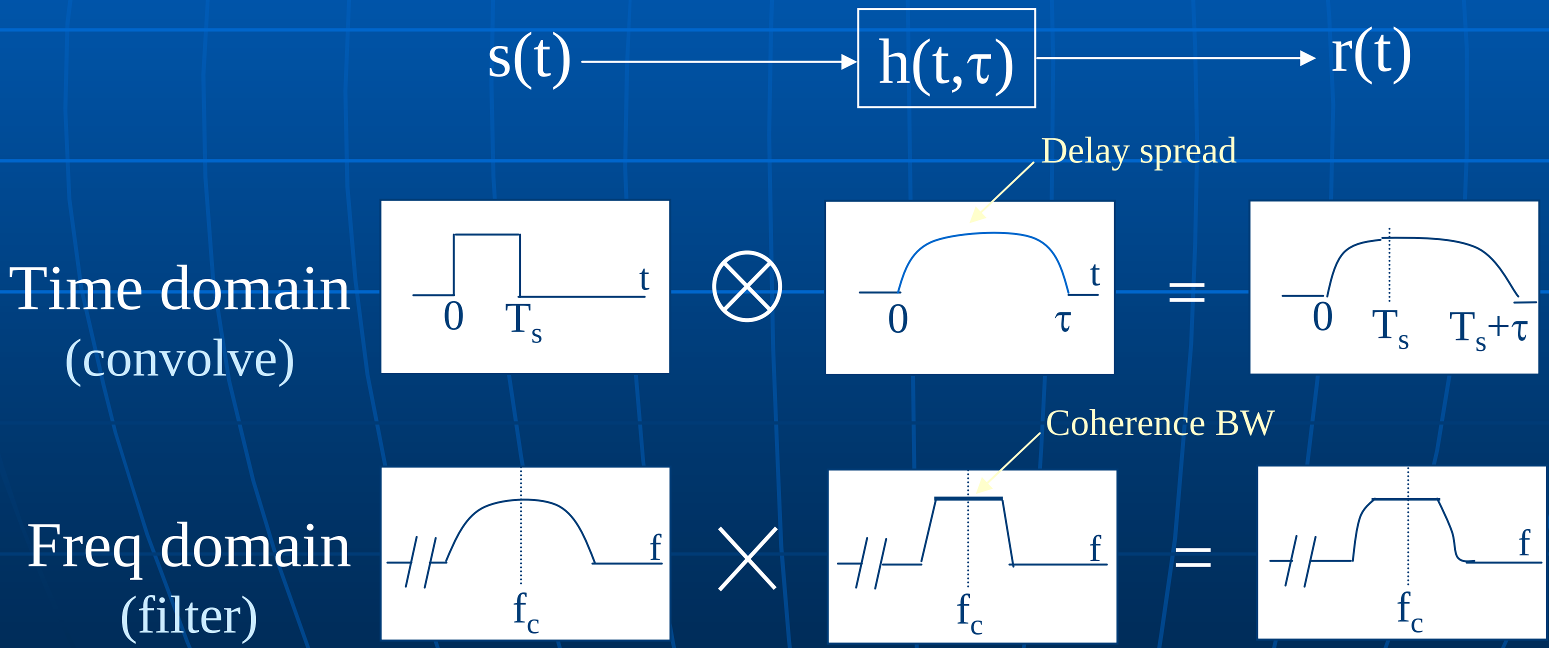
Flat Fading

- $T >> \tau_d$ and $W << B_C \Rightarrow$ minimal ISI



Frequency Selective Fading

- $T << \tau_d$ and $W >> B_C \Rightarrow$ ISI



Types of Fading on Doppler Spread

- Fast Fading
- Slow Fading

Fast Fading

- Fast fading or multipath or small-scale fading occurring with small movements of a mobile
- Channel Impulse Response changes rapidly with the symbol duration period.
- Coherence Time of channel is less than symbol period of the transmitted signal.
- Causes Frequency dispersion and signal is distorted.
- $T_s > T_c$

And $B_s < B_D$

Slow Fading

- Slow fading or shadowing or large-scale fading caused by larger movements of mobile or obstructions within the propagation environment.
- Channel impulse response changes at a rate much slower than the transmitted signal.
- $T_s << T_c$

And $B_s >> B_D$

Fading Examples

- Rayleigh Fading
- Rician Fading

Rayleigh Fading

- Statistical model for the effect of propagation on radio signal.
- Ideal model for tropospheric and ionospheric signal propagation.
- As well as the effect of heavily built-up urban environments on radio signal.
- Rayleigh fading most applicable when there is no line of sight.

Rician Fading

- Causes of multipath include atmospheric ducting, ionospheric reflection and refraction, and reflection from terrestrial objects, such as mountains and buildings.
- Effects of multipath include constructive and destructive interference and phase shifting of the signal.
- Rayleigh fading with strong line of sight content is said to have a Rician distribution, or to be Rician fading.

Rician Fading (Contd.)

- Digital radio communication multipath can cause errors and effect the quality of communication.
- Errors due to intersymbol Interference.
- Equalizers are often used to correct ISI.
- Alternatively OFDM and Rake Receiver may be used.

Fade Margin

- Design Allowance that provides sufficient system gain or sensitivity to accommodate expected fading.
- Purpose of ensuring that the required quality of service is maintained.
- Maintain specified threshold value.

Link Budget

- A link budget is the accounting of all of the gains and losses from the transmitter, through the medium (free space, cable, waveguide, fiber, etc.) to the receiver in a telecommunication system. It takes transmitted signal attenuation, loss or gains due to the antenna.
- Simple link budget equation looks like this:

Received Power (dBm) = Transmitted Power (dBm) + Gains (dB) − Losses (dB)

Link Budget (contd.)

- For a line of sight radio system, a link budget equation might look like this:
- where:

  PRX = power received (dBm)

  PTX = transmitter output power (dBm)

  GTX = transmitter antenna gain (dBi)

  LTX = transmitter losses (coax, connectors...) (dB)

  LFS = free space loss or path loss (dB)

  LM = miscellaneous losses (fading margin, polarization mismatch, other losses...) (dB)
  GRX = receiver antenna gain (dBi) *LRX* = receiver losses (coax, connectors...) (dB)