INTEGRATED TECHNICAL EDUCATION CLUSTER
AT ALAMEERIA

E-716-A
Mobile Communications Systems

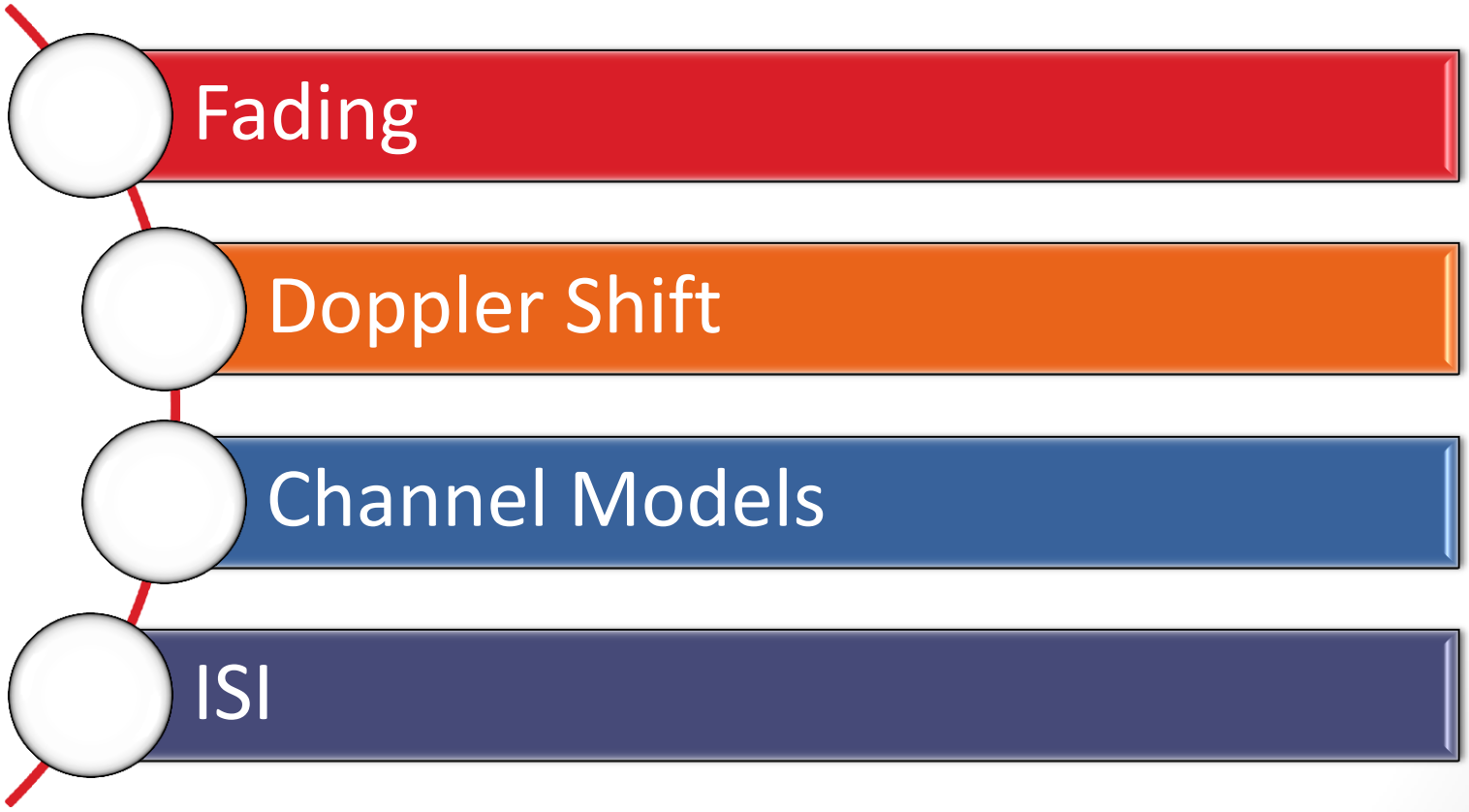
Lecture #11
Effects of Mobile Radio Propagation (p2)

Instructor:

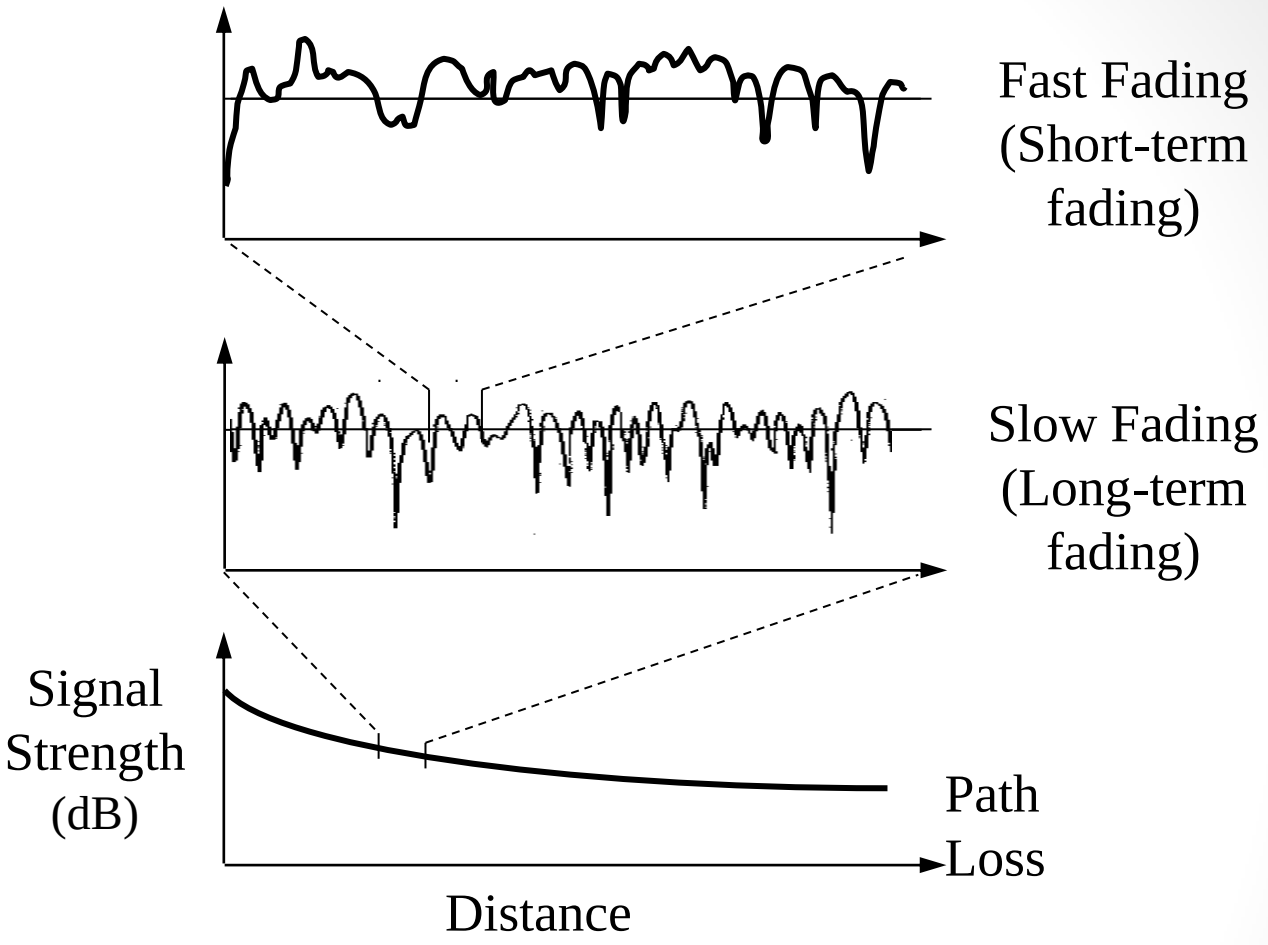
Dr. Ahmad El-Banna

JANUARY 2015

Agenda



Fading



- Large-scale fading (shadowing)
  - Long term variation in the mean signal level caused by the mobile unit moving into the shadow of surrounding objects
- Small-scale fading (multipath)
  - Short term fluctuation in the signal amplitude caused by the local multipath

Shadow Fading

- Shadow
- Long term
- Large Scale
- Log-normal
- Slow

- Long term shadow fading due to variations in radio signal power due to encounters with terrain obstructions such as hills or buildings.
- The measured signal power differ basically at different locations even though at the same radial distance from a transmitter.
- Represents the medium scale fluctuations of the radio signal strength over distances from tens to hundreds of meters.
- Many empirical studies demonstrate that the received mean power fluctuates about the average power with a log-normal distribution.
- Can be modeled by a Gaussian random variable with standard deviation σ.

Shadow fading..

- Log-normal distribution:

  - The pdf of the received signal level is given in decibels by

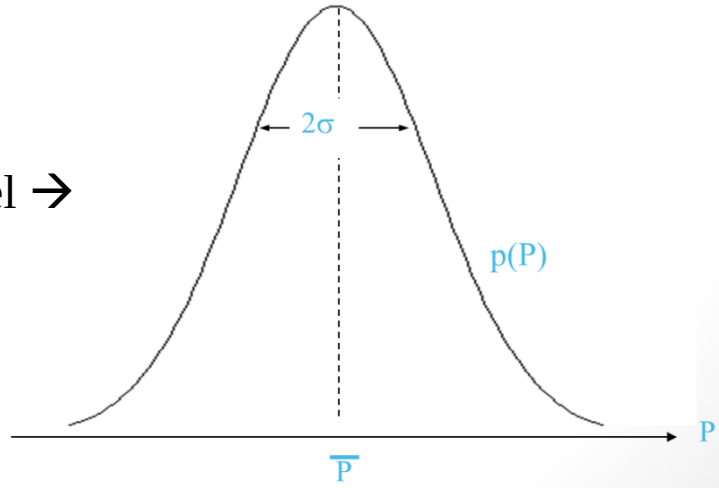
$$p(P) = \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{(P-\overline{P})^2}{2\sigma^2}}$$

where P is the true received signal level,

$\overline{P}$ is the area average (mean) signal level,

σ is the standard deviation

The pdf of the received signal level →

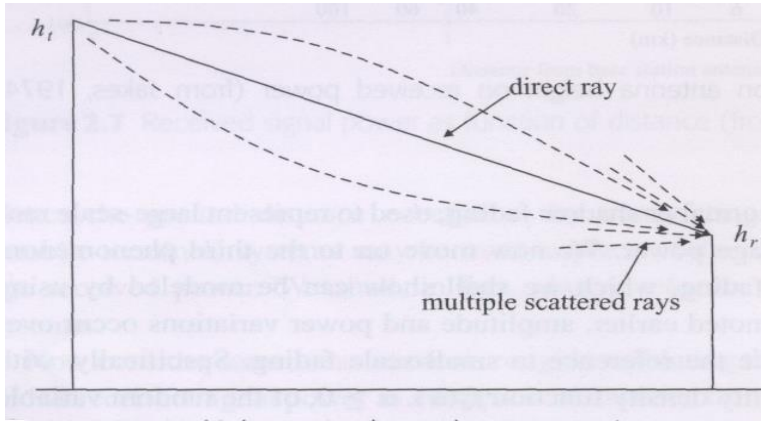


pdf : probability density function

Multipath Fading

- Multipath
- Short term
- Small Scale
- Fast

- A small scale fading that describes short-term, rapid amplitude fluctuations of the received signal during a short period of time.
- The actual power received over a much smaller distance vary considerably due to the destructive/constructive interference of multiple signals that follow multiple paths to the receiver.
- The direct ray is actually made up of many rays due to scattering multiple times by obstructions along its path, all travelling about the same distance.
- Each of these rays appearing at the receiver will differ randomly in amplitude and phase due to the scattering.



Multipath Fading..

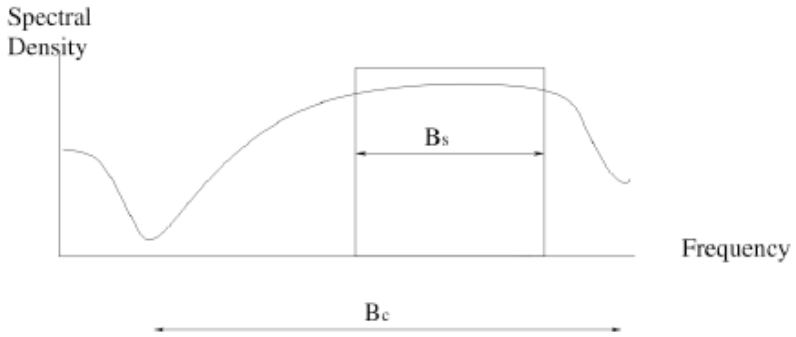
- Small-scale fading can be further classified into
  - Flat(or non-selective) Fading
  - Frequency Selective Fading

Flat fading

- Small-scale fading is defined as being flat if the received multipath components of a symbol do not extend beyond the symbol's time duration.
- If the delay of the multipath components with respect to the main component is smaller than the symbol's duration time, a channel is said to be subject to flat fading.

Flat Fading

- In a flat fading channel inter-symbol interference (ISI) is absent.
- The channel has a constant gain and a linear phase response over a bandwidth that is greater than the bandwidth of the transmitted signal.



- The spectral characteristics of the transmitted signal are preserved at the receiver.
- The channel does not cause any non-linear distortion due to time dispersion.
- However, the strength of the received signal generally changes slowly in time due to fluctuations caused by multipath.
- In a flat-fading channel, the bandwidth of the transmitted signal, Bs is much less than the Coherence bandwidth, Bc of the channel.

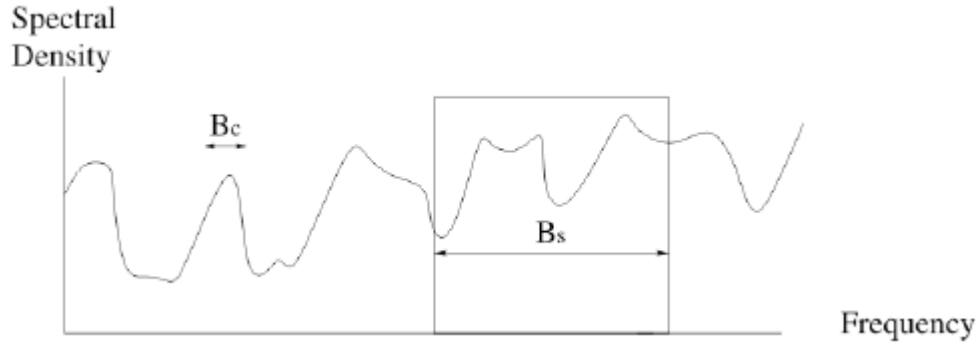
Frequency Selective Fading

- Small-scale fading is defined as being frequency selective if the received multipath components of a symbol extend beyond the symbol's time duration
- The effect of multipath fading on the reception of signals depends on the signal bandwidth.
- For relatively large bandwidth, different parts of the transmitted signal spectrum are attenuated differently.
- This is manifested in the inter-symbol interference (ISI)

- If the delay of the multipath components with respect to the main component is larger than the symbol's duration time, a channel is said to be subject to frequency selective fading
- The received signal includes multiple versions of the same symbol, each one attenuated (faded) and delayed.
- The received signal is distorted producing ISI.

Frequency Selective Fading..

- The channel has a constant gain and a linear phase response over a bandwidth that is much smaller than the bandwidth of the transmitted signal.



- The spectral characteristics of the transmitted signal are not preserved at the receiver
- Certain frequency components have larger gains than others.
- the bandwidth of the transmitted signal, Bs is much greater than the Coherence bandwidth of the channel Bc.

Multipath Fading Modeling

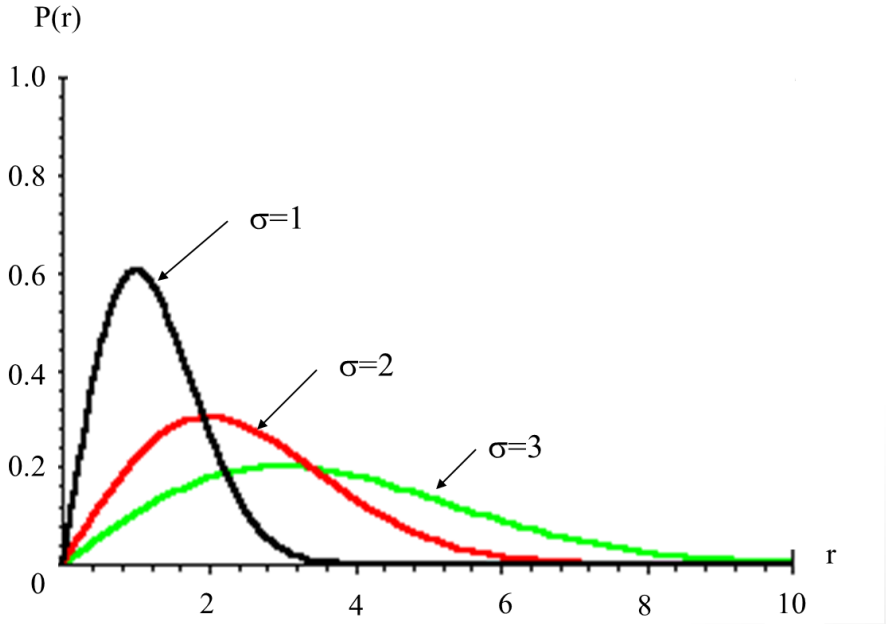
- For flat fading, it is found that the multipath can be modeled by using
  - Rayleigh statistics
  - Ricean statistics

- With Rayleigh statistics, the pdf of the random variable (r) is given by:

$$p(r) = \frac{r}{\sigma^2} e^{-\frac{r^2}{2\sigma^2}}, \quad r > 0$$

Rayleigh Fading

- Rayleigh fading is viewed as a reasonable model for urban environments where there are many objects in the environment that scatter the radio signal before it arrives at the receiver
- There is no dominant propagation along line of sight LOS between the transmitter and receiver.
- The envelope of the channel response will therefore be Rayleigh distributed.

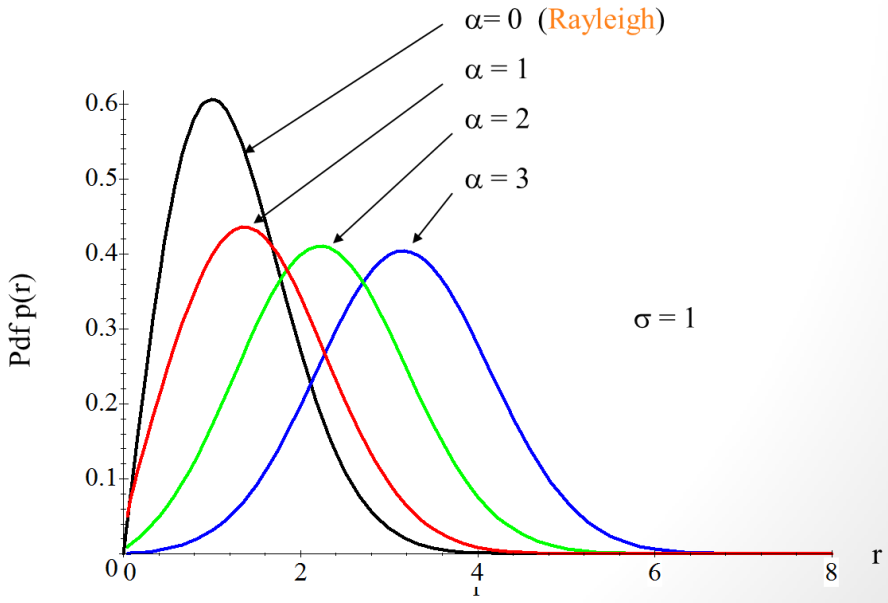


Rician Fading

- If the environment is such that, in addition to the scattering, there is a strongly dominant signal seen at the receiver, usually caused by a LOS, then the mean of the random process will no longer be zero, varying instead around the power-level of the dominant path.
- Such a situation may be better modeled as Rician fading.

$$p(r) = \frac{r}{\sigma^2} e^{-\frac{r^2+\alpha^2}{2\sigma^2}} I_0\left(\frac{r\alpha}{\sigma}\right), \quad r \geq 0$$

where:
σ is the standard deviation,
$I_0(x)$ is the zero-order Bessel function of the first kind,
α is the amplitude of the direct signal



Doppler shift

- Small-scale fading due to movements: Doppler shift
- How rapidly the channel fades will be affected by how fast the receiver and/or transmitter are moving .
- Motion causes Doppler shift in the received signal components
- It's the change in frequency of a wave for a receiver moving relative to the transmitter
  - 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.

Doppler shift

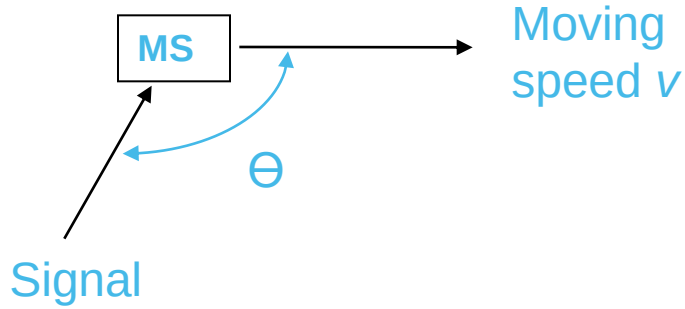
- Thus, the frequency of the received signal is

$$f_R = f_C - f_D$$

where f_C is the frequency of source carrier,
f_D is the Doppler frequency.

- Doppler Shift in frequency:

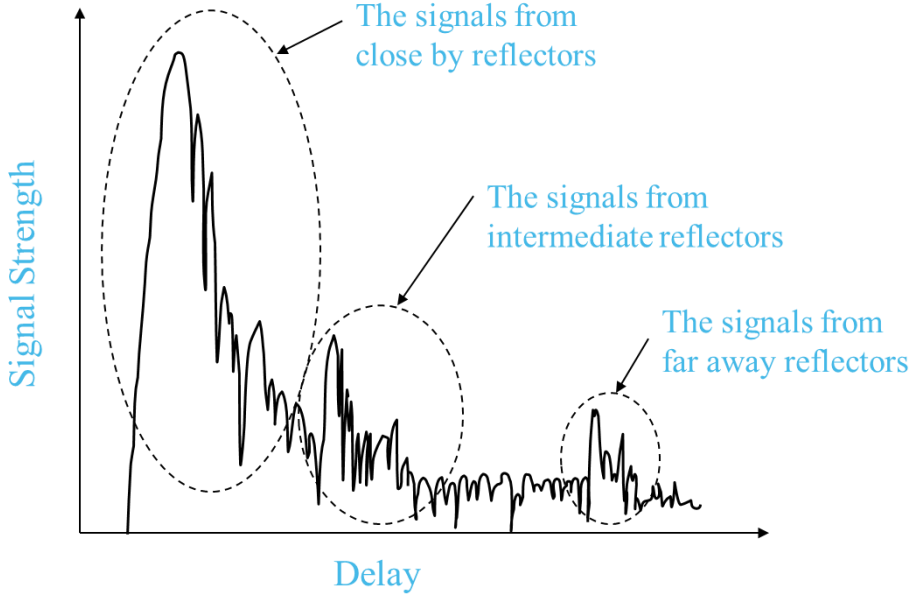
$$f_D = \frac{v}{\lambda}\cos\theta$$



where v is the moving speed,
λ is the wavelength of carrier.

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".



Fast and Slow Fading

- Slow or fast fading depends on the coherence time, Tc.
- Coherence time is the measure of period over which the fading process is correlated.
- Tc is related to the delay spread, Tc=1/ds
- The fading is said to be slow if the symbol duration, Ts is smaller than Tc the coherence time (or the bandwidth of the signal is greater than the Doppler spread).

Small-Scale Fading Summary

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

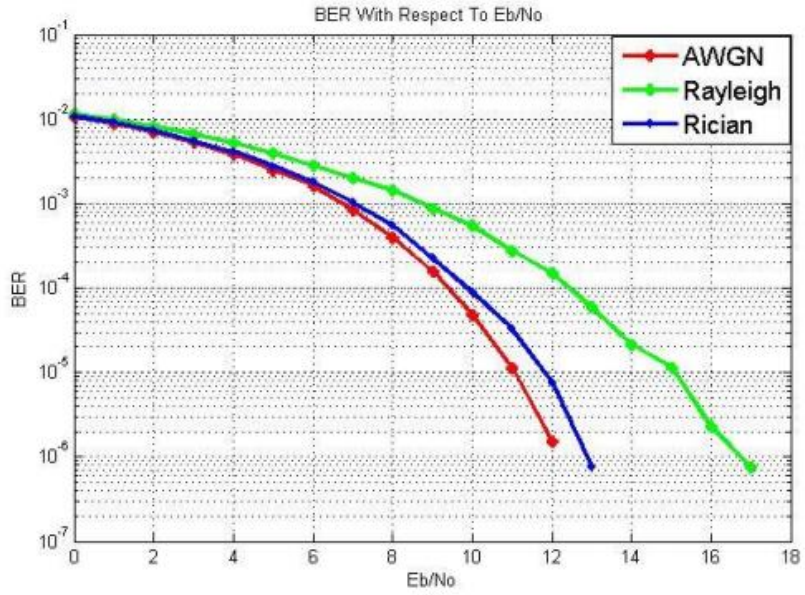
Small-Scale Fading
(Based on Doppler spread)

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

Channel Models Summary

- Gaussian →(Shadow Fading)
- Rician →(Multipath Flat Fading, LOS)
- Rayleigh →(Multipath Flat Fading, no LOS)



Bit error rate (BER) performance of AWGN, Raleigh and Rician channels for QAM modulation technique.

AWGN :
Additive White Gaussian Noise

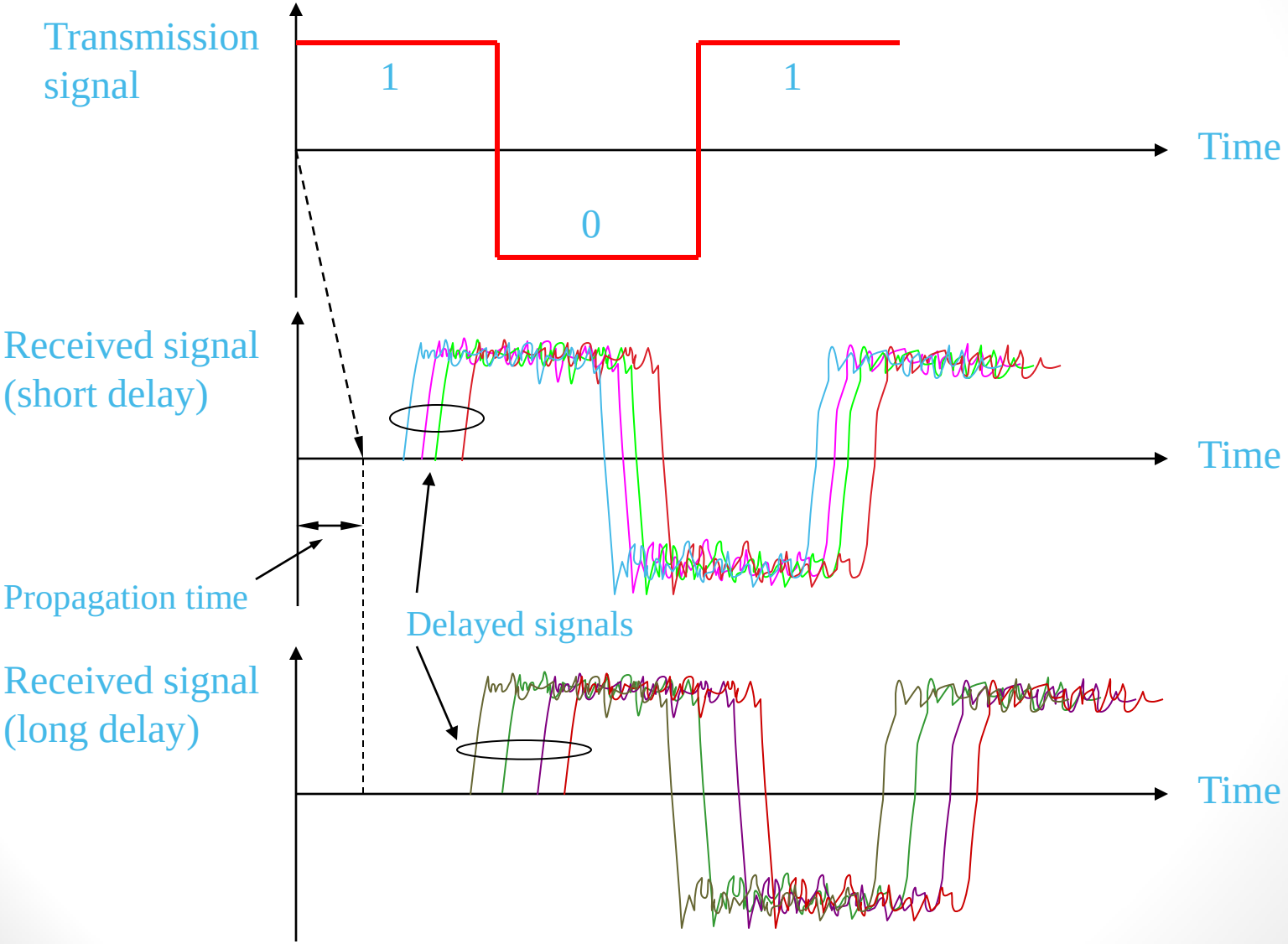
Inter Symbol Interference (ISI)

- Caused by time delayed multipath signals.
- Second multipath is delayed and is received during next symbol.
- For low bit-error-rate (BER)

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

- R (digital transmission rate) limited by delay spread t_d.

ISI..



- For more details, refer to:
  - A. Goldsmith, Wireless Communications, 2004.
  - T. Rappaport, Wireless Communications, principals and practice , 2002.
- The lecture is available online at:
  - https://speakerdeck.com/ahmad_elbanna
- For inquires, send to:
  - ahmad.elbanna@feng.bu.edu.eg