# SNS COLLEGE OF TECHNOLOGY

**Coimbatore – 35**

**An Autonomous Institution**

Accredited by NBA – AICTE and Accredited by NAAC – UGC with 'A+' Grade
Approved by AICTE, New Delhi & Affiliated to Anna University, Chennai

**DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING**


16EC401 / Wireless Communication

IV ECE/ VII SEMESTER

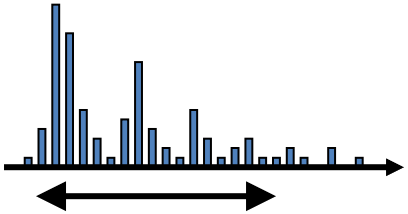
Unit IV **- MULTIPATH MITIGATION TECHNIQUES**

**Topic :** Error probability in fading channels With diversity reception

# Introduction

## *Narrowband system:*

Flat fading channel, single-tap channel model, performance enhancement through diversity



$$T >> T_m$$

$$T \propto W$$

↑ System bandwidth

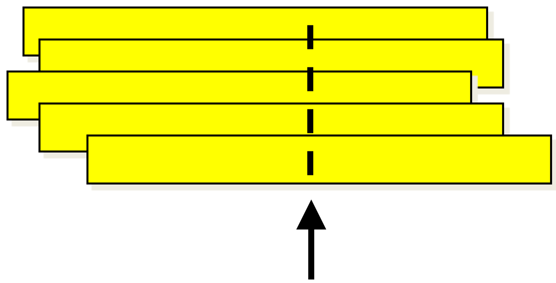
$T_m$ = delay spread of multipath channel

bit or symbol

← $T$ = bit or symbol duration →

# Introduction

Adjacent symbols (bits) do not affect the decision process (there is no intersymbol interference).

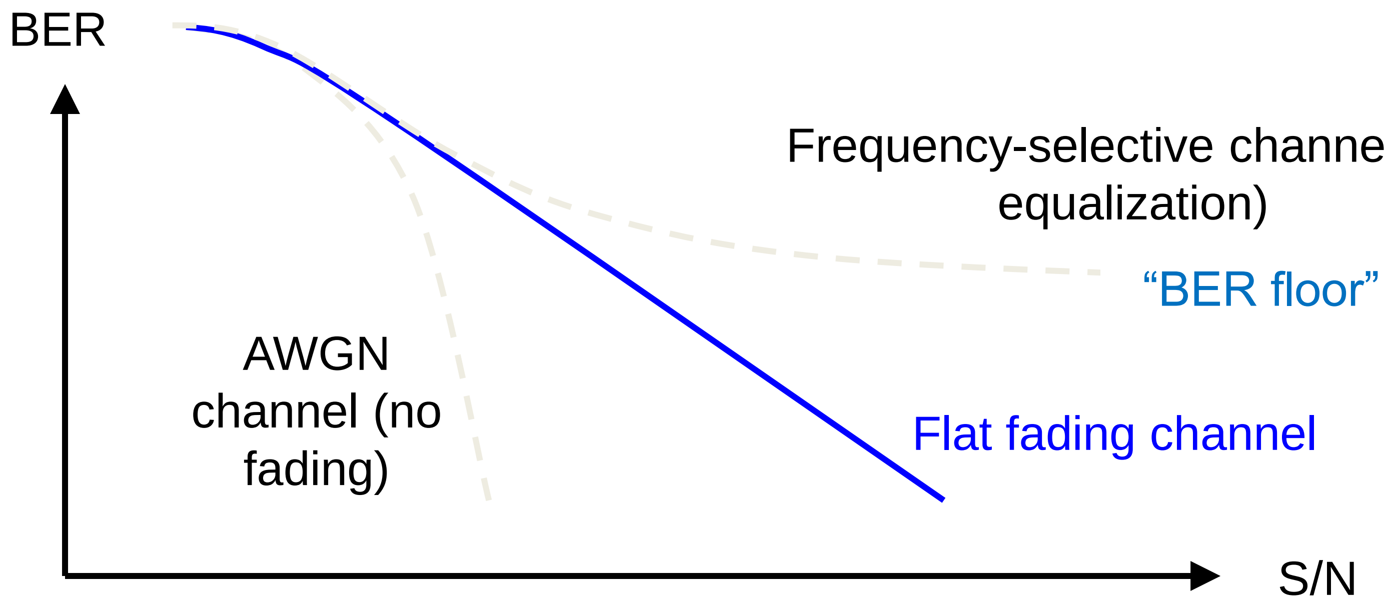


Received replicas of same symbol overlap in multipath channel

No intersymbol interference at decision time instant

However: Fading (destructive interference) is still possible

# Narrowband system: BER performance



# BER vs. SNR in a flat fading channel

In a flat fading channel (or narrowband system), the CIR (channel impulse response) reduces to a single impulse scaled by a time-varying complex coefficient.

The received (equivalent lowpass) signal is of the form

$$r(t) = a(t) e^{j\phi(t)} s(t) + n(t)$$

We assume that the phase changes "slowly" and can be perfectly tracked

=> important for coherent detection

# Activity

- Imagine folding a paper in half once
- Then take the result and fold it in half  again; and so on
- How many times can you do that?

# BER vs. SNR in a flat fading channel

We assume:

- The time-variant complex channel coefficient changes slowly (=> constant during a symbol interval)
- The channel coefficient magnitude (= attenuation factor) $a$ is a Rayleigh distributed random variable
- Coherent detection of a binary PSK signal (assuming ideal phase synchronization)

Let us define instantaneous SNR and average SNR:

$$\gamma = a^2 E_b / N_0 \qquad \gamma_0 = E\left\{a^2\right\} \cdot E_b / N_0$$

# BER vs. SNR in a flat fading channel

Since

$$p(a) = \frac{2a}{E\{a^2\}} e^{-a^2/E\{a^2\}} \qquad a \geq 0,$$

Rayleigh distribution

using

$$p(\gamma) = \frac{p(a)}{|d\gamma/da|}$$

we get

Exponential distribution

$$p(\gamma) = \frac{1}{\gamma_0} e^{-\gamma/\gamma_0} \qquad \gamma \geq 0.$$

# BER vs. SNR in a flat fading channel

The average bit error probability is

$$P_e = \int_0^\infty P_e(\gamma)\,p(\gamma)\,d\gamma$$

Important formula for obtaining statistical average

where the bit error probability for a certain value of $a$ is

$$P_e(\gamma) = Q\left(\sqrt{2a^2 E_b / N_0}\right) = Q\left(\sqrt{2\gamma}\right).$$

2-PSK

We thus get

$$P_e = \int_0^\infty Q\left(\sqrt{2\gamma}\right)\frac{1}{\gamma_0}e^{-\gamma/\gamma_0}\,d\gamma = \frac{1}{2}\left(1-\sqrt{\frac{\gamma_0}{1+\gamma_0}}\right).$$

# BER vs. SNR

Approximation for large values of average SNR is obtained in the following way. First, we write

$$P_e = \frac{1}{2}\left(1 - \sqrt{\frac{\gamma_0}{1+\gamma_0}}\right) = \frac{1}{2}\left(1 - \sqrt{1 + \frac{-1}{1+\gamma_0}}\right)$$

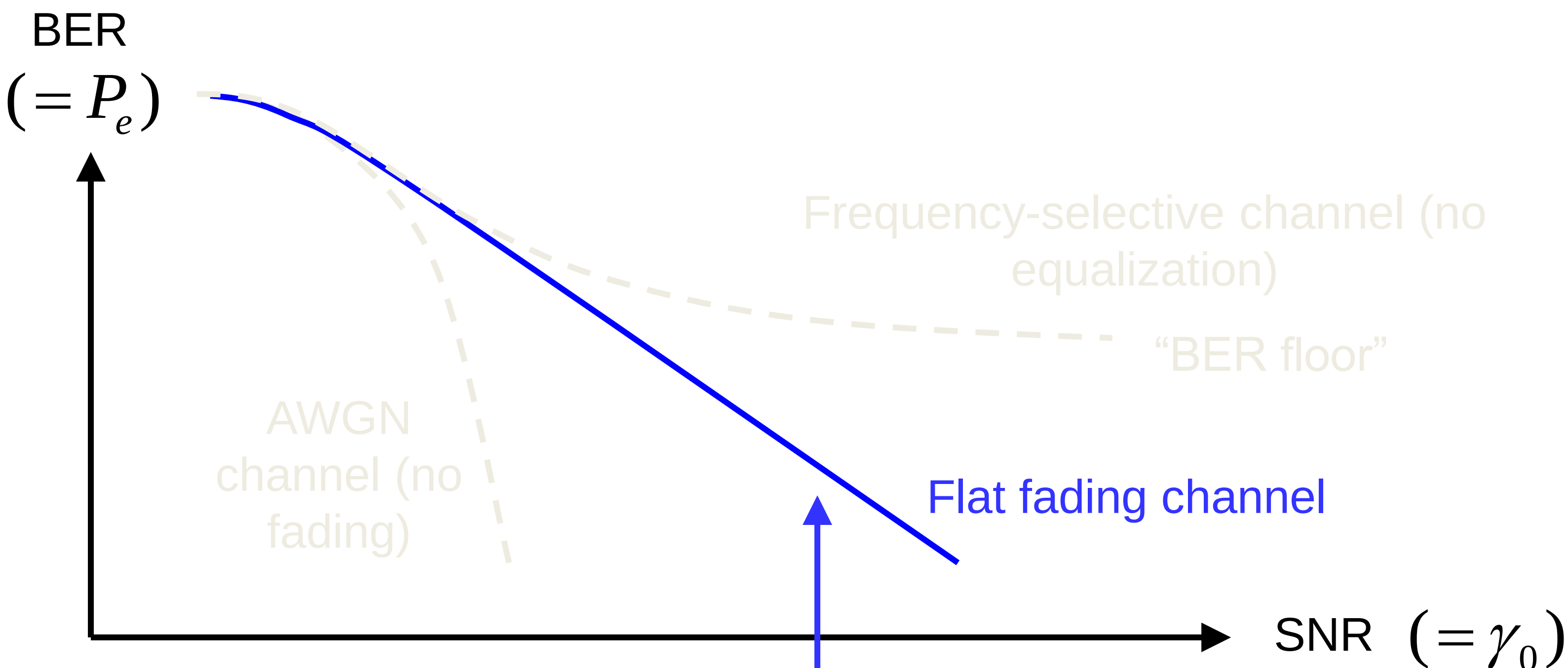
Then, we use

$$\sqrt{1+x} = 1 + x/2 + \dots$$

which leads to

$$P_e \approx 1/4\gamma_0$$ for large $\gamma_0$.

# BER vs. SNR




$P_e \approx 1/4\gamma_0$ means a straight line in log/log scale

# Summary

| Modulation | $P_e(\gamma)$ | $P_e$ | $P_e$ (for large $\gamma_0$) |
|---|---|---|---|
| 2-PSK | $Q\left(\sqrt{2\gamma}\right)$ | $\frac{1}{2}\left(1-\sqrt{\frac{\gamma_0}{1+\gamma_0}}\right)$ | $1/4\gamma_0$ |
| DPSK | $e^{-\gamma}/2$ | $1/(2\gamma_0+2)$ | $1/2\gamma_0$ |
| 2-FSK (coh.) | $Q\left(\sqrt{\gamma}\right)$ | $\frac{1}{2}\left(1-\sqrt{\frac{\gamma_0}{2+\gamma_0}}\right)$ | $1/2\gamma_0$ |
| 2-FSK (non-c.) | $e^{-\gamma/2}/2$ | $1/(\gamma_0+2)$ | $1/\gamma_0$ |

# Assessment

- **What are the modes of adaptive equalizer?**
  a) Training mode
  b) Tracking mode
  **c) Both of the mentioned**
  d) None of the mentioned

- **The ISI and adjacent channel interference is removed by**
  a) Cancelling filter
  b) Port processing equalizer
  **c) Both of the mentioned**
  d) None of the mentioned

# THANK YOU