Digital Communications Through Fading Multipath Channels

EE 573 Digital Communication II

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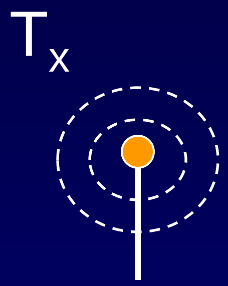
Basic Questions



What will happen if the transmitter
- changes transmit power ?
- changes frequency ?
- operates at higher speed ?

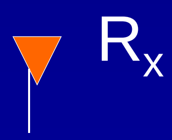
Transmit power, data rate, signal bandwidth, frequency tradeoff

What will happen if we conduct this experiment in different types of environments?

Desert | Metro | Street | Indoor

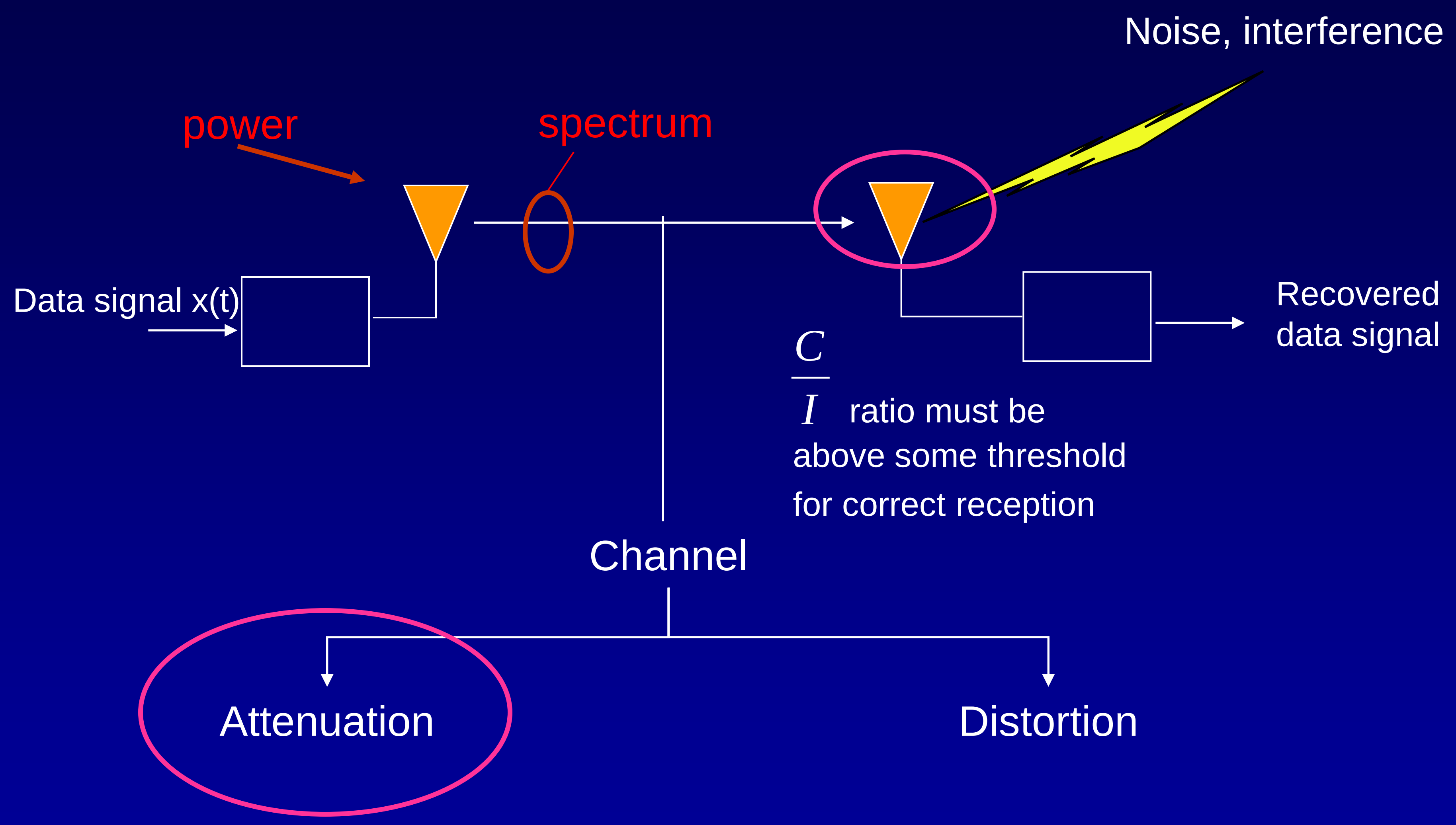
Channel efffects

What will happen if the receiver moves?

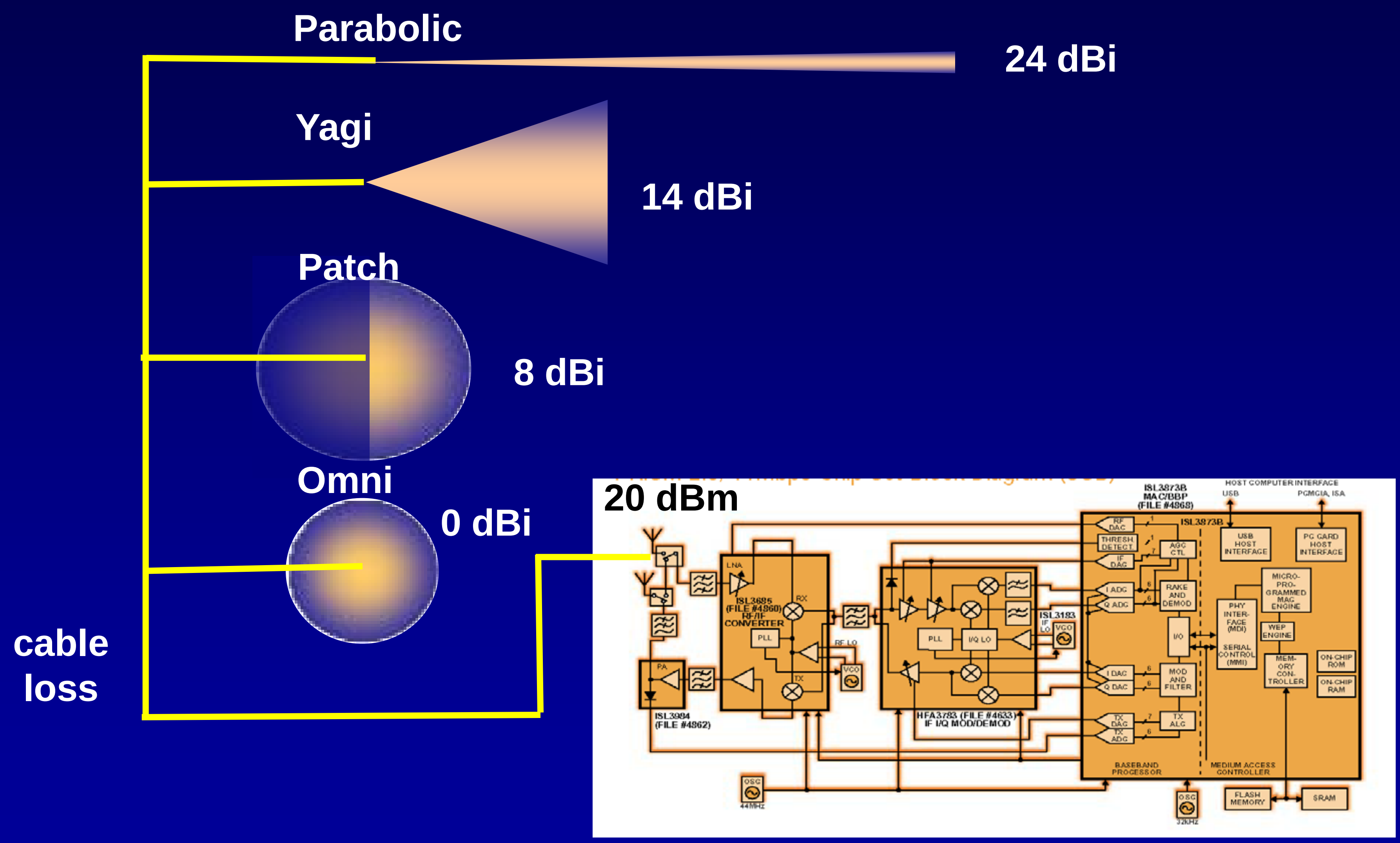


Effect of mobility

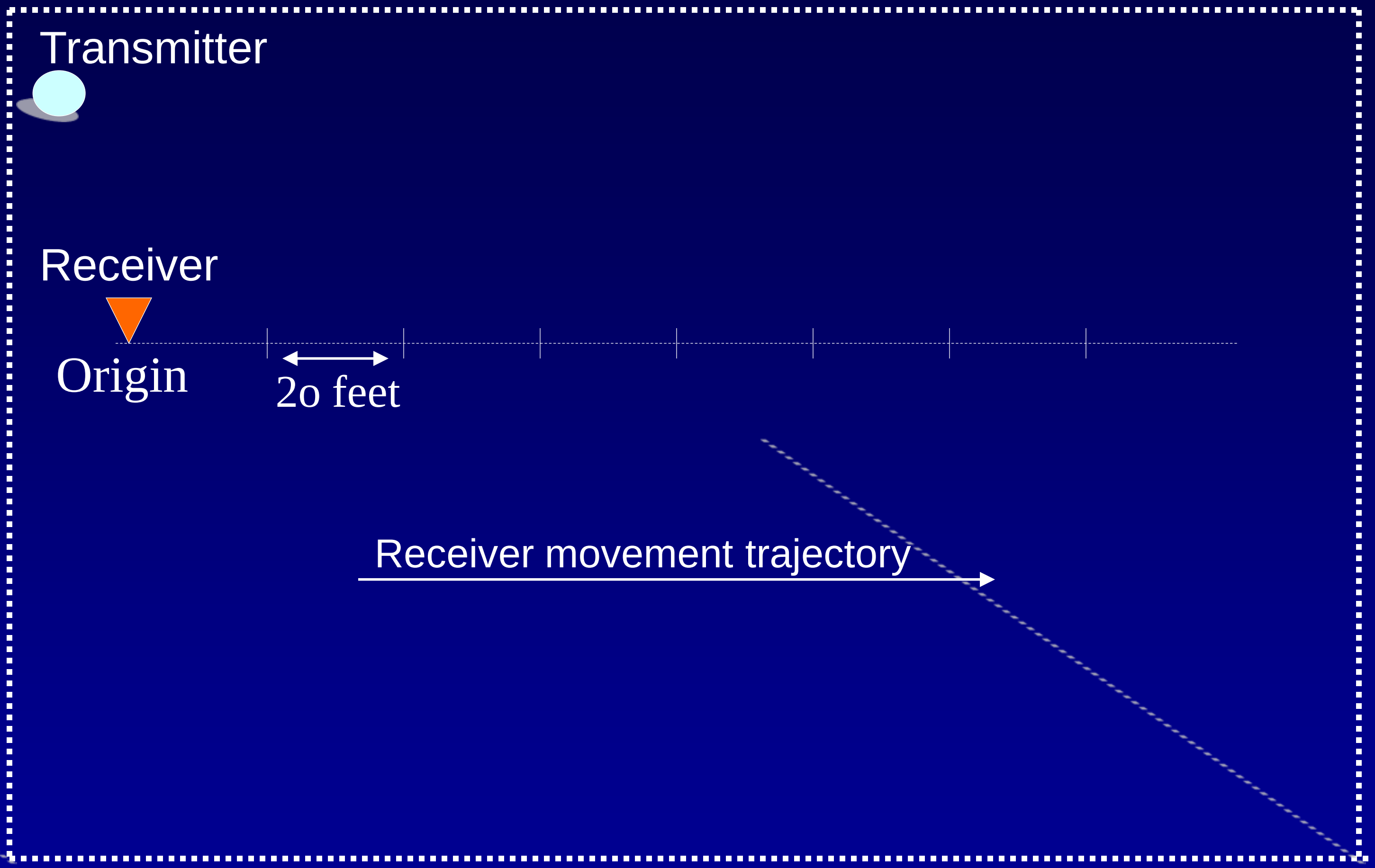
Fundamental Design considerations



Understanding the effect of attenuation

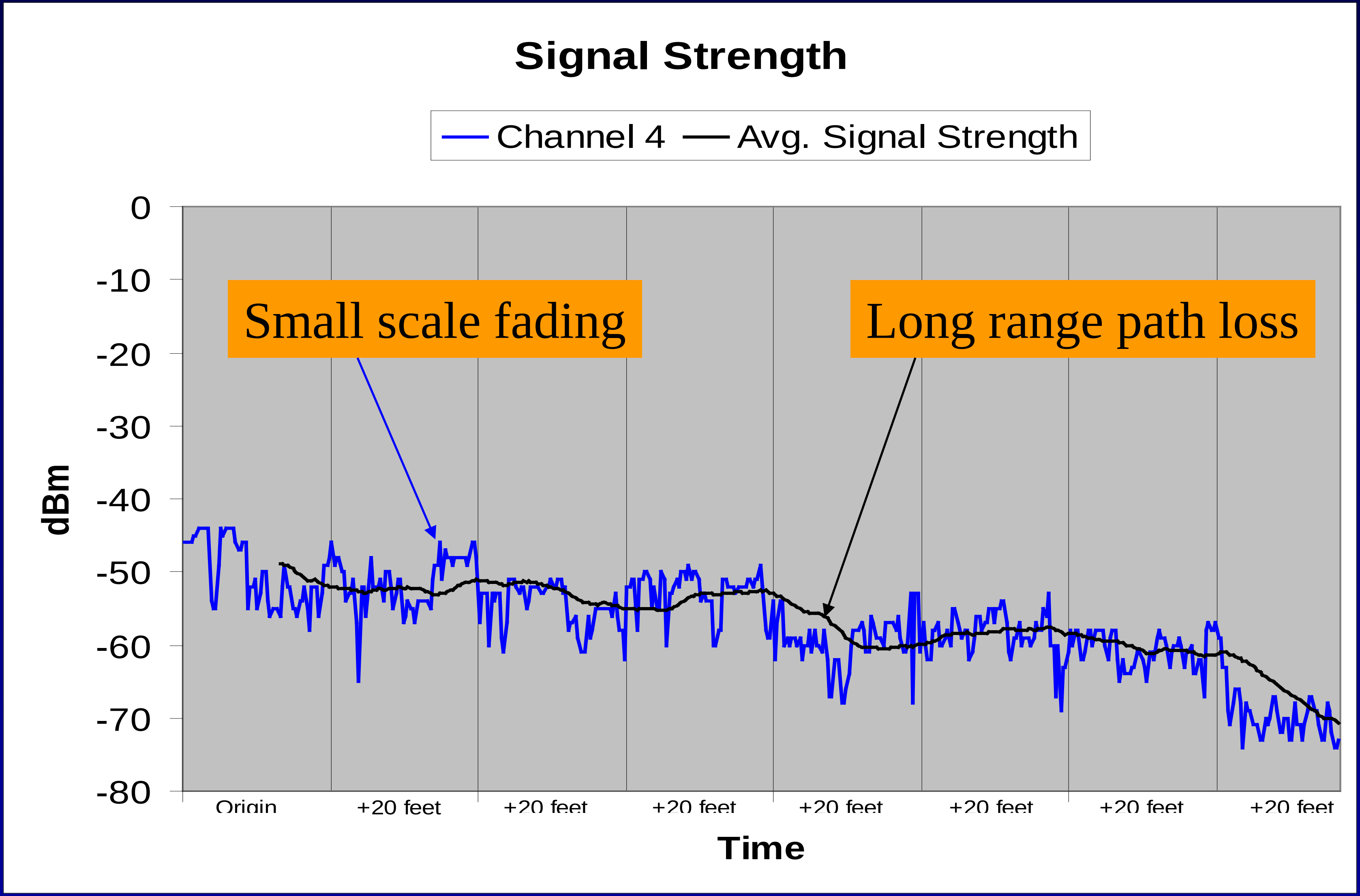


Trace Collection Setup

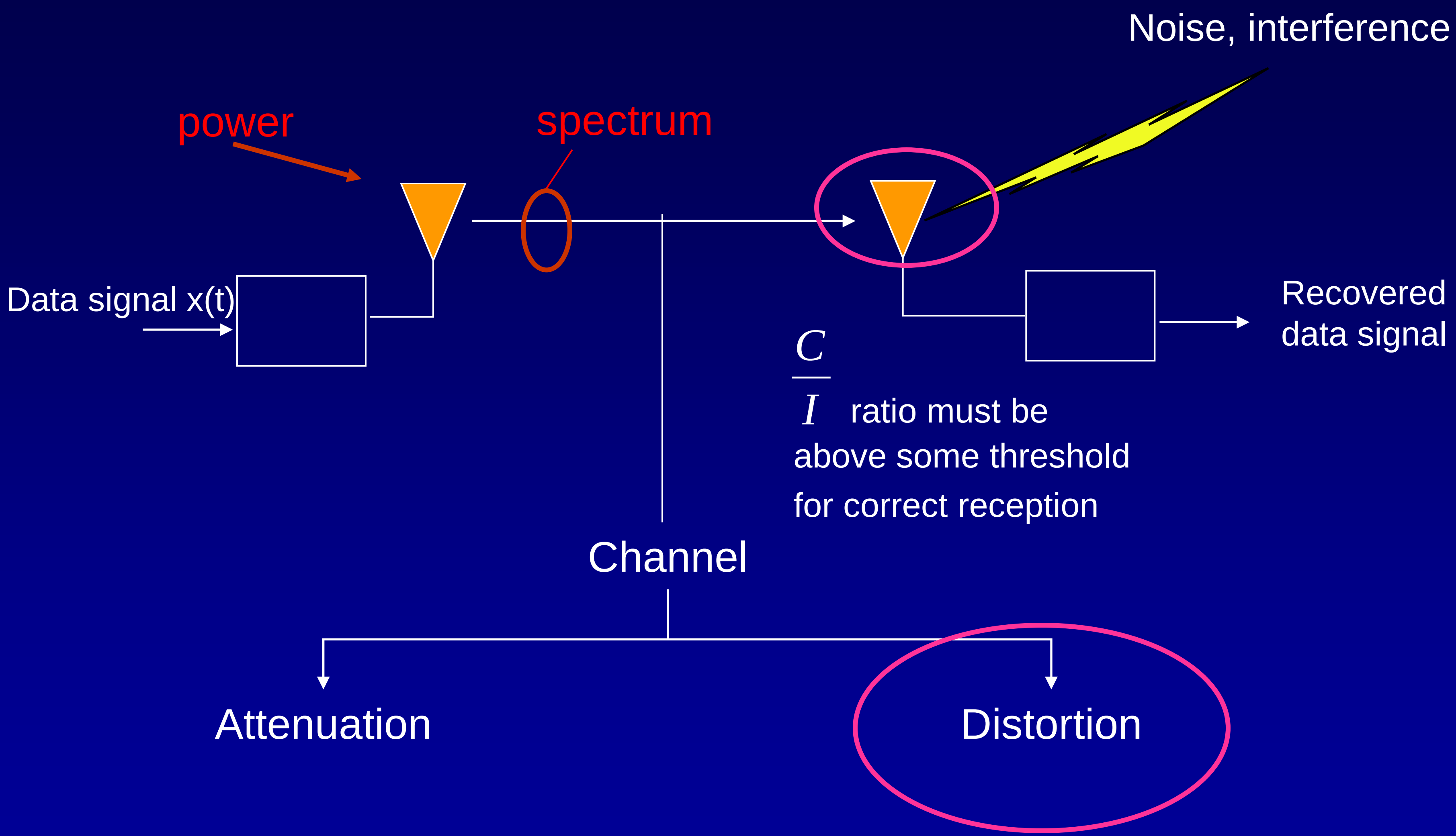


If you measure signal at the receiver, what do you expect to see?

Measured Signal

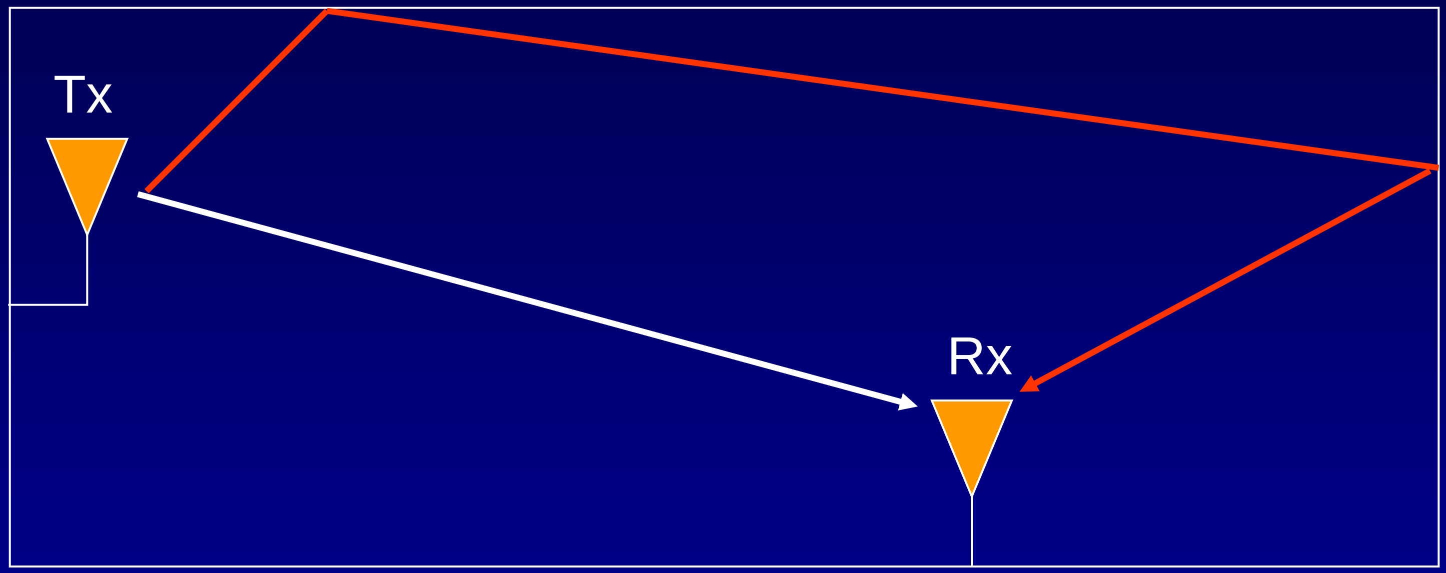


Fundamental Design considerations



Radio Propagation: Fading and multipath

Fading: rapid fluctuation of the amplitude of a radio signal over a short period of time or travel distance



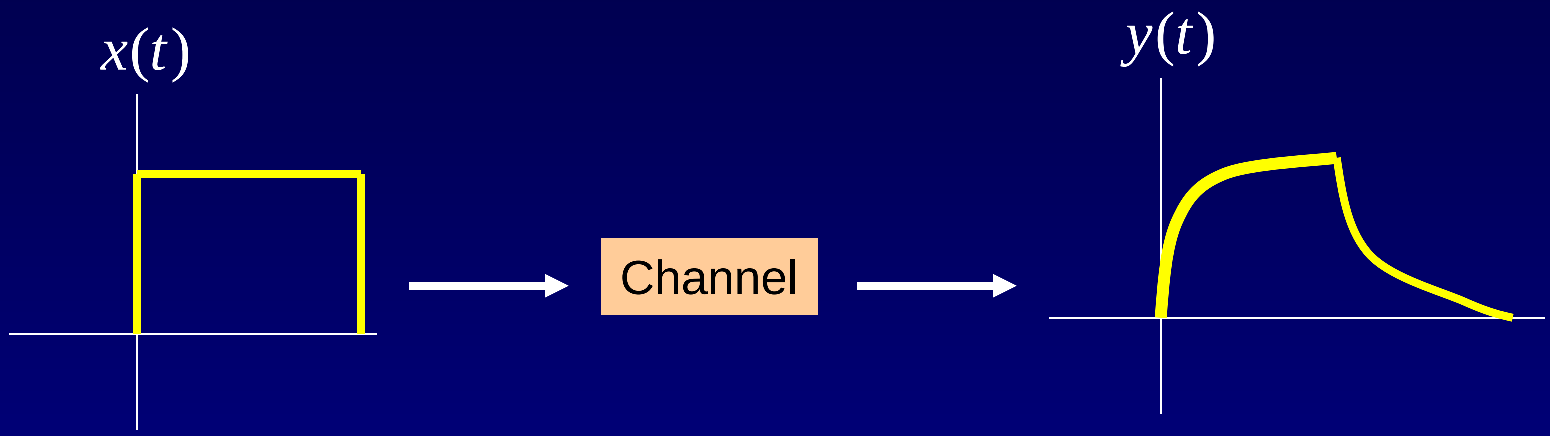
Effects of multipath

- Fading
- Varying doppler shifts on different multipath signals
- Time dispersion (causing inter symbol interference)

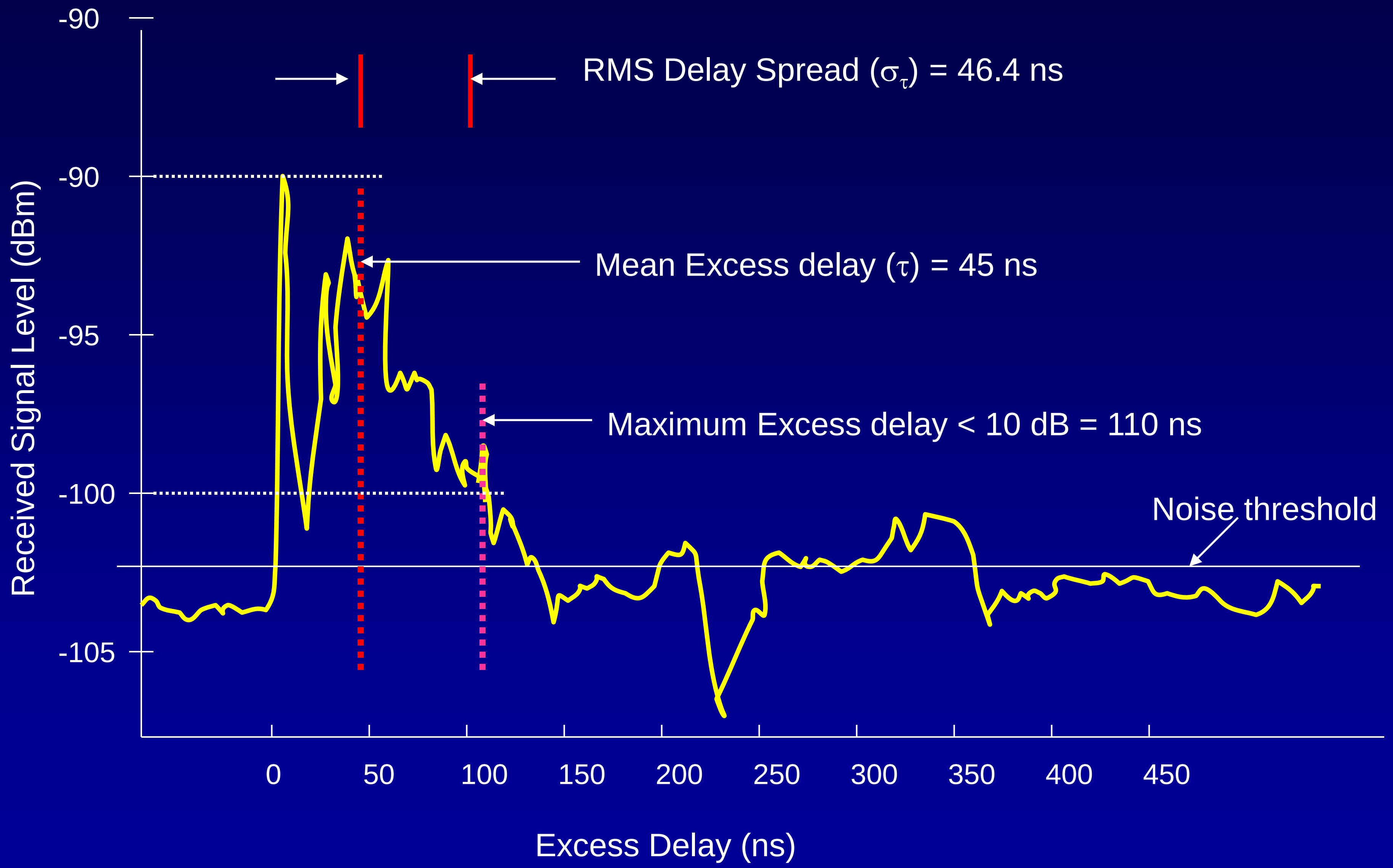
Review of basic concepts

- Fourier Transform
- Channel Impulse response
- Power delay profile
- Inter Symbol Interference
- Coherence bandwidth
- Coherence time

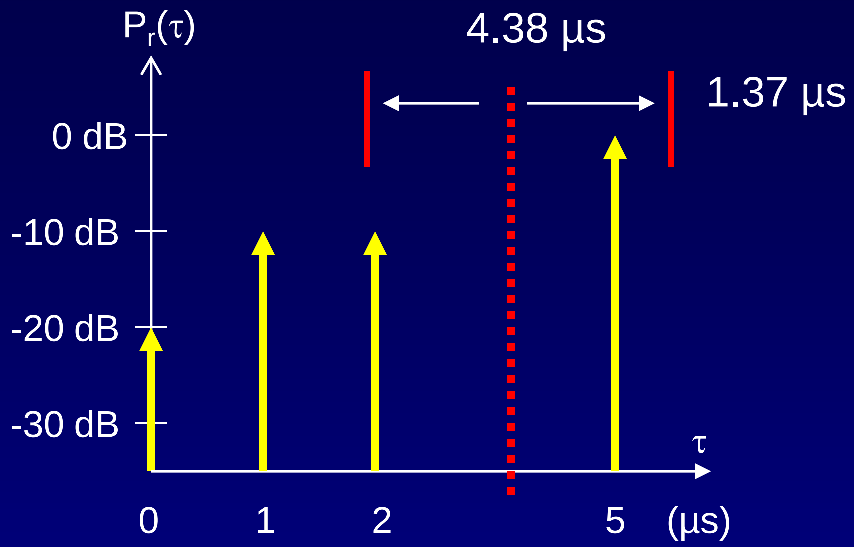
Channel Impulse Response



Power delay Profile



Example (Power delay profile)



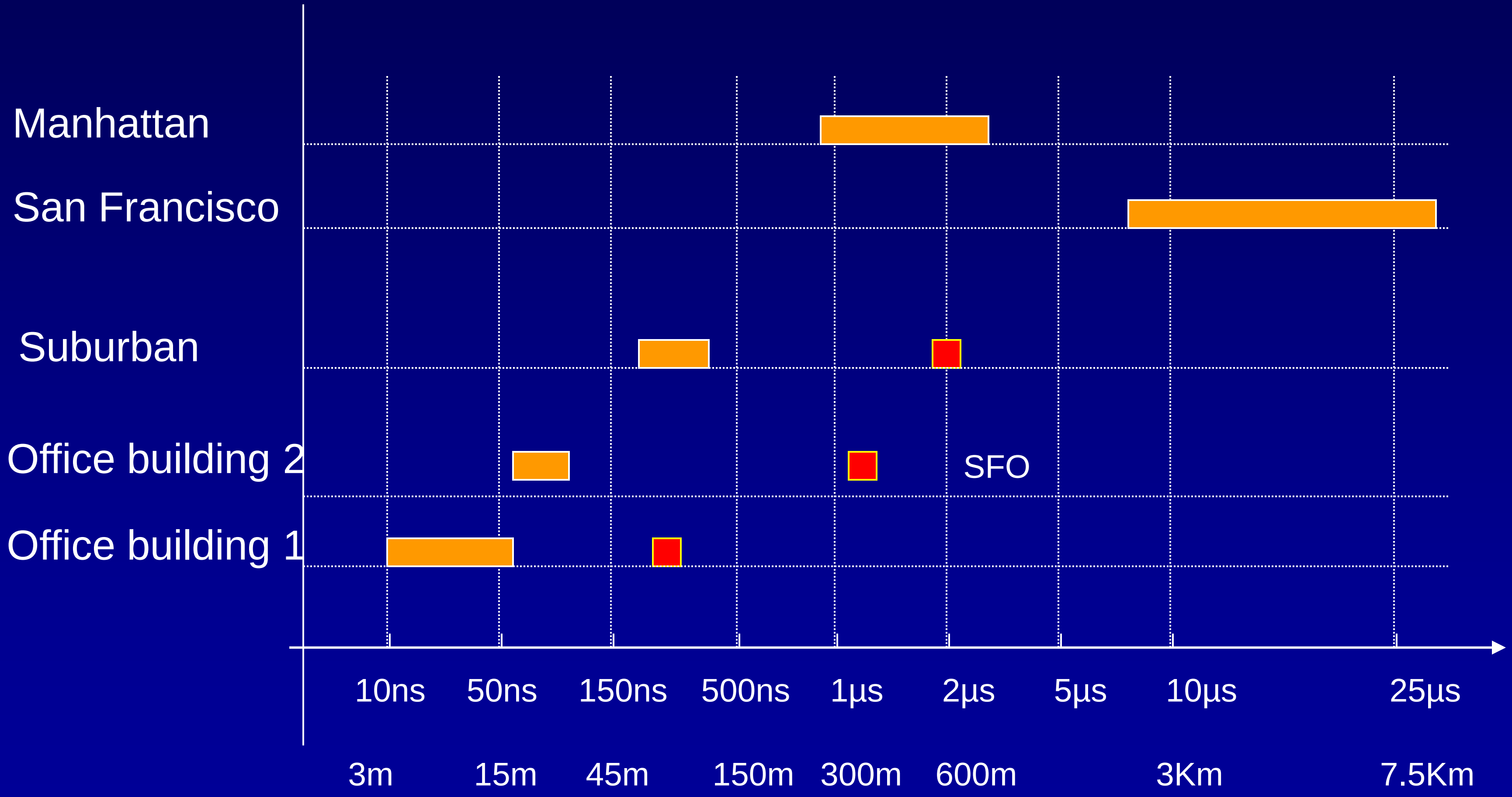
$$\bar{\tau} = \frac{(1)(5)+(0.1)(1)+(0.1)(2)+(0.01)(0)}{[0.01+0.1+0.1+1]} = 4.38\mu s$$

$$\overline{\tau^2} = \frac{(1)(5)^2+(0.1)(1)^2+(0.1)(2)^2+(0.01)(0)^2}{[0.01+0.1+0.1+1]} = 21.07\mu s^2$$

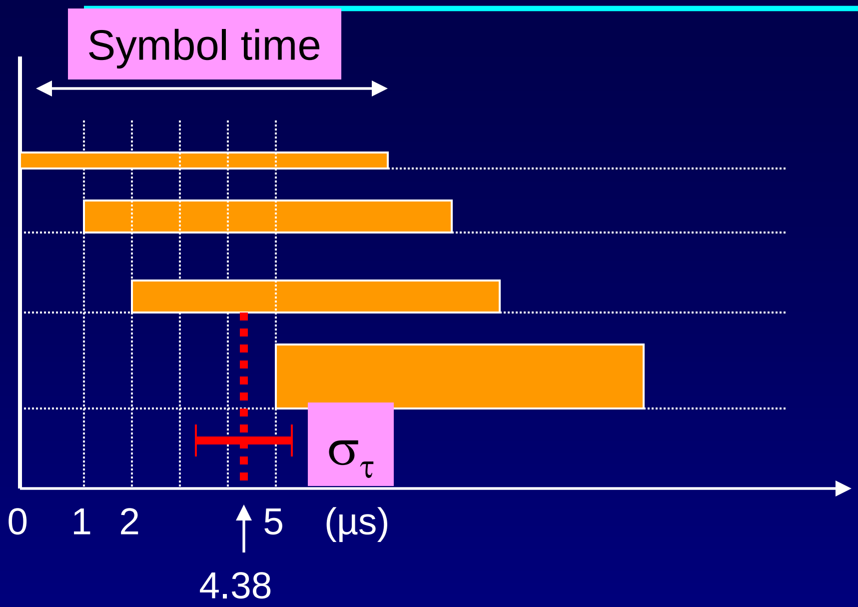
$$\sigma_\tau = \sqrt{21.07-(4.38)^2} = 1.37\mu s$$

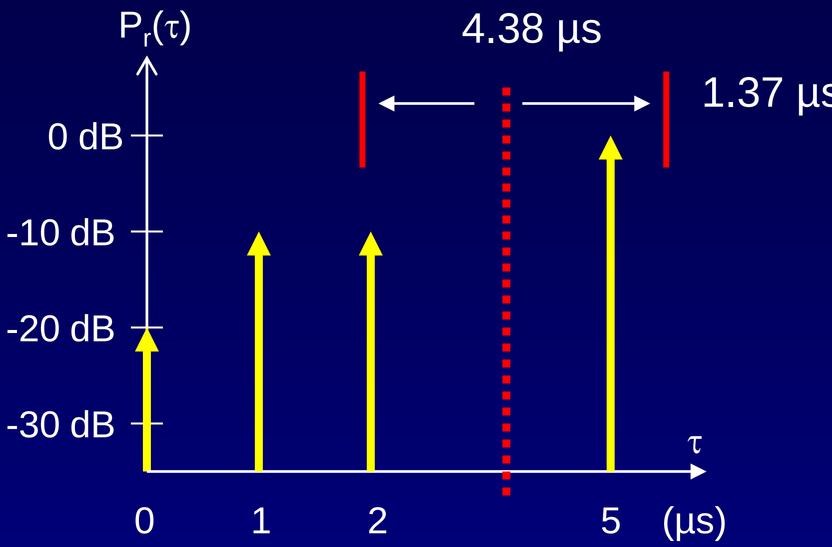
RMS Delay Spread: Typical values

Delay spread is a good measure of Multipath



Inter Symbol Interference



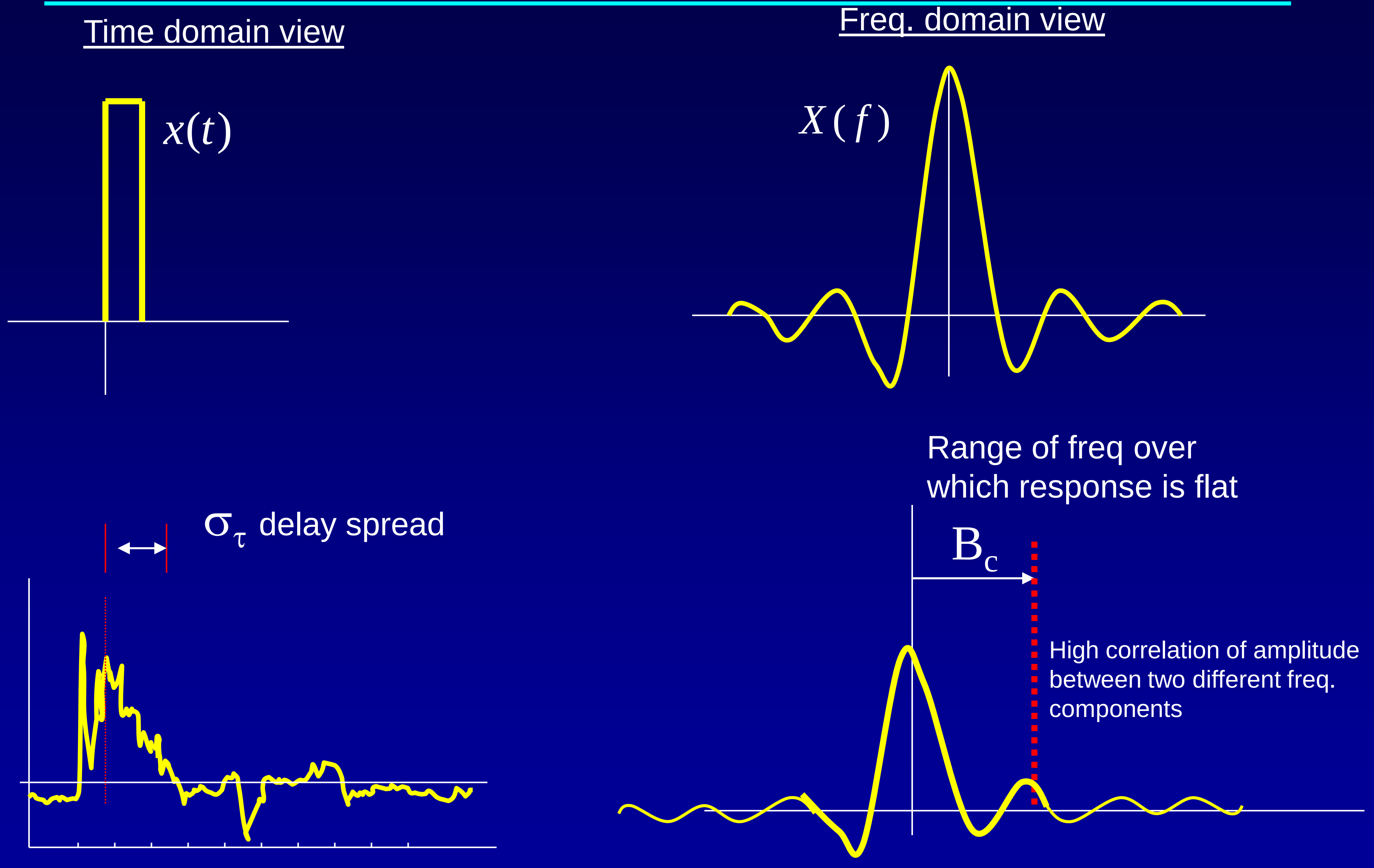


Symbol time > 10* σ_τ --- No equalization required

Symbol time < 10* σ_τ --- Equalization will be required to deal with ISI

In the above example, symbol time should be more than 14μs to avoid ISI.
This means that link speed must be less than 70Kbps (approx)

Coherence Bandwidth



RMS delay spread and coherence b/w

- RMS delay spread and coherence b/w (B_c) are inversely proportional

$$B_c \alpha \frac{1}{\sigma_\tau}$$

$$B_c \approx \frac{1}{50.\sigma_\tau}$$

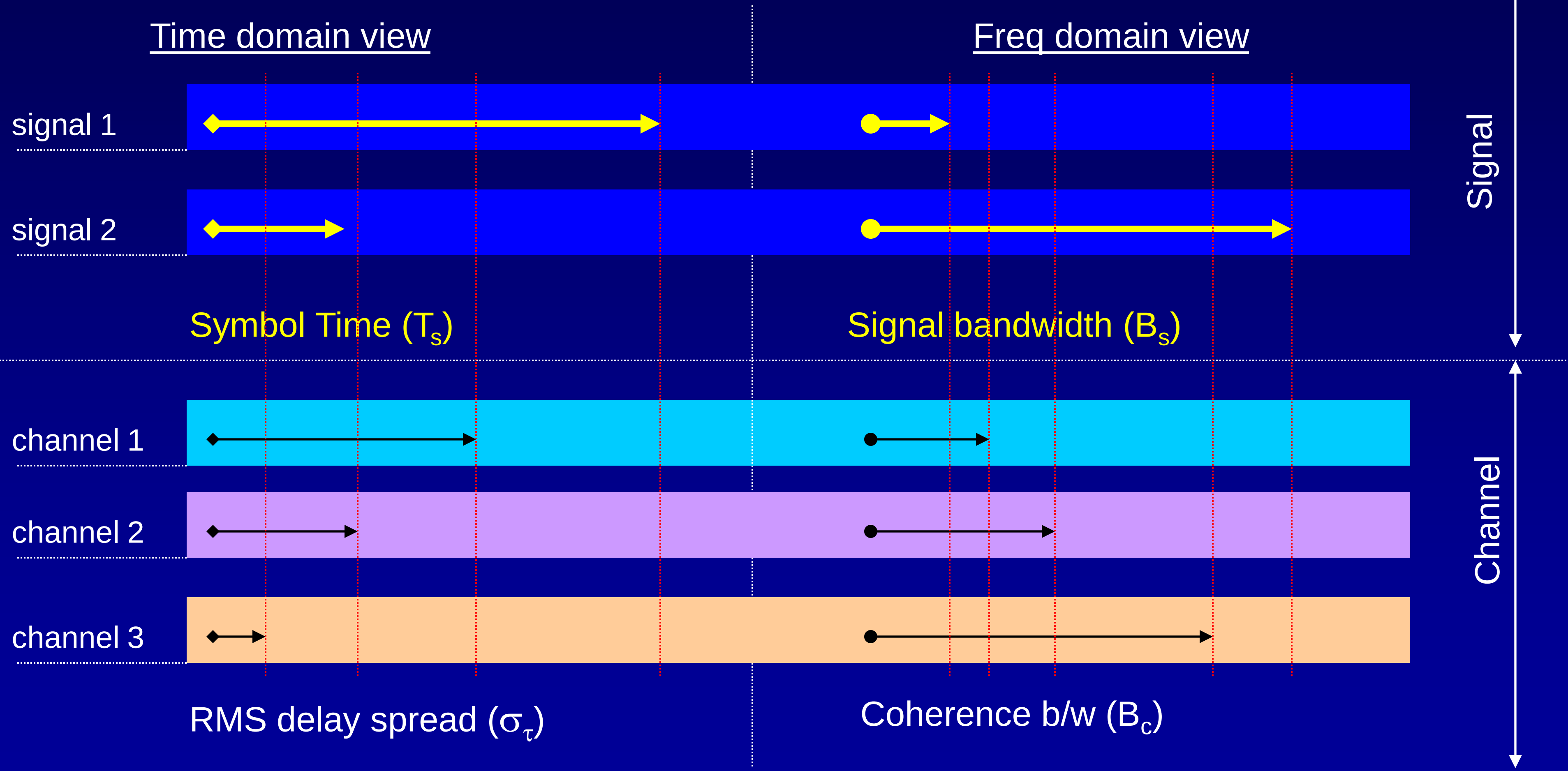
For 0.9 correlation

$$B_c \approx \frac{1}{5.\sigma_\tau}$$

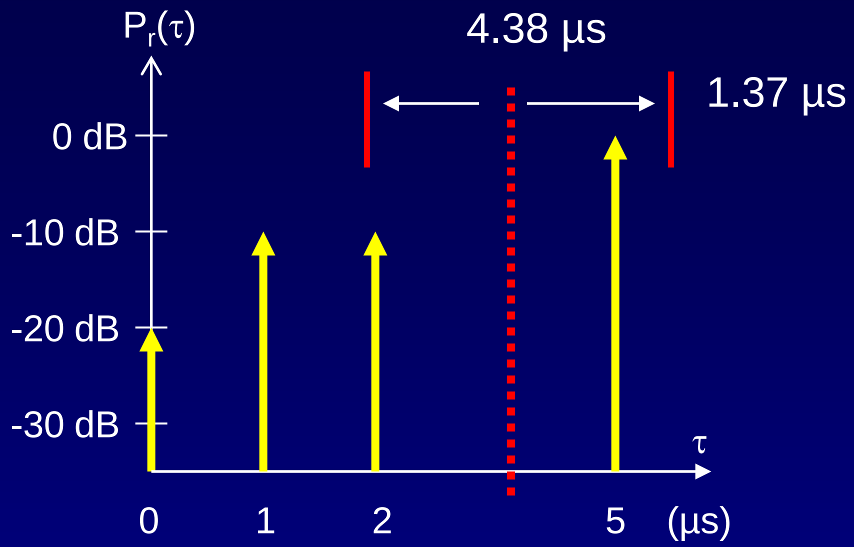
For 0.5 correlation

Time dispersive nature of channel

Delay spread and coherence bandwidth are parameters which describe the time dispersive nature of the channel.



Revisit Example (Power delay profile)



$$\bar{\tau} = 4.38 \mu s$$

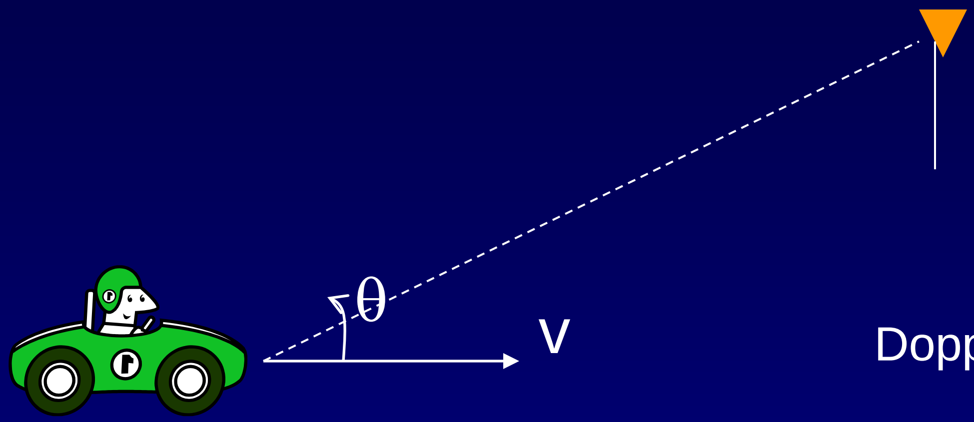
$$\bar{\tau}^2 = 21.07 \mu s^2$$

$$\sigma_\tau = 1.37 \mu s$$

$$(50\% - coherence) B_c \approx \frac{1}{5.\sigma_\tau} = 146 kHz$$

Signal bandwidth for Analog Cellular = 30 KHz
Signal bandwidht for GSM = 200 KHz

Doppler Shift



Doppler shift $$\Delta f = \frac{v\cos\theta}{\lambda}$$

<u>Example</u>

- Carrier frequency f_c = 1850 MHz (i.e. λ = 16.2 cm)
- Vehicle speed v = 60 mph = 26.82 m/s

- If the vehicle is moving directly towards the transmitter

$$\Delta f = \frac{26.82}{0.162} = 165 Hz$$

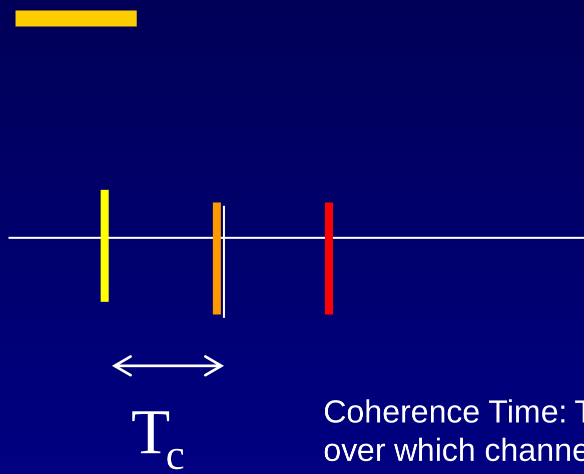
- If the vehicle is moving perpendicular to the angle of arrival of the transmitted signal

$$\Delta f = 0$$

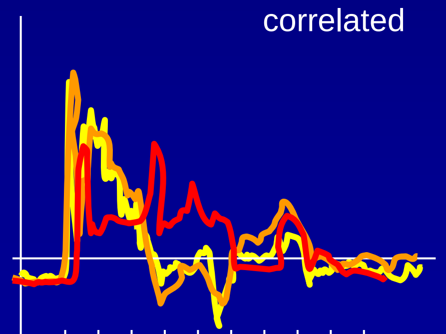
Coherence Time

Time domain view

symbol time

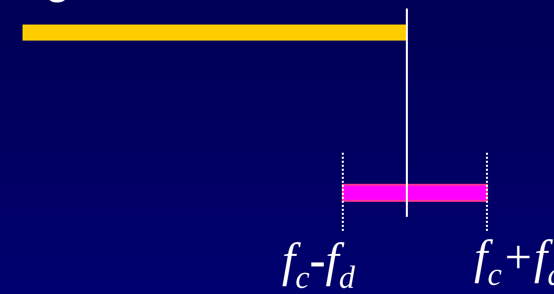


Coherence Time: Time interval over which channel impulse responses are highly correlated



Frequency domain view

signal bandwidth



Doppler spread and coherence time

- Doppler spread and coherence time (T_c) are inversely proportional

$$T_c \alpha \frac{1}{f_m}$$

f_m is the max doppler shift

$$T_c \approx \frac{9}{16\pi f_m}$$

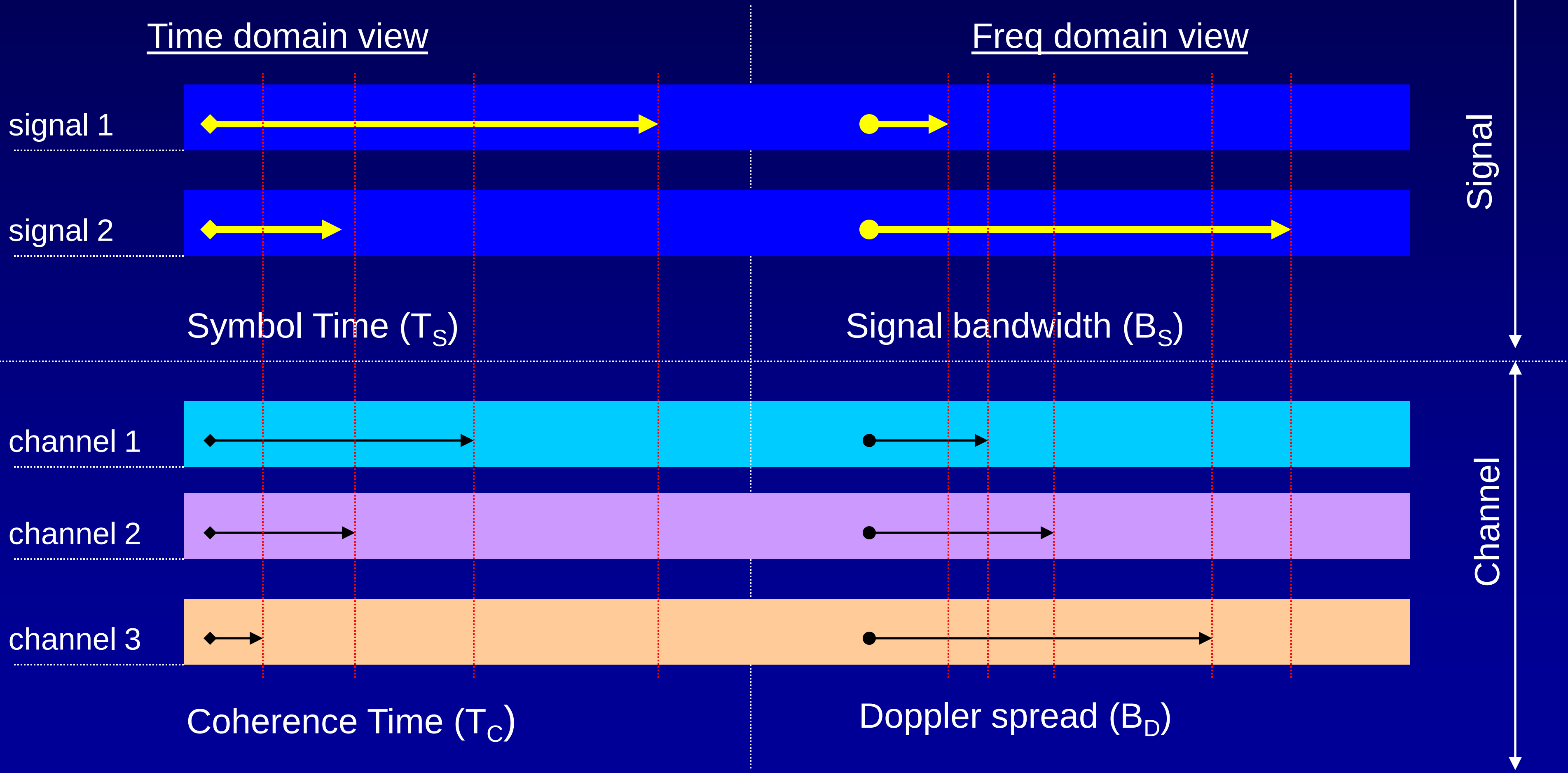
For 0.5 correlation

$$T_c \approx \frac{0.423}{f_m}$$

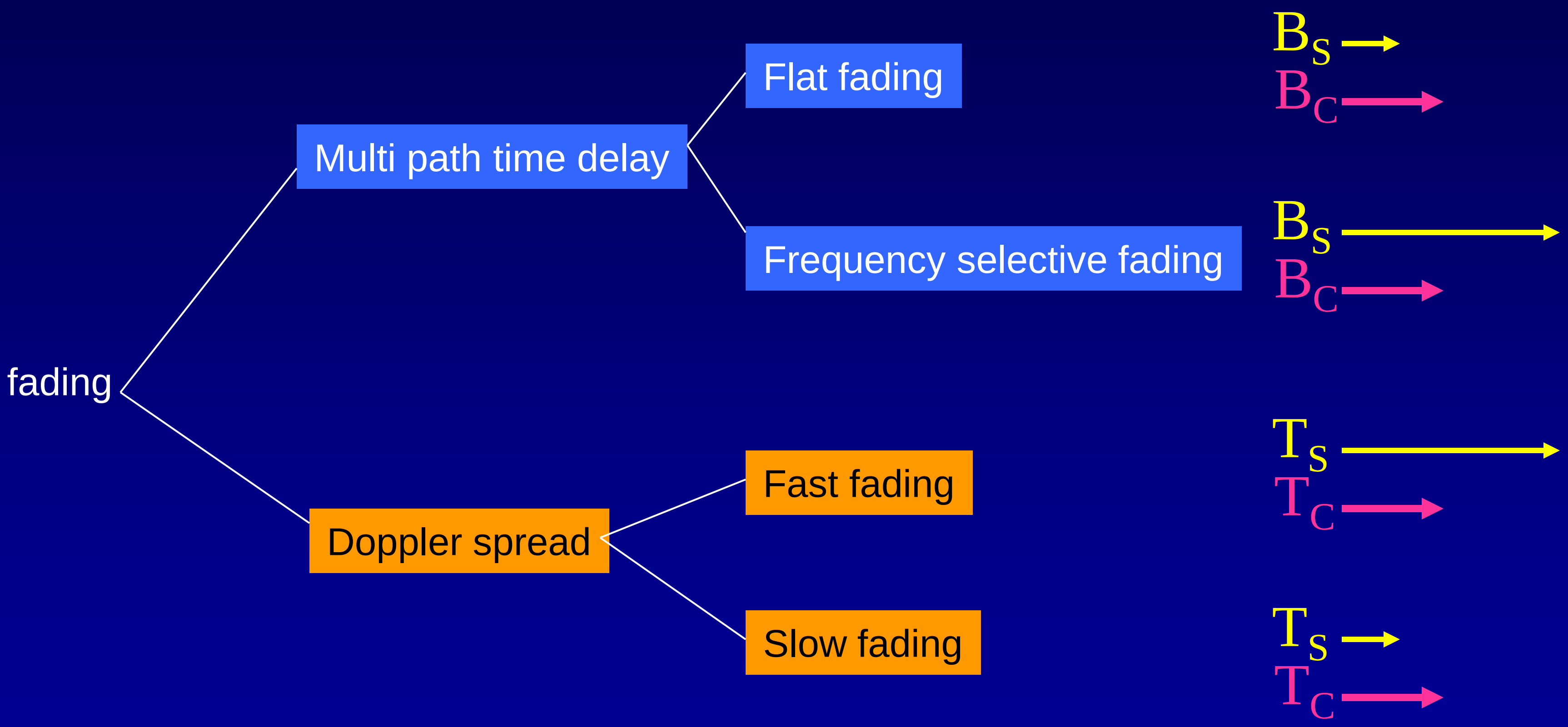
Rule of thumb

Time varying nature of channel

Doppler spread and coherence time are parameters which describe the time varying nature of the channel.



Small scale fading



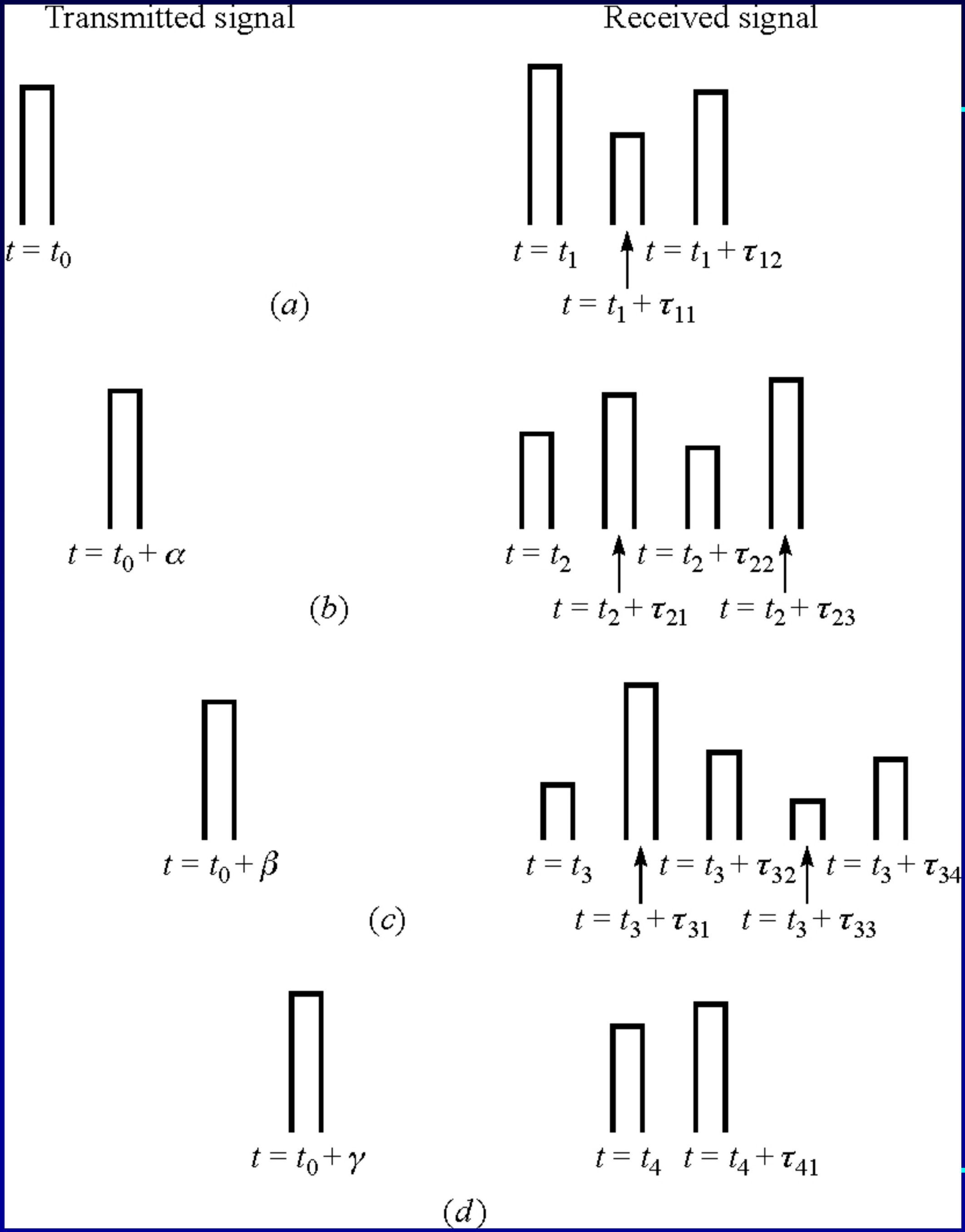


Figure 14.1-1

Example of the response of a time-variant multi-path channel to a very narrow pulse.

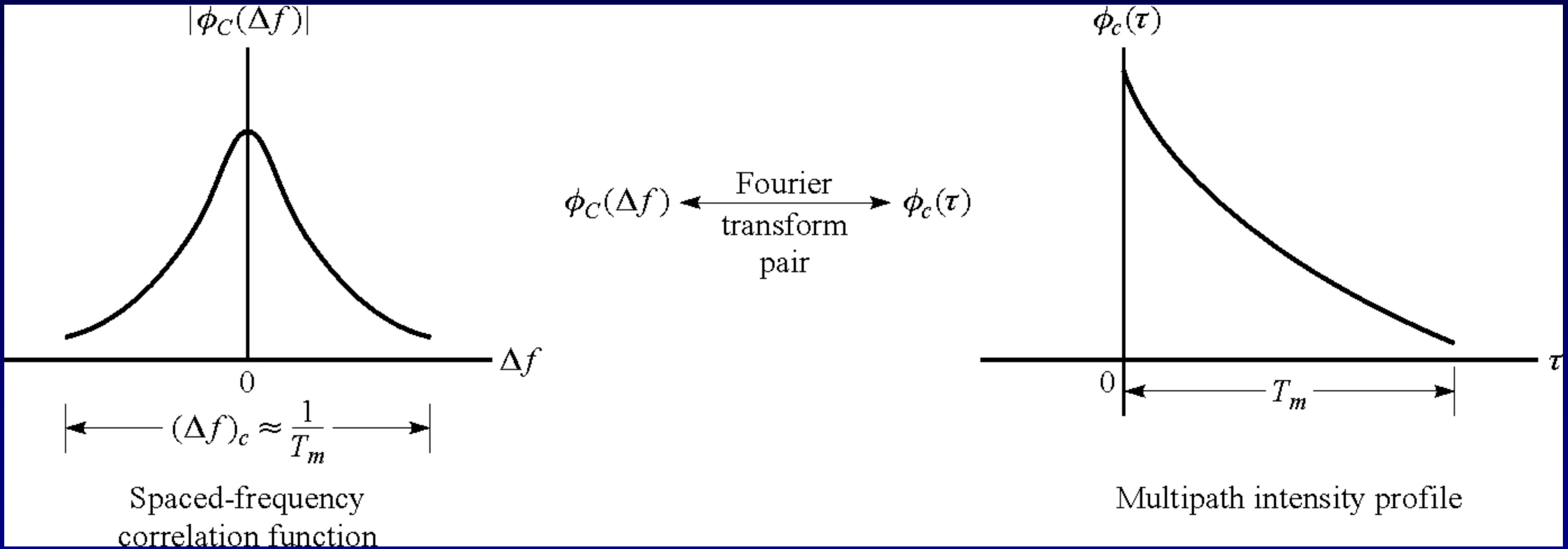


Figure 14.1-3

Relationship between $\phi_c(\Delta f)$ and $\phi_c(\tau)$.

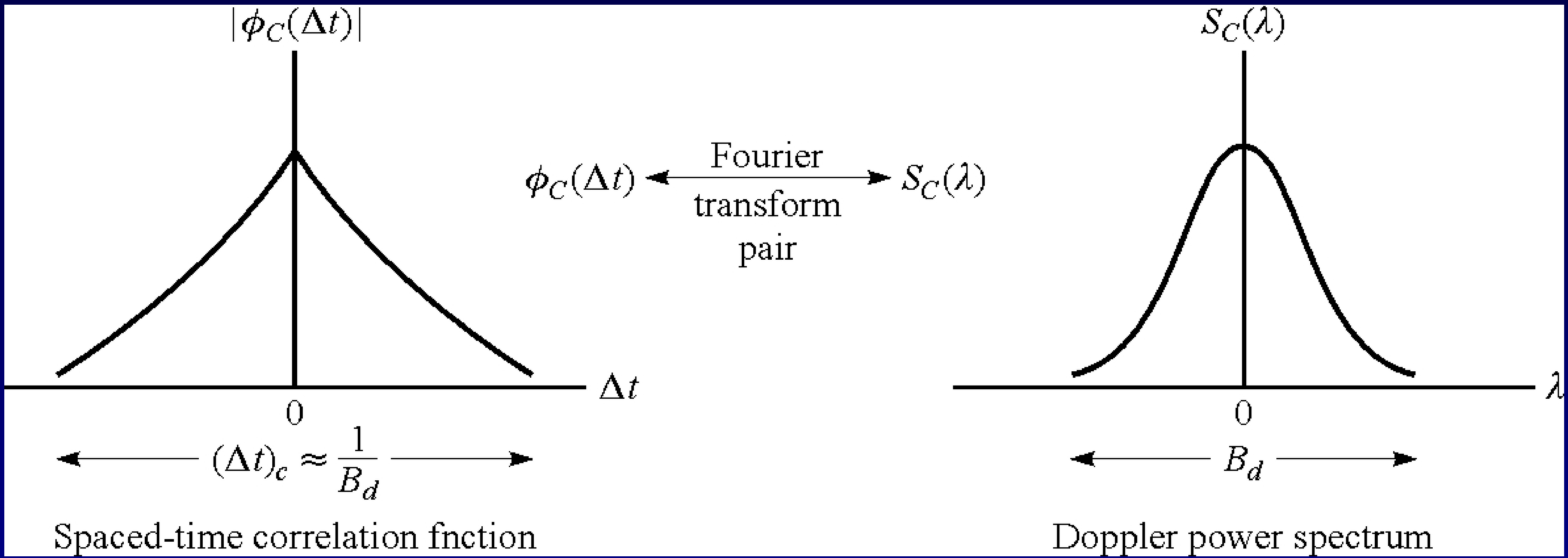


Figure 14.1-4

Relationship between $\phi_C(\Delta t)$ and $S_C(\lambda)$.

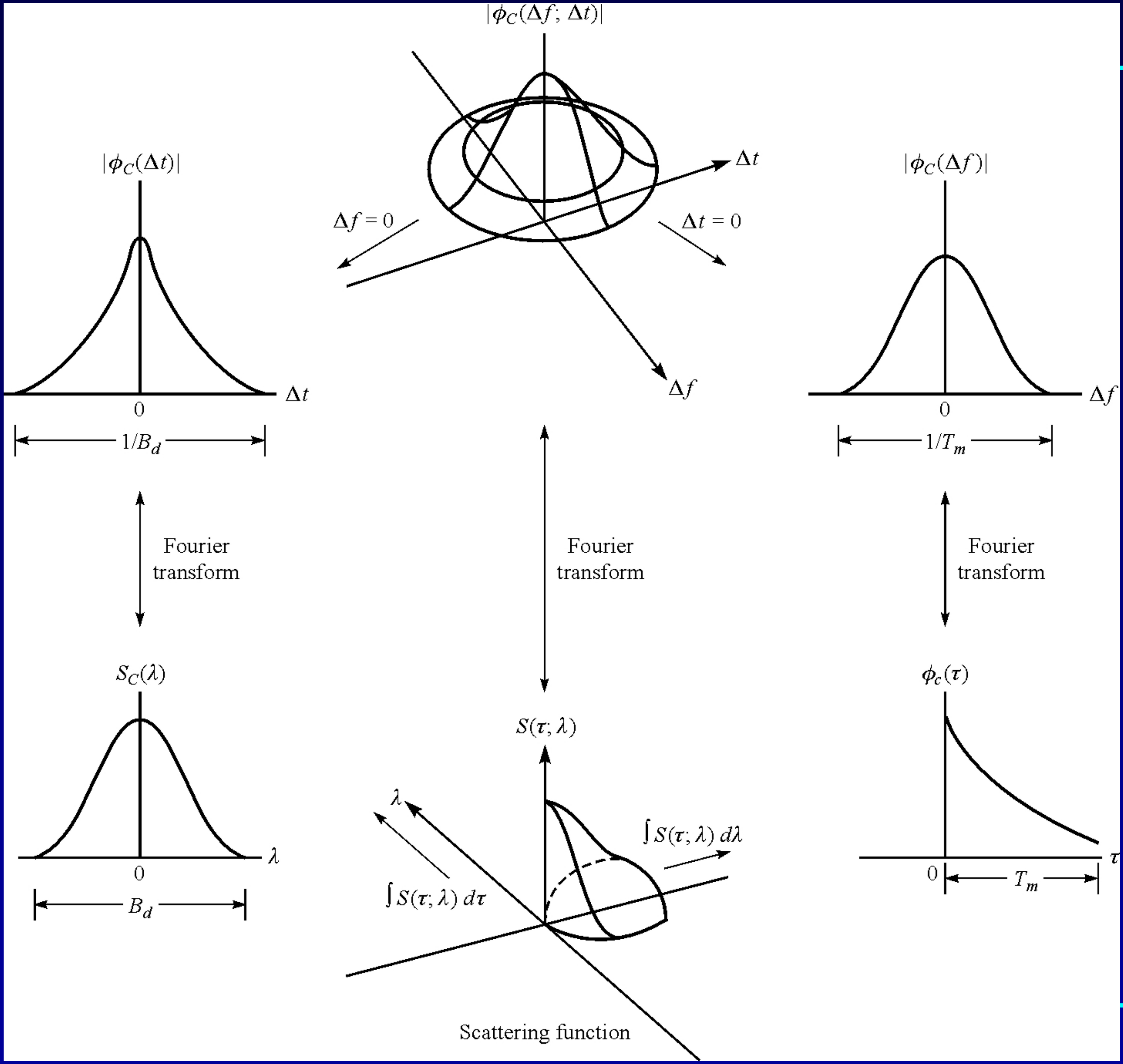


Figure 14.1-5 Relationships among the channel correlation functions and power spectra. [*From Green (1962), with permission.*]

Figure 14.1-6

Scattering function of a medium-range tropospheric scatter channel. The taps delay increment is 0.1 μs.

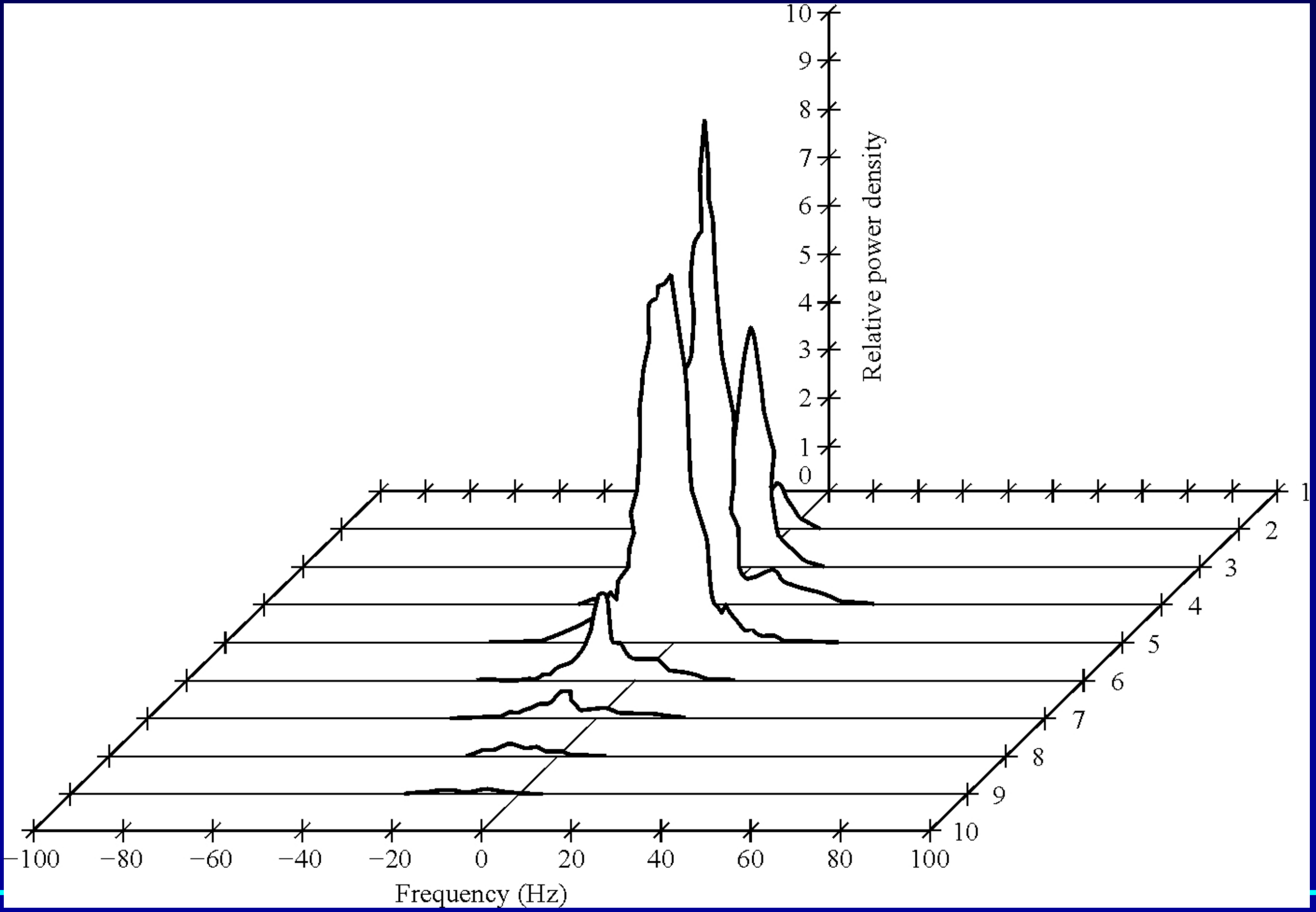
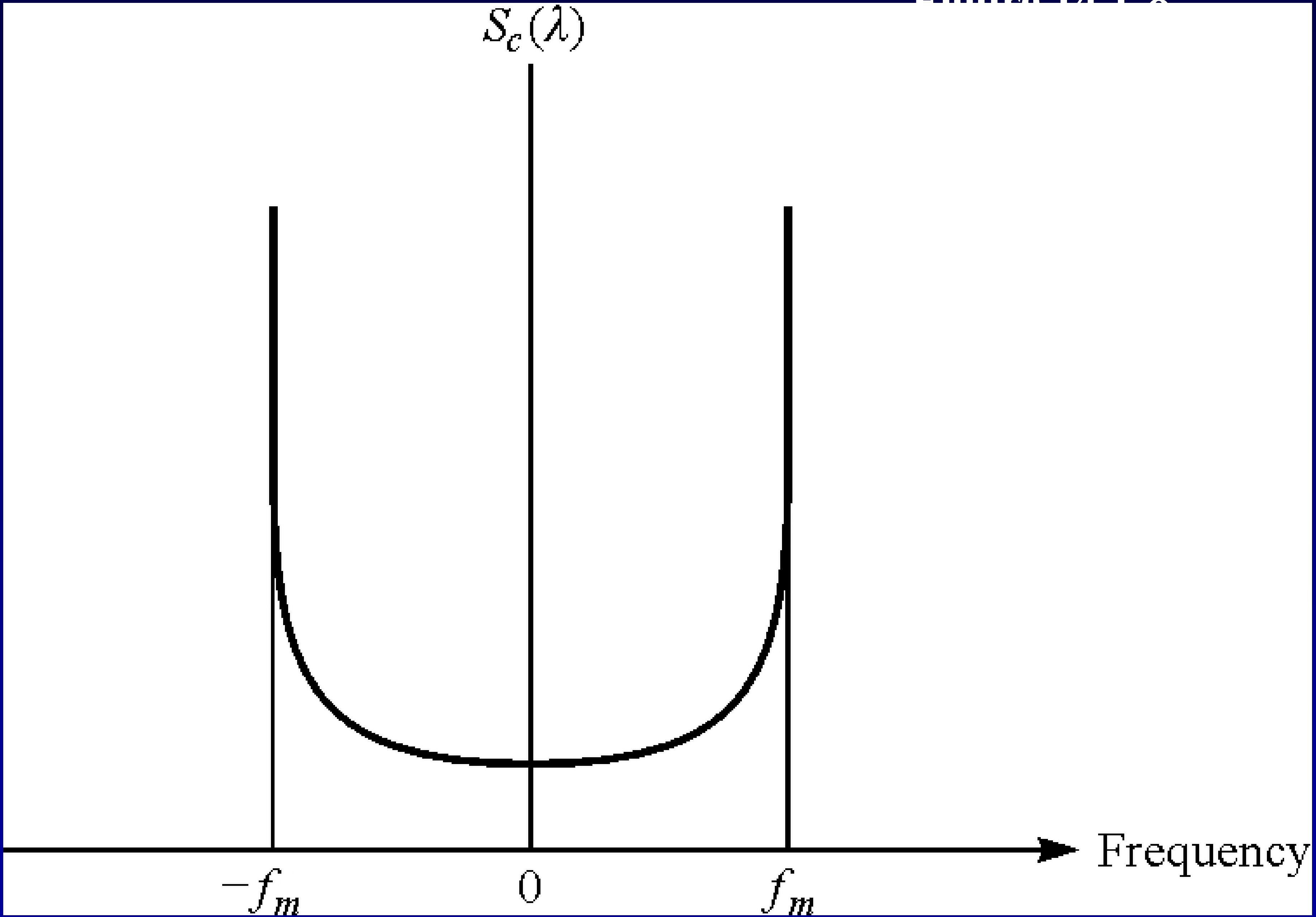


Figure 14.1-8



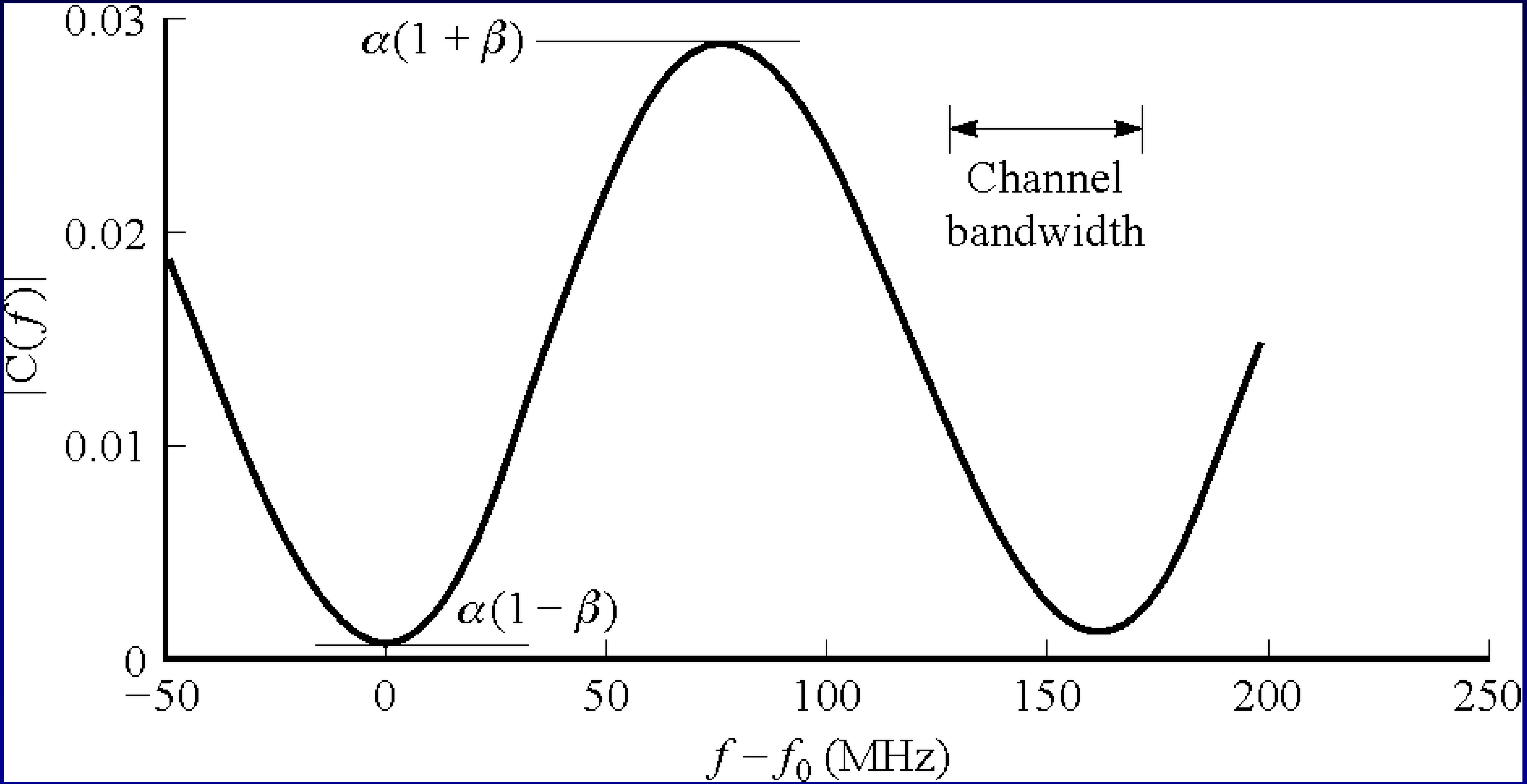


Figure 14.1-9
Magnitude frequency response of LOS channel model.

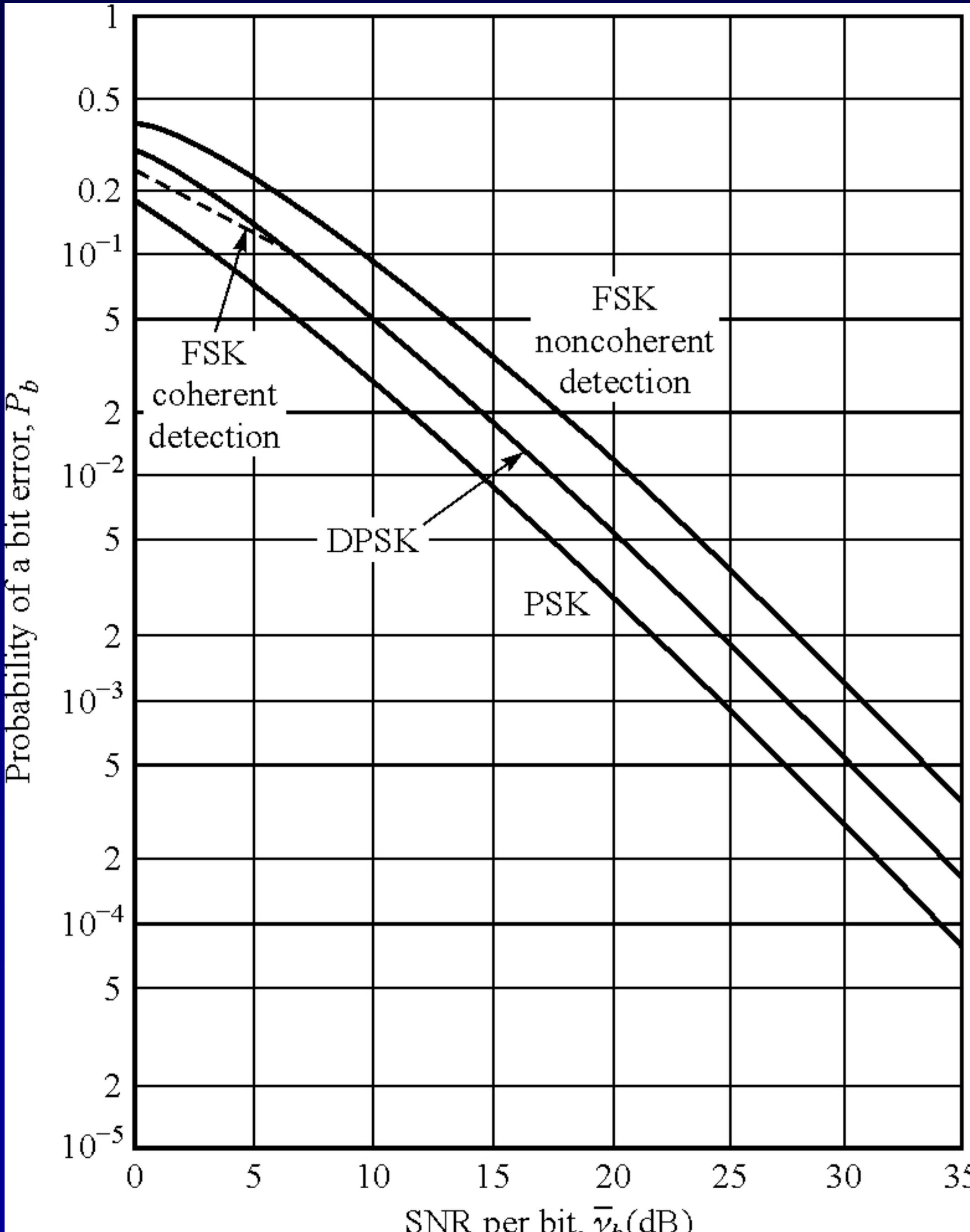


Figure 14.3-1
Performance of binary signaling on a Rayleigh fading channel.