① Types of Small-Scale Fading

- The time dispersion and frequency dispersion mechanisms in a mobile radio channel lead to four possible distinct effects, which are manifested depending on the nature of the transmitted signal, the channel, and the velocity.
- While multipath delay spread leads to time dispersion and frequency selective fading, Doppler spread leads to frequency dispersion and time selective fading.

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

(2)

Small-Scale Fading (Based on Doppler spread)

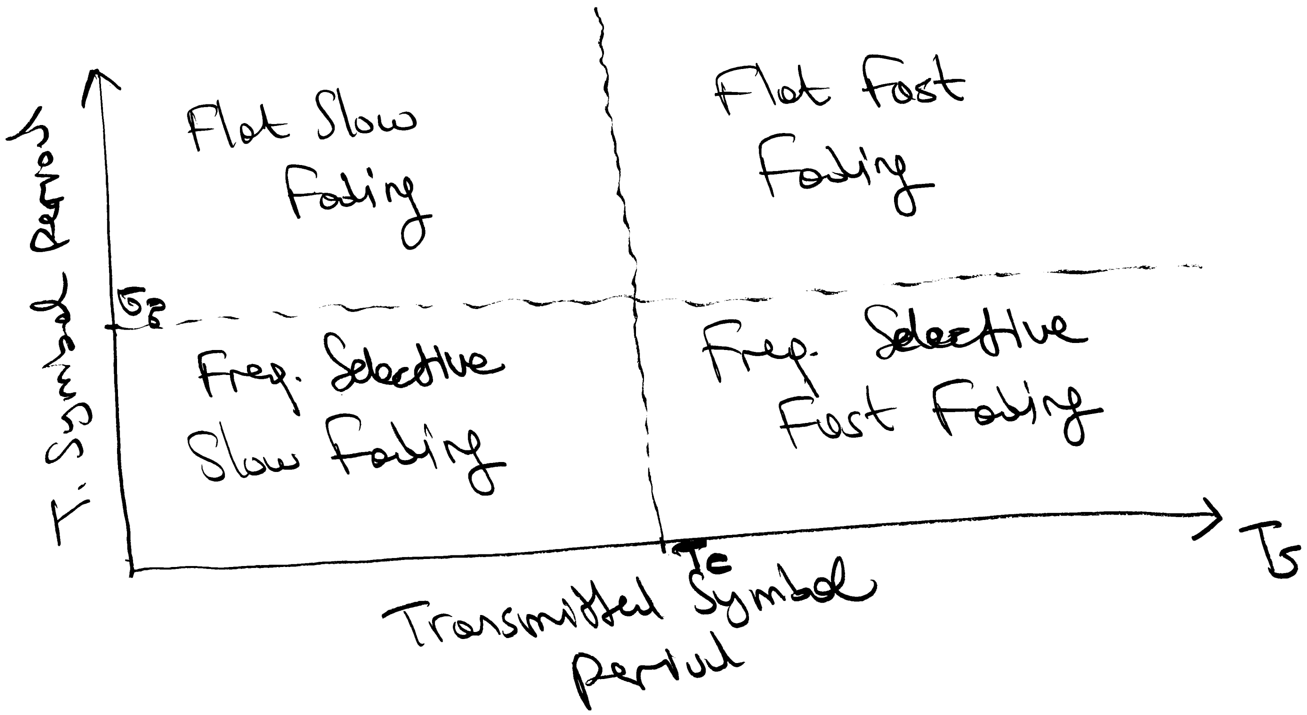
Fast Fading

1) High Doppler spread
2) Coherence time < Symbol period
3) Channel variations are 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

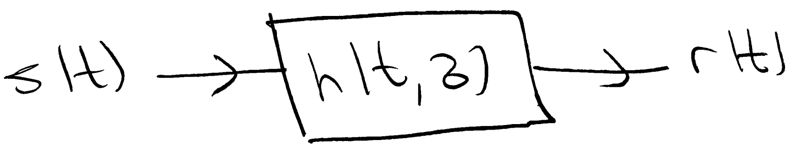
We can combine the above two charts as below

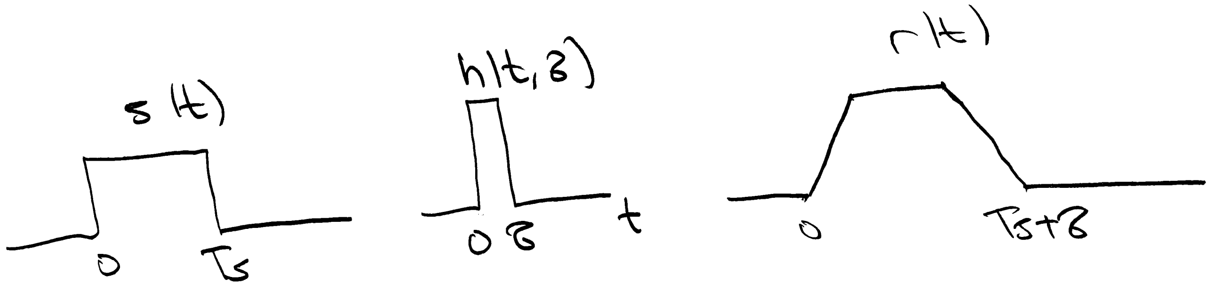


③

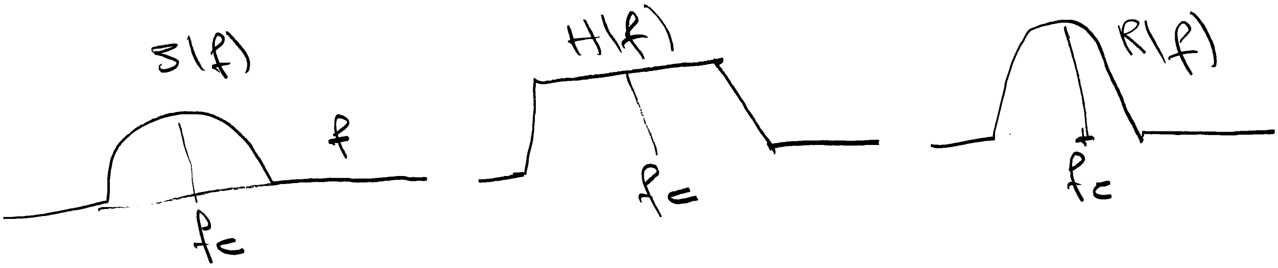
Flat Fading:

In flat fading the multipath structure of the channel is such that the spectral characteristics of the transmitted signal are preserved at the receiver

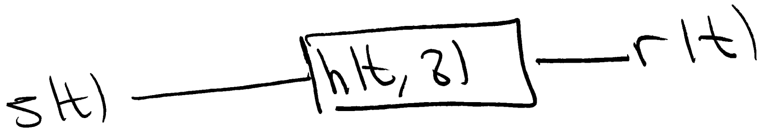




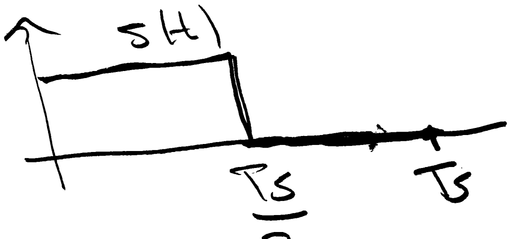
$\tau << T_s$



Ex:



$r(t) = s(t-0.5) + s(t-0.25) + s(t-0.125)$

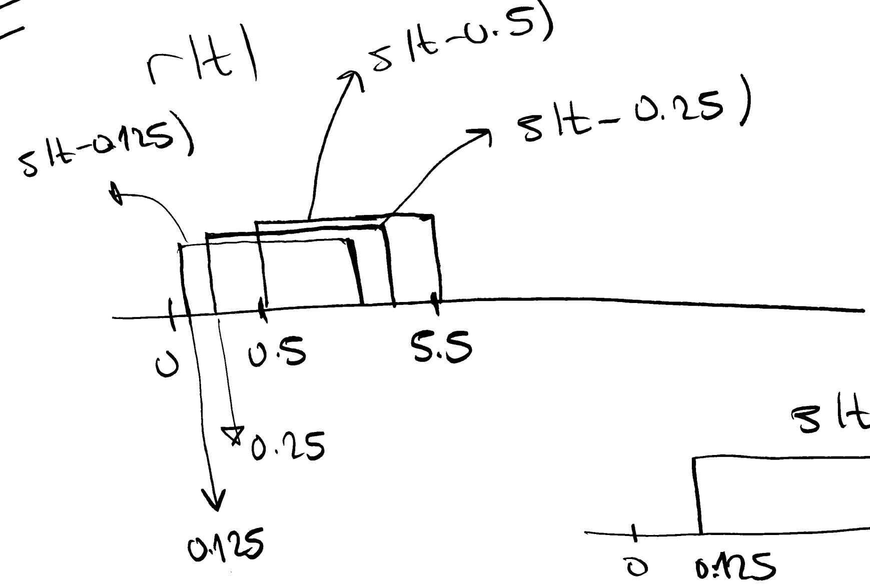


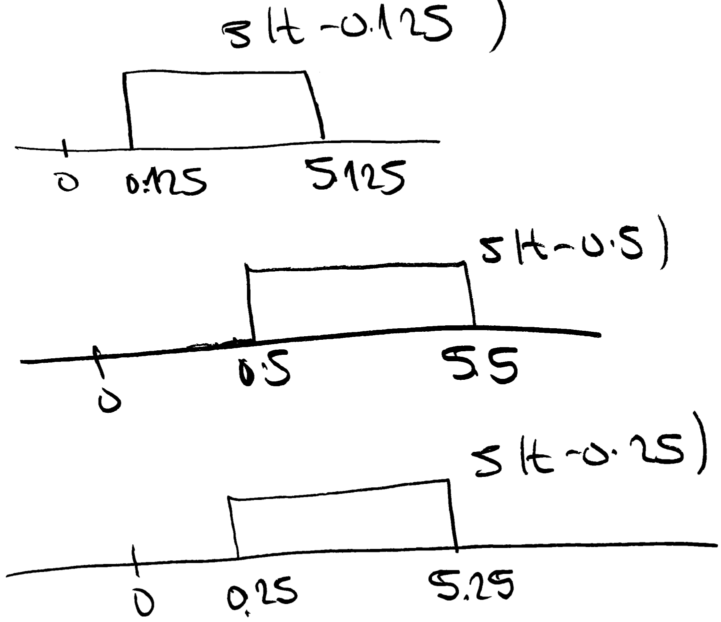
$T_s = 10$

Draw r(t)

Is it a flat channel?

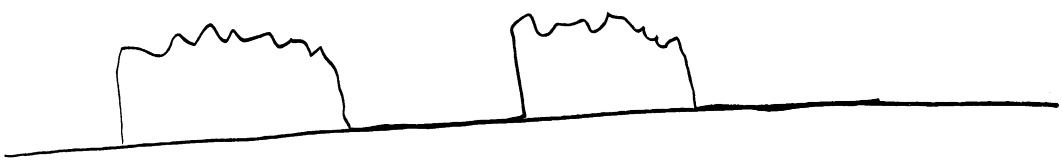
4) Sln:





If we transmit two pulses sequentially

r(t) → received signal



pulses do not overlap and can be detected

So our channel is flat fading channel

(5)

To summarize a signal undergoes flat fading if

$$B_s << B_c$$

B_s ↓ signal bandwidth

B_c ↓ coherence bandwidth

and

$$T_S >> \sigma_\tau$$

T_S ↓ Symbol period

σ_τ ↓ delay spread

Frequency Selective Fading:

If the channel possesses a constant-gain and linear phase response over a bandwidth that is smaller than the bandwidth of transmitted signal, then the channel creates frequency selective fading on the received signal

Frequency selective fading is due to time dispersion of the transmitted symbols within the channel. Thus the channel induces intersymbol interference (ISI). Viewed in the frequency domain, certain frequency components in the received signal spectrum have greater gains than others.

(6) Freq. selective fading channels are much more difficult to model than flat fading channels.

Frequency selective fading channels are also known as wideband channels since the bandwidth of the signal s(t) is wider than the bandwidth of the channel impulse response.

Usually channel measurements are done using wideband multipath channels, and models are developed from these measurements.

A signal undergoes frequency selective fading if

$B_s > B_c$

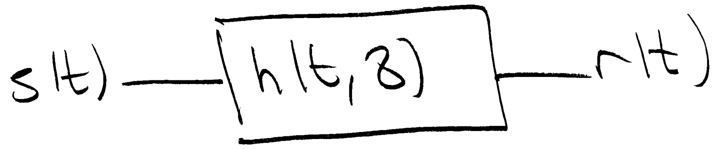
B_s → signal BW, B_c → channel BW

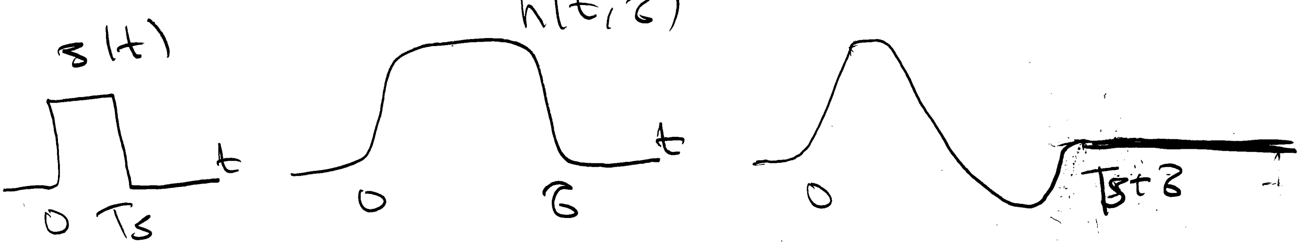
and

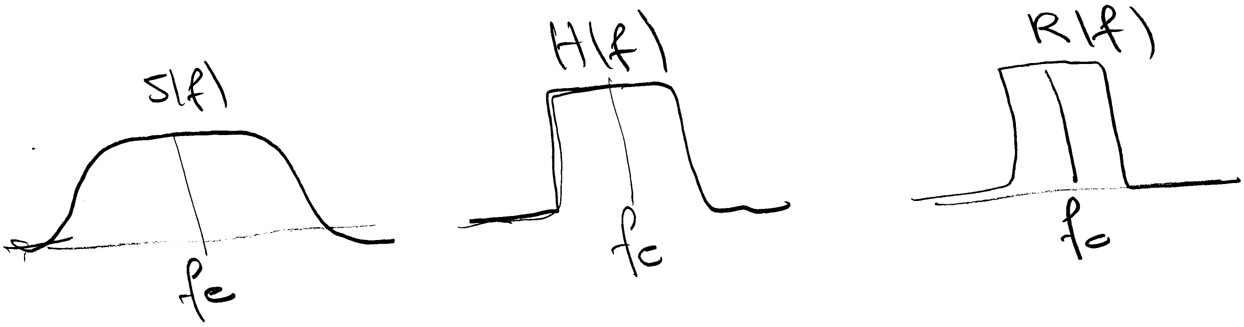
$T_s < \sigma_\tau$

T_s → symbol period, σ_τ → delay spread.

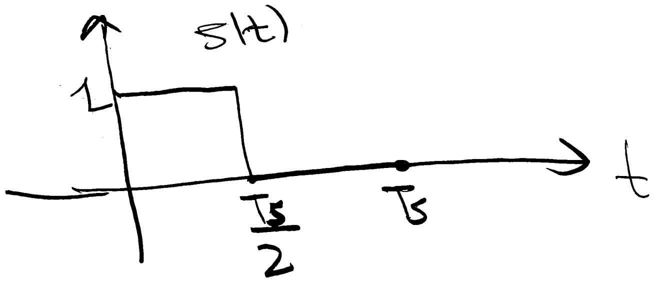
(7)







Ex:



$T_s = 4$

Assume that two consecutive s(t) pulses & −s(t) are transmitted

If $r(t) = s(t) + s(t-4)$

Draw r(t)

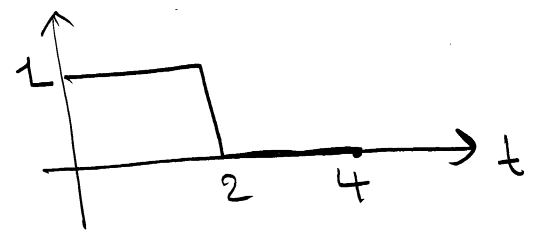
If $r(t) = s(t) + s(t-0.25)$

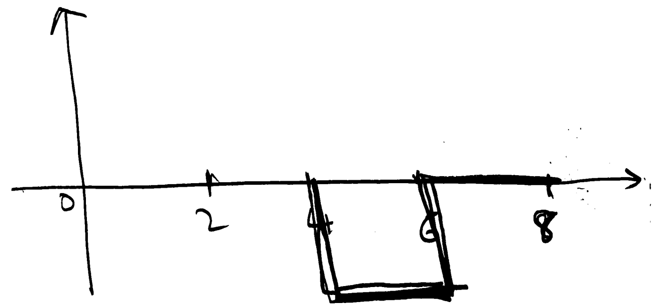
draw r(t)

(8)

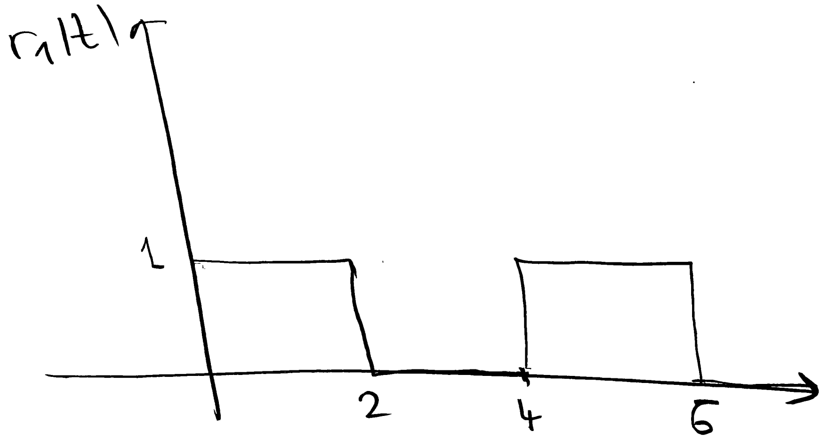
Sln:

$s_1(t)$ $s_2(t)$

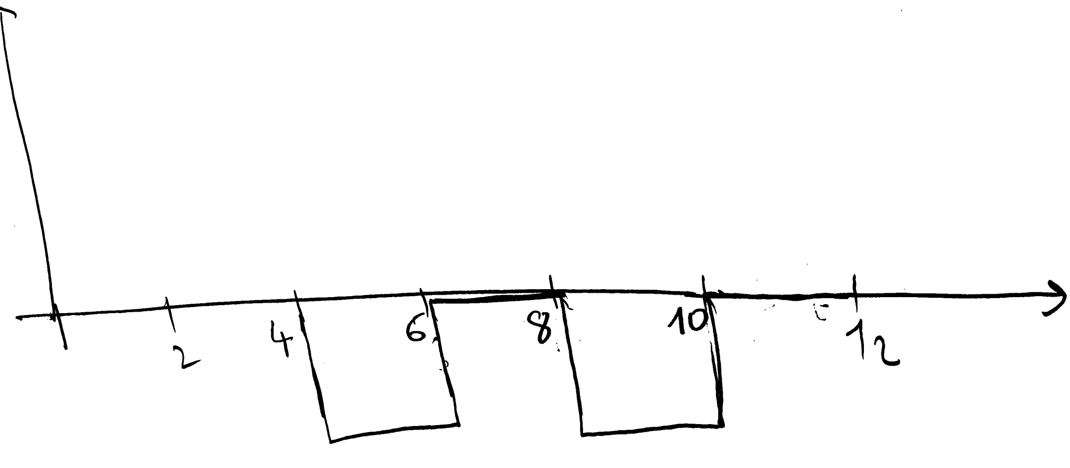




$r_1(t) = s_1(t) + s_1(t-4)$

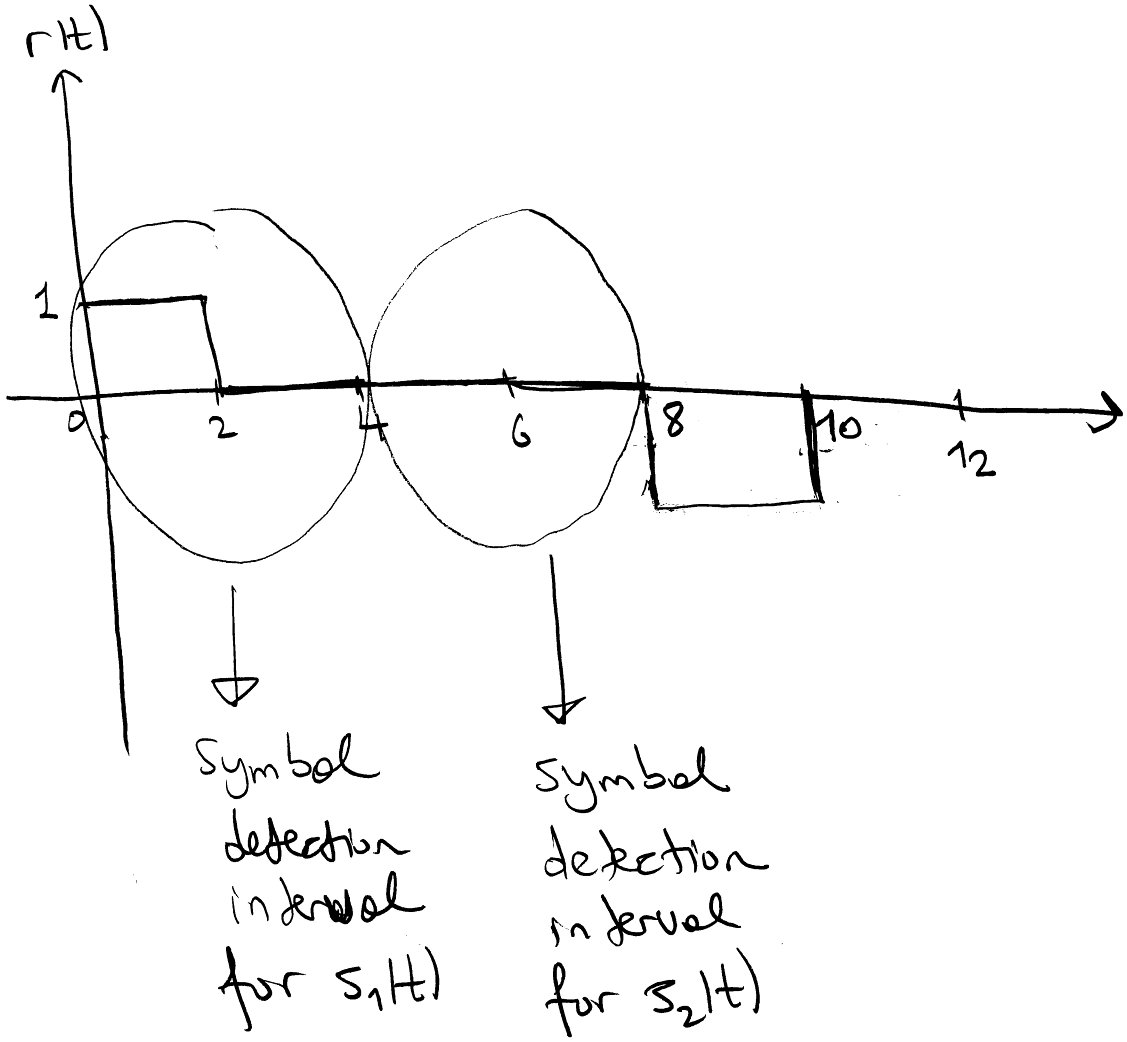


$r_2(t) = s_2(t) + s_2(t-4)$



$r(t) = r_1(t) + r_2(t)$

(9)



as you see from the above figure $s_2(t)$ is lost.

<u>Fast Fading:</u>

In a fast fading channel, the channel Impulse response changes rapidly within the symbol duration

<u>Slow Fading:</u>

In a slow fading channel, the channel impulse response changes at a rate much slower than the transmitted baseband signal $s(t)$.