



Wireless Physical Layer



Prof. Michael Tsai 2012/10/1

無線“通道”(channel)與有線“通道”非常不同

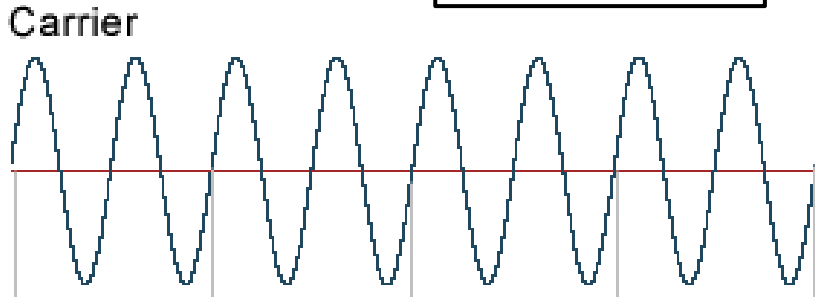
1. 多重傳輸路徑(multipath)→fading
 - ▶ 單一傳輸的訊號可能自己和自己干擾
 - ▶ 訊號強度變化非常頻繁
2. 隨著距離增加，接收到的能量減少得很快(且不規則)
 - ▶ 無法判斷是否有collision
 - ▶ 需要高感度(sensitivity)的接收器
3. 實質上永遠都是一個broadcast link
 - ▶ 共用頻譜，頻寬有限
 - ▶ 附近的傳輸會造成干擾，而且傳輸端不一定可以察覺



Wireless Modulation Example

QPSK (4-PSK)

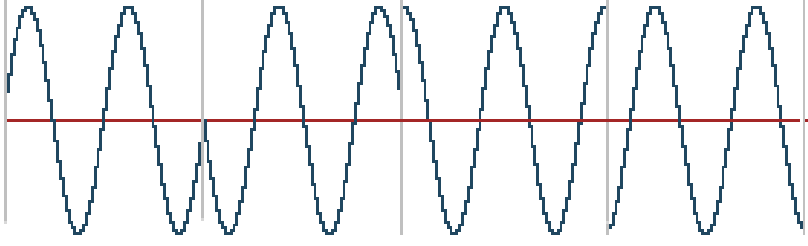
四種不同相位



Modulating value from two bits.

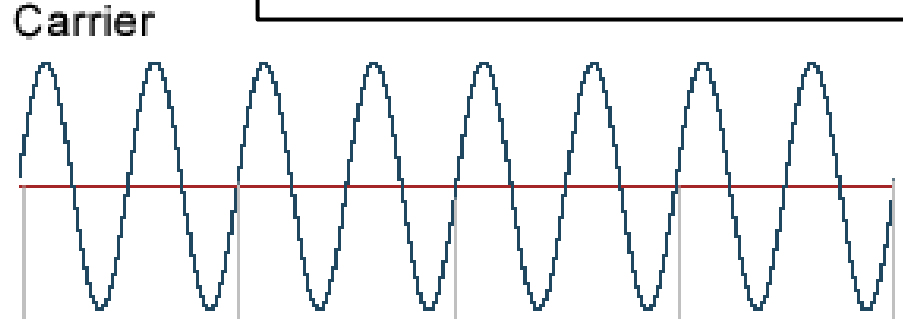
- 0 (00)
- 2 (10)
- 1 (01)
- 3 (11)

Modulated Result



8-QAM

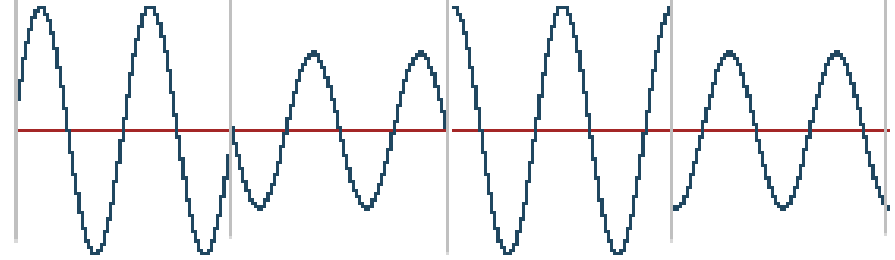
四種不同相位 x 兩種不同強度



Modulating value from three bits.

- 0 (000)
- 6 (110)
- 1 (001)
- 7 (111)

Modulated Result



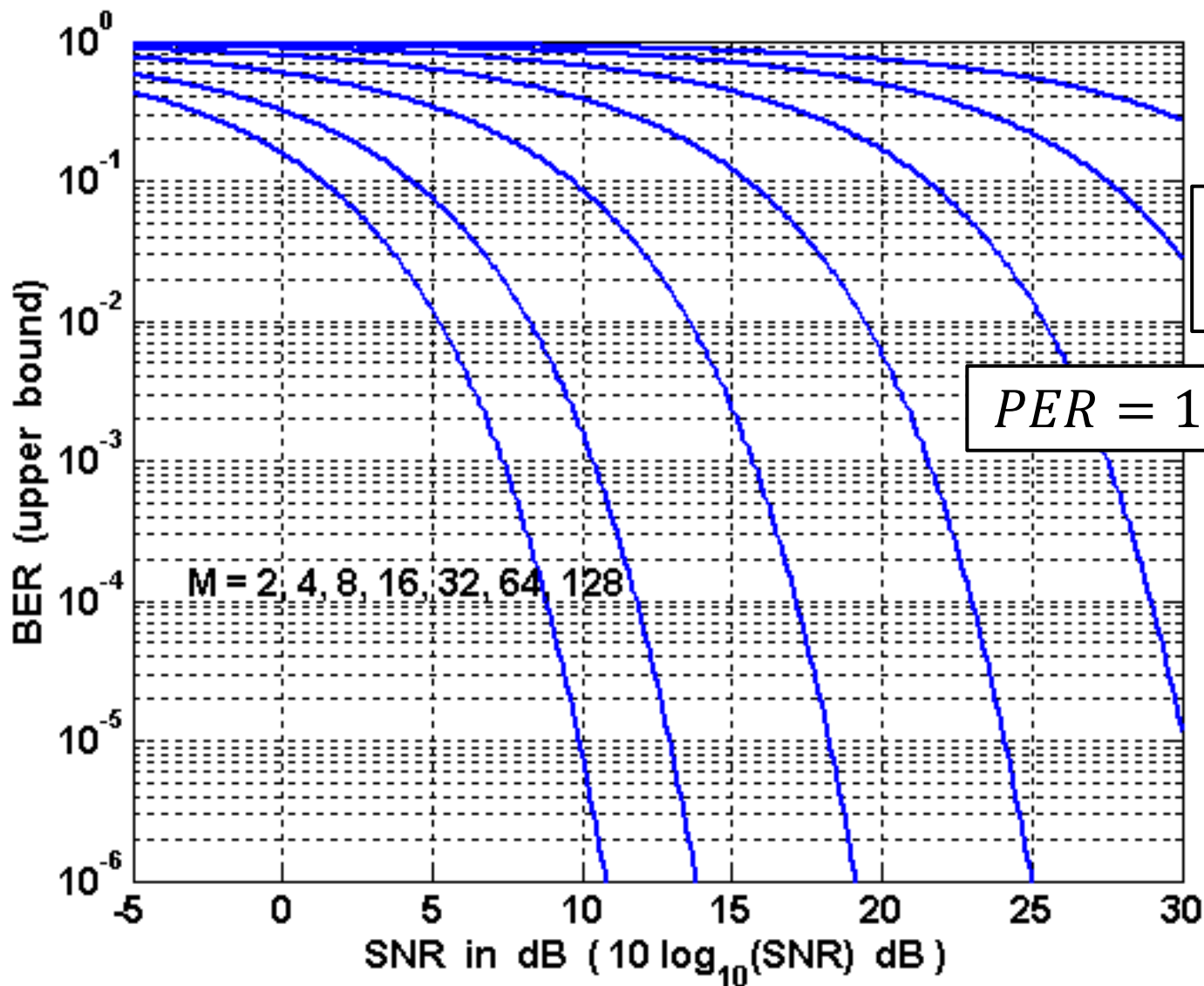
SNR & BER (M-PSK)

$$P_e \leq 2 \times Q \left(\sqrt{2 \times SNR} \sin \left(\frac{\pi}{M} \right) \right)$$

$$SNR = \frac{S}{N}$$

$$SINR = \frac{S}{N + I}$$

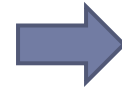
$$PER = 1 - (1 - BER)^L$$



Free Space Propagation

Friis Formula

$$P_r = \frac{P_t G_t G_r \lambda^2}{(4\pi d)^2}$$



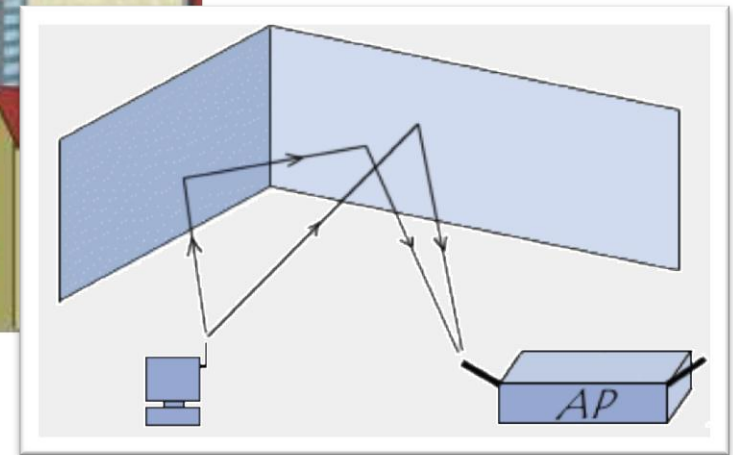
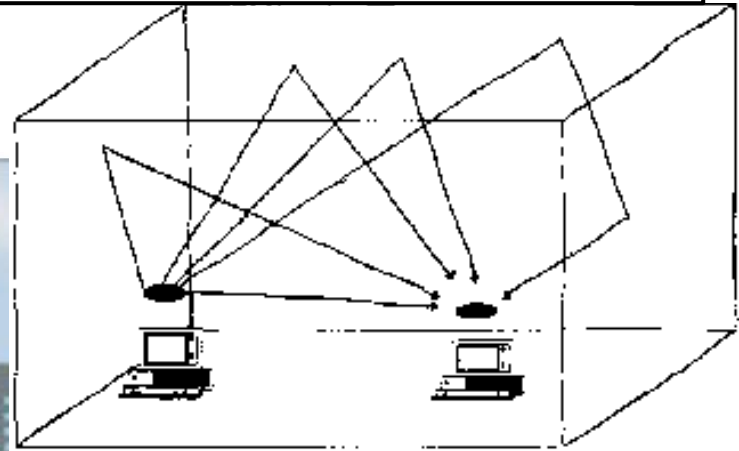
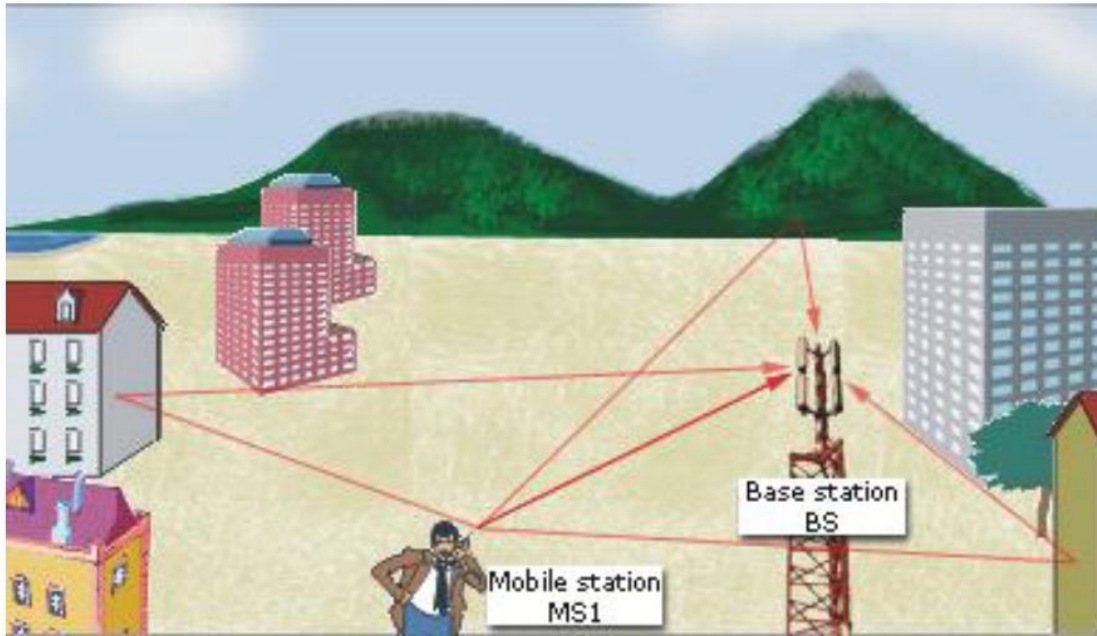
$$P_r \propto \frac{1}{d^2}$$

- ▶ P_t : Transmission power
- ▶ P_r : Reception power
- ▶ λ : 波長 (=c/f)
- ▶ G_t, G_r : Transmission & receiving antenna gain
- ▶ Useful tips:
 - ▶ 天線越大支，通常收得越好
 - ▶ 距離越遠，收到能量越少 (指數性衰退)
 - ▶ 頻率越高，能量衰減得越厲害
 - ▶ 設計一個系統，是要在多個參數之間要取得平衡

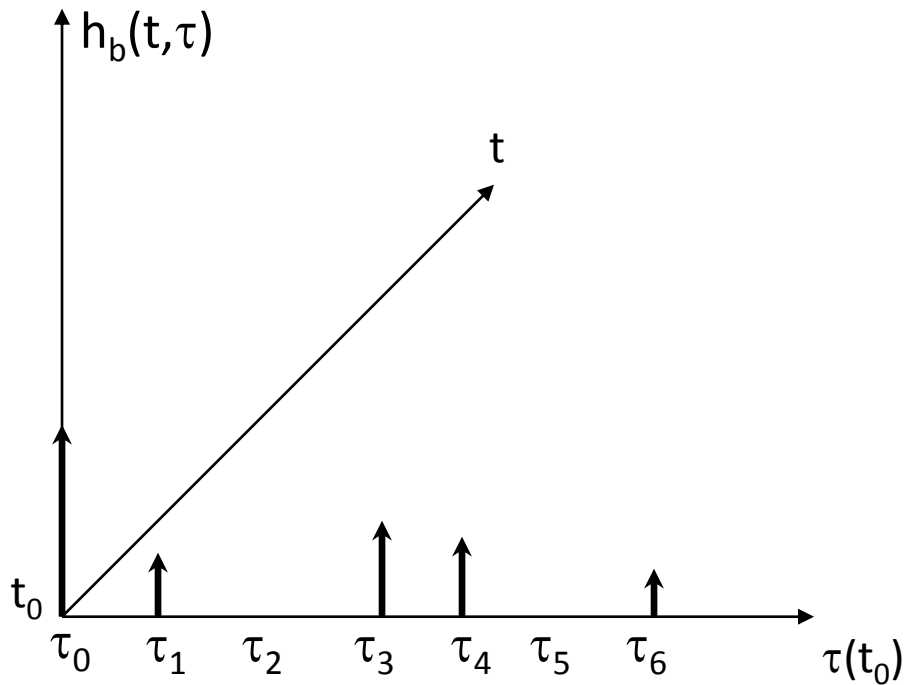


Multipath Propagation

接收端接收到的訊號是所有經不同**長度**路徑的到達的訊號加總



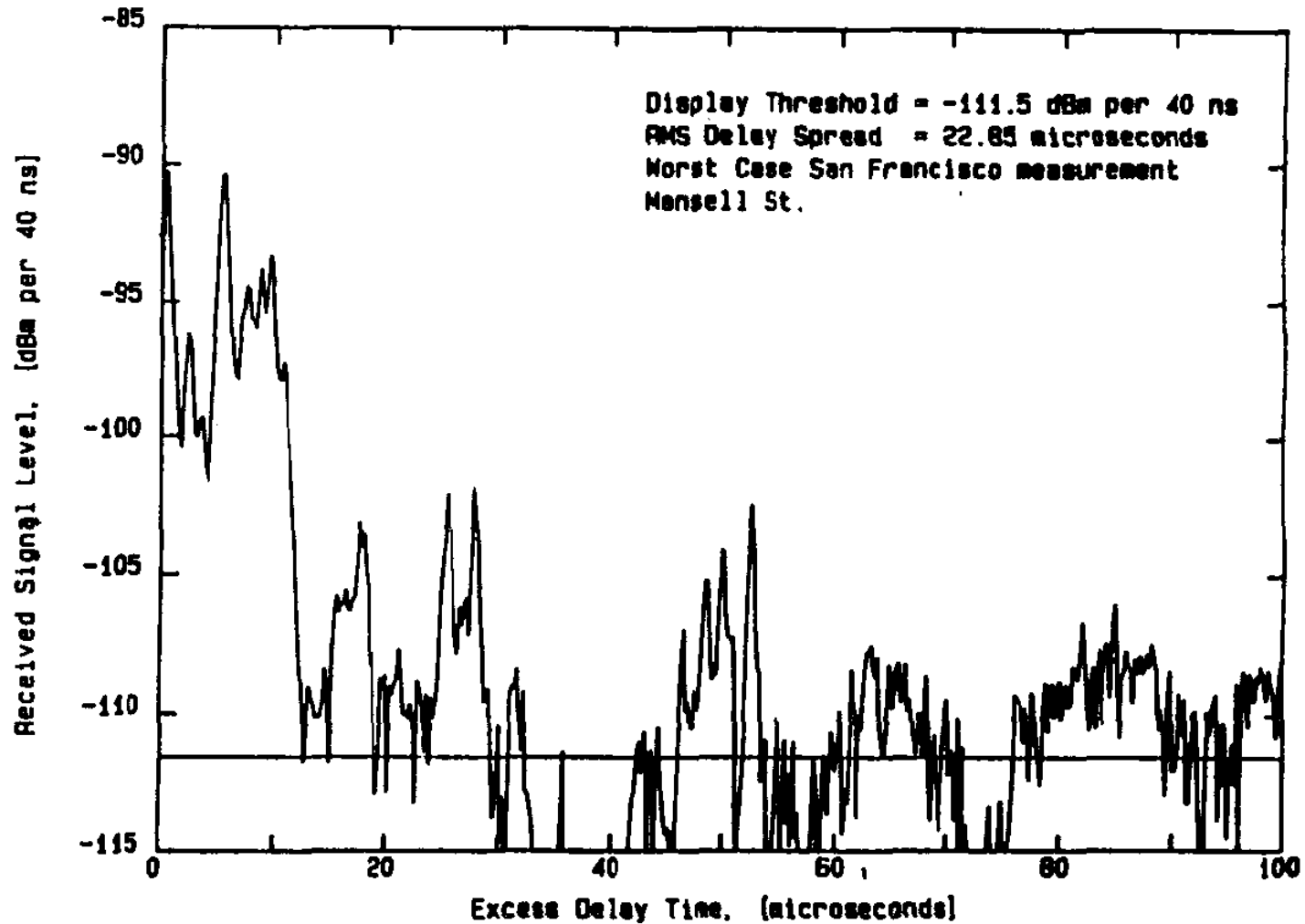
Power delay profile



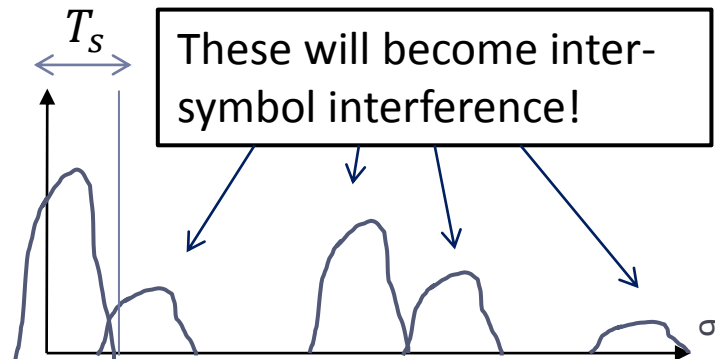
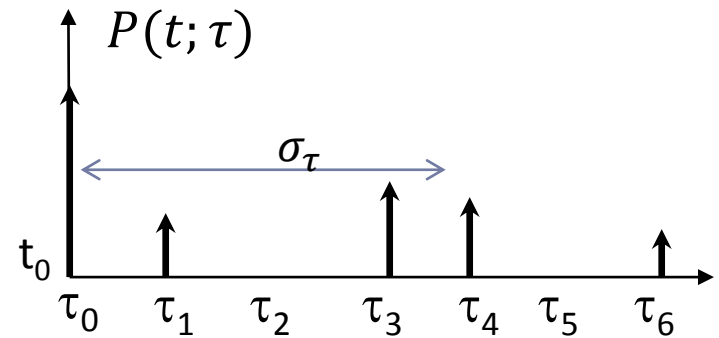
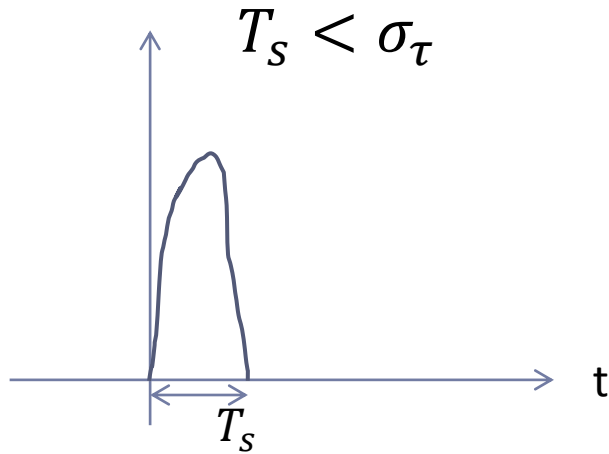
同一個訊號，經不同路徑傳遞後，
會在不同時間到達接收端，且強度不同



真實世界的power delay profile

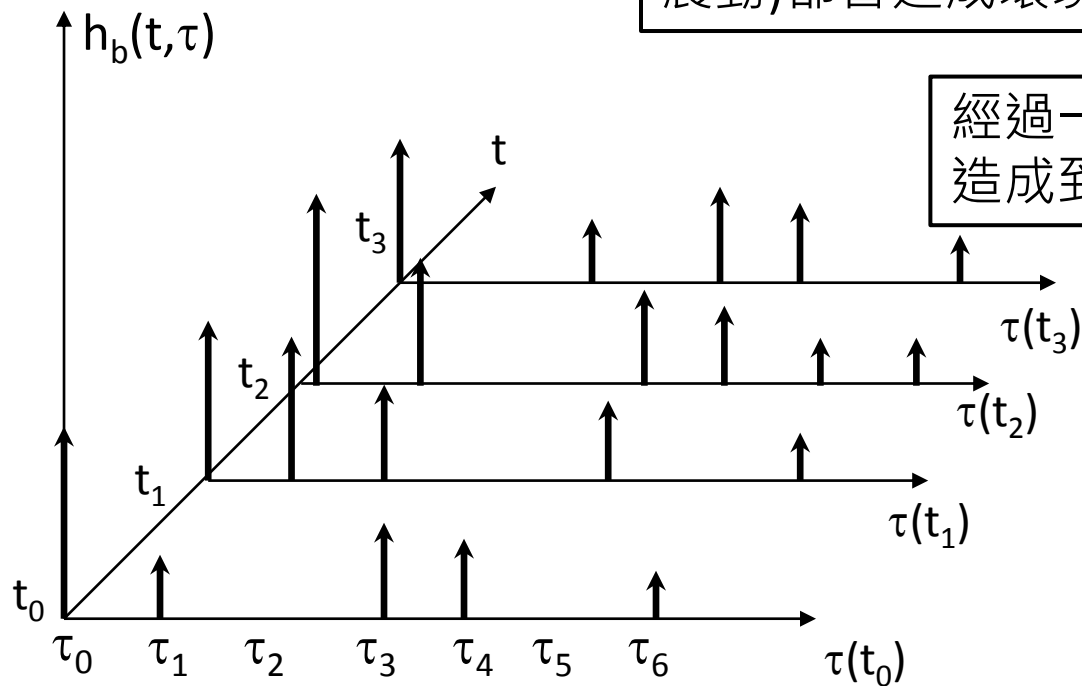


Inter-Symbol Interference



隨時間變化的無線通道

不管是傳輸端、接收端、或是反射物體的位置變化(移動，甚至是震動)都會造成環境變化!



經過一段時間後，環境又略有不同，造成到達強度&時間又有不同。

同一個訊號，經不同路徑傳遞後，會在不同時間到達接收端，且強度不同