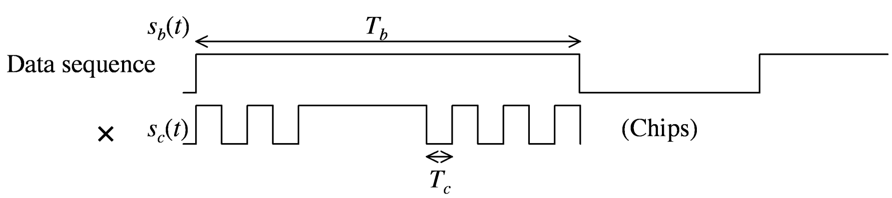
Wireless Communications
Lecture 16

[Spread Spectrum]

- Increase the bandwidth to reduce ISI and interference
- Is a multiple access technique
- First started in military for security reasons.(low detection probability)
- Is one of the main standards of US now.



DS-CDMA

$$\frac{T_b}{T_c} = K, \qquad \text{BW expansion } K \text{ times}$$

where K denotes *spreading factor* and *processing gain*.

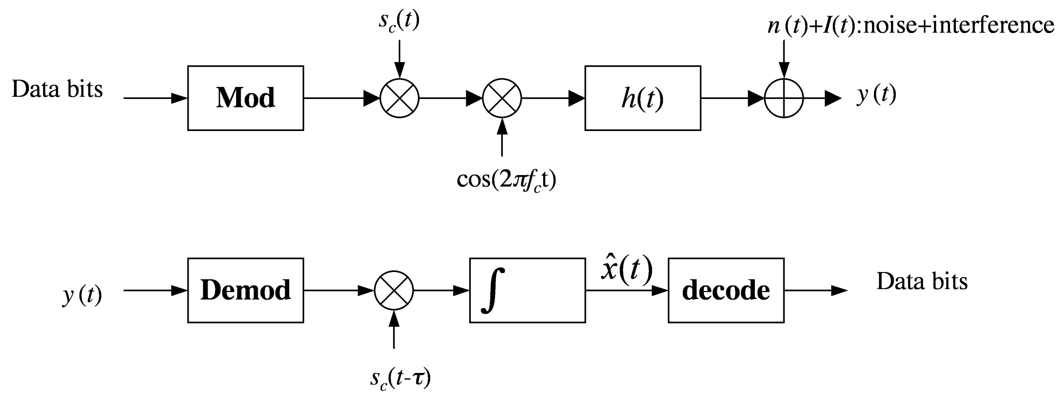
[Direct-Sequence Spread Spectrum(DSSS)]

- Pseudorandom(PN) sequences:

  Long codes where period is larger than T_b or *short* codes where period is same as T_b.
- Correlation properties: for short code

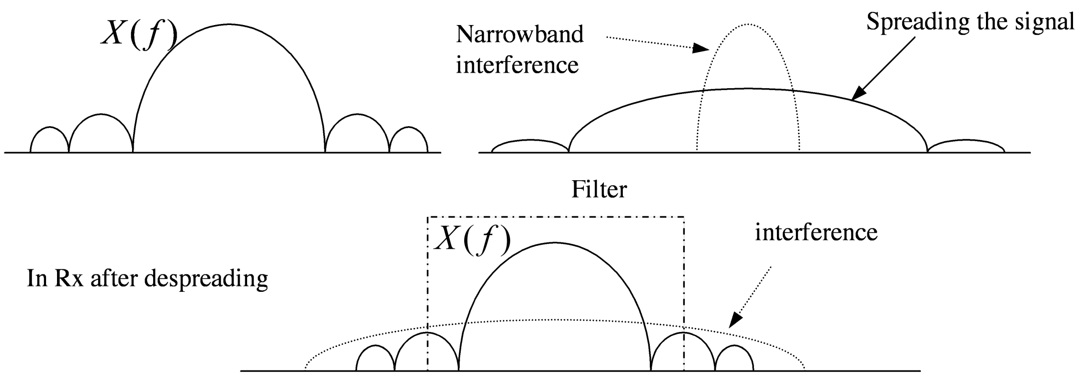
  $$\rho_c(\tau) = \int_0^{KT_c} s_c(t)s_c(t-\tau)dt$$

  In general, if code is periodic with period T, $\rho_c(\tau)$ is periodic with the same period.

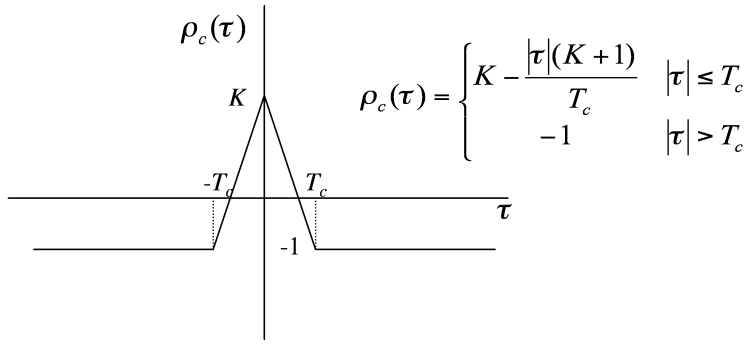


- Best code: delta correlation function and cross correlation function.
- If no delay spread, $\tau = 0$,

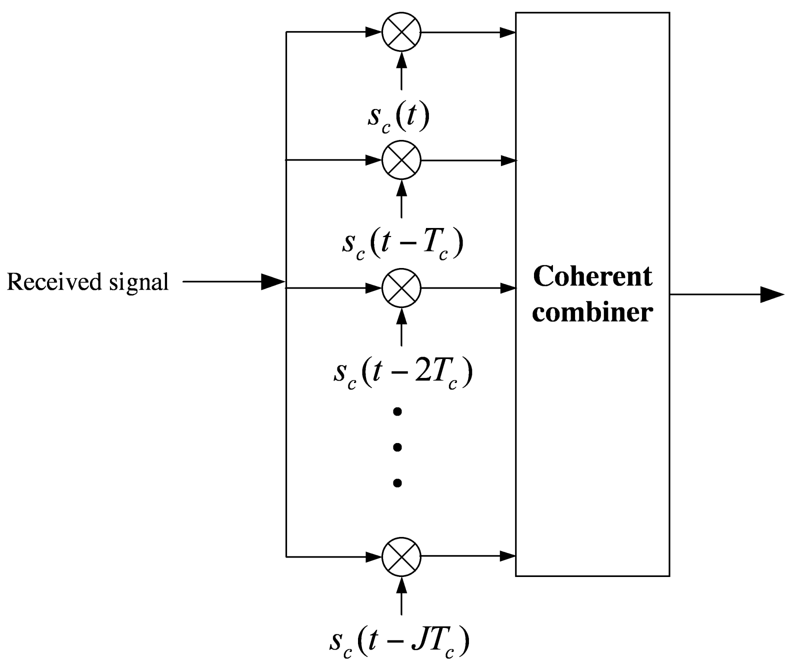
$$\hat{x}(t) = \int [x(t)s_c(t)]s_c(t)dt + \int n(t)s_c(t)dt + \int I(t)s_c(t)dt$$



- In reality building orthogonal codes is not possible. Maximal linear codes:

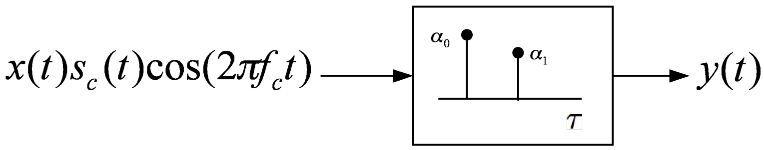


  - If we have delay spread, $s_c(t-\tau)$ can be tuned to the first channel tap. Then delays bigger then T_c will be attenuated $1/K$.
  - Disadvantage: perfect tuning.
  - Channel is typically learned through a training phase.
  - Rake receiver:

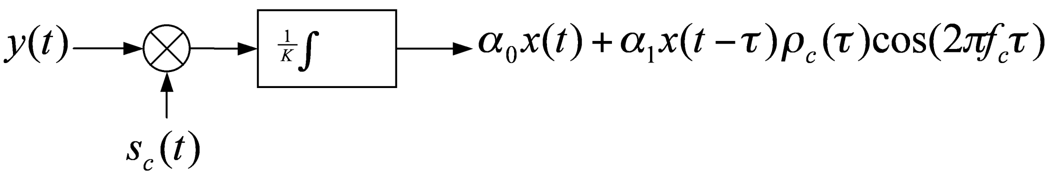


- Similar to diversity cases:

  What if I only match to one of the channel taps?



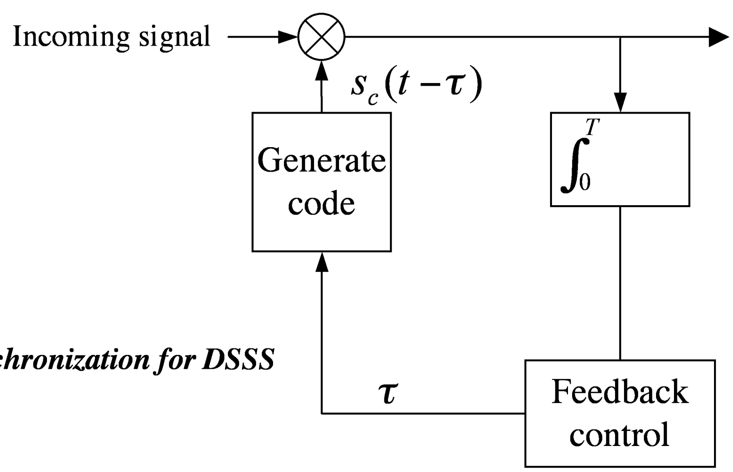
$$
\begin{aligned}
y(t) &= \alpha_0 x(t) s_c(t)\cos(2\pi f_c t) + \alpha_1 x(t-\tau) s_c(t-\tau)\cos(2\pi f_c (t-\tau) \\
LPF\{y(t)\times 2\cos(2\pi f_c t)\} &= \alpha_0 x(t) s_c(t) + \alpha_1 x(t-\tau) s_c(t-\tau)\cos(2\pi f_c \tau)
\end{aligned}
$$



[**Example**] Consider a spreading code using maximal linear codes with $T = T_s$ and $K = 100$ chips. There is only one LOS path and the synchronizer at the receiver has a delay 0.5 T_c. How much is the power reduced?

$$\begin{aligned}\frac{\rho(0.5T_c)}{K} &= 1 - \frac{0.5T_c(K+1)}{KT_c} \\ &= 1 - 0.5(1.01) \\ &= 0.495\end{aligned}$$

Power reduction is $0.495^2 = 0.245 = -6.11$dB.



Synchronization for DSSS

[**Example**] Consider $h(t) = \alpha_0\delta(t) + \alpha_1\delta(t-\tau_1) + \alpha_2\delta(t-\tau_2)$ at receiver the synchronization is tuned to $\delta(t)$. What should be the range for τ_1 and τ_2 to have minimum interference?

Assume maximal linear codes $T_c < \tau_1 < T_b - T_c$ and $T_c < \tau_2 < T_b - T_c$.