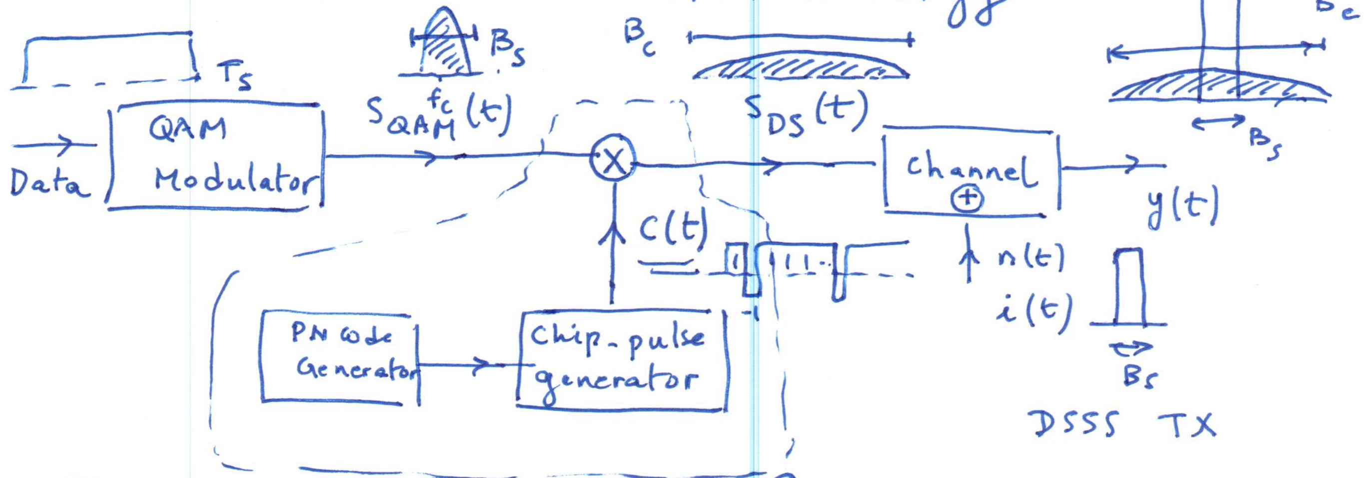
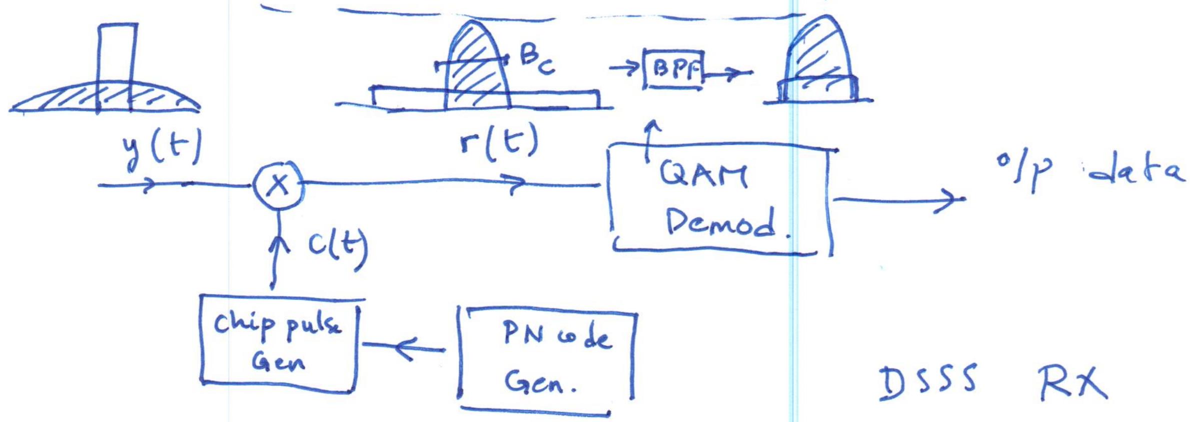
Lecture 19

② Direct Sequence Spread Spectrum (DSSS)

Has become the dominant CDMA technology



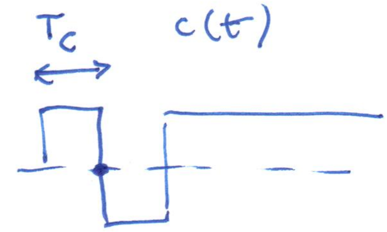
DSSS TX



DSSS RX

$$y(t) = s_{DS}(t) + i(t)$$

$$= s_{QAM}(t)\, c(t) + i(t)$$



$$r(t) = c(t)\, y(t)$$

$$= s_{QAM}(t)\, \underbrace{c^2(t)}_{1} + i(t)\, c(t)$$

$$= s_{QAM}(t) + \overbrace{i(t)\, c(t)}^{i'(t)}$$

De-spread signal

spread interference

Chip ~~duration~~ $T_c << T_s$

$$L = \frac{T_s}{T_c}$$

BW after spreading is L times broader than the original signal.

$$B_c = \underbrace{L B_s + B_s}_{\uparrow} = (L+1) B_s \simeq L B_s$$

convolution of spectra of s_{QAM} and $c(t)$

Let P_i be the total power of interference.

Interference spectral level before despreading $= \dfrac{P_i}{B_s}$, $f_c - \frac{B_s}{2} \leq f \leq f_c + \frac{B_s}{2}$

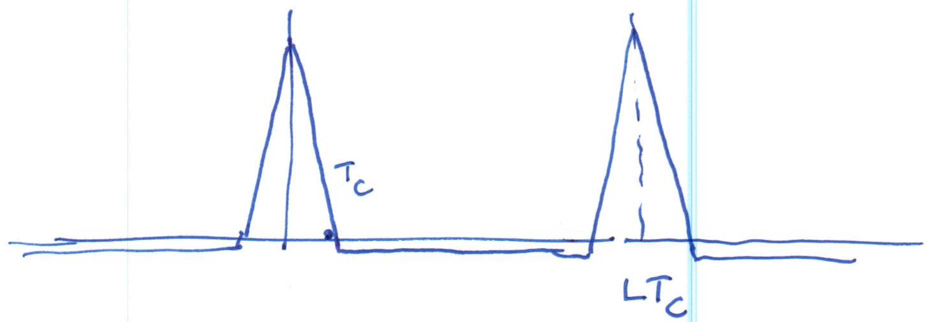
After despreading, the interf. spectral level $= \dfrac{P_i}{(L+1)B_s}$, $f_c - \frac{B_c}{2} \leq f \leq f_c + \frac{B_c}{2}$

$$\frac{\text{SIR before}}{\text{SIR after}} = \frac{\dfrac{E_b B_s}{P_i}}{\dfrac{E_b (L+1) B_s}{P_i}} = \frac{1}{L+1}$$

SIR improves by a factor of $(L+1) \simeq L$ which is the spreading factor.

DSSS is very effective against narrowband jamming signals

A good PN sequence $c(t)$ has an autocorrelation fn that is similar to that of white noise

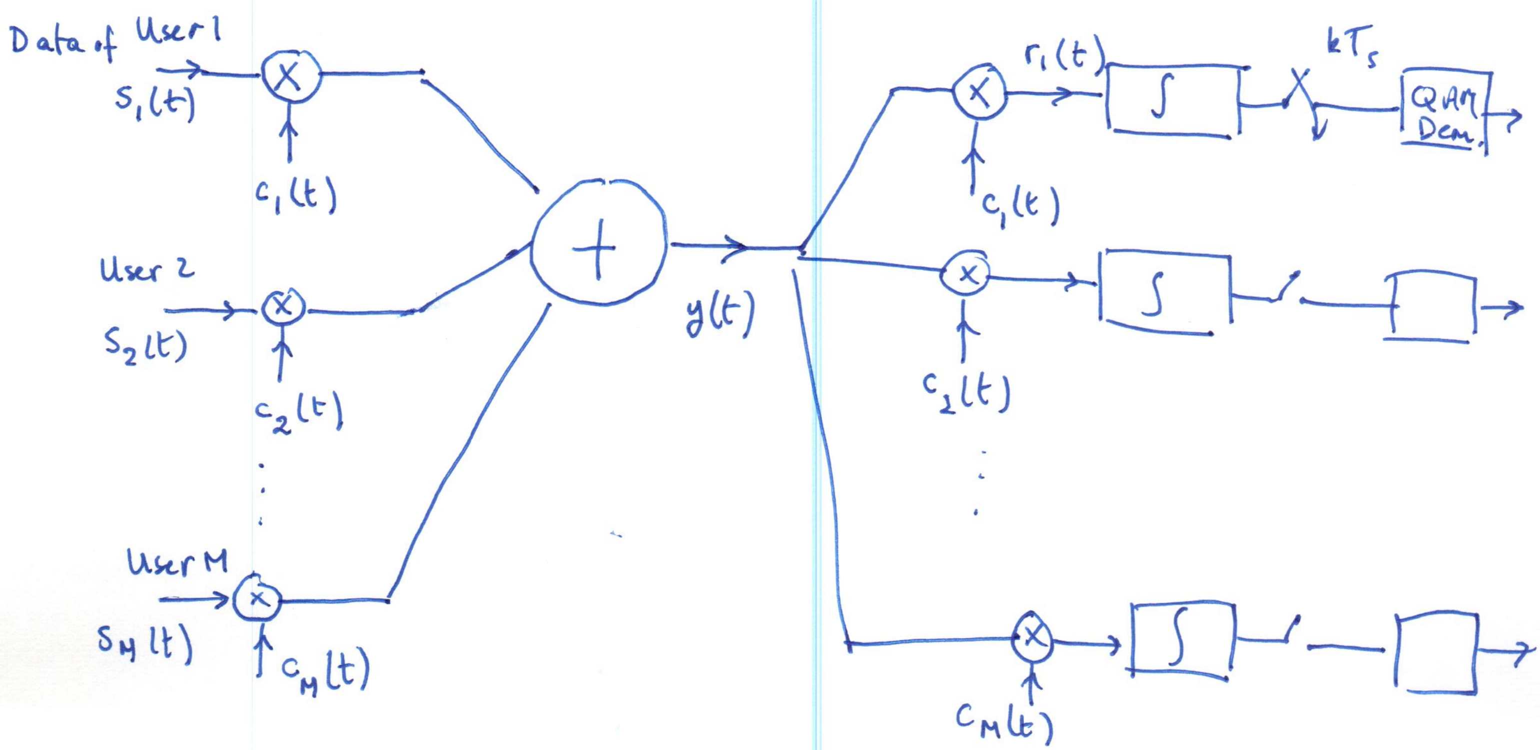


Also, cross correlation among PN sequences assigned to different users should be small to reduce mutual interference

PN-sequences are periodic (e.g. m-sequences, i.e. maximum length shift register sequences)

An m-stage shift register generates a sequence of length $L = 2^m - 1$ chips

CDMA:



$$y(t) = \sum_{i=1}^{M} s_i(t)\, c_i(t) + n(t)$$

<u>Despreading at RX 1</u> :

$$r_1(t) = y(t)\, c_1(t)$$

$$= s_1(t) \underbrace{c_1^2(t)}_{1} + \sum_{i \neq 1} s_i(t) \overbrace{c_i(t)\, c_1(t)} + n(t)\, c_1(t)$$

<u>After smoothing</u> :

The interference term is $\underbrace{\sum_{\substack{i=2 \\ i \neq 1}}^{M} \int s_i(t)\, c_1(t)\, c_i(t)\, dt}_{\substack{\text{Residual interference to user 1} \\ \text{Multiple Access Interference (MAI)}}} \simeq 0$

MAI is due to the fact that the codes are not fully orthogonal.