EECE 695M CM#17c

11-2

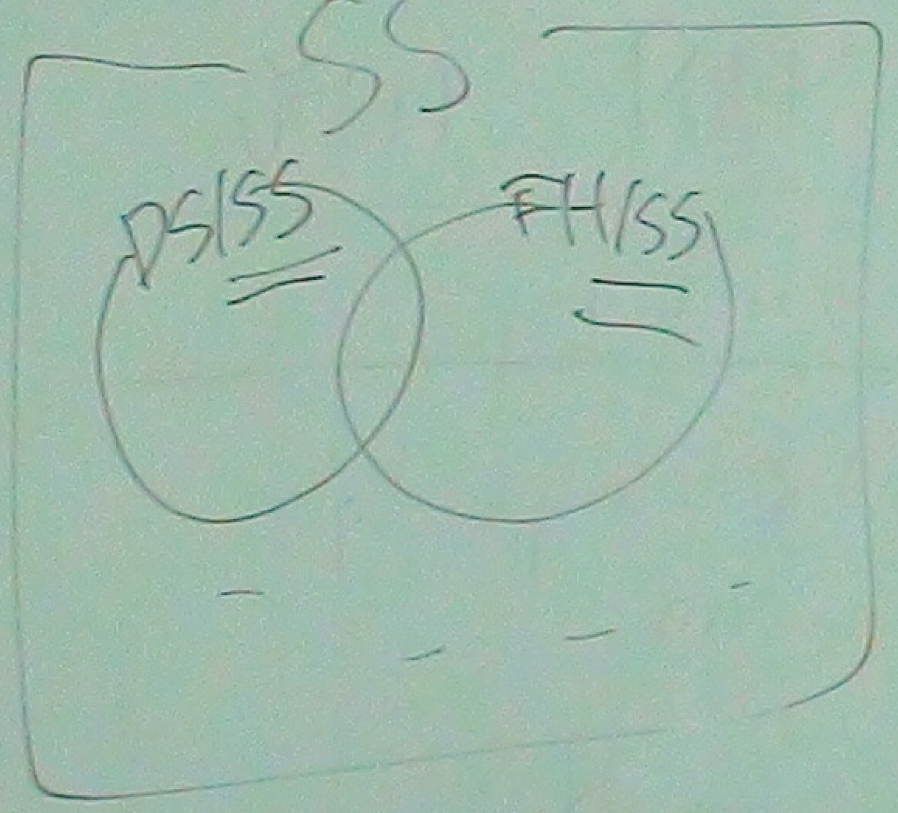
□ DS-CDMA

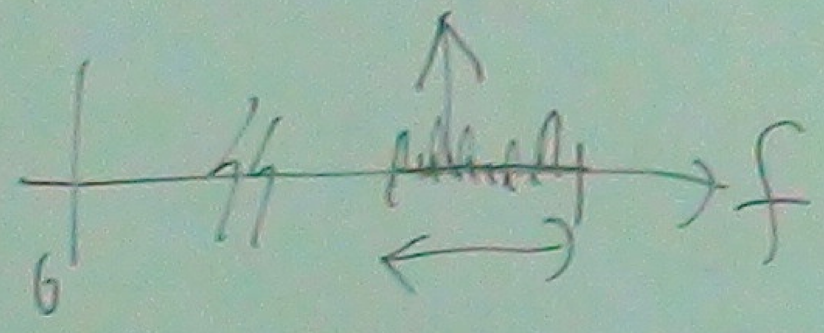
direct-sequence

DS/SS MA

spread spectrum

multiple access





Tx Rx known

of signal

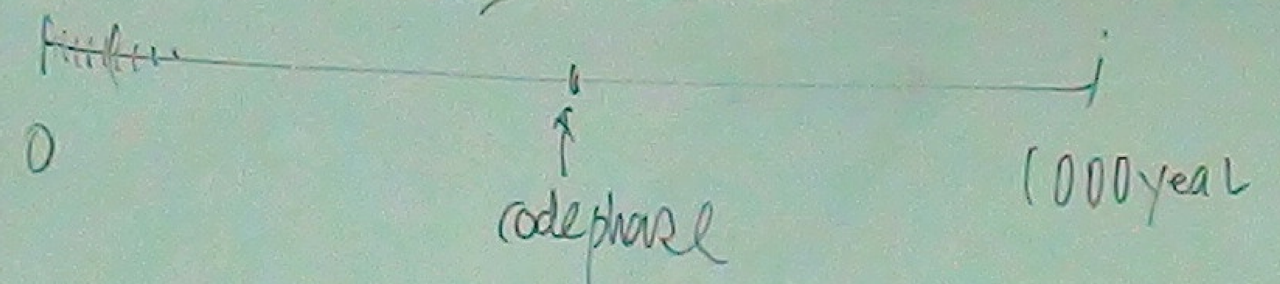
data

$\in \{1,-1\}$

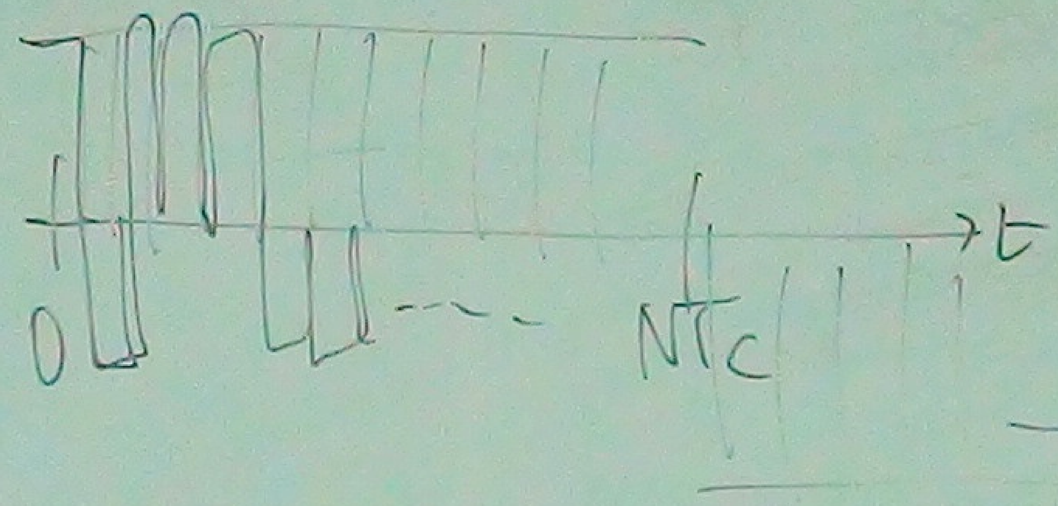
$$x_e(t) = \sum_{n=-\infty}^{\infty} a_r[n]\, b\left[\left\lfloor \frac{n}{N} \right\rfloor\right] p(t-nT_c) = \sum_{n=-\infty}^{\infty} c[n]\, p(t-nT_c)$$

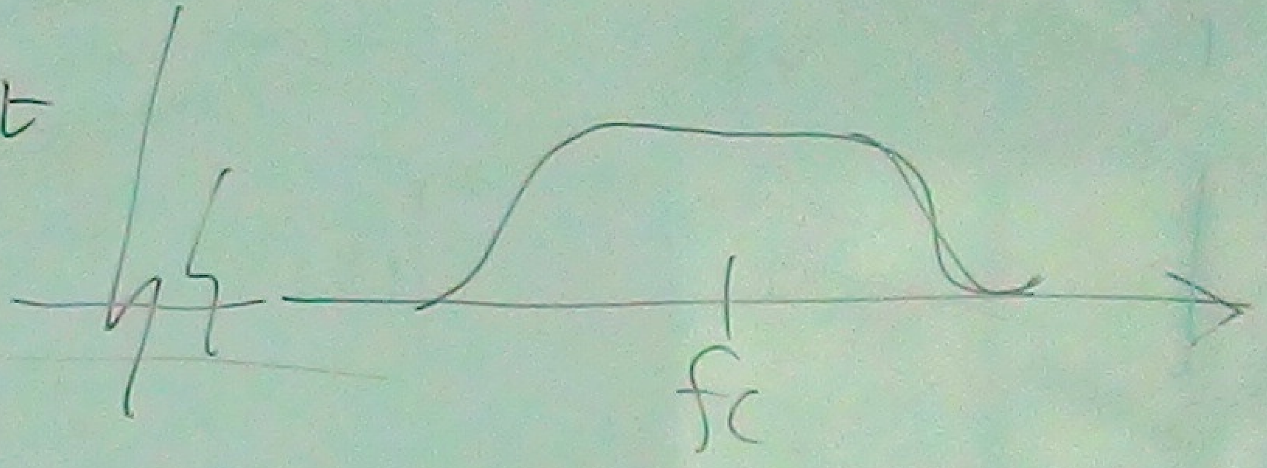
1 μsec

$c[n] \in \{1,-1\}$



$$S_{x_e x_e}(f) = \frac{1}{T_c} |P(f)|^2$$





LPI

□ OFDM w/ CP.

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$\overset{k}{u}$ 11-3

☐ Multi-Stream Decomposition

$$X_e(t) = X_1(t) + X_2(t)$$

$$S_{x_e x_e}(f) = S_{x_1 x_1}(f) + S_{x_1 x_2}(f) + S_{x_2 x_1}(f) + S_{x_2 x_2}(f) \overset{?!}{=} S_{x_1 x_1}(f) + S_{x_2 x_2}(f)$$

$$S_{x_1 x_2}(f) = \mathcal{F}\left[A\{R_{x_1 x_2}(t+\tau, t)\}\right]$$

If $R_{x_1 x_2} = 0$, orthogonal.

$$X_1(t) = \sum_n d_1[n] p_1(t - nT_1)$$

$$X_2(t) = \sum_n d_2[n] p_2(t - nT_2)$$

ex) OQPSK

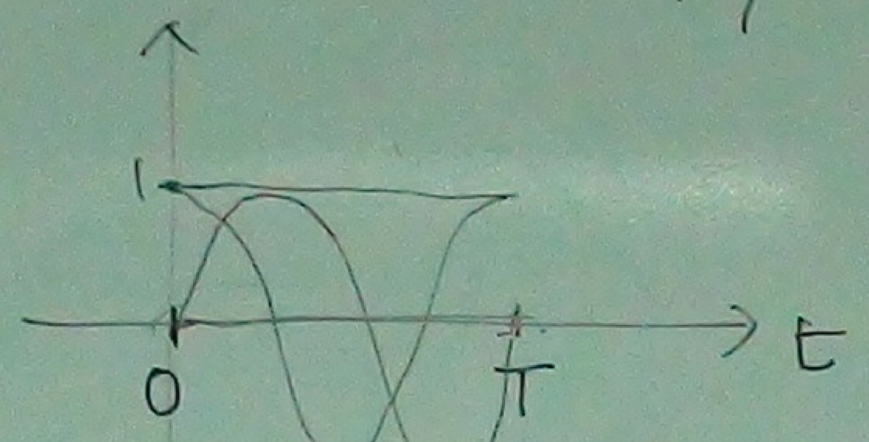
$$X_1(t) = \sum b_1[n] p(t-nT)$$

$$+ j \sum b_2[n] p(t - nT - \tfrac{T}{2})$$

$$S_{x_e x_e}(f) = \frac{2}{T}|P(f)|^2$$

☐ OFDM w/ CP (Cyclic Prefix)

– Model 1 (w/o CP)

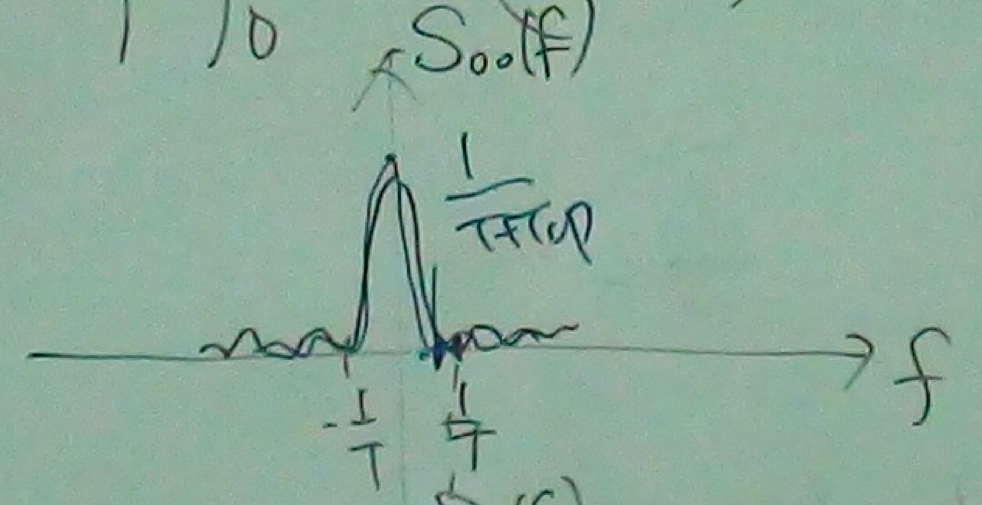


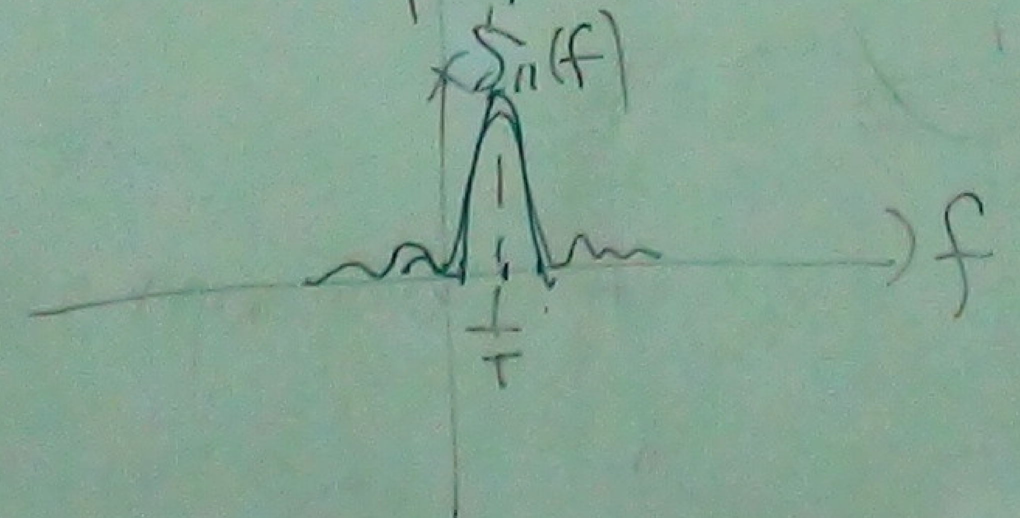
$$X_e(t) = \sum_{n=-\infty}^{\infty} \sum_{k=0}^{K-1} d_k[n] e^{j\frac{2\pi}{T}k(t-nT)} \quad k = 0, \dots, K-1$$

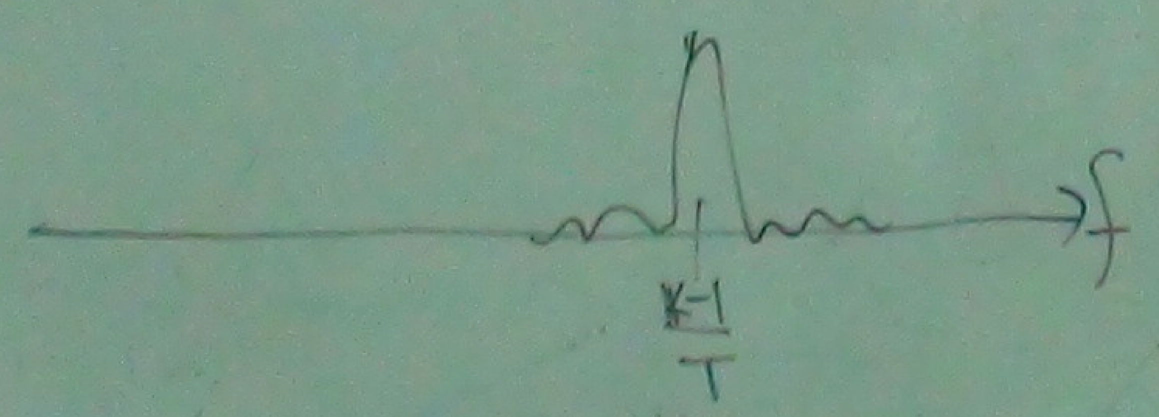
$d_k \in \mathbb{C}$. $\quad E[d_k] = 0, E\{|d_k|^2\} = 1.$

$$\frac{1}{T}\int_0^T X_e(t) \left(e^{j\frac{2\pi k'}{T}t}\right)^* dt = d_{k'}$$

$$\frac{1}{T}|P(f)|^2 = T\,\mathrm{sinc}^2(fT)$$







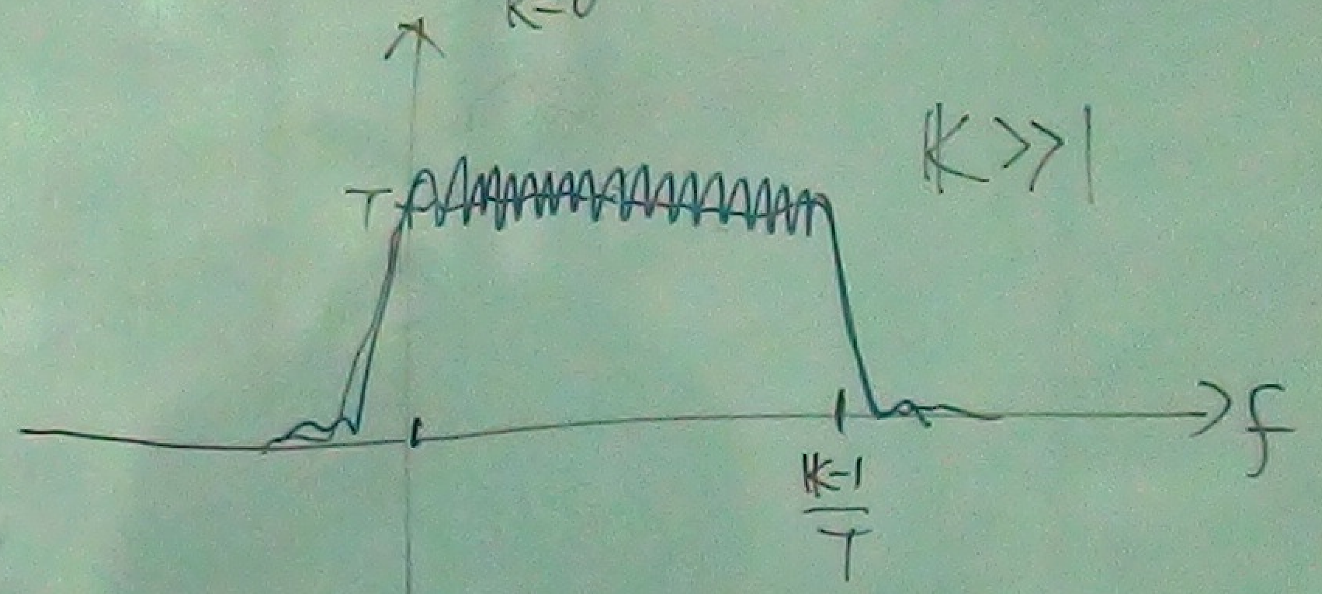
$$X_e(t) = \sum_{k=0}^{K-1} \left(\sum_{n=-\infty}^{\infty} d_k[n] e^{j\frac{2\pi}{T}k(t-nT)} \{u(t-nT) - u(t-(n+1)T)\} \right)$$

$$e^{j\frac{2\pi k}{T}t} e^{-j\frac{2\pi k}{T}(nT)}$$

$$\underbrace{}_{X_k(t)} = \left(\sum_{n=-\infty}^{\infty} d_k[n] p_T(t - nT)\right) e^{j\frac{2\pi k}{T}t}$$

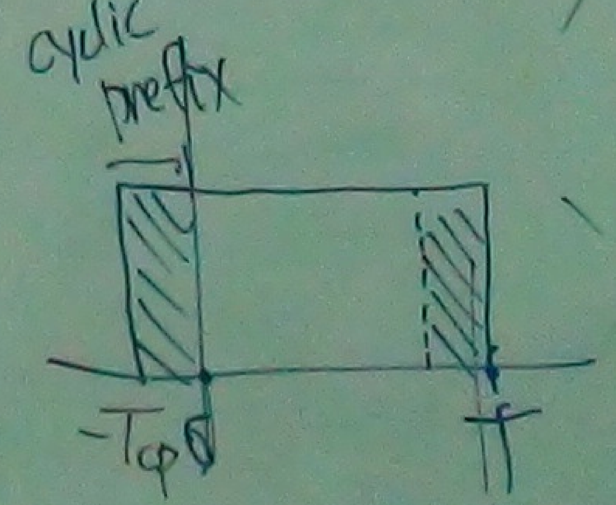
$$\therefore S_{x_e x_e}(f) = \sum_{k=0}^{K-1} T\,\mathrm{sinc}^2\left(\left(f - \frac{k}{T}\right)T\right)$$

$K \gg 1$



$$\because \sum_{n=-\infty}^{\infty} \mathrm{sinc}^2(f-n) = 1, \ \forall f.$$

– Model 1' (w/ CP)



$$S_{00}(f) = (T + T_{cp})\,\mathrm{sinc}^2(f(T+T_{cp}))$$

$$S_{x_e x_e}(f) = \sum_{k=0}^{K-1} (T+T_{cp})\,\mathrm{sinc}^2\left(\left(f - \frac{k}{T}\right)(T+T_{cp})\right)$$

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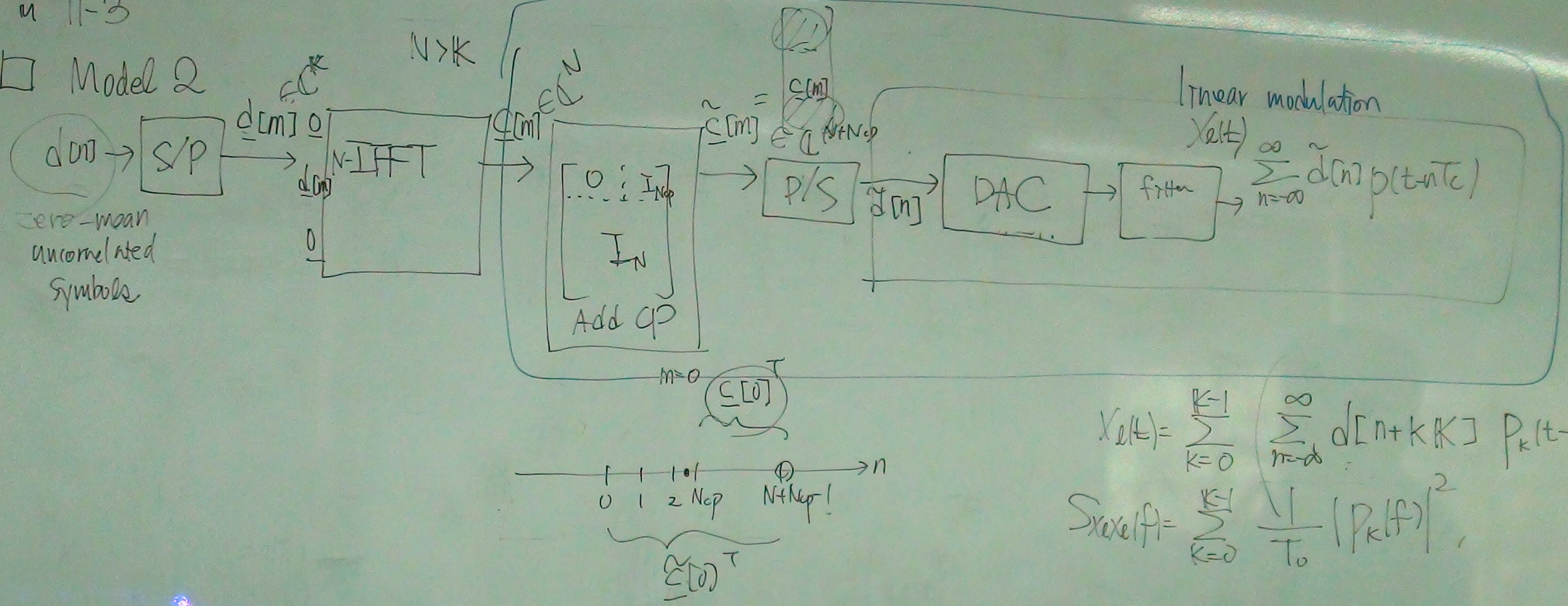
☐ Model 2



$$x_e(t) = \sum_{n=-\infty}^{\infty} \tilde{d}[n]\, p(t - nT_c)$$

$$x_e(t) = \sum_{k=0}^{K-1} \left(\sum_{n=-\infty}^{\infty} d[n + k K]\; p_k(t - nT_0) \right)$$

$$S_{x_e x_e}(f) = \sum_{k=0}^{K-1} \frac{1}{T_0} \left| P_k(f) \right|^2,$$

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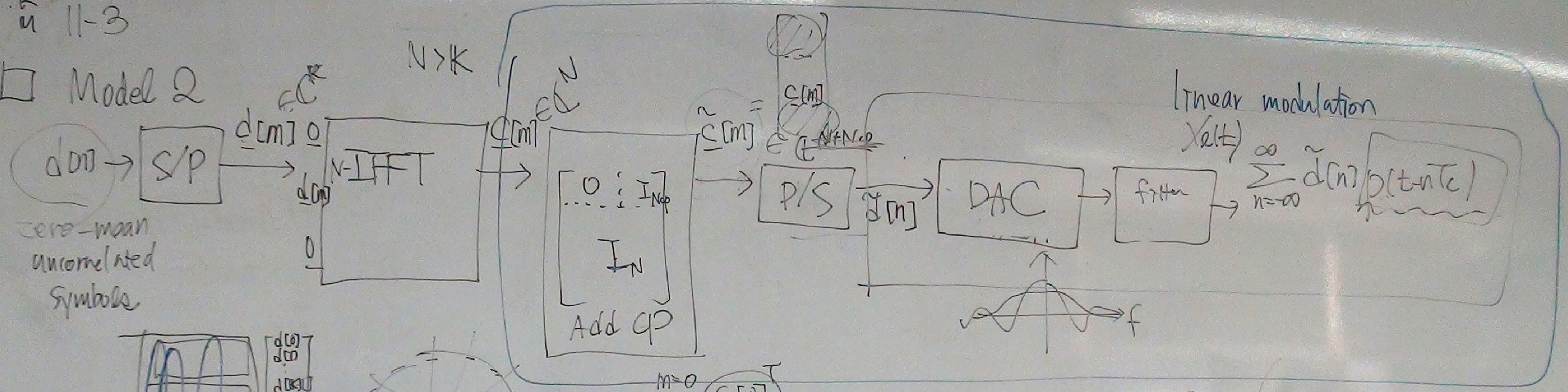
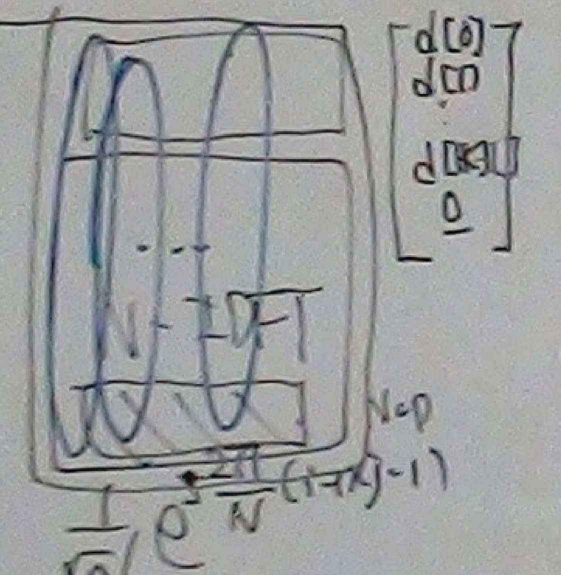
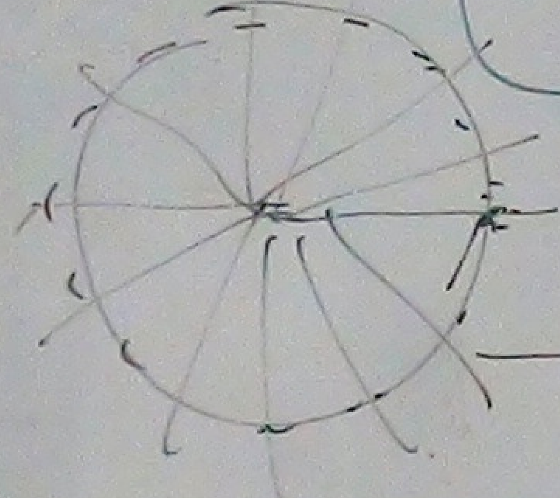
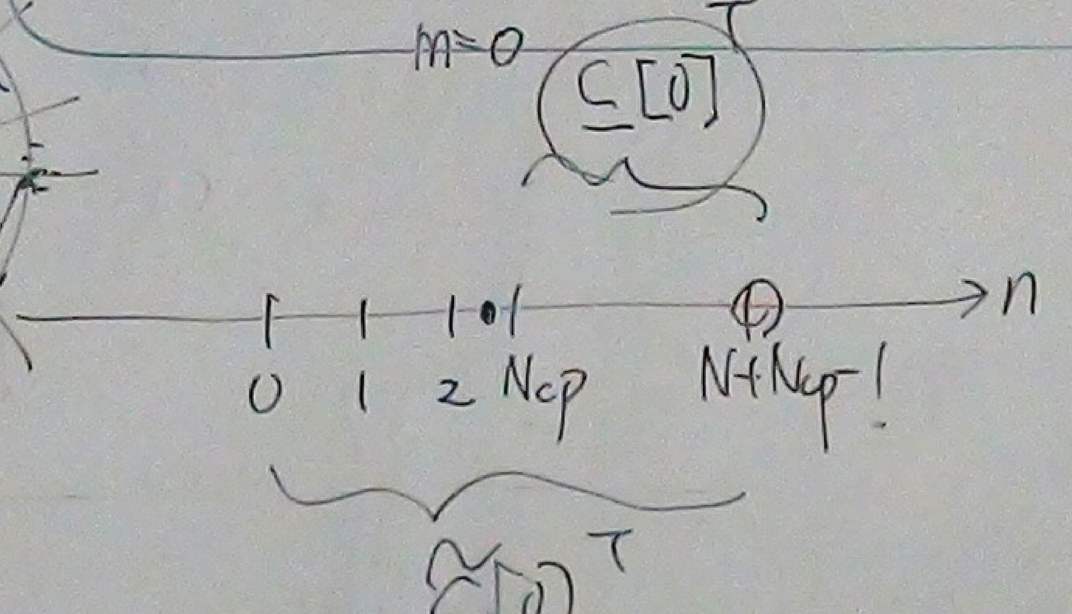
K/u 11-3

□ Model 2









$p(t)$

$p(t-T_c) = \frac{1}{\sqrt{N}}$ d[0] + d[1] ⋯ + d[K-1]

$p(t-2T_c)$

$e^{j\frac{2\pi}{N}0}$, $e^{j\frac{2\pi}{N}1}$, …, $e^{j\frac{2\pi}{N}n}$

$$\frac{1}{\sqrt{N}}\left(p(t)+p(t-T_c)+\cdots+p(t-(N+N_{cp}-1)T_c)\right) d[0] = p_0(t)\, d[0]$$

$$\frac{1}{\sqrt{N}}\left(p(t-(N+N_{cp})T_c)+\cdots\right.$$

$$d[K] = p_0(t-(N+N_{cp})T_c)\, d[K]$$

$$\vdots \qquad p_0(t-2(N+N_{cp})T_c)\, d[2K]$$

$$X_e(t) = \sum_{k=0}^{K-1} \sum_{n=-\infty}^{\infty} d[k+nK]\, p_k(t-n(N+N_{cp})T_c)$$

$$S_{X_e X_e}(f) = \sum_{k=0}^{K-1} \frac{1}{T_0} |P_k(f)|^2$$

$$p_0(t) = \frac{1}{\sqrt{N}}\left(1\cdot p(t) + 1\cdot p(t-T_c) + 1\cdot p(t-2T_c) + \cdots + 1\cdot p(t-(N+N_{cp}-1)T_c)\right)$$

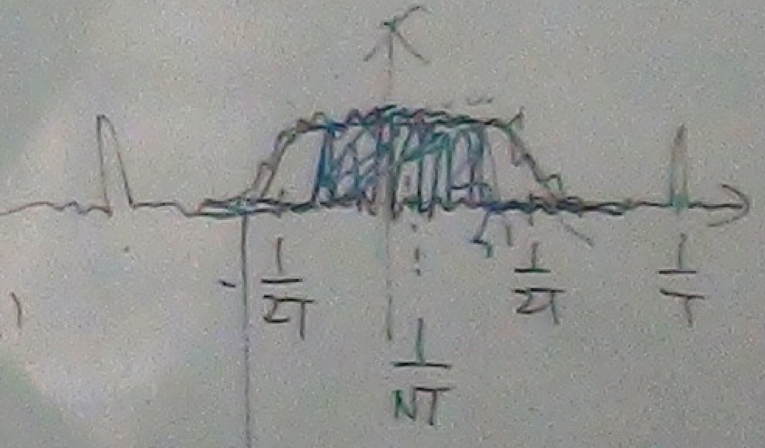
$$p_1(t) = \frac{1}{\sqrt{N}} e^{\cdots}$$

$$p_2(t) = \cdots$$

$$p_k(t) = (\mathrm{DFT}_k)^H \begin{bmatrix} p(t) \\ p(t-T_c) \\ \vdots \\ p(t-(N+N_{cp}-1)T_c) \end{bmatrix}$$

$$P_k(f) = \bigcirc\, P(f)$$

$e^{j\frac{2\pi}{N}0}$ $e^{j\frac{2\pi}{N}}$



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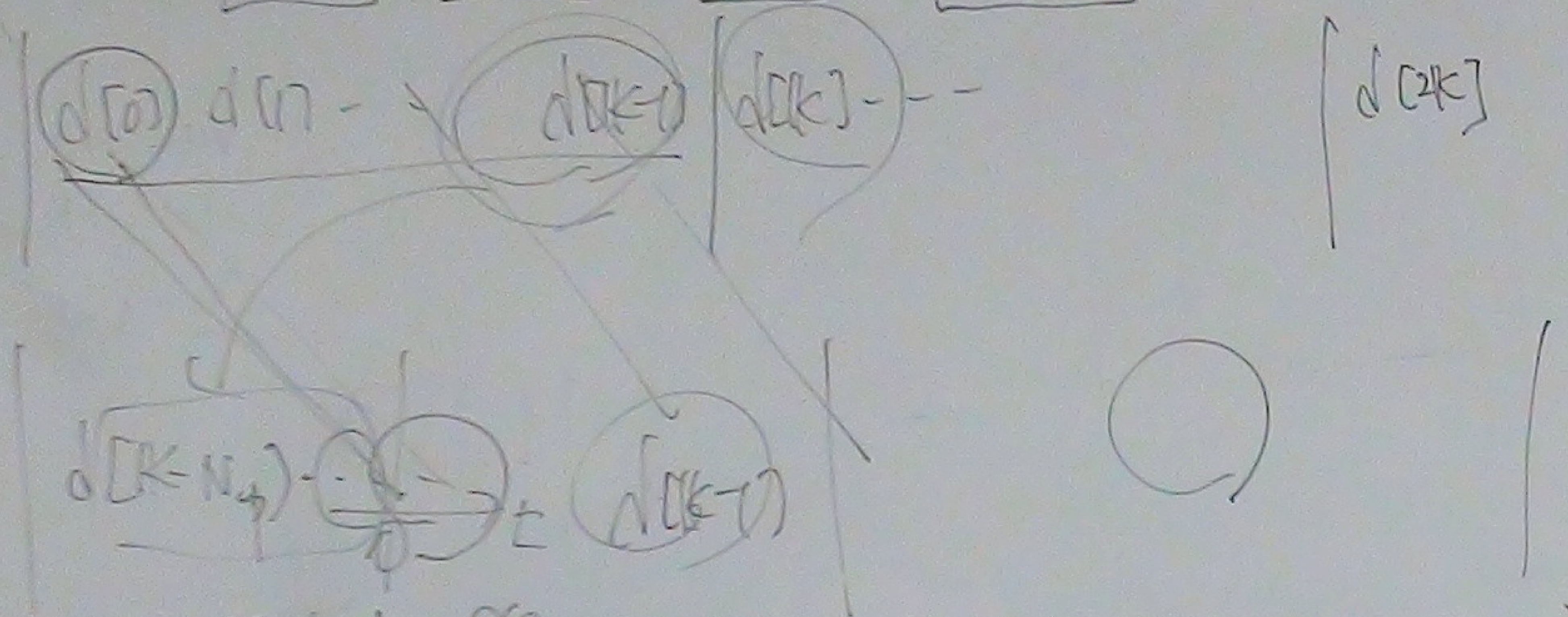
□ SC Block Transmission w/ CP

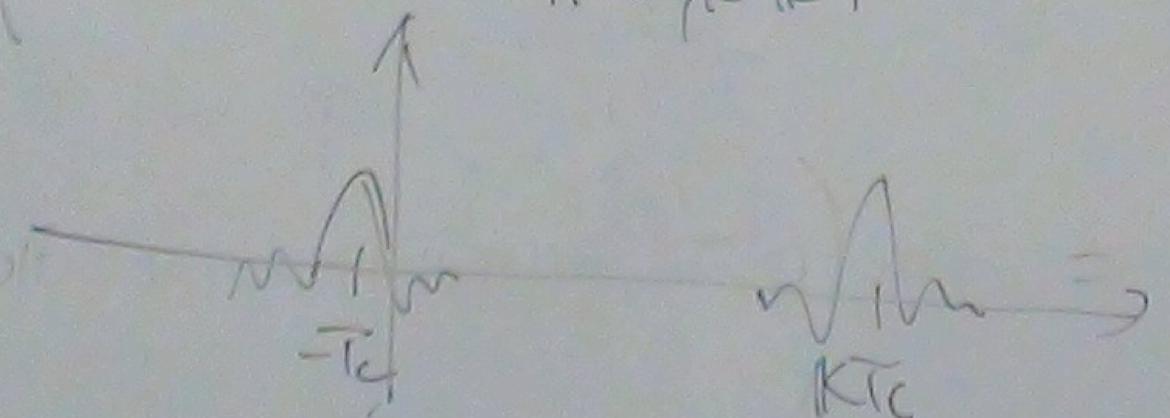
$d[n] \rightarrow \boxed{S/P} \rightarrow \boxed{\text{Add CP}} \rightarrow \boxed{P/S} \rightarrow \boxed{\text{QAM modulatn}} \rightarrow$



$$x_c(t) = \sum_{k=0}^{K-N_{cp}-1} \sum_{n=-\infty}^{\infty} d[k+nK]\, p(t - kT_c - n(K+N_{cp})T_c)$$

$$+ \sum_{k=K-N_{cp}}^{K-1} \sum_{n=-\infty}^{\infty} d[k+nK] \left(p(t - kT_c - n(K+N_{cp})T_c) + p(t - kT_c - nN_{cp}T_c) \right)$$

$n=0,\ k=K-1$



$$S_{x_cx_c}(f) = \frac{(K-N_{cp})}{(K+N_{cp})T_c} |P(f)|^2 + \frac{N_{cp}}{(K+N_{cp})T_c} |P(f)|^2 \boxed{\left|1 + e^{-j2\pi f K T_c}\right|^2}$$

$$= \frac{1}{T_c} |P(f)|^2 + \frac{2N_{cp}}{(K+N_{cp})T_c} |P(f)|^2 \cos(2\pi f K T_c)$$

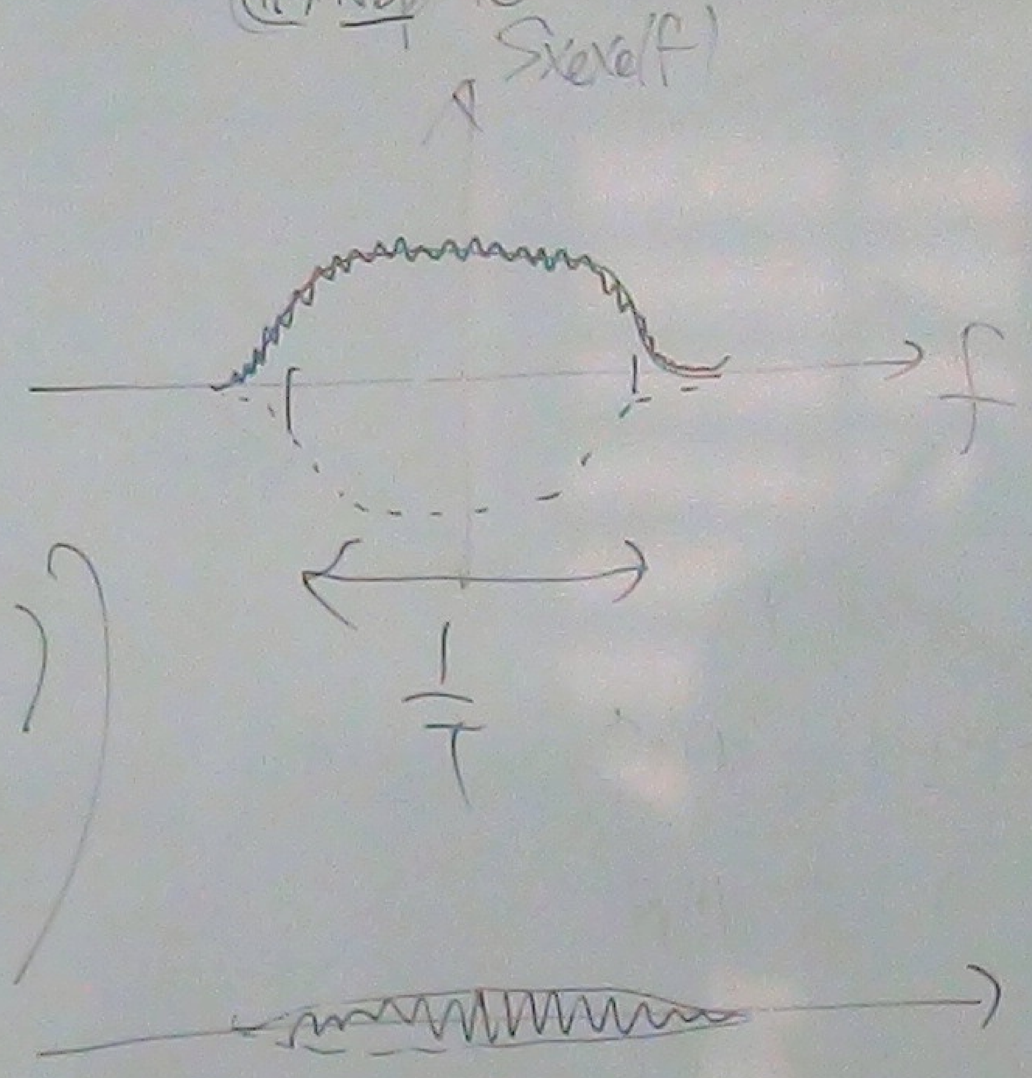
$$= \left| 2 e^{-j\pi f K T_c} \left(\frac{e^{j\pi f K T_c} + e^{-j\pi f K T_c}}{2} \right) \right|^2$$

$$= 4\cos^2(\pi f K T_c)$$

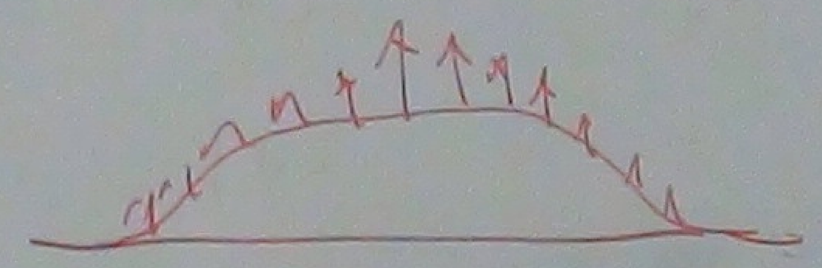
$$= 4\, \frac{1 + \cos(2\pi f K T_c)}{2}$$

$$= 2(1 + \cos(2\pi f K T_c))$$

$$= 2 + 2\cos(2\pi f K T_c)$$



□ SC Block Transmission w/ UW (Unique Word)



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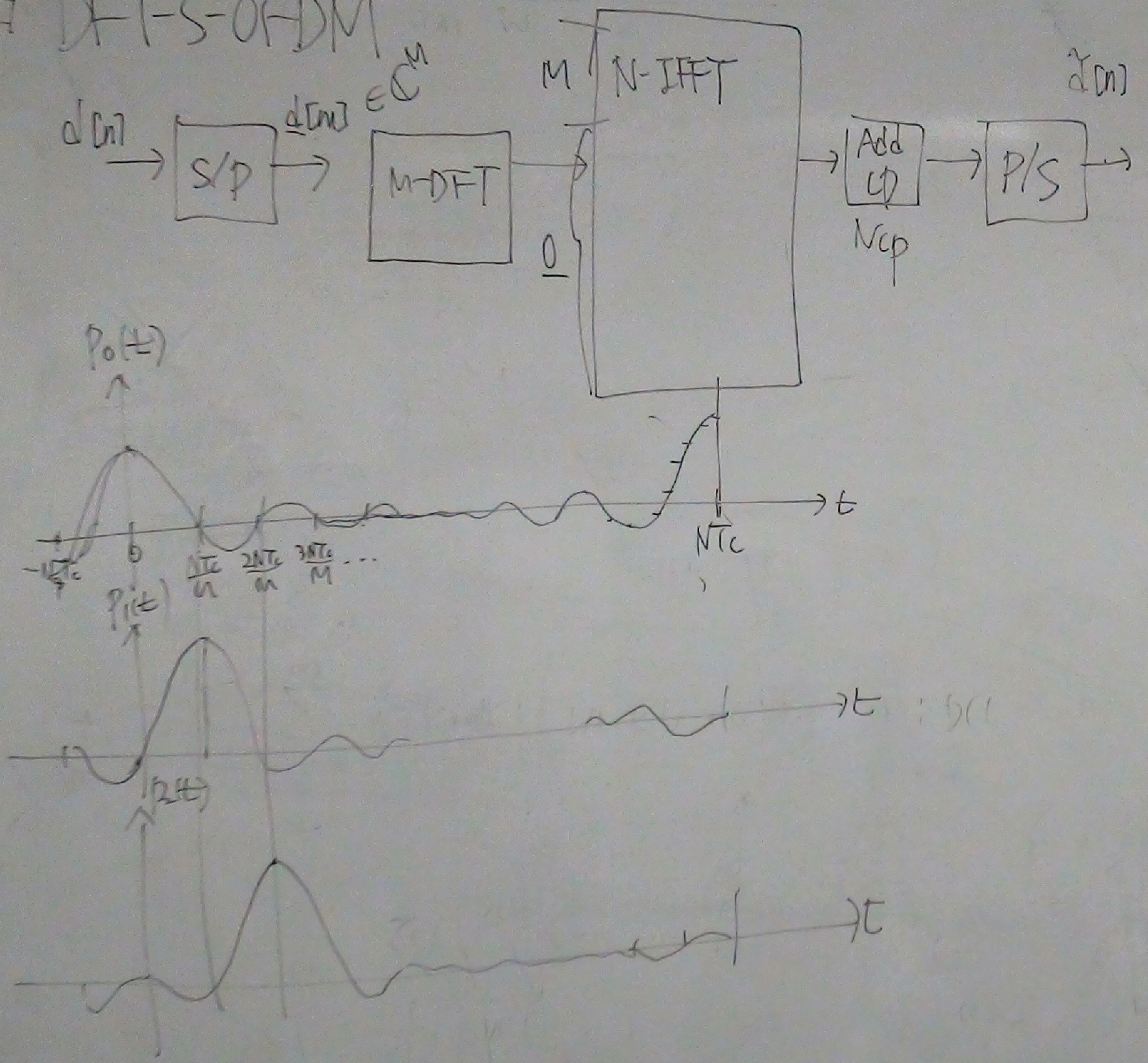
□ DFT-S-OFDM



$$x_e(t) = \sum_{n=-\infty}^{\infty} \tilde{d}[n]\, p(t-nT_c) \qquad p(t) = p_{T_c}(t)$$

$$= \sum_{k=0}^{M-1} \left(\sum_{n=-\infty}^{\infty} d[nM+k]\, p_k(t-kT_c-n(N+N_{cp})T_c) \right)$$