EECE 604M CM #15 d

숙제 10-1, 2, 3

□ $X(t) = \mathrm{Re}\{X_e(t) e^{j2\pi f_c t}\}$,

$Y(t) = a X(t - t_0)$

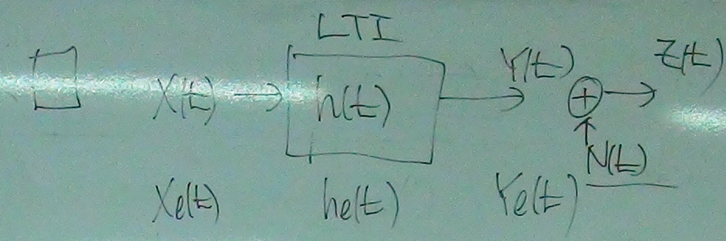
$S_{YY}(f) = |a|^2 S_{XX}(f)$

$S_{Y_e Y_e}(f) = |a|^2 S_{X_e X_e}(f)$.

$\therefore Y(t) = \mathrm{Re}\{\underbrace{a X_e(t-t_0) e^{-j2\pi f_c t_0}}_{= Y_e(t)} e^{j2\pi f_c t}\}$

$R_{Y_e Y_e}(t_1, t_2) = E\{(a X_e(t_1 - t_0) e^{-j2\pi f_c t_0})(a X_e(t_2 - t_0) e^{-j2\pi f_c t_0})^*\}$

$= |a|^2 R_{X_e X_e}(t_1, t_2)$



$Y_e(t) = \frac{1}{2} h_e(t) * X_e(t)$

$S_{YY}(f) = \frac{S_{X_e X_e}(f - f_c) + S_{X_e X_e}(-(f + f_c))}{4}$

$S_{Y_e Y_e}(f) = \frac{1}{4} |H_e(f)|^2 S_{X_e X_e}(f)$

∴

□ ... AWGN

ACGN

⋮

ASK, PSK, ...

PAM

QAM

OFDM ←

DS-CDMA

DFT-S-OFDM ←

숙제 10-3

11-1, 2, 3

EECE 695M CM #16a

ch 10-3

□ $X(t) = \mathrm{Re}\{X_e(t) e^{j2\pi f_c t}\}$

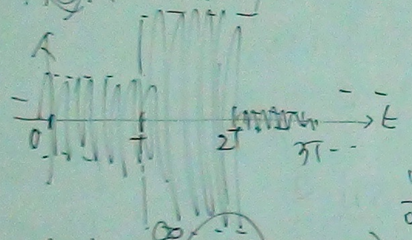
$= X_c(t)\cos 2\pi f_c t - X_s(t)\sin 2\pi f_c t$

$= A(t)\cos(2\pi f_c t + \Theta(t))$

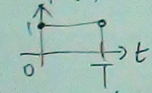
$X_e(t) = X_c(t) + jX_s(t) = A(t)e^{j\Theta(t)}$, $A(t) \in \mathbb{R}$

CW. → abruptly change

□ ASK Key



$p_T(t)$



$A(t) = \sum_{n=-\infty}^{\infty} a[n] p_T(t-nT)$

$a[n] \in A$, $|A| = M$

$\Theta(t) = \theta$, $\forall t$.

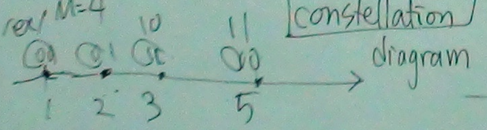
transmission

$1/T$: symbol rate

T: symbol time duration

$a[n]$: nth symbol

ex) $M=4$



constellation diagram

- Gray Encoding
- Natural Binary Encoding

examples)

- $M=2$. $A=\{0,1\}$ OOK
- ASK = OOK.
- PAM = ASK.

- $M=2$. $A=\{-1,1\}$ $f_c=0$.
  binary antipodal signaling
- BPSK. 2-ASK. B-ASK.

- M-ASK
- $M=4$ $A=\{-3,-1,1,3\}$ 4-ASK

□ PSK.

- $A(t) = A_1, \forall t$
- $\Theta(t) = \sum_{n=-\infty}^{\infty} \theta[n] p_T(t-nT)$ ∀t

$\theta[n] \in B \subset [0, 2\pi)$

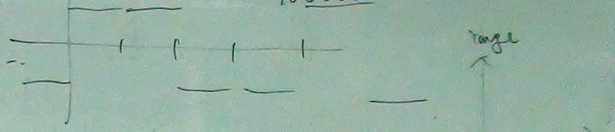
$|B| = M$.

$f_c=0$. BPSK

□ Unified View on ASK & PSK

$X(t) = \mathrm{Re}\{X_e(t) e^{j2\pi f_c t}\}$

$X_e(t) = \sum_{n=-\infty}^{\infty} d[n] p_T(t-nT)$



where

$d[n] \in A$ for ASK

$e^{j\theta[n]} \in A$ for PSK

$e^{j\sum_{n=-\infty}^{\infty}\theta[n]p_T(t-nT)}$

$= \sum_{n=-\infty}^{\infty} e^{j\theta[n]} p_T(t-nT)$. quadriphase sk.

□ PSD

(i) $f_c = 0$

(ii) $f_c \gg \frac{1}{T}$

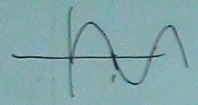
EECE 695M CM #16b

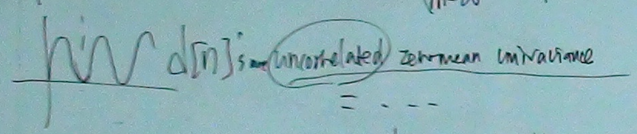
10-3

PSD of ASK & PSK

$$R_{x_c x_c}(t+\tau,t) = E\{x_c(t+\tau)x_c^*(t)\}$$

$$= E\left\{\left(\sum_{n=-\infty}^{\infty} a[n]\,p_T(t+\tau-nT)\right)\left(\sum_{m=-\infty}^{\infty} a[m]\,p_T(t-mT)\right)^*\right\}$$



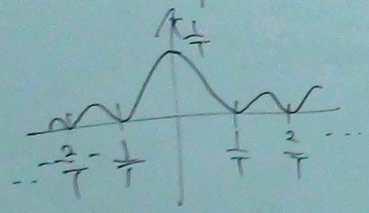


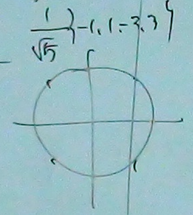
$a[n]$'s are uncorrelated zero-mean unit-variance

$$= \cdots$$

$$R_{x_c x_c}(\tau) = \frac{1}{T} p_T(\tau) * p_T^*(-\tau)$$

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





$$R_{x_c x_c}(t+\tau,t) = \sum_{n=-\infty}^{\infty} p_T(t+\tau-nT)\,p_T^*(t-nT) = R_{x_c x_c}(t+T+\tau,t+T)$$

$$R_{x_c x_c}(\tau) = A\left[R_{x_c x_c}(t+\tau,t)\right] = \frac{1}{T}\int_{\langle T\rangle} R_{x_c x_c}(t+\tau,t)\,dt$$

$$= \frac{1}{T}\int_{\langle T\rangle}\sum_{n=-\infty}^{\infty} p_T(t+\tau-nT)\,p_T^*(t-nT)\,dt$$

$$= \frac{1}{T}\sum_{n=-\infty}^{\infty}\int_0^T p_T(t+\tau-nT)\,p_T^*(t-nT)\,dt$$

$$= \frac{1}{T}\int_{-\infty}^{\infty} p_T(t+\tau)\,p_T^*(t)\,dt$$

$$= \frac{1}{T}\,p_T(\tau) * p_T^*(-\tau).$$

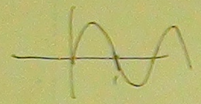
EECE 695M CM #16

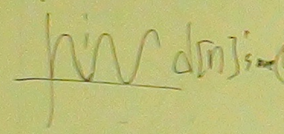
5/4 10-3

PSD of ASK & PSK

$$R_{xx}(t+\tau,t) = E\{X_c(t+\tau)X_c^*(t)\}$$

$$= E\left\{\left(\sum_{n=-\infty}^{\infty} d[n]\,p_T(t+\tau-nT)\right)\left(\sum_{m=-\infty}^{\infty} d[m]\,p_T(t-mT)\right)^*\right\}$$



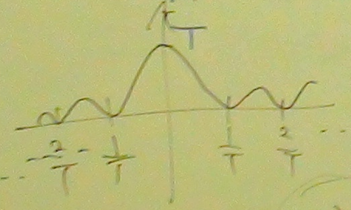


d[n]'s are uncorrelated zero-mean wide-sense stationary

$$= \cdots$$

$$R_{X_cX_c}(\tau) = \frac{1}{T}\,p_T(\tau) * p_T^*(-\tau)$$

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

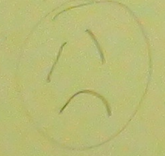


$\frac{1}{f^2} = f^{-2}$

-20 dB/decade

$10\log_{10} f^{-2}$

$= -20\log_{10} f$



$$R_{X_cX_c}(t+\tau,t) = \sum_{n=-\infty}^{\infty} p_T(t+\tau-nT)\,p_T^*(t-nT) = R_{X_cX_c}(t+T+\tau,t+T)$$

$$R_{X_cX_c}(\tau) = A\left[R_{X_cX_c}(t+\tau,t)\right] = \frac{1}{T}\int_{\langle T\rangle} R_{X_cX_c}(t+\tau,t)\,dt$$

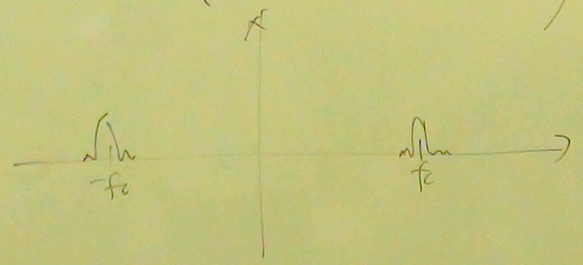
$$= \frac{1}{T}\int_{\langle T\rangle}\sum_{n=-\infty}^{\infty} p_T(t+\tau-nT)\,p_T^*(t-nT)\,dt$$

$$= \frac{1}{T}\sum_{n=-\infty}^{\infty}\int_0^T p_T(t+\tau-nT)\,p_T^*(t-nT)\,dt$$

$$= \frac{1}{T}\int_{-\infty}^{\infty} p_T(t+\tau)\,p_T^*(t)\,dt$$

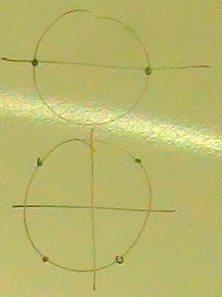
$$= \frac{1}{T}\,p_T(\tau) * p_T^*(-\tau).$$

$$S_{XX}(f) = \frac{1}{4}\left(S_{X_cX_c}(f-f_c) + S_{X_cX_c}(-(f+f_c))\right)$$

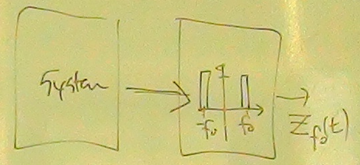


BPSK

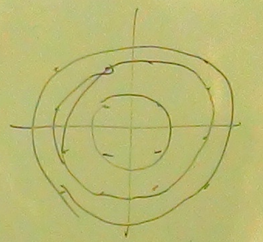
QPSK



PSD { cannot distinguish M-PSK's
ignores complementary correlation.



- pulse-shaped ASK → PAM
  PSK.



QAM (pulse-shape)

EECE 695M CM #6C

§ 11-1 PAM, QAM PSD

□ $X(t) = \mathrm{Re}\{X_c(t) e^{j2\pi f_c t}\}$

$X_c(t) = \sum_{n=-\infty}^{\infty} d[n] p(t-nT)$

$p(t)$ transmit pulse (waveform)

T symbol period time

$1/T$ symbol rate

$d[n] \in A$

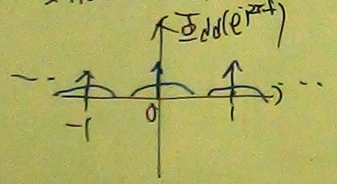
$|A| = M$.

$d[n]$ is a WSS r.p. (complex)

$\phi_{dd}[m] = E\{d[n+m] d^*[n]\}$

$\updownarrow$ $\mathcal{F}$ (DTFT)

$\Phi_{dd}(e^{j2\pi f})$ ↘ If non-zero mean



□ PSD

$X_c(t)$

$R_{X_c X_c}(t+\tau, t) = \cdots$

$R_{X_c X_c}(\tau) = \frac{1}{T} \sum_{l=-\infty}^{\infty} \phi_{dd}[l] \tilde{p}(\tau - lT)$

where $\tilde{p}(\tau) = p(\tau) * p^*(-\tau)$

$S_{X_c X_c}(f) = \frac{1}{T} \Phi_{dd}(e^{j2\pi f T}) |P(f)|^2$

□ Half-Sine pulse

$p(t) = \sqrt{\frac{2}{T}} \sin\left(\frac{\pi t}{T}\right)$