EECE 695M CM #16C

Ch 11-1 PAM, QAM PSD

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

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

$p(t)$ transmit pulse (waveform)

T symbol period time

$1/T$ symbol rate

$d[n] \in A$

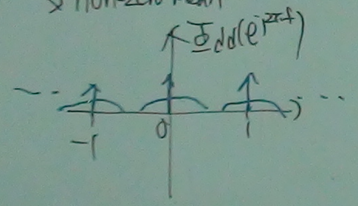
$|A| = M$.

$d[n]$ 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

$X_e(t)$

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

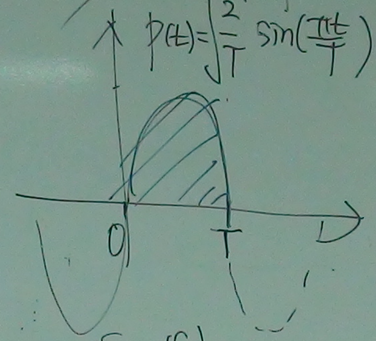
$$R_{X_e X_e}(\tau) = \frac{1}{T} \sum_{\ell=-\infty}^{\infty} \phi_{dd}[\ell] \tilde{p}(\tau - \ell T)$$

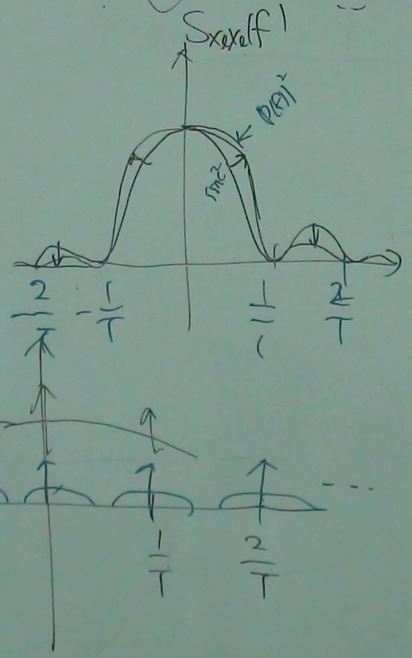
where $\tilde{p}(\tau) = p(\tau) * p^*(-\tau)$

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

Half-Sine pulse

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





EECE 694M CM #17a

9-1

☐ PAPR. EVM. PSD... BER.

☐ PAPR peak-to-average power ratio

$X(t) = \mathrm{Re}\{X_e(t) e^{j(2\pi f_c t + \theta)}\}$

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

"PAPR of $X(t)$"

$$\text{PAPR} = \frac{\max_{t\in[T_1,T_2)} \left(X(t)\right)^2}{\frac{1}{T_1-T_2}\int_{T_1}^{T_2} E\{(X(t))^2\}\,dt}$$

- unitless
- dependent on $[T_1, T_2]$
- numerator increases as $|T_2 - T_1| \uparrow$,
- denominator $R_{XX}(0)$

$$A\left[E\{(X(t))^2\}\right]$$

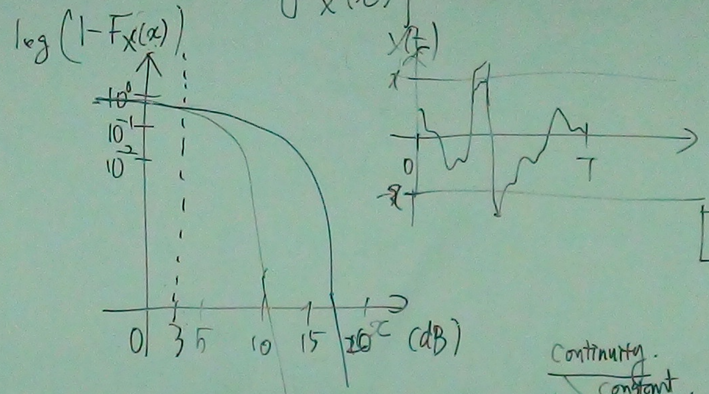
- WSS $R_{XX}(0)$
- $nT = T_2 - T_1 \Rightarrow \frac{1}{T}\int_{\langle T\rangle} E\{(X(t))^2\}\,dt$
- T_1, T $X(t)$ independent & identically distributed
- $\Rightarrow$ (non-ergodic)

$X_i = \text{PAPR}_{\langle i\rangle}$ $i = 1, \cdots K$

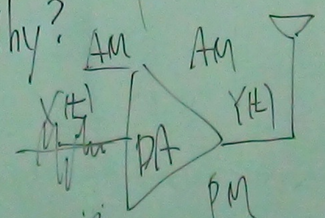
$X^{(K)} = \text{PAPR}_{\langle K\rangle}$

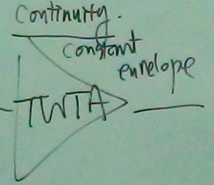
$F_{X^{(K)}}(x) = \Pr(X_1 \le x, X_2 \le x, \cdots X_K \le x)$

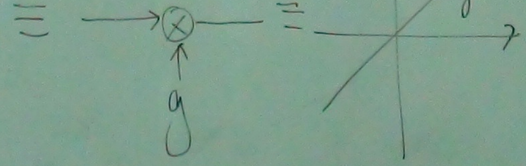
$= \{F_X(x)\}^K$

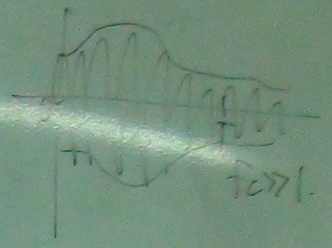


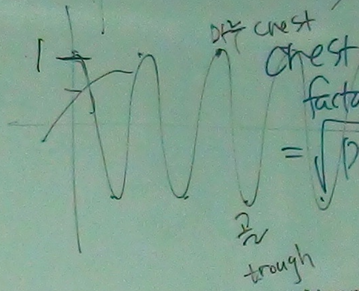
☐ Why?











$\rightarrow \text{PAPR} = \frac{2}{1} = \frac{1}{\frac{1}{2}} = 2 = 3\text{dB}$

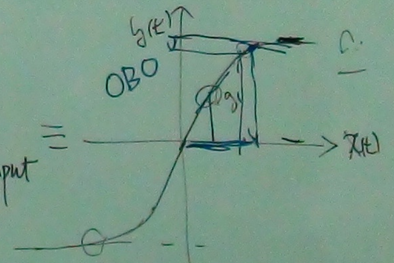
$\text{Crest factor} = \sqrt{\text{PAPR}}$

☐ PMEPR Peak-to-Mean Envelope power ratio

$$\text{PMEPR} = \frac{\max\left(|X_e(t)|^2\right)}{A\left[E\{|X_e(t)|^2\}\right]} \downarrow = 1 \text{ 0dB}$$

$\doteq \text{PAPR of } X_e(t)$

$\therefore$ -3dB of PAPR $X(t)$



☐ ASK. PSK. $\Rightarrow$ PAPR = 0 dB

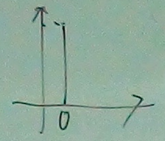
half-sine. PAPR = 3dB

EECE 695M CM #17 b

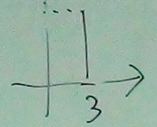
K 9-1
M

□ PAPR peak-to-average power ratio

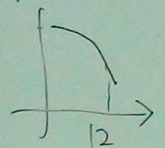
ex) (2-ASK, PSK) PAPR = 0dB



(half-sine shaped BPSK, QPSK) PAPR = 3dB



OFDM PAPR ≃ 12dB



PSD spectral regrowth

continuity of envelope of $x_e(t)$

proper-complex WSS Gaussian

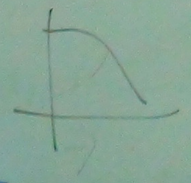
extreme value theorem

$$\text{PAPR}_T \quad 1 - F_x(x) = e^{-\sqrt{\pi \ln(W_{rms}T)}\, W_{rms}T\, e^{-x}}$$

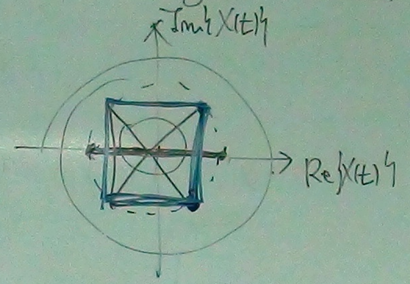
double exponential

$$\ln g = -\sqrt{\pi \ln(WT)}\, WT\, e^{-x}$$

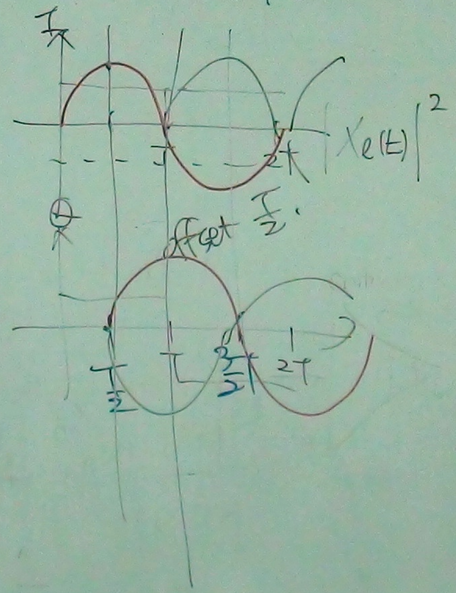
$$= -\sqrt{\pi \ln(WT)}\, WT\, e^{-e^{\ln x}}$$

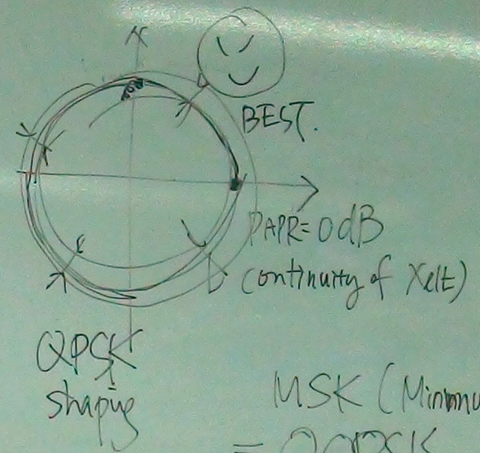


□ Trajectory of $x_e(t)$



BPSK, QPSK,





QPSK shaping

MSK (Minimum Shift Keying)
= OQPSK
SQPSK w/ half-sine pulse.

$$\text{PSD} = \frac{1}{T}|P(f)|^2$$

half-sine의 ESD.

GMSK

0 dB.