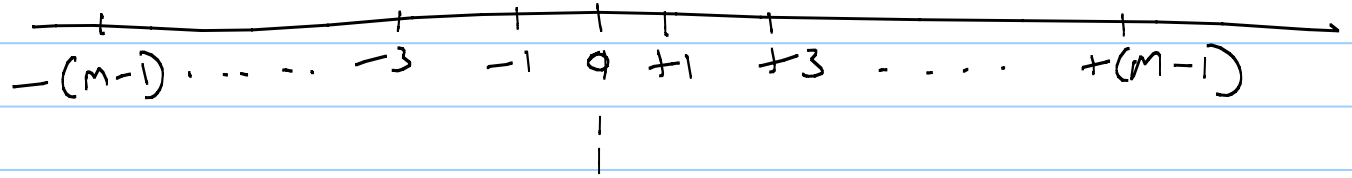
Lecture 9

Note Title 8/12/2008

M-PAM: $\varphi_1(t) = \sqrt{\frac{1}{T}}$, $0 \le t \le T$



$N = \log_2 M$ $\quad \underline{b} = [b_1 \; b_2 \; \cdots \; b_N]$

$E[X^2] = \frac{M^2-1}{3}$

$Y = X + N$ $\quad N(0, \frac{N_0}{2})$

(5) Quadrature Phase Shift Keying:
(QPSK)

(4-PSK)

$N = 2 \qquad \underline{b} = [b_1 \;\; b_2]$

$f_0 = \frac{m_0}{T}$

"centre freq"

$$x_{00}(t) = \sqrt{\frac{2E_s}{T}} \cos 2\pi f_0 t, \quad 0 \le t \le T$$

$$x_{01}(t) = \sqrt{\frac{2E_s}{T}} \sin 2\pi f_0 t, \quad 0 \le t \le T$$

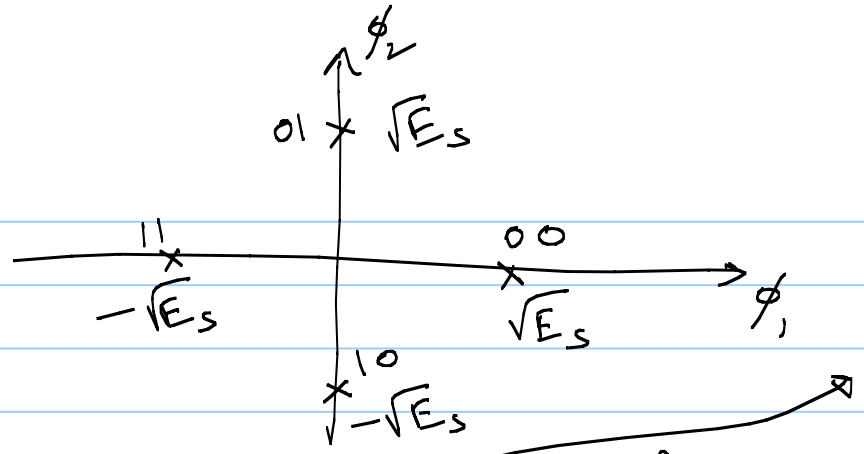
$$x_{11}(t) = -\sqrt{\frac{2E_s}{T}} \cos 2\pi f_0 t, \quad "$$

$$x_{10}(t) = -\sqrt{\frac{2E_s}{T}} \sin 2\pi f_0 t, \quad "$$

Basis:

$$\phi_1(t) = \sqrt{\frac{2}{T}} \cos 2\pi f_0 t, \quad 0 \le t \le T$$

$$\phi_2(t) = \sqrt{\frac{2}{T}} \sin 2\pi f_0 t, \quad 0 \le t \le T$$



$$\underline{x}_{00} = [\sqrt{E_s} \quad 0]^T$$

$$\underline{x}_{01} = [0 \quad \sqrt{E_s}]^T$$

$$\underline{x}_{11} = [-\sqrt{E_s} \quad 0]^T$$

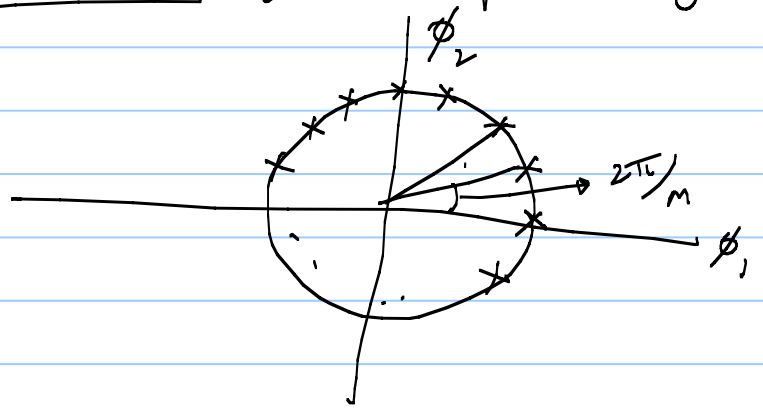
$$\underline{x}_{10} = [0 \quad -\sqrt{E_s}]^T$$

uniform

$$\underline{Y} = \underline{X} + \underline{N}$$

$\underline{N} \rightarrow$ iid $N(0, \frac{N_0}{2})$

(6) M-PSK, M: power of 2



M-points on unit circle

$$\sqrt{E_s}\, e^{j\frac{2\pi m}{M}}, \quad m = 0, \ldots, M-1$$

$$x_m(t) = \sqrt{\frac{2E_s}{T}} \cos\left(2\pi f_0 t - \frac{2\pi m}{M}\right), \quad 0 \le t \le T$$

$m = 0, \dots, M-1$

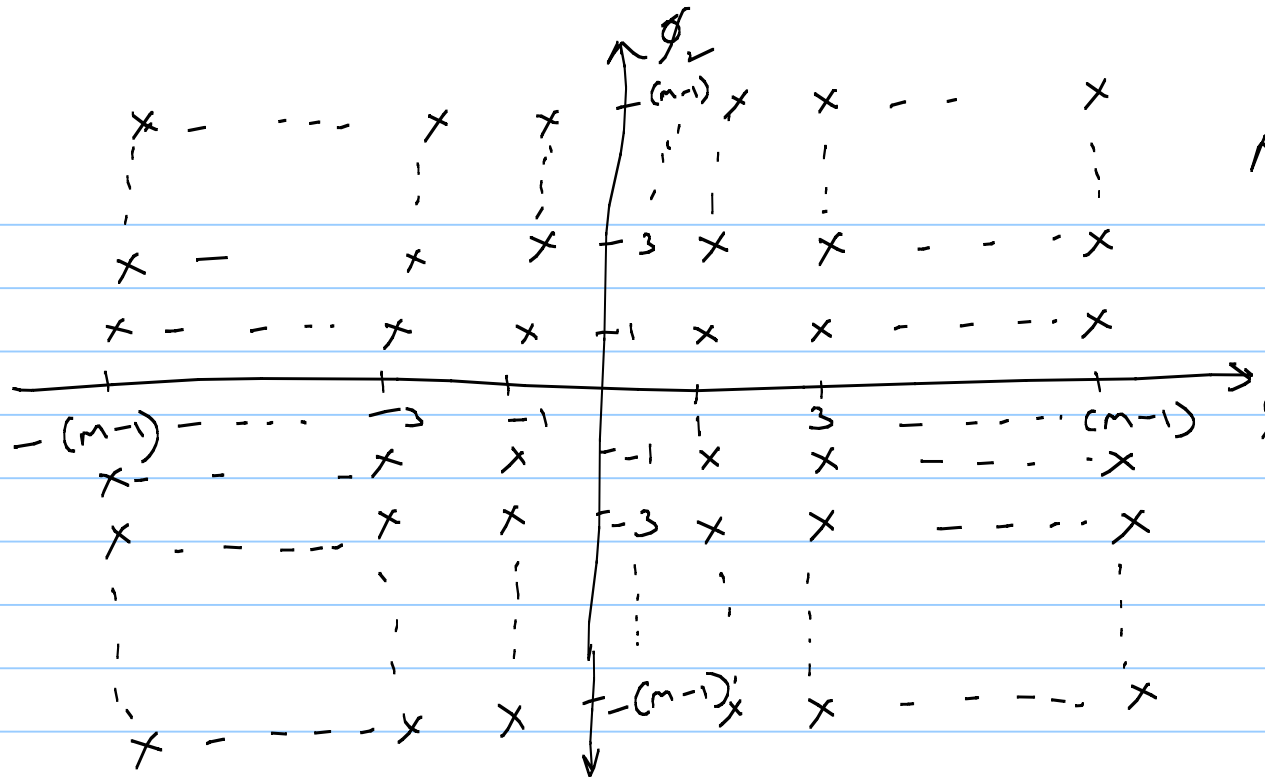
Signal corresponding to $\sqrt{E_s}\, e^{j\frac{2\pi m}{M}}$

$$\tilde{x}_m(t) = \sqrt{\frac{2E_s}{T}}\, e^{-j\frac{2\pi m}{M}}, \quad 0 \le t \le T$$

$e^{-j\frac{2\pi m}{M}}$ → complex envelope

⑦ M^2 — QAM, M: power of 2

⟶ passband version of M-PAM



M^2-QAM

$a + jb \qquad a, b \in \{\pm 1, \pm 3, \ldots, \pm(m-1)\}$

$$\underline{X} = \begin{bmatrix} X_1 \\ X_2 \end{bmatrix} \qquad X_i : \text{unif in } \{\pm 1, \pm 3, \ldots, \pm(m-1)\}$$

$$E[|\underline{X}|^2] = \frac{m^2 - 1}{3}$$

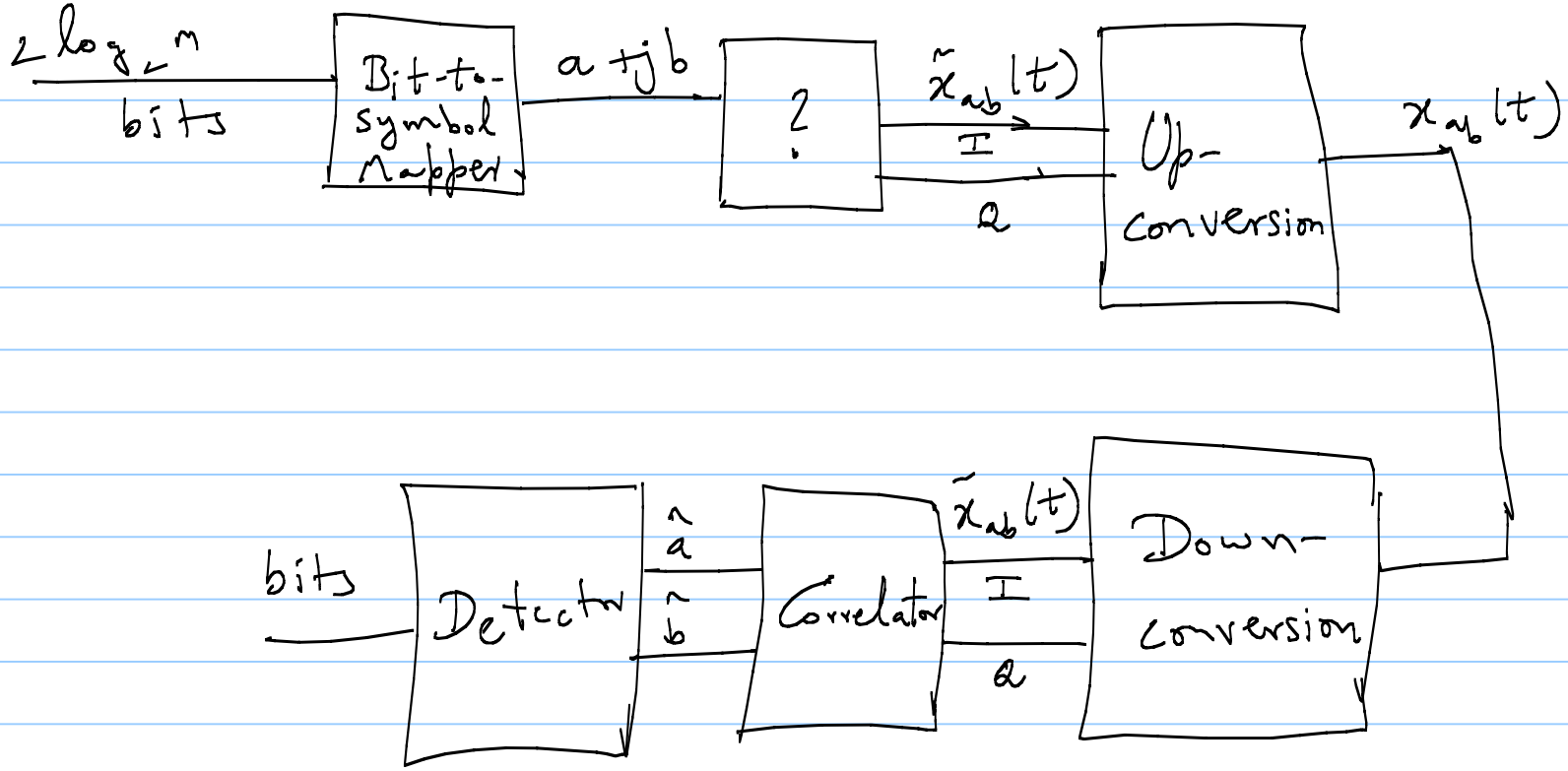
$$a+jb \longleftrightarrow x_{ab}(t) = a\sqrt{\frac{2}{T}}\cos 2\pi f_0 t + b\sqrt{\frac{2}{T}}\sin 2\pi f_0 t, \quad 0 \le t \le T$$

$$x_{ab}(t) = \mathrm{Re}\left\{\sqrt{\frac{2}{T}}(a-jb)e^{j2\pi f_0 t}\right\}$$

$$\tilde{x}_{ab}(t) = \sqrt{\frac{2}{T}}(a-jb), \quad 0 \le t \le T$$

$$\tilde{X}_{ab}(f) = \sqrt{\frac{2}{T}}(a-jb)e^{-jfT\pi}T\,\mathrm{sinc}(fT)$$

$$X_{ab}(f) = ?$$


$\log_2 m$
bits
Bit-to-symbol Mapper
$a+jb$
?
$\tilde{x}_{ab}(t)$
I
Q
Up-conversion
$x_{ab}(t)$
bits
Detector
$\hat{a}$
$\hat{b}$
Correlator
$\tilde{x}_{ab}(t)$
I
Q
Down-conversion