Zoom class #1

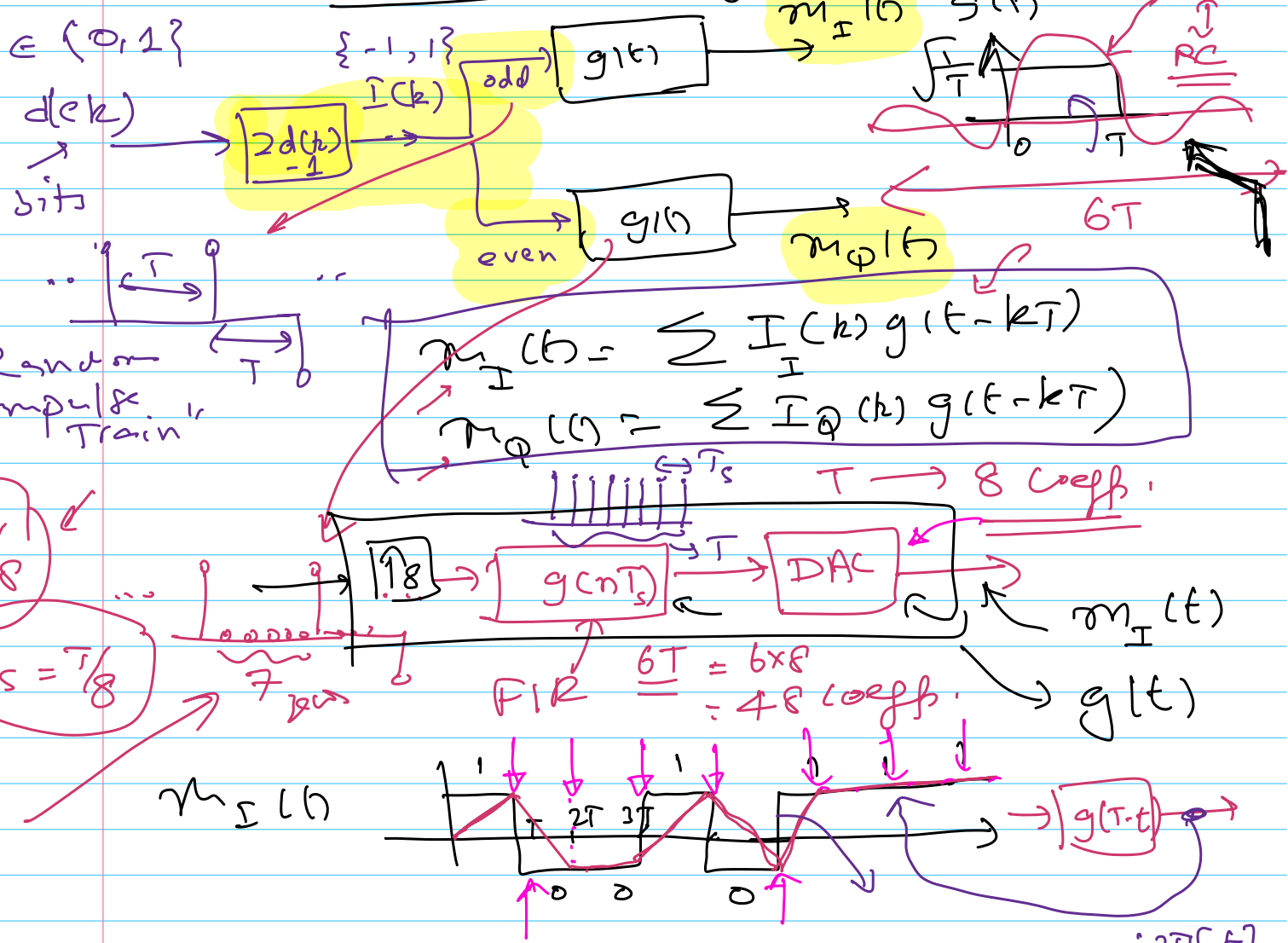
Sept. 13, 2025

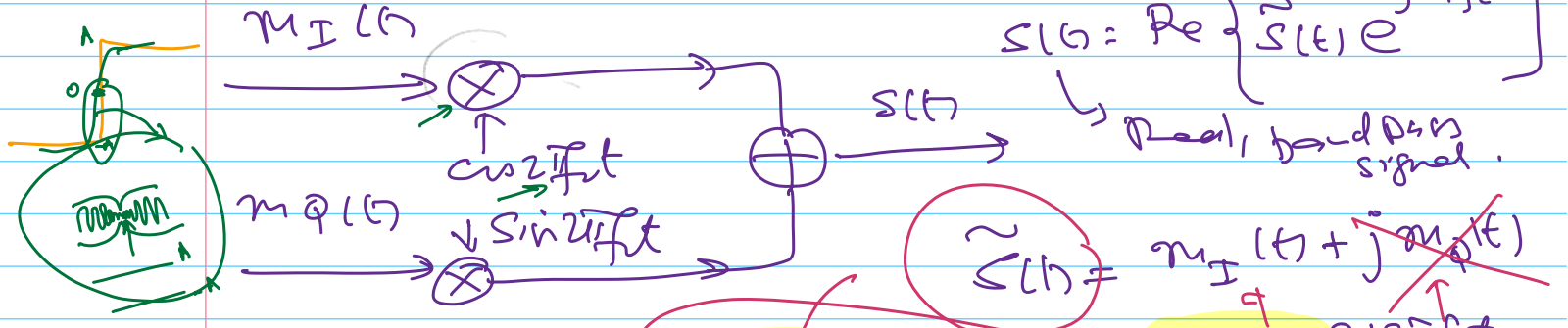
EE 4140

→ Signal Repn. → "Time domain description" of digital bandpass signals.

QPM

Tx Block Diagram



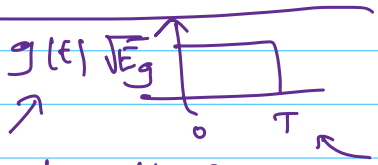


1. Pulse Amplitude Modulation (PAM) ✓
2. Phase shift keyed Mod. (PSK) ✓
3. Quadrature Amplitude Mod. (QAM) ✓
4. Freq. shift keying (FSK) ← orthogonal signals

DSB-SC → $m(t)\cos 2\pi f_c t$ → PAM → Real.
QCM → PSK / QAM

Full-AM / DSB-SC / SSB-SC / VSB / QCM $m_I(t) \longleftrightarrow m_Q(t)$

PAM $\quad s(t) \Rightarrow s_m(t)$



$kT \le t \le (k+1)T$

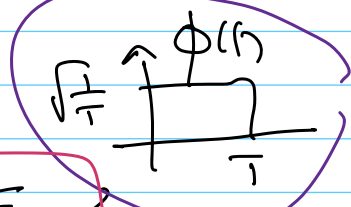
$$s_m(t) = \mathrm{Re}\left\{ A_m g(t) e^{j2\pi f_c t} \right\}$$

$$s_m(t) = A_m g(t) \cos 2\pi f_c t, \quad m = 1, 2, \dots M$$

Amplitude

where $A_m = (2m - 1 - M)d, \quad m = 1 \dots M$

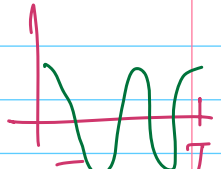
$M = 4$, $A_m \in \{-3d, -d, d, 3d\}$ (spacing $2d$)



$$s_m(t) = s_m \cdot \phi(t), \quad s_m = A_m \sqrt{\frac{E_g}{2}}$$

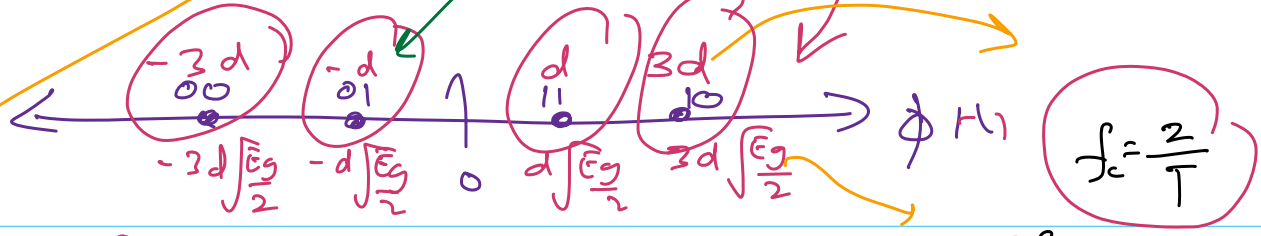
Symbol energy of the m^{th} signal

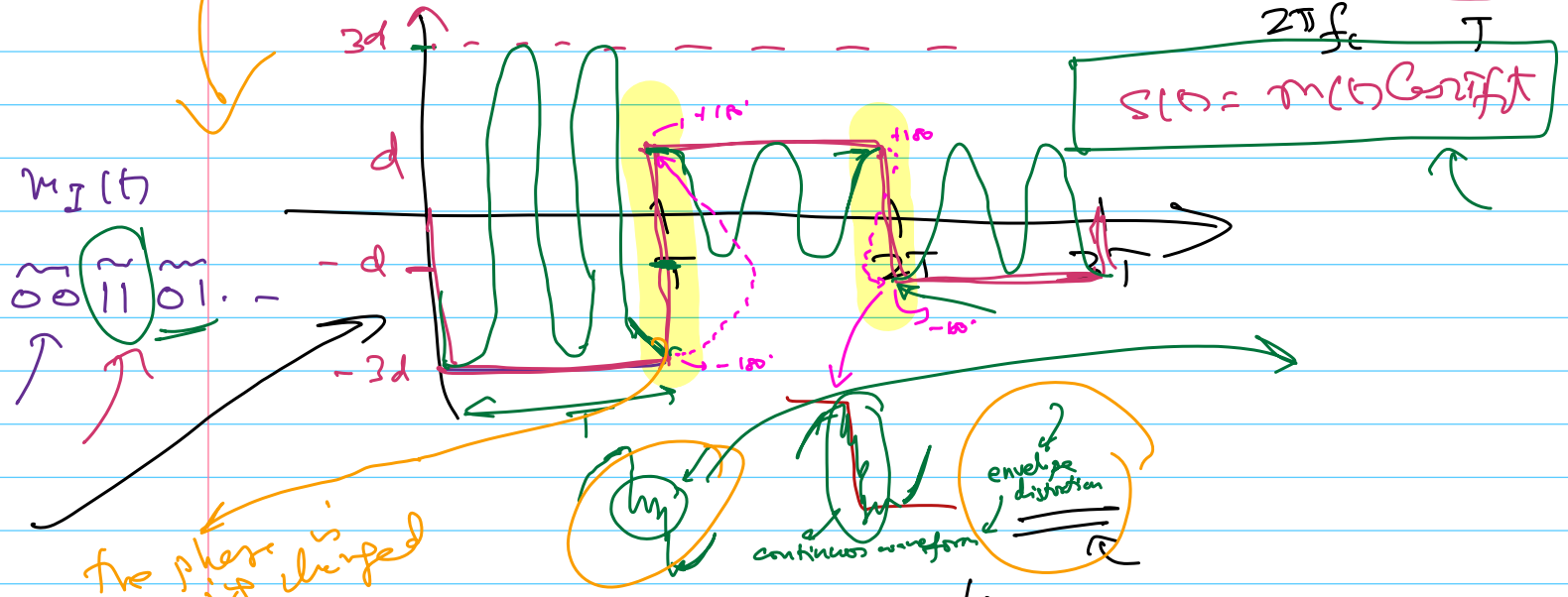
$$E_m = \int_0^T s_m^2(t)\,dt = \frac{A_m^2}{2} \underbrace{\int_0^T g^2(t)\,dt}_{E_g}$$



$$\phi(t) = \sqrt{\frac{2}{E_g}}\, g(t) \cos 2\pi f_c t \longrightarrow \text{unit energy.}$$

M = 4
PAM





the phase is being changed at the "edge" of T = No!

PAM / PSK / QAM → linear Modulation

CPM → CPFSK, MSK

GSM → GMSK

non-linear mod.

continuous phase mod.

T

PSK

$s_m(t) = \mathrm{Re}\left\{ g(t)\, e^{j\frac{2\pi(m-1)}{M}} \cdot e^{j2\pi f_c t} \right\}$

$m = 1 \dots M$

$A_m + jB_m$

$1 \leftarrow \cos\left(2\pi\frac{m-1}{M}\right) + j\sin\left(2\pi\frac{m-1}{M}\right)$

M-ary PSK

M = 8 → 8-PSK
M = 4 → QPSK
M = 2 → BPSK