Sistemi banda traslata

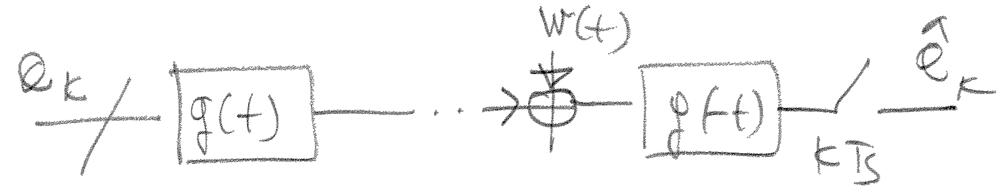
B. BASE: M-PAM

$$P_s(E) = 2\frac{(M-1)}{M}\, Q\left(\sqrt{\frac{2E_g}{N_0}}\right)$$

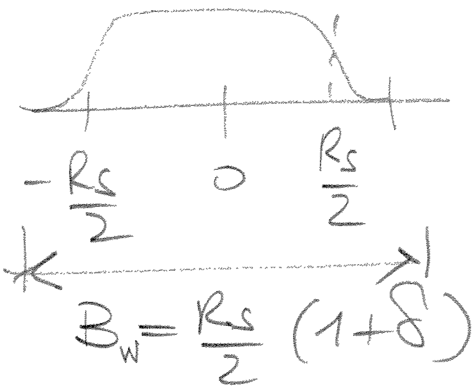
$$E_s = E_g\,\frac{M^2-1}{3}$$

$$E_b = E_s/\log_2 M$$

$$\left.\begin{aligned} P_s &= E_s \times R_s \\ P_n &= \frac{N_0}{2} \times R_s \end{aligned}\right\} \frac{P_s}{P_n} = \frac{2E_s}{N_0}.$$



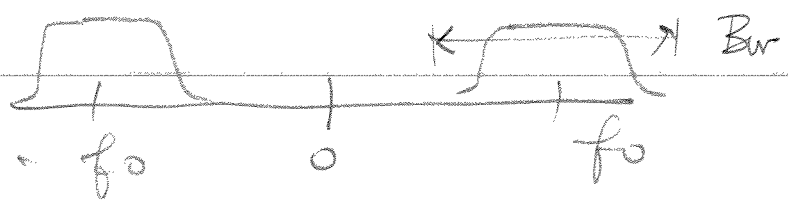
simboli (R_s) $g(t)$ RRC



Prob. errore non dipende dalla f. d'onda ma solo da E_g.

Se: $\tilde{g}(t) = \sqrt{2}\cdot g(t)\cdot \cos\omega_0 t$.

$$\tilde{G}(f) = \sqrt{2}\, G(f) * \left(\frac{\delta}{2}(f-f_0) + \frac{\delta}{2}(f+f_0)\right)$$



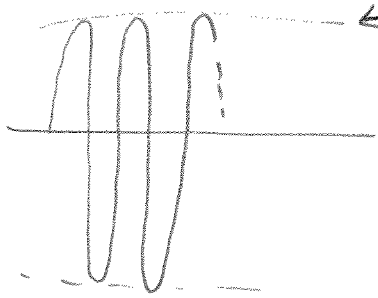
Analisi proprietà $\tilde{g}(t) = \sqrt{2}\, g(t) \cos\omega_0 t$ QAM 2

con $g(t)$ RRC.

A

$$E_{\tilde{g}} = 2\int g^2(t)\cos^2\omega_0 t\, dt = 2\int g^2(t)\left(\frac{1}{2}+\frac{1}{2}\cos 2\omega_0 t\right)dt$$

$$= E_g + \underbrace{\int g^2(t)\cos 2\omega_0 t}\, dt \simeq E_g$$



← variazioni lente $g^2(t)$ rispetto a $\frac{1}{f_0}$ → integrale nullo.

B

$$R_{\tilde{g}}(\tau) = \tilde{g}(t) * \tilde{g}(-t) = \int \tilde{g}(t+\tau)\tilde{g}(t)\, dt =$$

$$= 2\int g(t+\tau)g(t)\underbrace{\cos(\omega_0(t+\tau))\cos(\omega_0 t)}_{\frac{\cos\omega_0\tau + \cos(2\omega_0 t+\omega_0\tau)}{2}}dt =$$

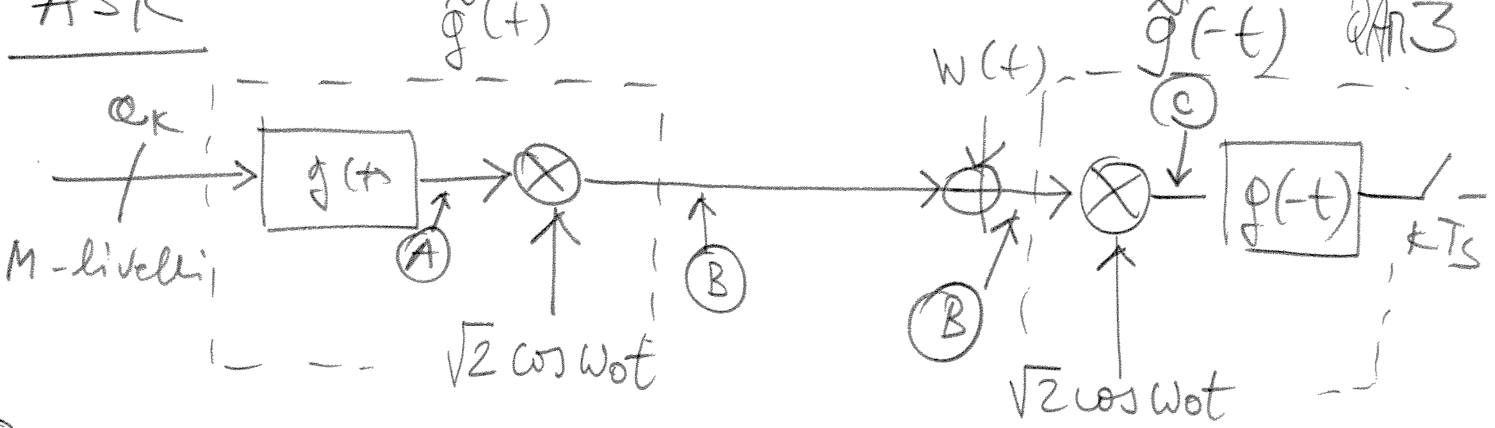
$$= \int g(t+\tau)g(t)\,dt\,\cos\omega_0\tau + \underbrace{\int g(t+\tau)g(t)\cos(2\omega_0 t+\omega_0\tau}$$

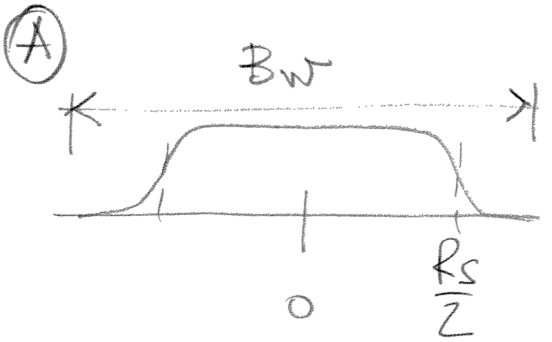
se la variazione di $g(t)$ è lenta rispetto a $1/f_0$ → **zero**.

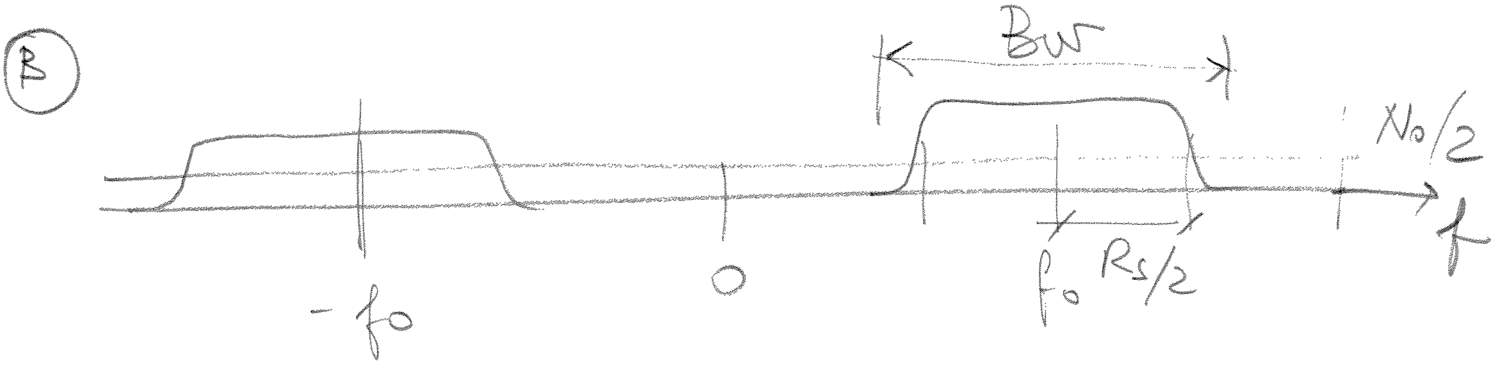
$$R_{\tilde{g}}(\tau) = R_g(\tau)\cos\omega_0\tau$$

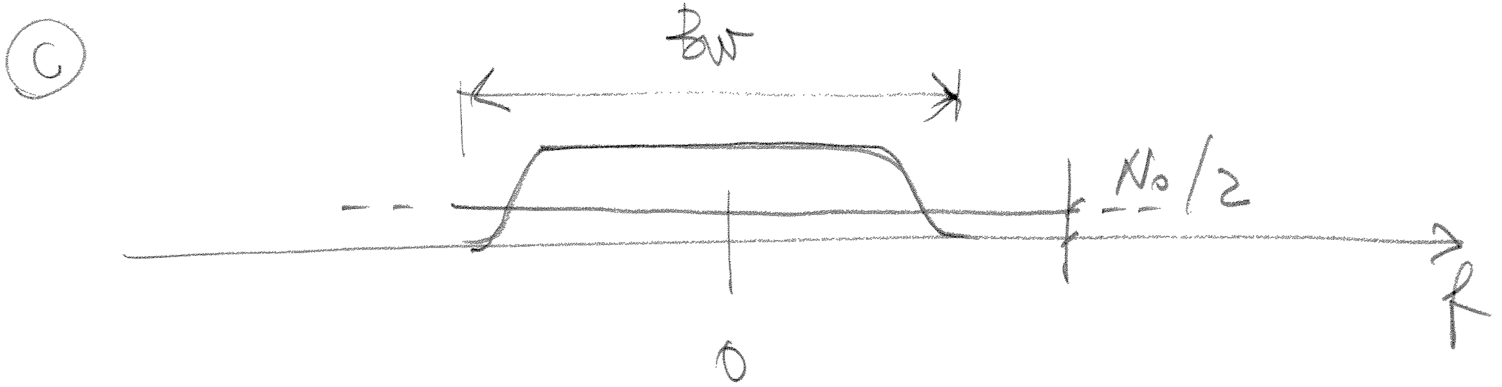
quindi, se $R_g(\tau) = \begin{cases} 1 & \tau = 0 \\ 0 & \tau = \pm T_s, \pm 2T_s, \dots \end{cases}$ | condiz. Nyquist per $\tilde{g}(t)$.

ASK





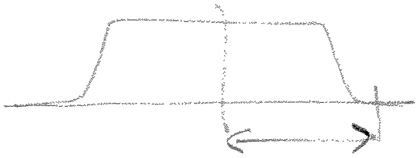




la soluzione è equivalente ad un sistema M-PAM in banda traslata.

Eff. spettrale: $\boxed{\rho = \frac{R_b}{B_W}}$ [bit/s/Hz]

Analisi M-PAM:



$0 \quad B_W = \frac{R_s}{2}(1+\delta)$

$$R_s = \frac{R_b}{\log_2 M}$$

$$\rho = \frac{R_b}{\frac{R_b}{2\log_2 M}(1+\delta)} = \frac{2\log_2 M}{1+\delta} \xrightarrow[\delta=0]{} 2\log_2 M.$$

(min banda)

2PAM $\rightarrow \rho = 2$ bit/s/Hz

4PAM $\rightarrow \rho = 4$ bit/s/Hz

8PAM $\rightarrow \rho = 6$ bit/s/Hz.

⋮

M-ASK $\quad B_W = R_s(1+\delta) \rightarrow \rho = \frac{\log_2 M}{1+\delta} \xrightarrow[(\delta\to 0)]{} \log_2 M$

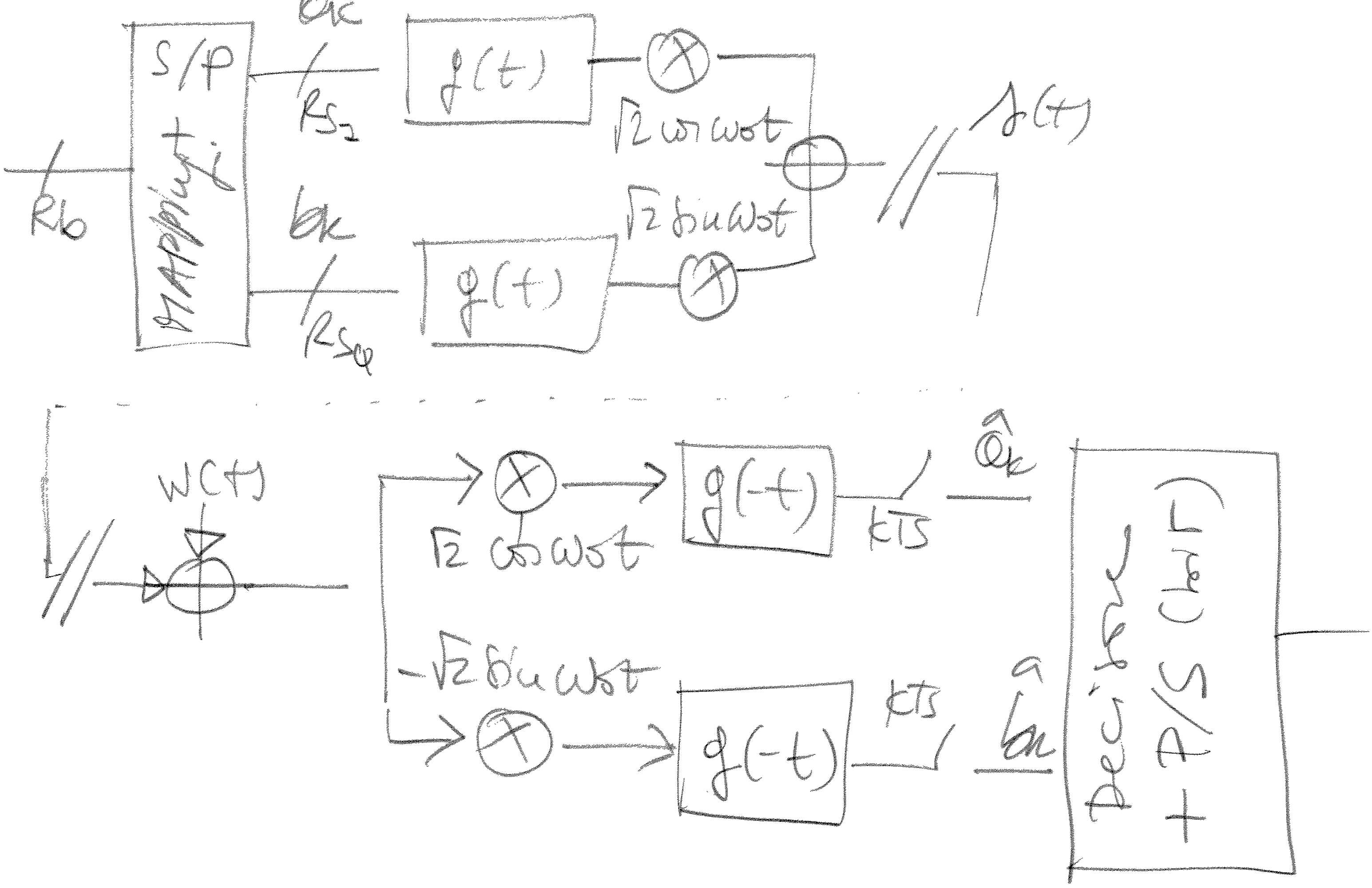
2ASK $\rightarrow \rho = 1$ bit/s/Hz

4ASK $\rightarrow \rho = 2$ bit/s/Hz

8ASK $\rightarrow \rho = 3$ bit/s/Hz

se ASK è trasmesso in SSB $\rightarrow \rho_{M\text{-}ASK} = \rho_{M\text{-}PAM}$.

Modulazione I&Q : M-QAM   QAM 5



$$s(t) = \underbrace{\sum_k a_k\, g(t-kT_s)\cos\omega_0 t}_{\text{modulazione I: } x_I(t)} + \underbrace{\sum_k b_k\, g(t-kT_s)\sin\omega_0 t}_{\text{modulaz. Q : } x_Q(t)}$$

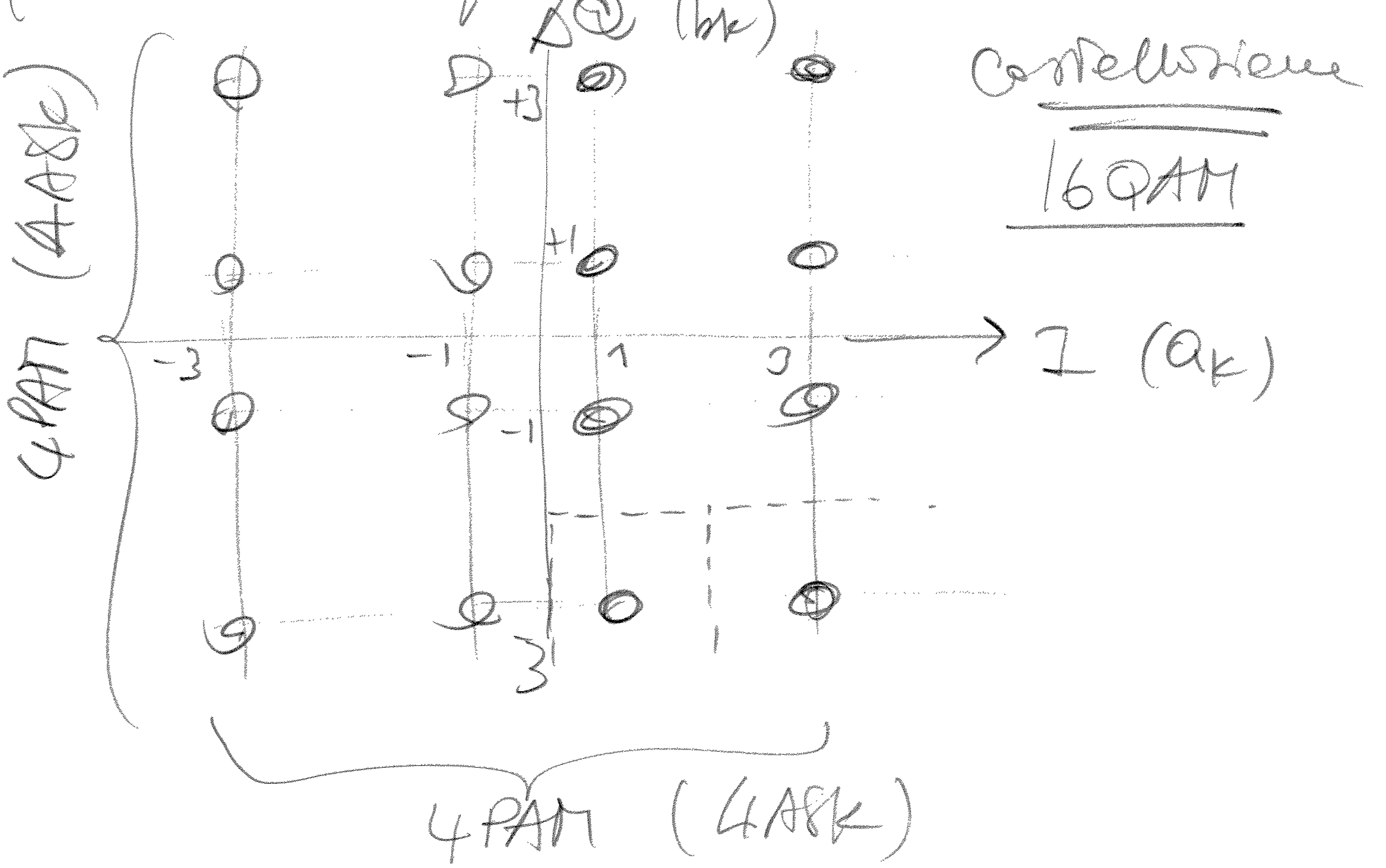
$$= a(t)\cos\left[\omega_0 t + \varphi(t)\right]$$

$$a(t) = \sqrt{x_I^2(t) + x_Q^2(t)}$$

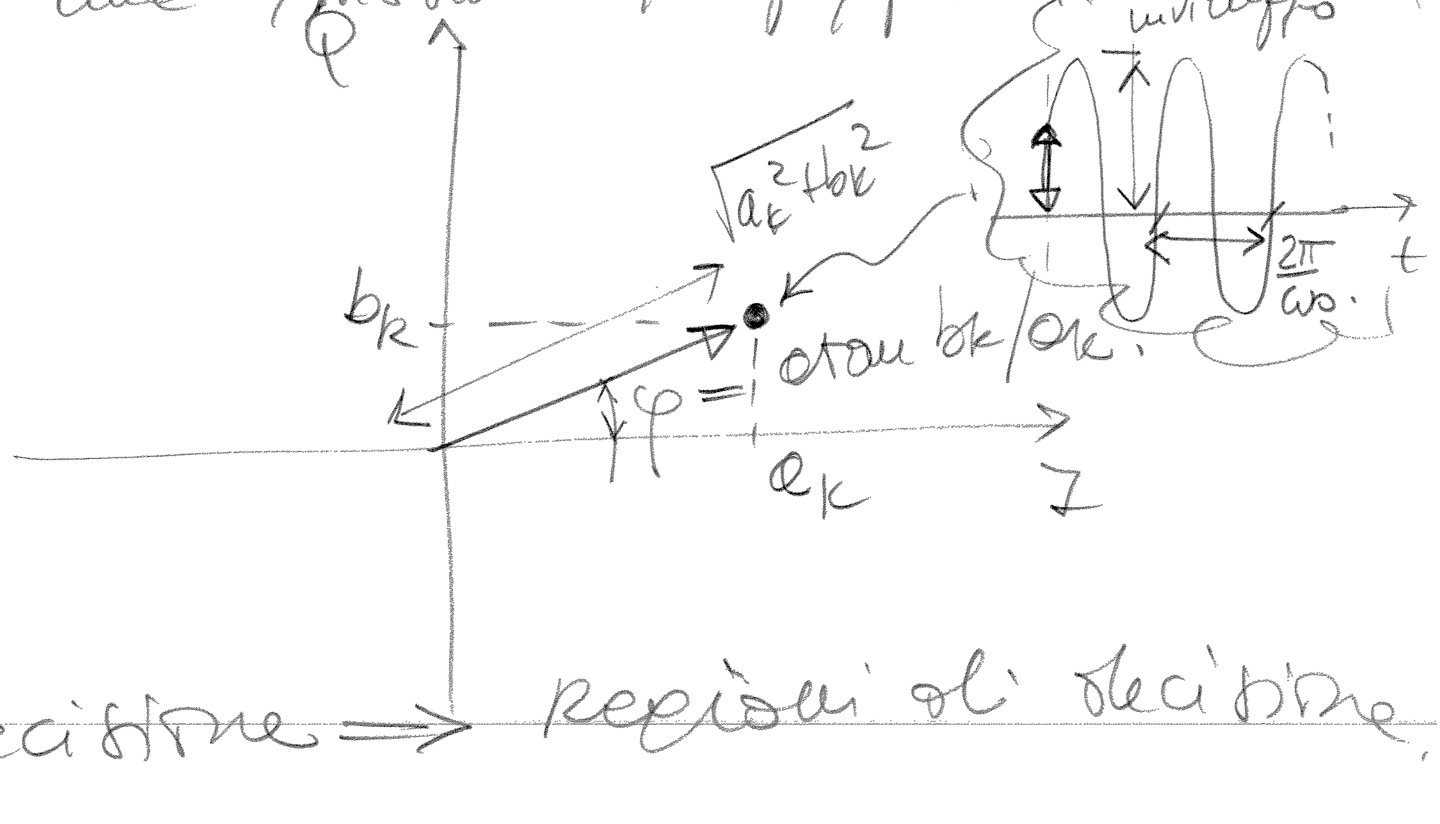
$$\varphi(t) = \operatorname{atan}\frac{x_Q(t)}{x_I(t)}$$

} modulazione ampiezza $a(t)$ (inviluppo) e fase $\varphi(t)$.

ogni sottosistema è un ASK QAM 16 (due ASK in parallelo) con 4ASK si ha:



Nota che ogni punto è rappresentato da una modulaz. amp. / fase

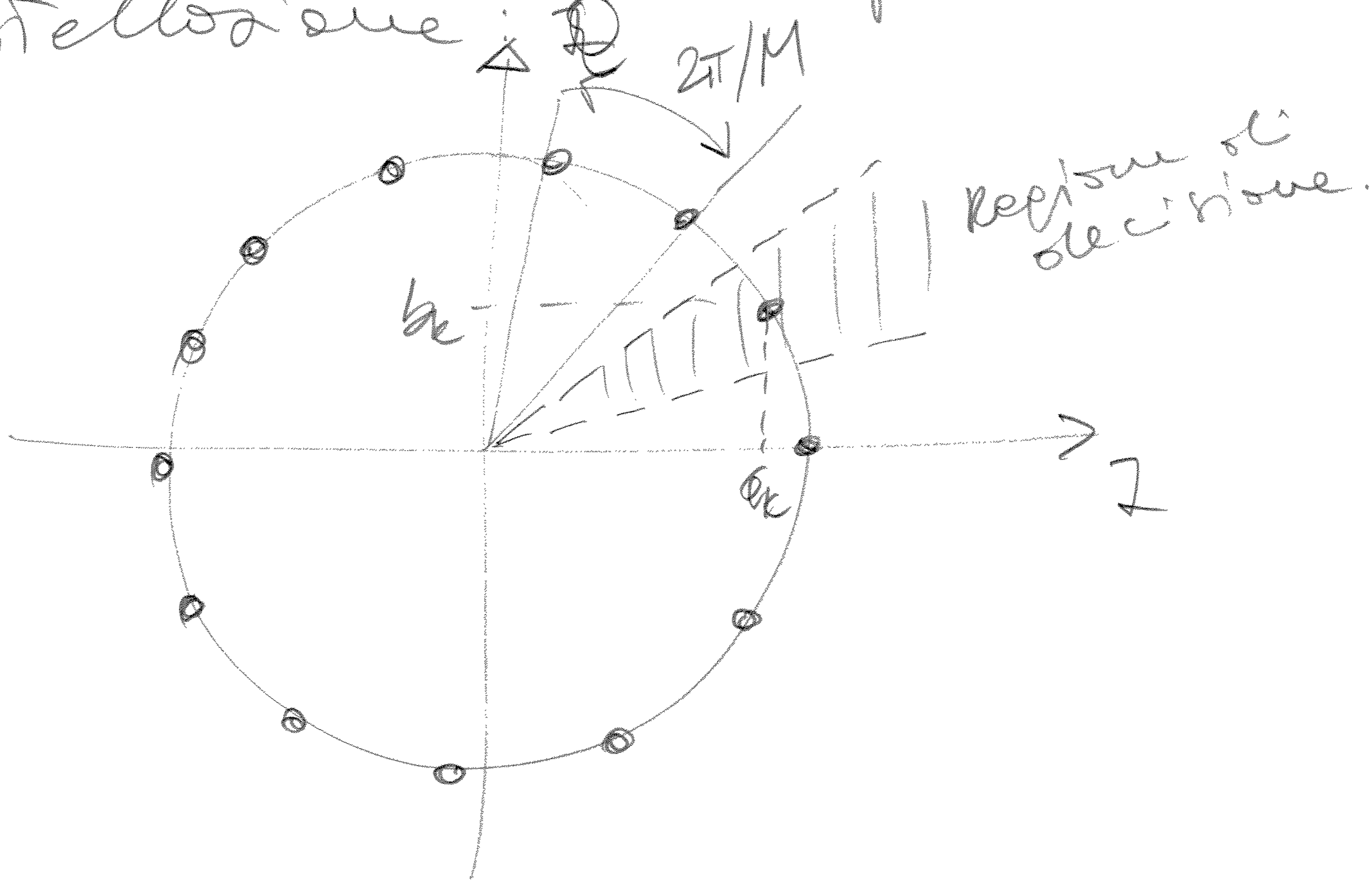


Decisione ⟹ regioni di decisione.

M - PSK

lo schema a blocchi di generazione/ricezione è "uguale" al M-QAM (quello in fig. è il più generale possibile per modul. lineari)

Costellazione:



$$s(t) = (\ldots)\cos(\omega_0 t + \varphi_k) = (\ldots)\cos\left(\omega_0 t + \frac{2\pi}{M}\cdot k\right)$$

$$= (\ldots)\underbrace{\cos\frac{2\pi}{M}k}_{a_k} \times \cos\omega_0 t - (\ldots)\underbrace{\sin\frac{2\pi}{M}k}_{b_k} \times \sin\omega_0 t$$

$$a_k = \cos\frac{2\pi}{M}k \qquad k = 0, 1, 2, \ldots, M-1$$

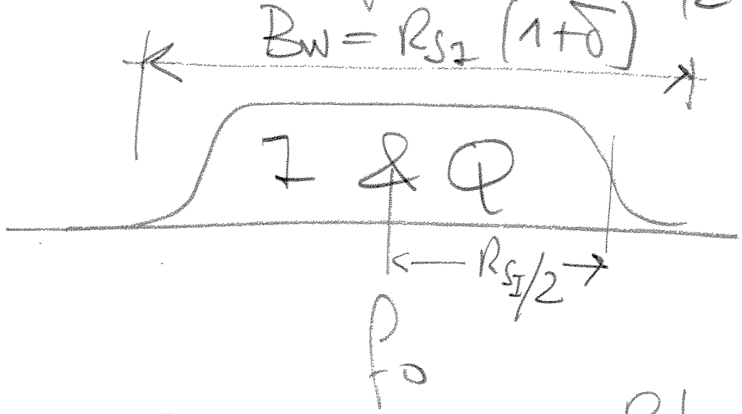
$$b_k = \sin\frac{2\pi}{M}k$$

Eff. spettrale :

M-QAM → L-ASK, L-ASK tale che $L^2 = M$ (costellaz. quadrata)

flusso binario/canale

$$R_{S_I} = R_{S_Q} = \frac{R_b/2}{\log_2 L} = \frac{R_b}{2\log_2 L} = \frac{R_b}{\log_2 L^2} = \frac{R_b}{\log_2 M}$$



$$B_{W\,(min),\ \delta=0} = R_{S_I} = R_{S_Q} = \frac{R_b}{\log_2 M}$$

$$\rho = \frac{R_b}{B_{W\,min}} = \log_2 M.$$

$M = 4$ (4QAM)

$\rho_{4QAM} = 2$ bit/s/Hz.

(sono 2PAM in parall. oppure 2×2ASK su bande sovrapposte)

notazione:

2QAM = 2ASK = BPSK

4QAM = 2 × BPSK = QPSK

Analisi delle prestazioni per $g(t)$ rettangolari:

<u>vantaggi</u>

Analisi semplice & intuitive

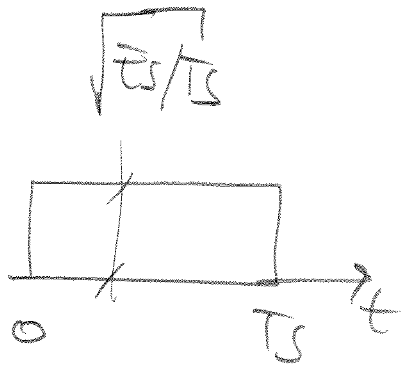
<u>svantaggi</u>

occupazione di banda $> R_s$.

prestazioni non dipendono forma $g(t)$

trattazione generale (spazio dei segnali) per analisi BER.

$$g(t) = \sqrt{\frac{E_s}{T_s}}\, \text{rect}\left[\left(t - T_s/2\right)/T_s\right]$$



1) $E_g = \left(\sqrt{\frac{E_s}{T_s}}\right)^2 \times T_s = E_s$.

2) f. adattato: $\sqrt{\frac{E_s}{T_s}} \int_0^{T_s} (\cdot)\, dt$

3) $g(t) \cos \omega_0 t$ è facilmente visualizzabile →