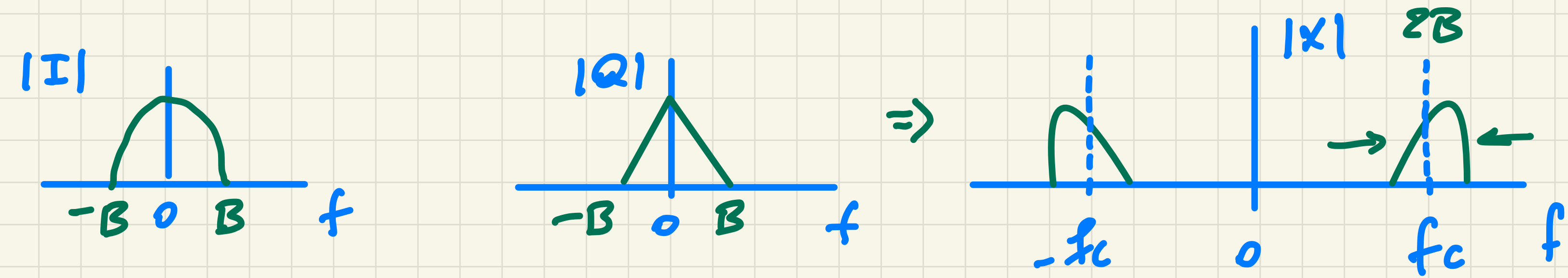
RF Circuit Design

L2

Spectrum of quadrature modulation

$$x(t) = I(t)\cdot\cos\omega_c t - Q(t)\cdot\sin\omega_c t$$

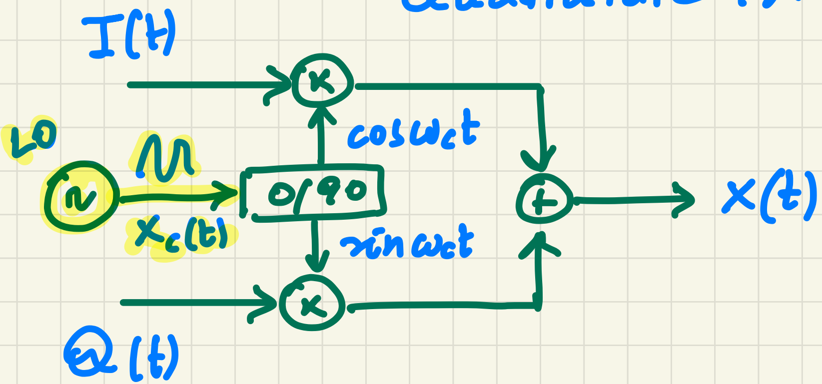
$\bar{x}(t) = I(t) + j\,Q(t)$ is the phasor of $x(t)$



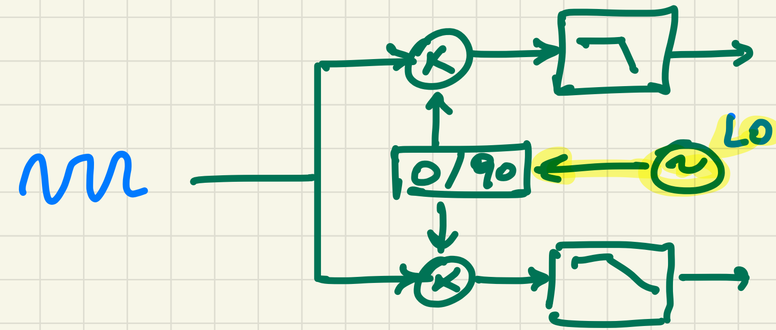
BW occupation is 2B at RF → max. spectral efficiency

Spectral purity of the carrier (Local Oscillator)

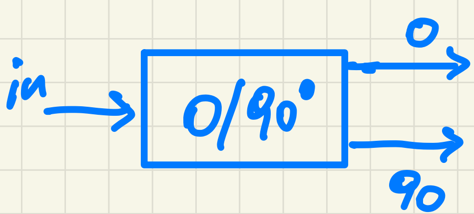
Quadrature TX

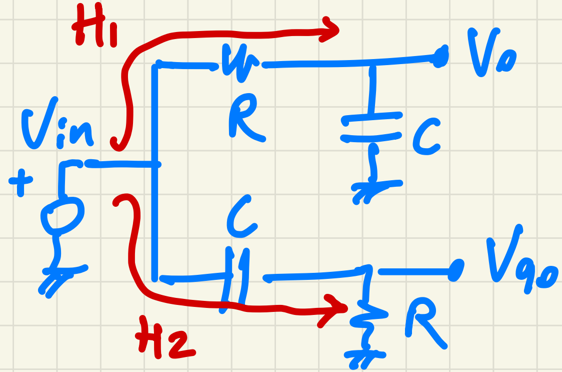


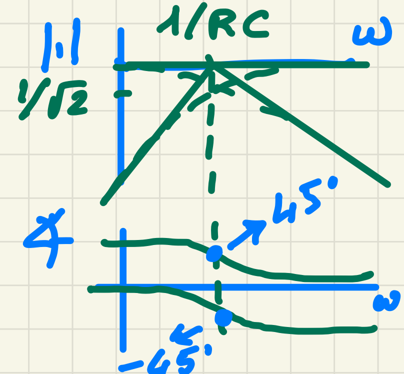
RX



Possible circuit implementation of a phase shifter







Spectrum of an <u>IDEAL</u> sinusoid : $x_c(t) = A_c \cos\omega_c t$

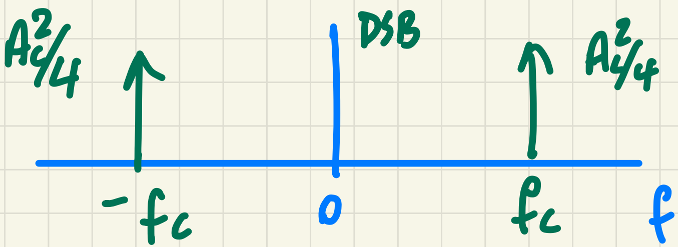
autocorrelation

$$r_x(\tau) = \frac{1}{T}\int_0^T A_c\cos\omega_c t \; A_c\cos(\omega_c t + \omega_c\tau)\,dt =$$

$$= \frac{1}{T}\int_0^T A_c^2 \cdot \frac{1}{2}\cos\omega_c\tau\,dt \quad + \quad 0 \quad =$$

$$= \frac{A_c^2}{2}\cdot\cos\omega_c\tau \quad \longleftrightarrow \quad S_x^{DSB}(f) = \frac{A_c^2}{4}\delta(f-f_c) + \frac{A_c^2}{4}\delta(f+f_c)$$

spectrum



Carrier : $x_c(t) = A_c \cdot \cos[\omega_c t + \underbrace{\varphi_m(t)}_{\text{unwanted phase modulation}}]$

- SPURIOUS TONES or SPURS :

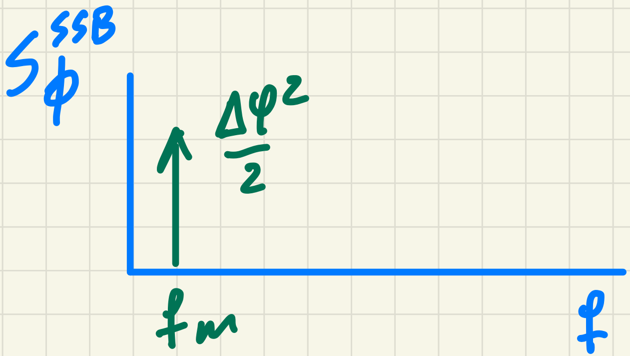
$\varphi_m(t) = \Delta\varphi \cdot \cos \omega_m t$ induced by disturbances + noise

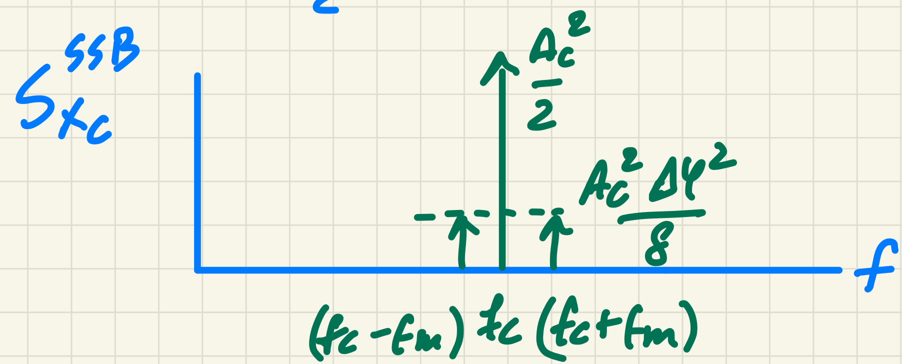
$\Rightarrow x_c(t) \simeq A_c \cos \omega_c t - A_c \Delta\varphi \cos \omega_m t \cos \omega_c t =$

$= A_c \cos \omega_c t - \frac{A_c \Delta\varphi}{2} \sin(\omega_c + \omega_m)t +$

$+ \frac{A_c \Delta\varphi}{2} \sin(\omega_c - \omega_m)t$

NBFM
$\Delta\varphi \ll 1\,\text{rad}$





Definition : $\mathcal{L}$ script or SSCR (single-sideband-to-carrier ratio)

$$\mathcal{L}(f_m) \triangleq 10\cdot\log_{10}\frac{P(f_c \pm f_m)}{P(f_c)}$$

spur power

carrier power

[dBc]

"carrier" referred to carrier power

$$\mathcal{L}(f_m) = \frac{\frac{A_c^2\,\Delta\varphi^2}{8}}{\frac{A_c^2}{2}} = \frac{\Delta\varphi^2}{4} = \frac{S_\phi^{SSB}(f_m)}{2}$$

$$\boxed{\mathcal{L}(f_m) = \frac{S_\phi^{SSB}(f_m)}{2}}$$

• Phase Noise

$$x_c(t) = A_c \cos\left[\omega_c t + \underbrace{\varphi_n(t)}\right]$$

φ_n, ω_n stochastic processes

$S_{\omega_n} = W$

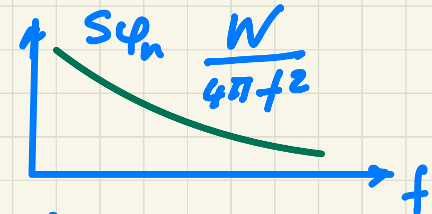
$$\varphi_n(t) = \int_{-\infty}^{t} \omega_n(t')\,dt'$$

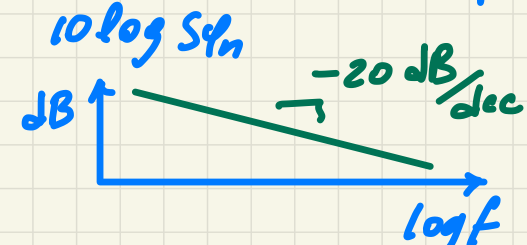
$\int dt \overset{\mathcal{F}}{\longleftrightarrow} \dfrac{1}{j2\pi f}$

$$S_x \longrightarrow \boxed{|H(f)|^2} \longrightarrow S_y$$

$\Downarrow$

$$S_{\omega_n}(f) \longrightarrow \boxed{\frac{1}{4\pi f^2}} \longrightarrow S_{\varphi_n}(f)$$





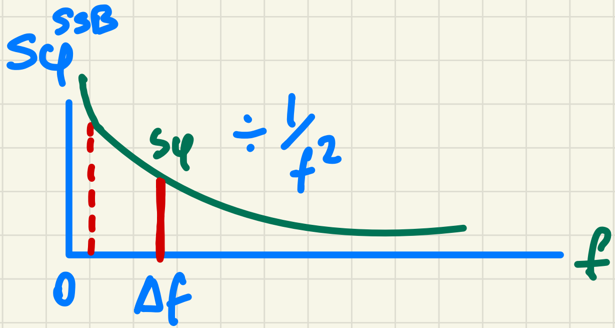
If $\omega_n(t)$ is WHITE noise (FM noise)

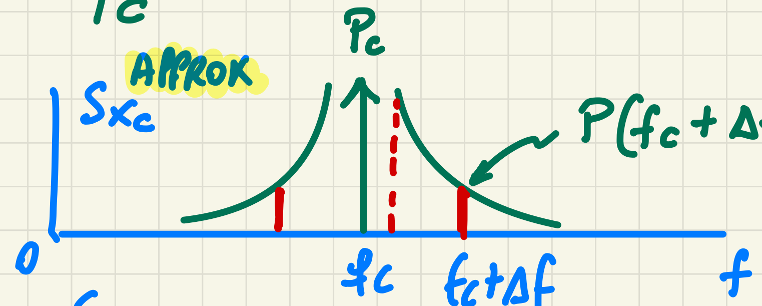
$\Rightarrow$ $\varphi_n(t)$ is RANDOM WALK noise $(1/f^2)$

Flicker FM $\Rightarrow$ $1/f^3$ phase noise

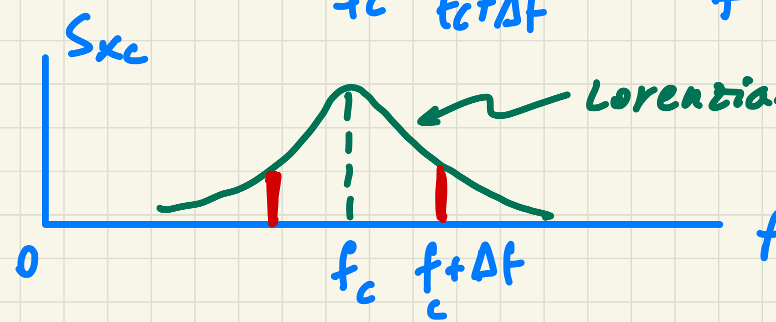
-30 dB/dec slope

$$\mathcal{L}(f) \triangleq \frac{P(f_c + f) \text{ in } 1\,\text{Hz}}{P_c} \overset{\text{NBFM}}{\simeq} \frac{S_\varphi^{SSB}(f)}{2}$$





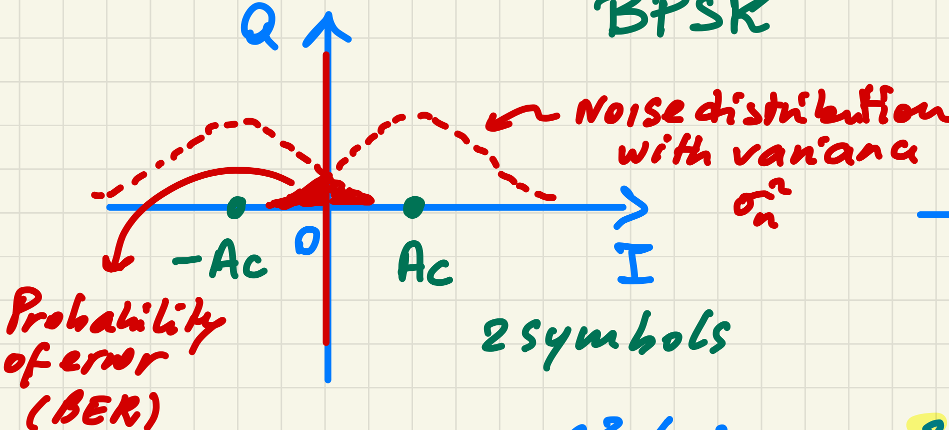
$$P(f_c + \Delta f) = \frac{S_\varphi}{2} \cdot P_c$$



Lorentzian shape

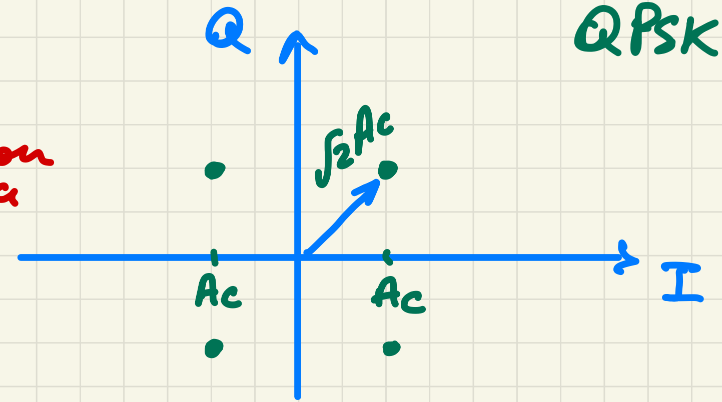
Digital modulations

BPSK

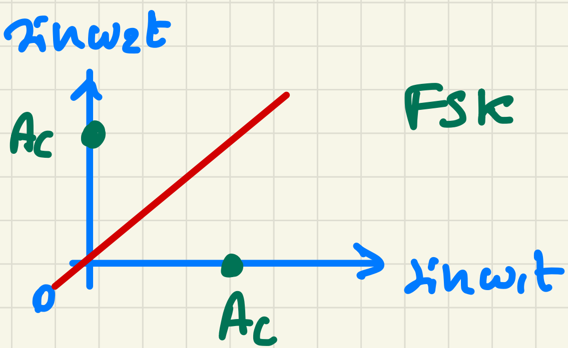


2 symbols

QPSK



- SNR = A_c^2/σ_n^2 $\xrightarrow{2x}$ SNR = $\frac{2A_c^2}{\sigma_n^2}$
- 2x symbols ⇒ 2x bit rate for same BW occupation



FSK (orthogonal)

$$\int_0^{T_s} \sin\omega_1 t \sin\omega_2 t \, dt = 0$$