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* $V_{pkpk} = 2\sqrt{2}\,V_{rms}$

* Antenna $\propto \lambda = \frac{c}{f} = \frac{300m}{f_{MHz}}$ ($L = \lambda/2$ or $\lambda/4$)

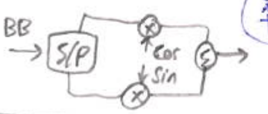
$\Rightarrow \cos A \cos B = \frac{1}{2}\left(\cos(A+B) + \cos(A-B)\right)$

$\sin A \sin B = \frac{1}{2}\left(\cos(A-B) - \cos(A+B)\right)$

* Error Vector Mag. $EVM_1 = \frac{1}{V_{rms}}\sqrt{\frac{1}{N}\sum_{j=1}^{N} e_j^2}$

$EVM_2 = \frac{1}{P_{av}} \frac{1}{N} \sum e_j^2$

* Quad Mod. (QPSK) $A\cos(\omega t + \theta) = \underbrace{A\cos\theta}_{I} \cos\omega t + \underbrace{A\sin\theta}_{Q} \sin\omega t$



QPSK: symbol rate $= \frac{1}{2}$ Bit rate

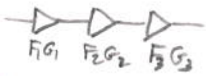
16QAM: symbol rate $= \frac{1}{4}$ Bit rate

* Noise floor $= kTB \rightarrow = -174\,dBm + 10\log BW$ @ room temp.

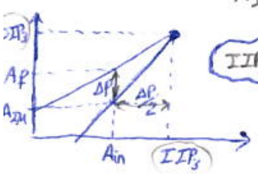
$\boxed{NF = 10\log \frac{SNR_{in}}{SNR_{out}}}$

* Friis Formula

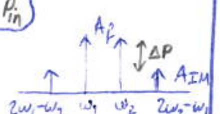
$F_t = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2}$



1. Gain Compression: $A_{1dB} = \sqrt{0.145\left|\frac{\alpha_1}{\alpha_3}\right|}$
2. Desensitization: $(\alpha_1 + \frac{3}{2}\alpha_3 A_2^2)A_1 \simeq 0$
3. Intermodulation: $A_{IIP_3} = \sqrt{\frac{4}{3}\left|\frac{\alpha_1}{\alpha_3}\right|}$



$IIP_3 = \frac{\Delta P}{2} + P_{in}$



* Parallel Resonance:

$Q = \frac{R}{\omega_0 L} = \omega_0 RC = \omega_0 \frac{E}{P_{av}} = \frac{R}{\sqrt{L/C}} = \frac{\omega_0}{BW}$

$\omega_0 = \frac{1}{\sqrt{LC}}$

$Z_0 = \sqrt{L/C}$

$|I_C| = |I_L| = Q\,|I_{in}|$

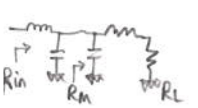
* series Resonance:

$Q = \frac{\omega_0 L}{R} = \frac{1}{\omega_0 RC}$ $\quad |V_C| = |V_L| = Q\,|V_{in}|$

$\Rightarrow$ series to parallel: $R_P = R_S(1+Q^2)$

$L_P = L_S \frac{1+Q^2}{Q^2}, \quad C_P = C_S \frac{Q^2}{1+Q^2}$

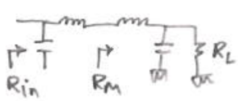
T-match



$R_M > R_L, R_{in}$

$Q = \sqrt{\frac{R_M}{R_L} - 1} + \sqrt{\frac{R_M}{R_{in}} - 1}$

Π-match



$R_M < R_L, R_{in}$

$Q = \sqrt{\frac{R_L}{R_M} - 1} + \sqrt{\frac{R_{in}}{R_M} - 1}$

* Hartley Rx

$IRR = \frac{4}{\epsilon^2 + \Delta\theta^2}$

$Q = \sqrt{\frac{R_P}{R_S} - 1}$

(LNA) * flicker $\Rightarrow \overline{V_n^2} = \frac{K}{WLC_{ox}} \frac{1}{f}$

* $NF = 1 + \frac{\overline{V_{n,in}^2}}{4kTR_S}$

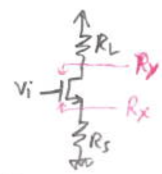
* $\Gamma = \left|\frac{Z_{in} - R_S}{Z_{in} + R_S}\right|$ (20 log)

* $\frac{1}{IP_{3t}^2} = \frac{1}{IP_{3LNA}^2} + \frac{A_{V_{LNA}}^2}{IP_{3Mix}^2}$

* $K = \frac{1 + |\Delta|^2 - |S_{11}|^2 - |S_{22}|^2}{2|S_{21}S_{12}|} > 1$

$\Delta = S_{11}S_{22} - S_{12}S_{21} < 1$ $\quad S_{12}\downarrow$

* fractional BW $= \frac{\Delta\omega}{\omega_0} = \frac{1}{Q}$



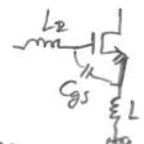
$A_V = \frac{R_L}{\frac{1}{g_m} + R_S}$

$R_X = \frac{r_o + R_L}{1 + g_m r_o}$

$R_Y = r_o + R_S + g_m r_o R_S$

$g_m = \mu_n C_{ox} \frac{W}{L}(V_{GS} - V_{th}) = \frac{2I}{V_{GS} - V_{th}} = \sqrt{2K'\frac{W}{L} I}$

$Z_{in} = \frac{1}{sC_{gs}} + s(L_1 + L_2) + \frac{g_m L_1}{C_{gs}}$



with $C_{gd} \rightsquigarrow Z_{in} \times \left(1 - \frac{2C_{gd}}{C_{gs}}\right)$

$A_V = \frac{1}{2} Q_{in} g_m R_1$ $\quad Q_{in} = \frac{1}{\omega_0 C_{gs} R_S}$

$NF = 1 + \frac{\gamma}{Q^2 g_m R_S}$

(Mixer) $V_{out}(t) = V_{RF}(t) \cdot V_{LO}(t)$

$V_{out}(f) = V_{RF}(f) * \sum_{n=-\infty}^{\infty} \frac{\sin(n\pi/2)}{n\pi} \delta(f - \frac{n}{T})$

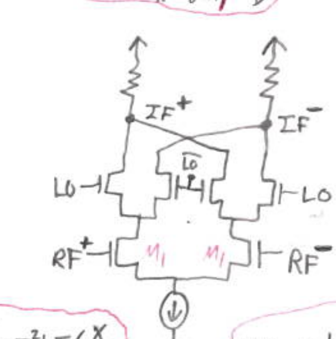
$\boxed{CG = \frac{1}{\pi}}$

* square-law Mixer

$\hookrightarrow \boxed{CG = \frac{k'}{2} \frac{W}{L} V_{LO}}$

* Gilbert Cell (Double Balanced)

$\hookrightarrow \boxed{CG = \frac{2}{\pi} g_{m_1} R_D}$



$\overline{V_{n,in}^2} = \pi^2 kT\left(\frac{\gamma}{g_{m1}} + \frac{2}{g_{m1}^2 R_D}\right) \rightsquigarrow NF_{SSB} = 1 + \frac{\overline{V_{n,in}^2}}{4kTR_S}$

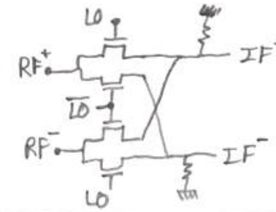
$-3 = NF_{DSB}$

(1) RZ Mixer

a) single path: $CG = 20\log\frac{1}{\pi} = -10\,dB$

b) single balanced: $CG = 20\log\frac{2}{\pi} = -4\,dB$

c) double balanced: $CG = -4\,dB$



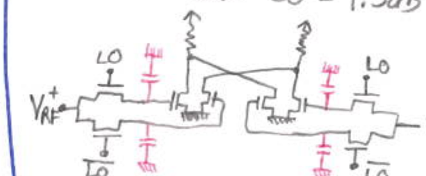
(2) Sampling Mixer

a) single path: $CG = 20\log\sqrt{\frac{1}{\pi^2} + \frac{1}{4}} = -4.5\,dB$

b) single balanced: $CG = 1.5\,dB$

c) double balanced: $CG = -4\,dB$

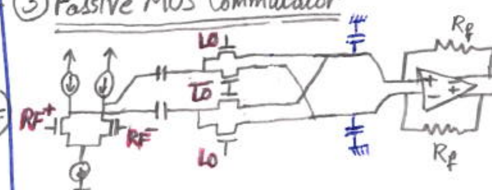
d) Combine currents: $CG = 1.5\,dB$



* Duty Cycle: $I_{IF} = \frac{2}{\pi} \frac{\sin \pi d}{2d} I_{RF} \cos\omega_{IF} t$

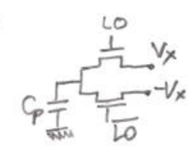
25% duty cycle $\Rightarrow$ +3dB in CG

(3) Passive MOS Commutator



$Q_t = C_P V_X - (-C_P V_X) = 2C_P V_X$ in $1T$

$I_X = \frac{Q_t}{T} = 2C_P V_X f_{LO}$



$R_P = \frac{V_X}{I_X} = \frac{1}{4 f_{LO} C_P}$

$\overline{V_o^2} = \left(1 + \frac{2R_f}{R_P}\right)^2 \overline{V_{amp}^2}$

* lossy stage: $NF = L$, $G = 1/L$

* $E = \frac{1}{2} C V_{PK}^2$