Electronics of Radio (Supplement)

Notes on David Rutledge’s book

John Manferdelli

johnmanferdelli@hotmail.com

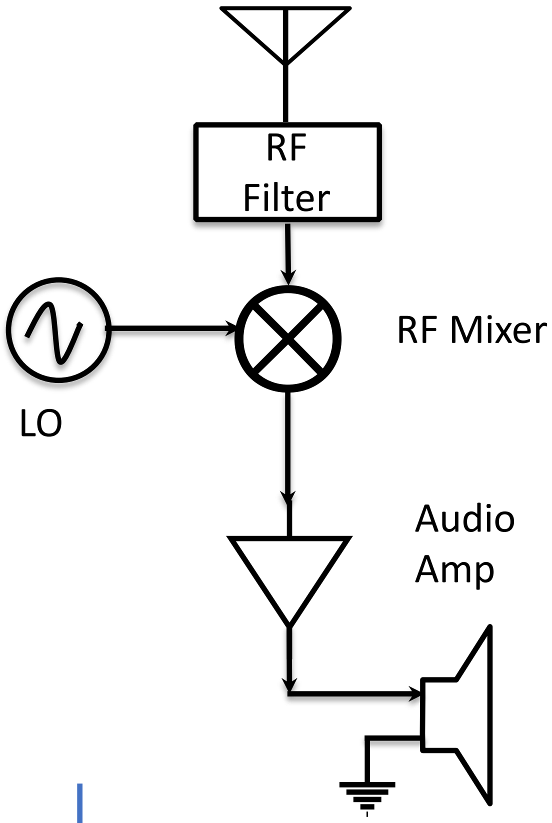
11062021 12:12

Modulation

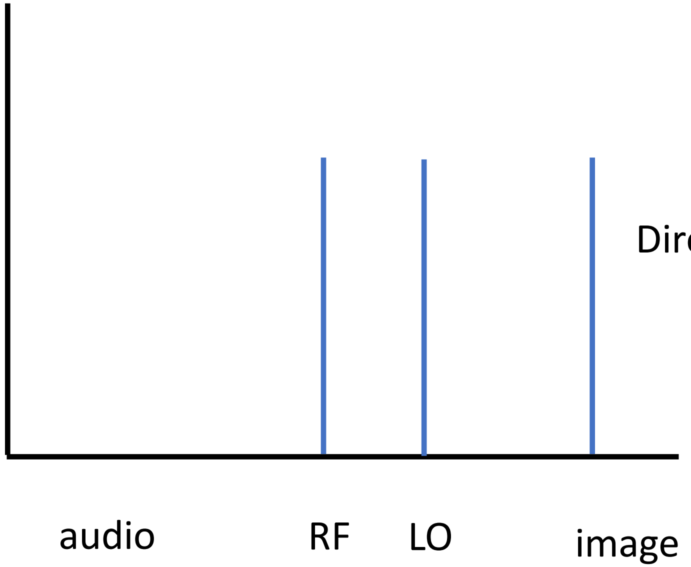
- AM: $V(t) = a(t)\cos(\omega_c t) + V_c\cos(\omega_c t)$
- FM: $V(t) = V_c\cos([\omega_c + a(t)]t)$
- FSK: $V(t) = V_c\cos(\omega_1 t)$, if 1 [mark]; $V_c\cos(\omega_0 t)$, if 0 [space]
- PSK: $V(t) = V_p\cos(\omega_c t)$, if 1; $-V_p\cos(\omega_c t)$, if 0 [space]
- Gain: $G = \frac{P_o}{P_i}$, Loss: $L = \frac{P_o}{P_{max}}$, Rejection: $\mathrm{R} = \frac{P_{max}}{P_{pb}}$,

Direct conversion receivers

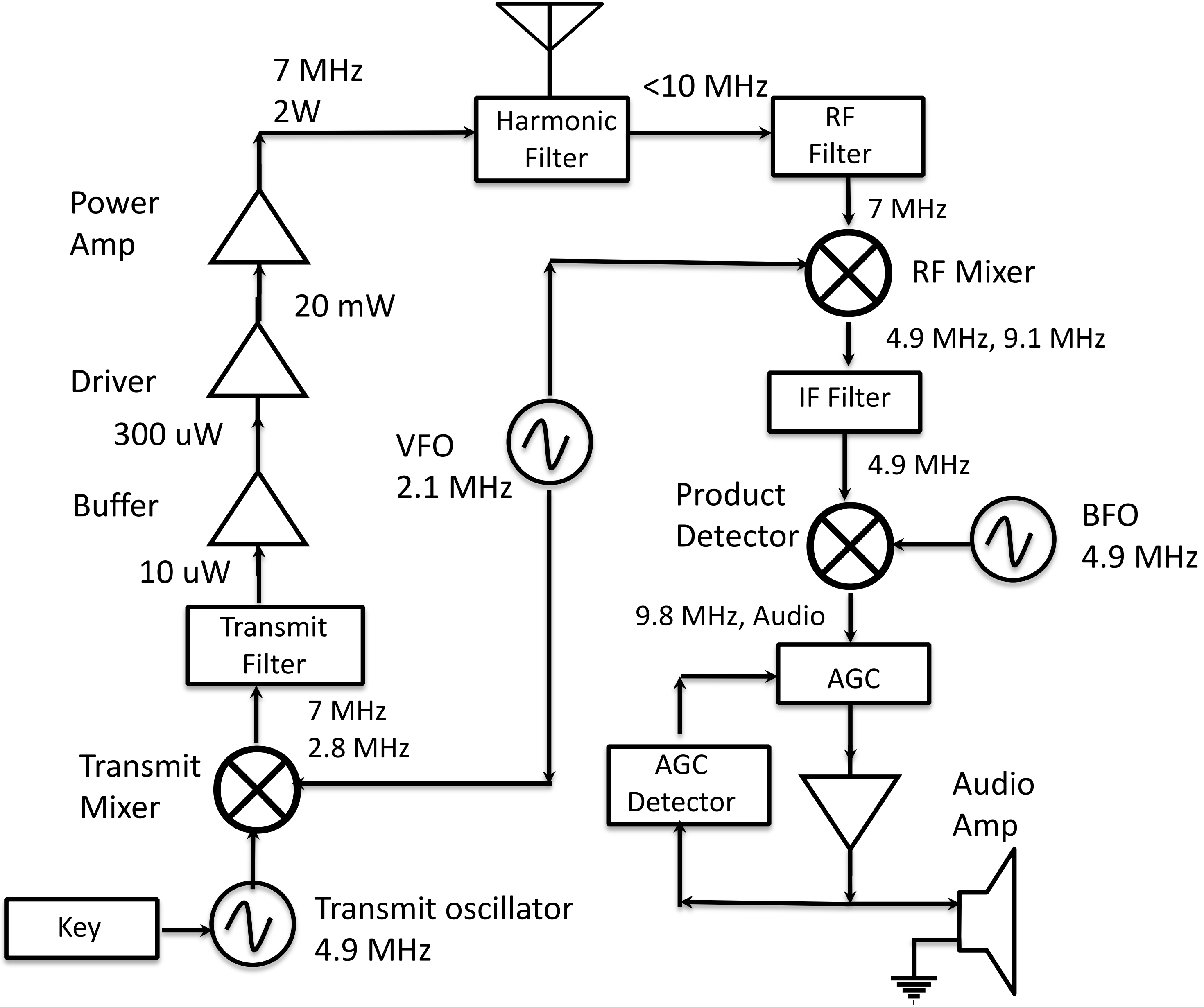
- Mixer
  - $V(t) = \cos(\omega_1 t)\cos(\omega_2 t) = \frac{1}{2}[\cos\big((\omega_1 + \omega_2)t\big) + \cos\big((\omega_1 - \omega_2)t\big)]$
- Image frequency
  - $\omega_{vi} = \omega_{LO} + \omega_a$
  - $\omega_{rf} = \omega_{LO} - \omega_a$
- RF filter removes image
- Downside:
  - Not tunable



Direct conversion



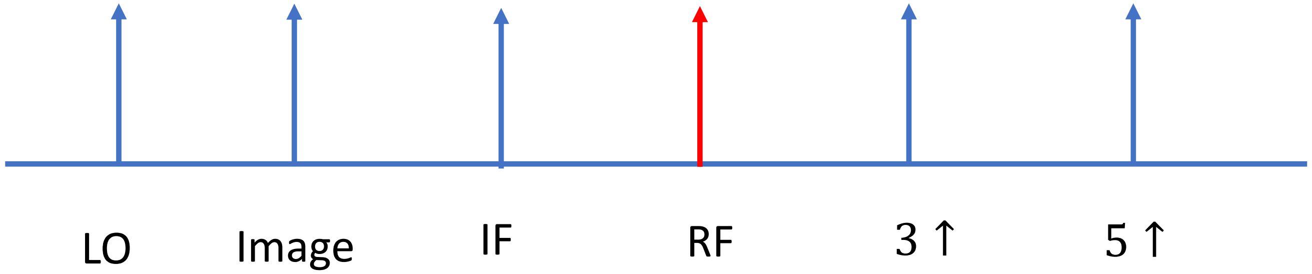
Norcal 40A



7 MHz
2W
Harmonic Filter
<10 MHz
RF Filter
7 MHz
Power Amp
RF Mixer
20 mW
4.9 MHz, 9.1 MHz
Driver
IF Filter
300 uW
VFO
2.1 MHz
4.9 MHz
Product Detector
BFO
4.9 MHz
Buffer
10 uW
9.8 MHz, Audio
Transmit Filter
AGC
7 MHz
2.8 MHz
Transmit Mixer
AGC Detector
Audio Amp
Key
Transmit oscillator
4.9 MHz

Mixers

- $V_{lo}(t)$ is a square wave with period ω_{lo}. Expanding this in a Fourier series, we get:
- $V_{lo}(t) = \frac{4}{\pi}(\cos(\omega_{lo}t) - \frac{\cos(3\omega_{lo}t)}{3} + \frac{\cos(5\omega_{lo}t)}{5} \ldots)$, $V_{rf}(t) = V_{rf}\cos(\omega_{rf}t)$
- $V_{lo}(t)V_{rf}(t) = \frac{2V_{rf}}{\pi}(\cos(\omega_{-}t) - \frac{\cos(3\omega_{-}t)}{3} + \frac{\cos(5\omega_{-}t)}{5} \ldots) + \frac{2V_{rf}}{\pi}(\cos(\omega_{+}t) - \frac{\cos(3\omega_{+}t)}{3} + \frac{\cos(5\omega_{+}t)}{5} \ldots)$
- $\omega_{+} = \omega_{lo} + \omega_{rf}$ and $\omega_{-} = |\omega_{lo} - \omega_{rf}|$
- We define $\omega_{k+} = (k\omega_{lo} + \omega_{rf})$ and $\omega_{k-} = |k\omega_{lo} - \omega_{rf}|$ and $V_{k+}(t) = \frac{2V_{rf}}{k\pi}\cos(\omega_{k+}t)$ and $V_{k-}(t) = \frac{2V_{rf}}{k\pi}\cos(\omega_{k-}t)$
- $\omega_i = \omega_{if} - \omega_{lo}$ and $\omega_{if} = \omega_{if} + \omega_i$, ω_i is a spurious signal. ω_{k+} and ω_{k-} are the spurs from the kth harmonic



Phasors

- $V(t) = RI(t)$
- $V(t) = L\dot{I}(t)$
- $I(t) = C\dot{V}(t)$
- Suppose $V(t) = Acos(\omega t + \theta)$ and $\mathrm{I}(t) = Bcos(\omega t + \phi)$. If $\phi > \theta$, we say the current leads the voltage.
- $V(t) = Re(e^{j(\omega t+\theta)})$, and $\mathrm{I}(t) = Re(e^{j(\omega t+\phi)})$
- Now define $V = Ae^{j\theta}$ and $I = Be^{j\phi}$, so $|V| = A$, $|I| = B$, $\angle V = \theta$, and $\angle I = \phi$. V and I are called phasors and do not include time. Note that $V(t) = Re(Ve^{j\omega t})$ and $\mathrm{I}(t) = Re\left(Ie^{j\omega t}\right)$.
- Note that $I = CVj\omega$, for a capacitor and $V = LIj\omega$, for an inductor
- $\hat{V} = Z\hat{I}, Z = R + jX$
- $\hat{I} = Y\hat{V}, Y = G + jB$

Series resonance and Q

- At ω_u and ω_l, $X = \pm R$ [ω_u is upper 3dB cutoff and ω_l is lower 3dB cutoff]
- $\omega_u L - \frac{1}{\omega_u C} = R$, $\omega_l L - \frac{1}{\omega_l C} = -R$
- Define $Q = \frac{X}{R}$
- $\frac{\omega_u}{\omega_0} - \frac{\omega_0}{\omega_u} = \frac{R}{\omega_0 L} = \frac{1}{Q}$ and $\frac{\omega_l}{\omega_0} - \frac{\omega_0}{\omega_l} = -\frac{R}{\omega_0 L} = -\frac{1}{Q}$

- $\frac{\omega_u}{\omega_0} - \frac{\omega_0}{\omega_u} = \frac{\omega_0}{\omega_l} - \frac{\omega_l}{\omega_0}$, so ${\omega_0}^2 = \omega_u \omega_l$ and $\frac{\omega_u - \omega_l}{\omega_0} = \frac{1}{Q}$

Parallel resonance and Q

- $\frac{\omega_u}{\omega_0} - \frac{\omega_0}{\omega_u} = \frac{G}{\omega_0 C} = \frac{1}{Q_p}$ and $\frac{\omega_l}{\omega_0} - \frac{\omega_0}{\omega_l} = -\frac{G}{\omega_0 C} = -\frac{1}{Q_p}$

Power

- $P(t) = I(t)V(t)$
- Complex power: $P = \frac{V\bar{I}}{2} = Z\frac{|I|^2}{2} = P_a + jP_r = R\frac{|I|^2}{2} + \mathrm{j}X\frac{|I|^2}{2}$
  - P_a is power delivered to resistor, P_r is power stored in inductor and capacitor
- $P_r = \frac{\omega L|I|^2}{2} - \frac{\omega C|V_c|^2}{2} = \omega(E_L - E_C)$
- $Q = \omega\frac{L|I|^2}{R|I|^2} = \omega\frac{L}{R} = \omega\frac{E_L}{P_a}$

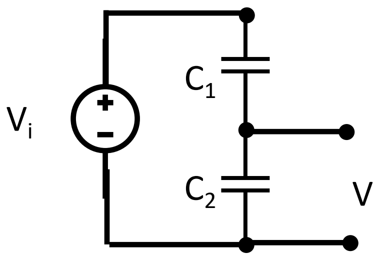
General formulas for Q

- x

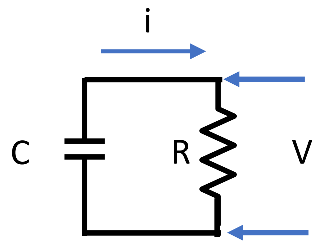
Exercises

- Calculate wave form through bridge and after “smoothing capacitor”

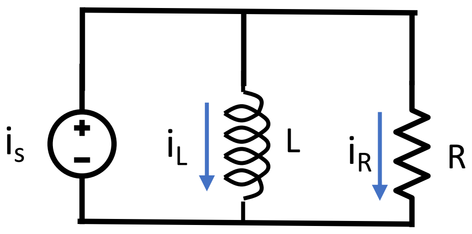
Misc-1



- $\frac{V}{V_i} = \frac{C_1}{C_1+C_2}$



- $I = \frac{V}{R} = -CV', \tau = RC,$



- $\frac{L}{R} I_R{}' + I_R = 0$
- $i_s = i_r + i_L$

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