97.455 Formula Sheet 2004 revision 1

Noise Figure

$$\text{NF} = 10\log_{10}\frac{(S/N)_{in}}{(S/N)_{out}} = 10\log_{10}\frac{N_{out}}{GN_{in}}$$

Resistor Noise $= 4kTR$ in V^2/Hz where $KTR \approx 2\times10^{-19}$ V^2/Hz for R=50 Ω, $T = 297$ K.

h-parameters

$$\begin{bmatrix} v_{be} \\ i_c \end{bmatrix} = \begin{bmatrix} h_{ie} & h_{re} \\ h_{fe} & h_{oe} \end{bmatrix} \begin{bmatrix} i_b \\ v_{ce} \end{bmatrix}$$

Inductor

If $Q_L \gg 1$ then $Q_L = \dfrac{\omega_0 L}{r_s} = \dfrac{r_p}{\omega_0 L}$

Tuned Circuit

$$B = \frac{1}{RC}, \quad \omega_0 = \frac{1}{\sqrt{LC}}, \quad Q = \frac{\omega_0}{B}$$

Transformer

$$\frac{v_2}{v_1} = \frac{n_2}{n_1} = \frac{i_1}{i_2}, \quad Z_1 = \left(\frac{n_1}{n_2}\right)^2 Z_2$$

General Formulas

$$\sin(\alpha \pm \beta) = \sin\alpha\cos\beta \pm \cos\alpha\sin\beta$$
$$\cos(\alpha \pm \beta) = \cos\alpha\cos\beta \mp \sin\alpha\sin\beta$$
$$2\cos\alpha\cos\beta = \cos(\alpha-\beta) + \cos(\alpha+\beta)$$
$$2\sin\alpha\sin\beta = \cos(\alpha-\beta) - \cos(\alpha+\beta)$$
$$2\sin\alpha\cos\beta = \sin(\alpha-\beta) + \sin(\alpha+\beta)$$

(AM) $A(1 + K\cos\omega_m t)\cos\omega_c t$

PLL Lock range $= \pm K = \pm K_{phase}K_{vco}A_0$ for sinusoidal phase detector, $\pm\frac{\pi}{2}K$ for X-Or.

$$\frac{\theta_o}{\theta_i} = \frac{KF(s)}{s + KF(s)} \quad \frac{v_c}{\theta_i} = \frac{sK_{phase}A_0F(s)}{s + KF(s)}$$

$$\frac{\epsilon}{\theta_i} = \frac{s}{s + KF(s)} \quad \text{if } F(s) = \frac{s\tau_2 + 1}{s\tau_1}$$

$$\text{then} \quad \frac{\theta_o}{\theta_i} = \frac{K(s\tau_2+1)}{\tau_1(s^2 + 2\zeta\omega_n s + \omega_n^2)}$$

$$\text{where } \omega_n = \sqrt{\frac{K}{\tau_1}} \text{ and } \zeta = \frac{\omega_n\tau_2}{2}$$

Mod. Bandwidth Estimate $W < 2\omega_n\zeta$

FM input : max phase error at $\omega_m = \omega_n$, $\epsilon_p = \left(\dfrac{\Delta\omega}{\omega_n}\right)\dfrac{1}{2\zeta}$

Distortion and Linearity inputs at f_1, f_2, intermod IM3 at $2f_1 - f_2$ and $2f_2 - f_1$. $P_o \propto P_{in}$, IM3 $\propto P_{in}^3$. Intercept point: IP3 where P_o and IM3 have the same power.

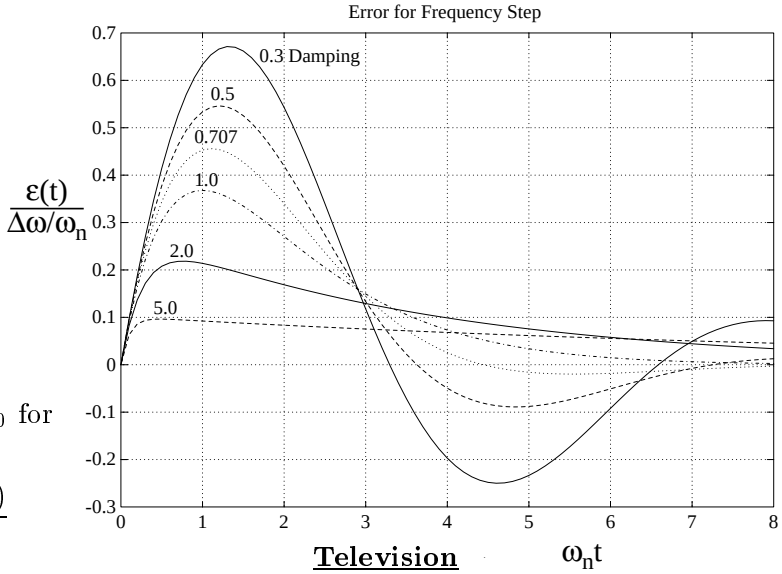
Harmonics: HD2 at $2f_{in}$, HD3 at $3f_{in}$.

Class C and Frequency Multiplier

$$i_c = I_p(\cos\omega t - \cos\theta)$$
$$I_{DC} = \frac{I_p}{\pi}(\sin\theta - \theta\cos\theta)$$
$$I_1 = \frac{I_p}{2\pi}[2\theta - \sin 2\theta]$$
$$I_n = \frac{2I_p}{\pi}\left[\frac{(\cos\theta\sin n\theta - n\sin\theta\cos n\theta}{n(n^2-1)}\right]$$

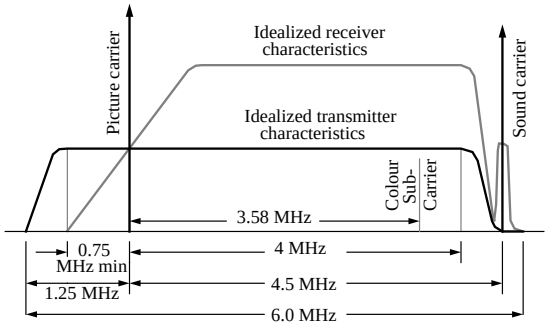
(FM) for small β, $\gamma = \omega_c t$, $\alpha = \omega_m t$

$$\cos(\gamma + \beta\sin\alpha) \approx \cos\gamma - \beta\sin\alpha\sin\gamma$$



Television

$$Y = 0.30R + 0.59G + 0.11B$$
$$E_T = Y + 0.877(R-Y)\sin\omega_S t + 0.493(B-Y)\cos\omega_S t$$



Simplified Spectrum of a Television Channel

Oscillator

$$X_1 + X_2 + X_3 = 0$$

$$A_v \geq \frac{X_2}{X_1}$$

for amplifier with no input current, e.g., MOS where $A_v = g_m r_o$.

$$\beta \geq \frac{X_1}{X_2}$$

for amplifier with input current and current gain β, e.g., Bipolar