LNA Stability Issues--Step 1

Briefly reviewing, the small signal hybrid-π version of the "y" parameters is as follows:

$$C_\pi = \frac{g_m}{\omega_T} - C_\mu \quad or \quad C_\pi + C_\mu = \frac{g_m}{\omega_T}$$

$$r_\pi = \frac{\beta}{g_m}$$

$$y_i = \frac{g_m}{\beta} + j\omega(C_\pi + C_\mu) = \frac{g_m}{\beta} + j\omega\left(\frac{g_m}{\omega_T}\right)$$

$$y_f = g_m - j\omega C_\mu$$

$$y_r = 0 - j\omega C_\mu$$

$$y_o = \frac{1}{r_o} + j\omega C_\mu$$

most of the "action" will be associated with C_μ

Stability Criteria (the minimalist's view)

There are two stability criteria formulae. The <u>Stern criteria</u> will be used here for discussion. The equations are derived in terms of network theory (and feedback) that considers conditions when the denominator of the transfer function (i.e. A=a/[1-af]) can become zero.

$$K \equiv \frac{2(g_i + G_S)(g_o + G_L)}{(|y_f y_r| + \mathrm{Re}(y_f y_r))}$$

$$Stability \quad for \ \boxed{K \triangleright 1} \ or$$

$$2(g_i + G_S)(\underbrace{g_o}_{0} + G_L) \triangleright (|y_f y_r| + \mathrm{Re}(y_f y_r))$$

$$and \ \ in \ \ terms \ \ of \ \ hybrid - \pi :$$

$$|y_f y_r| \sim g_m \omega C_\mu$$

Bottom-line (ultra-simplified) Equation

$$\mathrm{Re}\left(y_f y_r\right) = -\left(\omega C_\mu\right)^2$$

$$\textit{assume that } g_o \lhd\lhd G_L$$

$$\boxed{2\left(\frac{g_m}{\beta} + G_S\right)(G_L) \rhd g_m \omega C_\mu - \left(\omega C_\mu\right)^2}$$

LHS RHS

Now, let's take some typical numbers for transistor parameters and look at the effects of:

- **bias, frequency**
- **loading from G_s and G_L.**

Assume the following values for the transistor:

$$\beta = 100$$

$$C_\mu = 0.5pF$$

Putting some numbers into the Equation

Assuming that I_c=2mA, resulting in a value of g_m=0.077, then the following table gives values for the two RHS terms

ω	ωC_μ	$g_m \omega C_\mu$	$\left(\omega C_\mu\right)^2$
$20\,MHz$	$6.28x10^{-5}$	$4.84x10^{-6}$	$3.94x10^{-9}$
$200\,MHz$	$6.28x10^{-4}$	$4.84x10^{-5}$	$3.94x10^{-7}$
$1\,GHz$	$3.14x10^{-3}$	$2.42x10^{-3}$	$9.86x10^{-6}$

Assuming g_i=G_S and G_L=10KΩ, and computing the LHS of the boxed equation gives:

$$2x(1.54x10^{-3})(10^{-4}) = 3.08x10^{-7}$$

(which for ALL frequencies would NOT satisfy the K-stability criteria).

Getting a stable amplifier

Now choosing G_S=500Ω and G_L=1KΩ, again computing the LHS gives:

$$2x(7.7x10^{-4}+2.0x10^{-3})(10^{-3})=5.54x10^{-6}$$

(which **does satisfy the K-stability criteria at 20MHz** (but NOT at 200MHz). In turn, this would set the voltage gain at $A_v=-g_mR_L=-77$).

Clearly, if one needs to go to higher frequencies, several things would be needed:

- **Lower G_s and G_L**
- **Larger g_m**
- **A better transistor (with lower C_μ)**