Receiver System
Centimeter Regime

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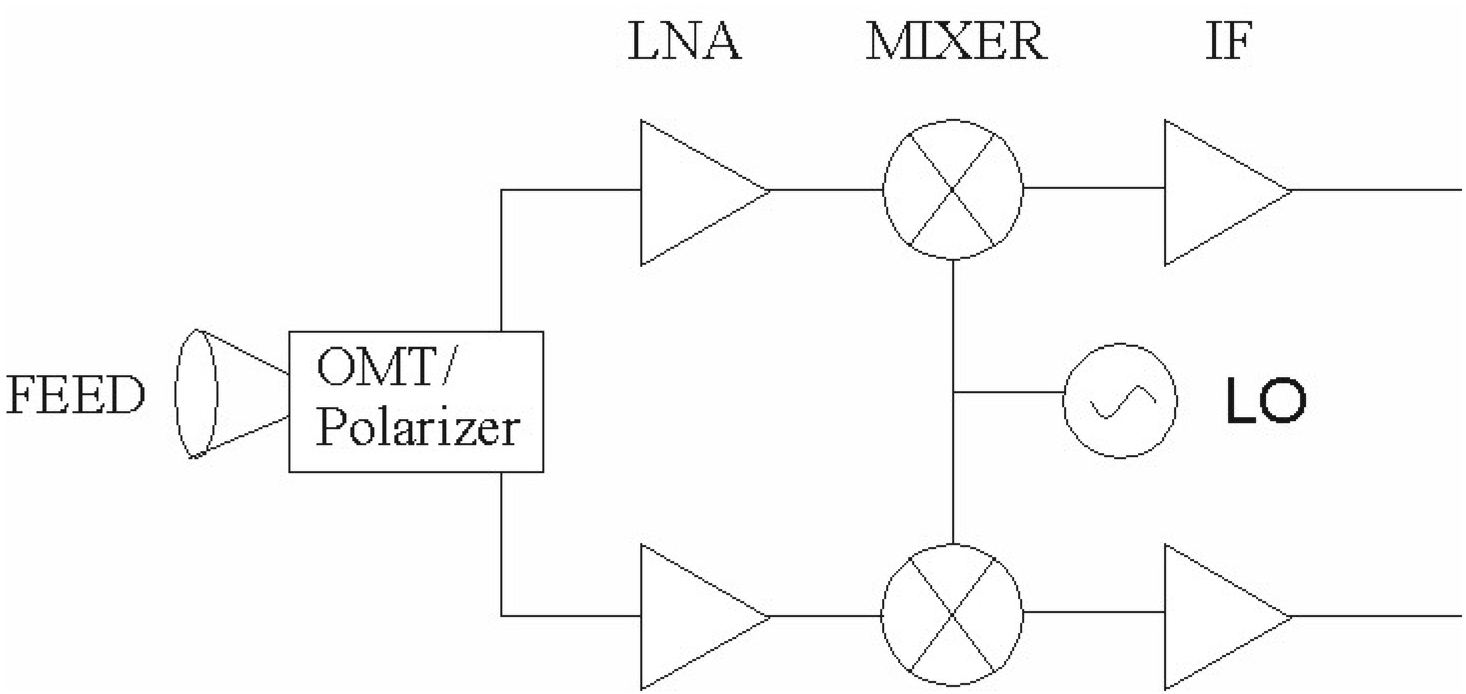
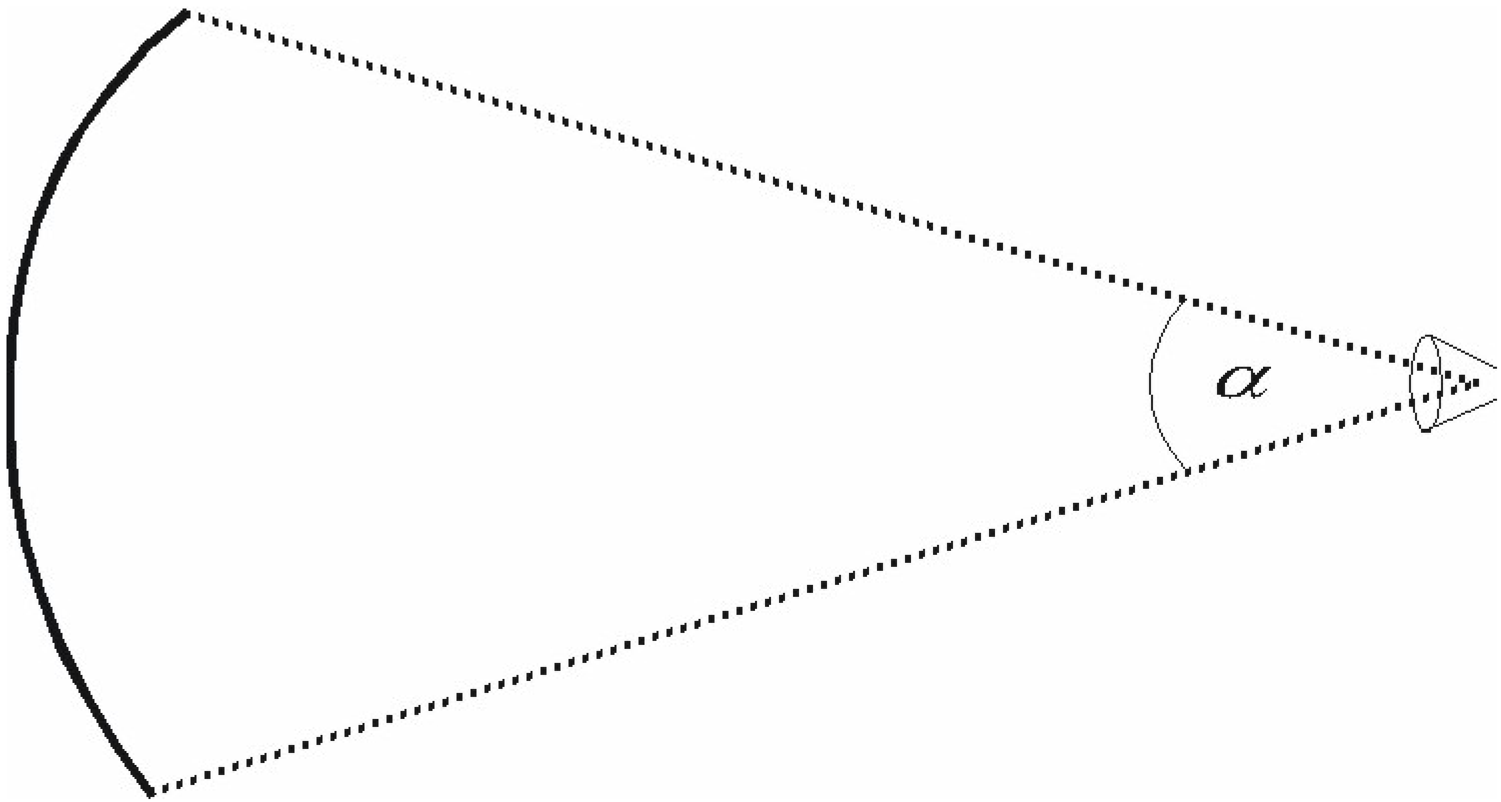
Typical Hetrodyne Receiver

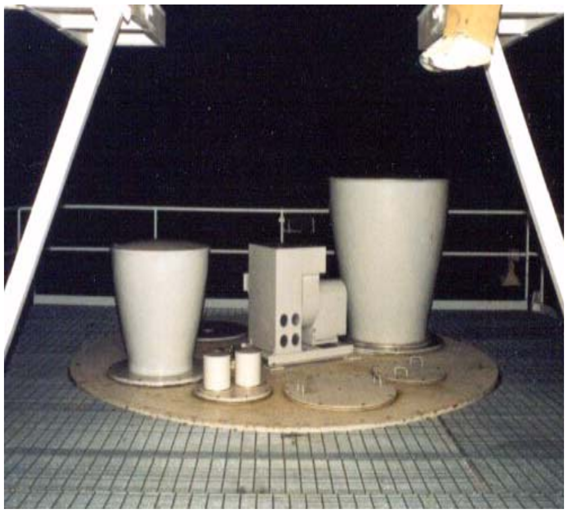


Reflector Feeds

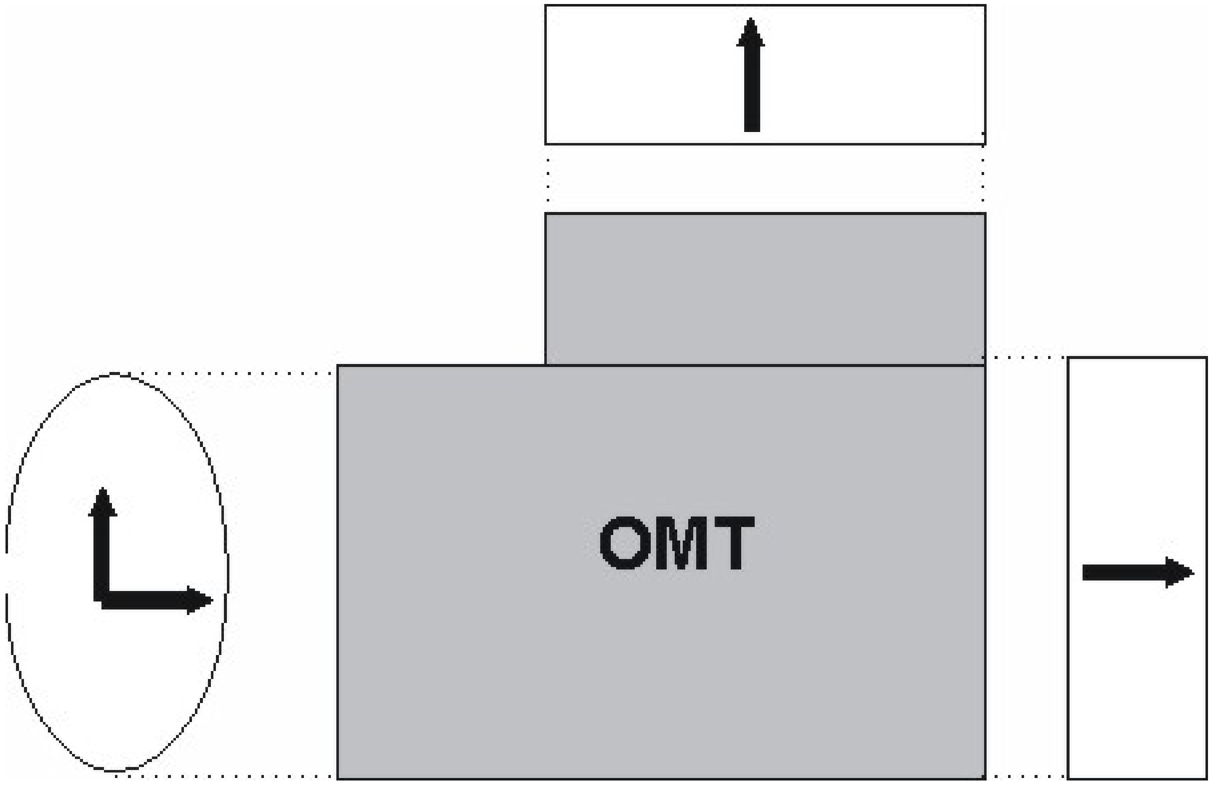


Feeds

And More Feeds

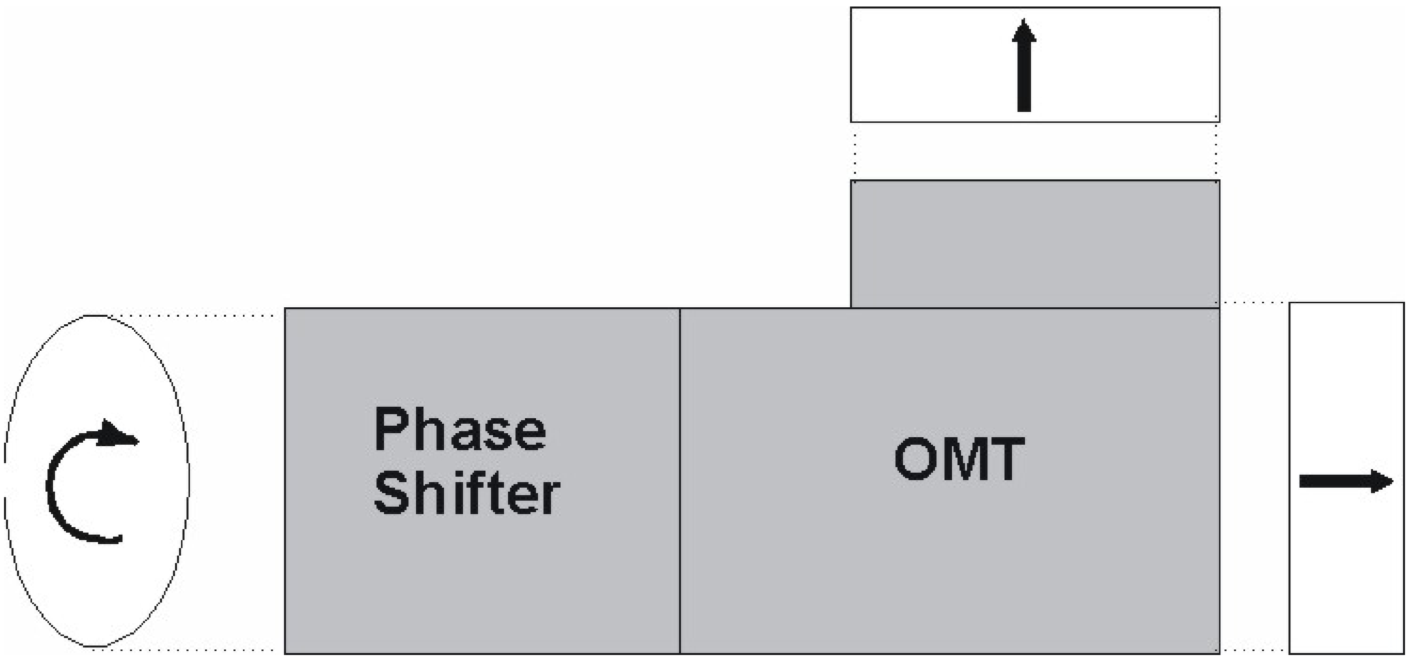


Linear Polarization



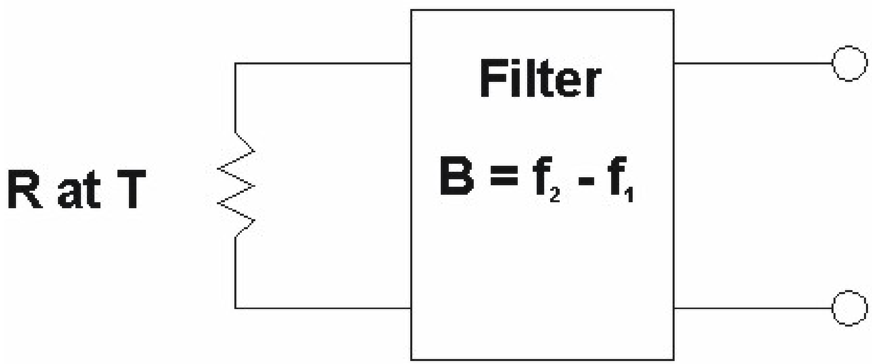
Orthomode Transducer

Circular Polarization



A Variety of OMTs

Thermal Voltage Fluctuations

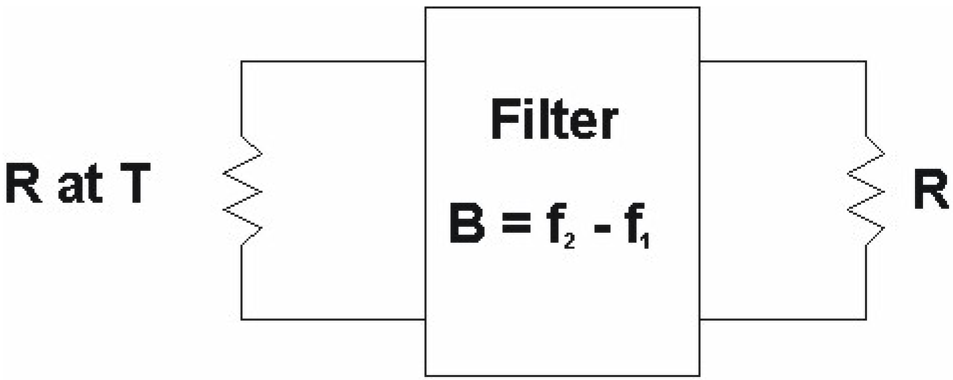


$$V_{rms}^2 = 4kTR\int_{f1}^{f2}\left(\frac{\alpha}{e^{\alpha}-1}\right)df$$

$$\alpha = \frac{hf}{kT}$$

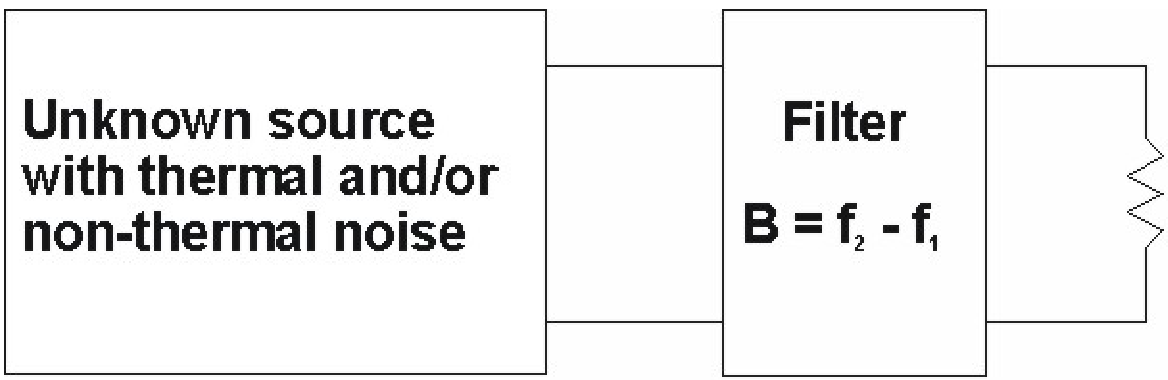
If $\alpha \ll 1$, $V_{rms}^2 = 4RkBT$

Available Noise Power



$$P_n = kBT$$

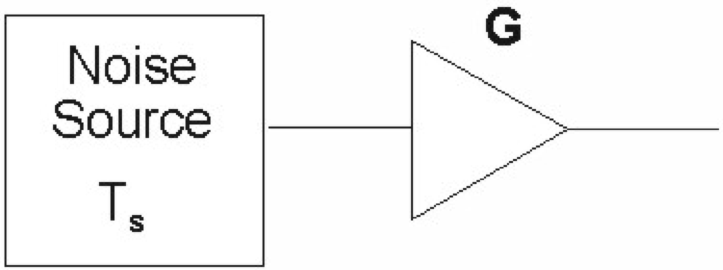
Equivalent Noise



Measure P_n, calculate:

$$T_s = \frac{P_n}{kB}$$

Amplifier Equivalent Noise



P_o (bandlimited to B)

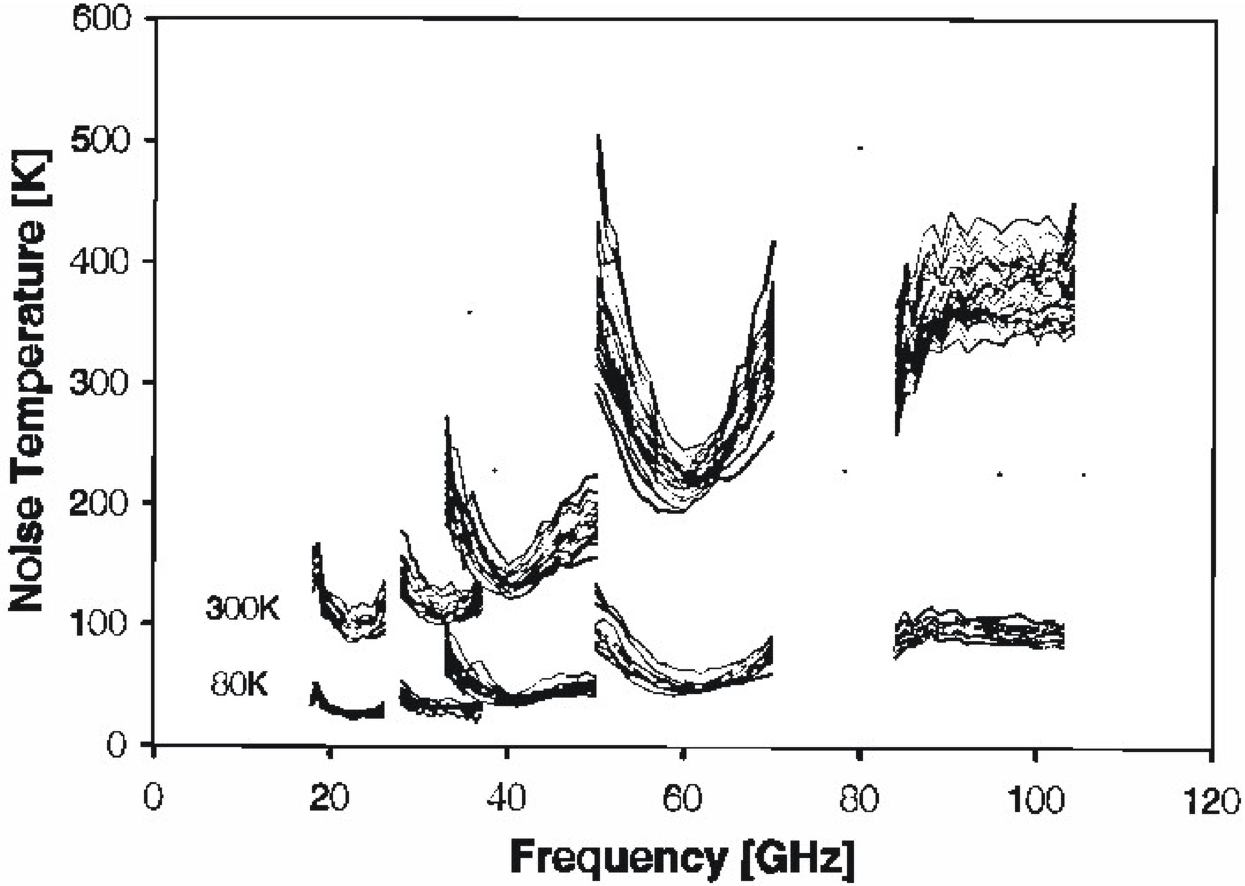
$P_o = GkBT_s + K$

Define $K = GkBT_e$

Then, $P_o = GkB(T_s + T_e)$

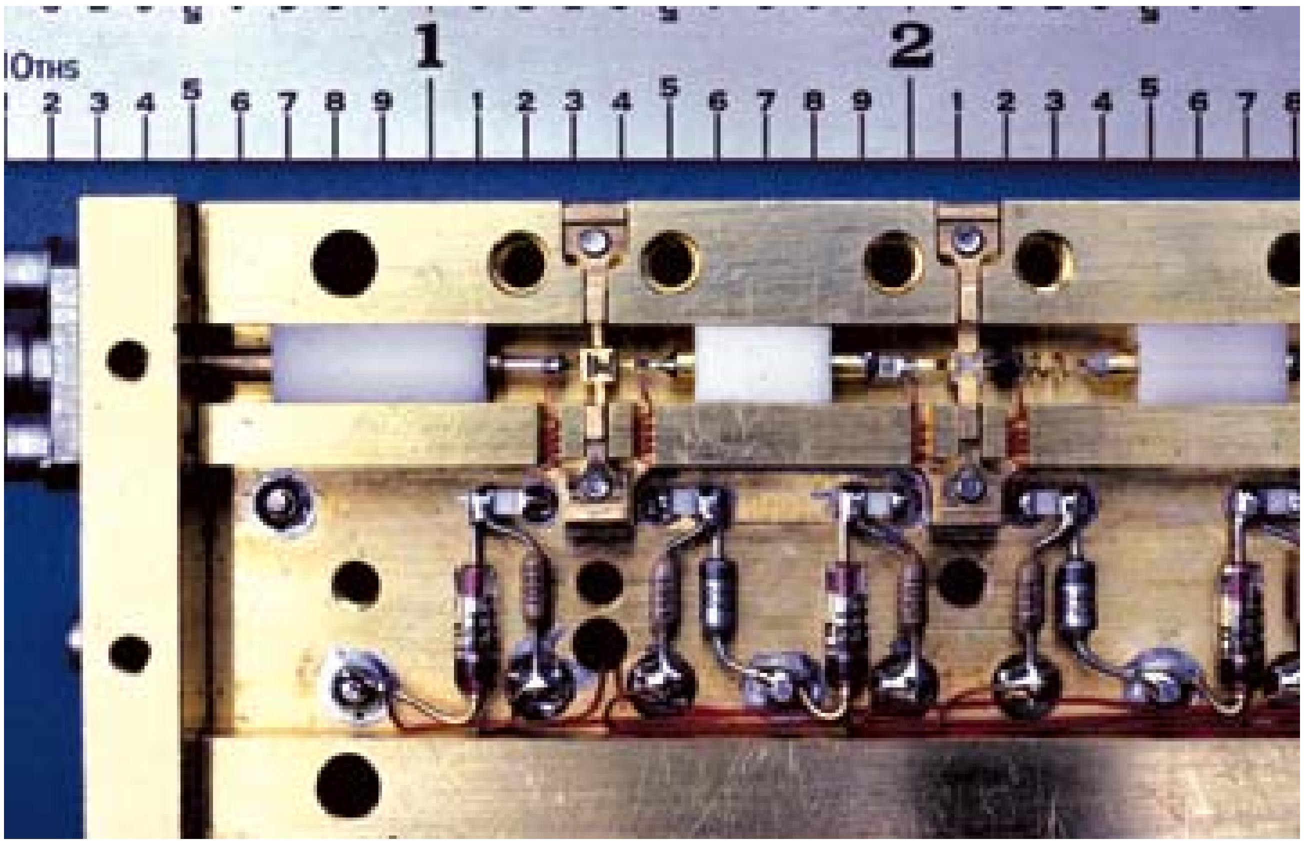
T_e is the amplifier *Equivalent Input Noise Temperature*

HFET Noise Temperature

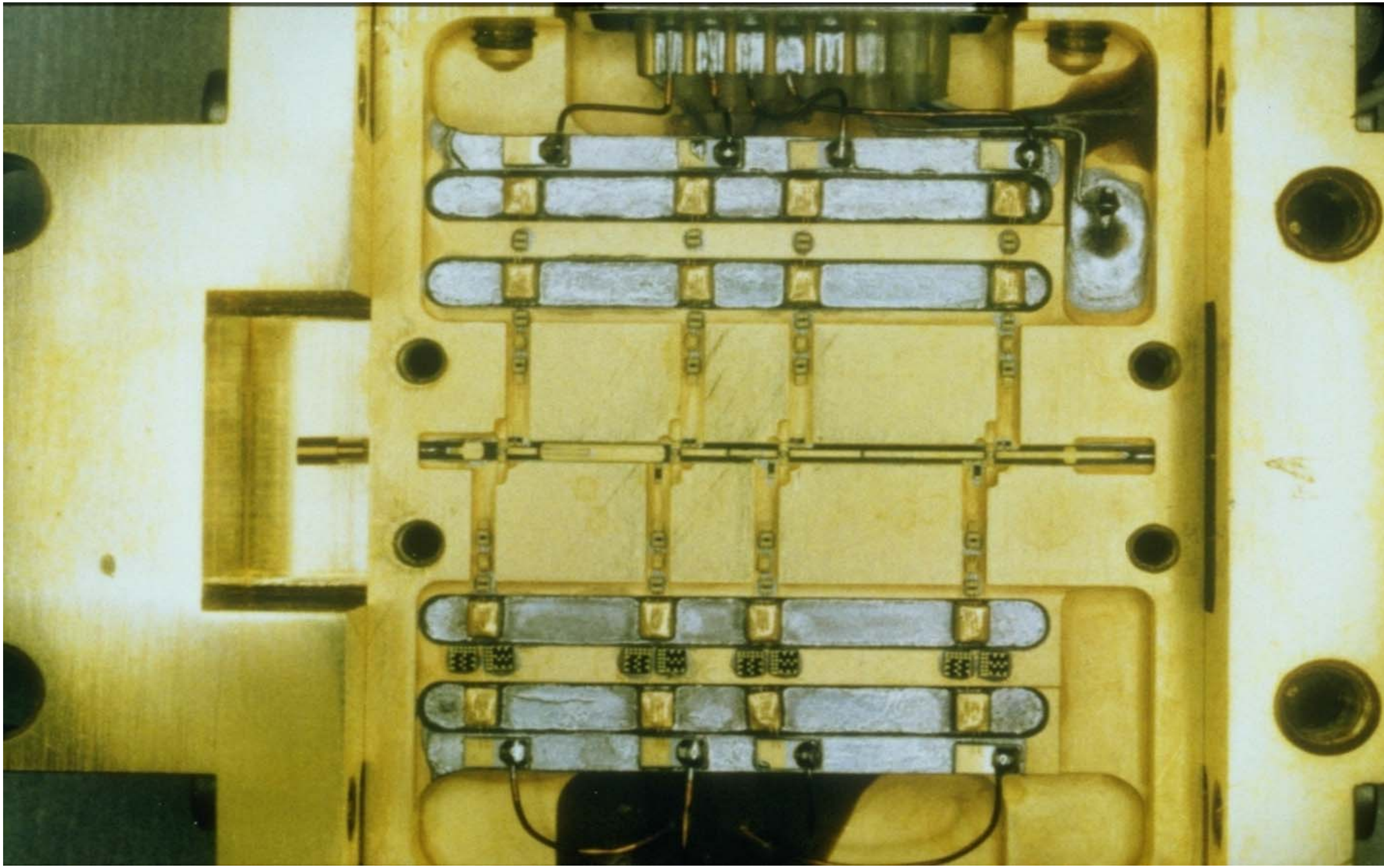


Data courtesy M. Pospieszalski of NRAO Central Development Laboratory

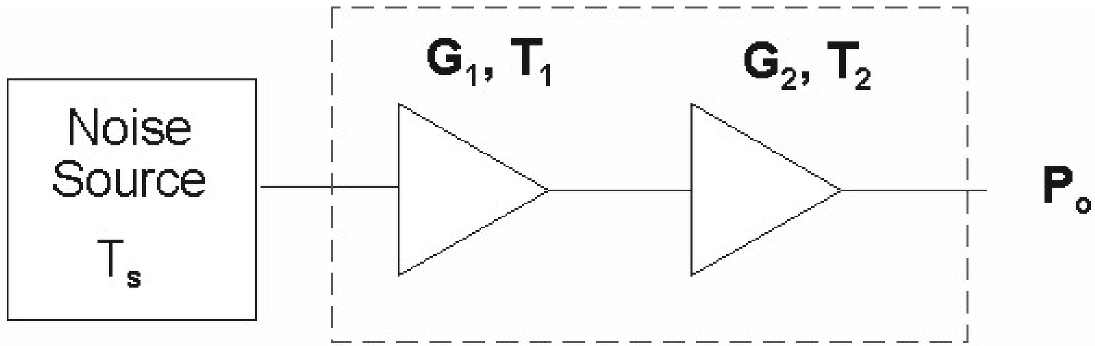
A HFET LNA



K-band Map Amplifier



Amplifier Cascades



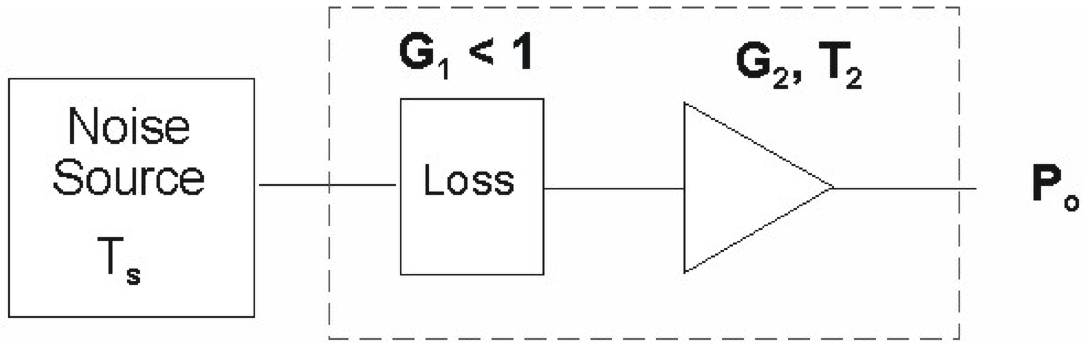
$$P_o = G_1G_2kBT_s + G_1G_2kBT_1 + G_2kBT_2$$

or,

$$P_o = G_1G_2kB\ (\ T_s + (T_1 + T_2/G_1))$$

So, Amplifier Cascade has equivalent noise $T_1 + T_2/G_1$

Input Losses



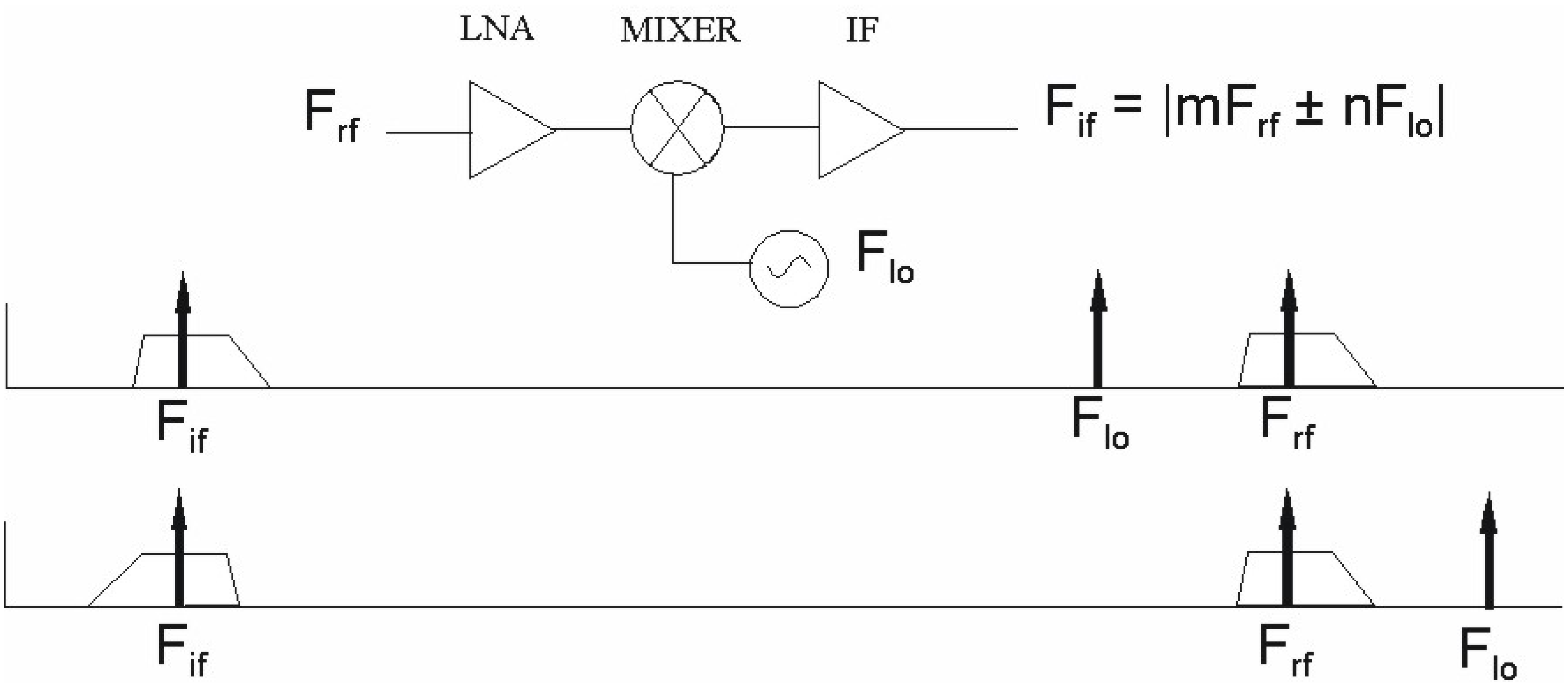
Let $L = 1/G_1$, then for ohmic loss at physical temperature T_o,

the effective noise temperature of the loss is $(L-1)T_o$.

Effective noise temperature of the loss - amplifier cascade

is: $\boxed{(L-1)T_o + LT_2}$.

Frequency Conversion



Filter Response vs Ripple

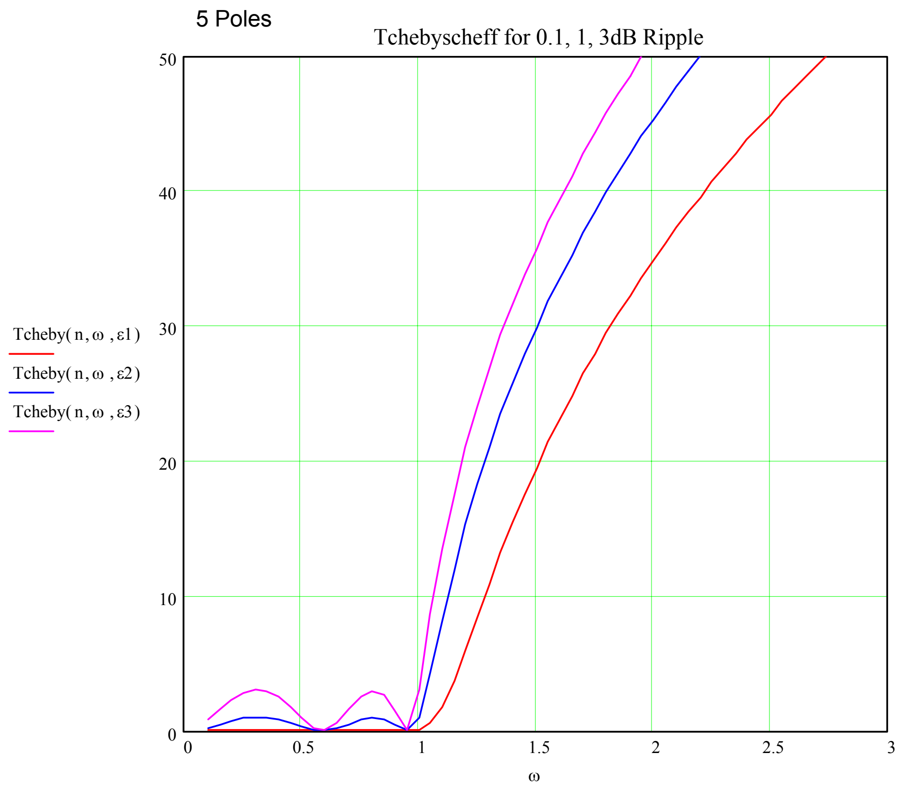
Tchebyscheff filter response in dB:

$$\mathrm{Tcheby}(n,\omega,\varepsilon) := \begin{cases} \left(10\cdot\log\left(1+\varepsilon\cdot\cos(n\cdot\mathrm{acos}(\omega))^2\right)\right) & \text{if } \omega \le 1 \\ \left(10\cdot\log\left(1+\varepsilon\cdot\cosh(n\cdot\mathrm{acosh}(\omega))^2\right)\right) & \text{if } \omega > 1 \end{cases}$$

$n := 5$ Number of Resonators

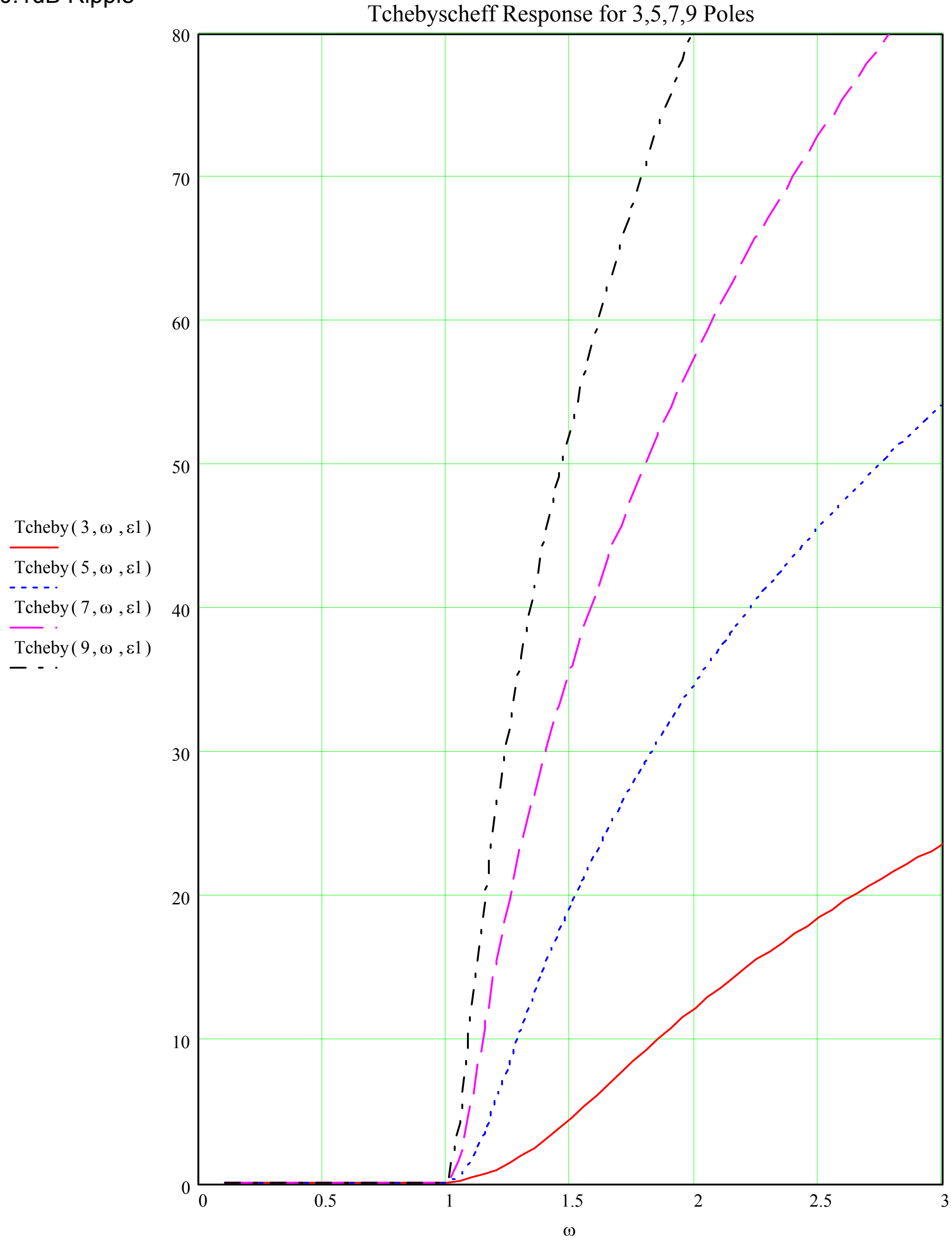
$\varepsilon 1 := 10^{\left(\frac{0.1}{10}\right)} - 1$ 0.1dB Ripple $\varepsilon 2 := 10^{\left(\frac{1}{10}\right)} - 1$ 1dB Ripple $\varepsilon 3 := 10^{\left(\frac{3}{10}\right)} - 1$ 3 dB Ripple

$\omega := 0.1, 0.15 .. 3$

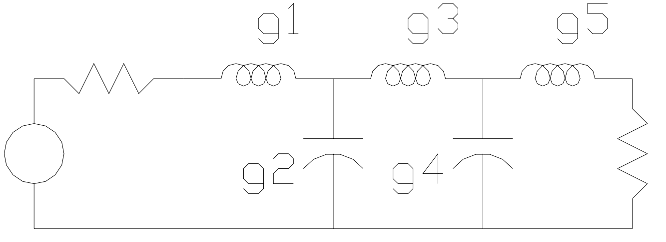


0.1dB Ripple

Filter Response vs. Resonators



Lowpass Realization



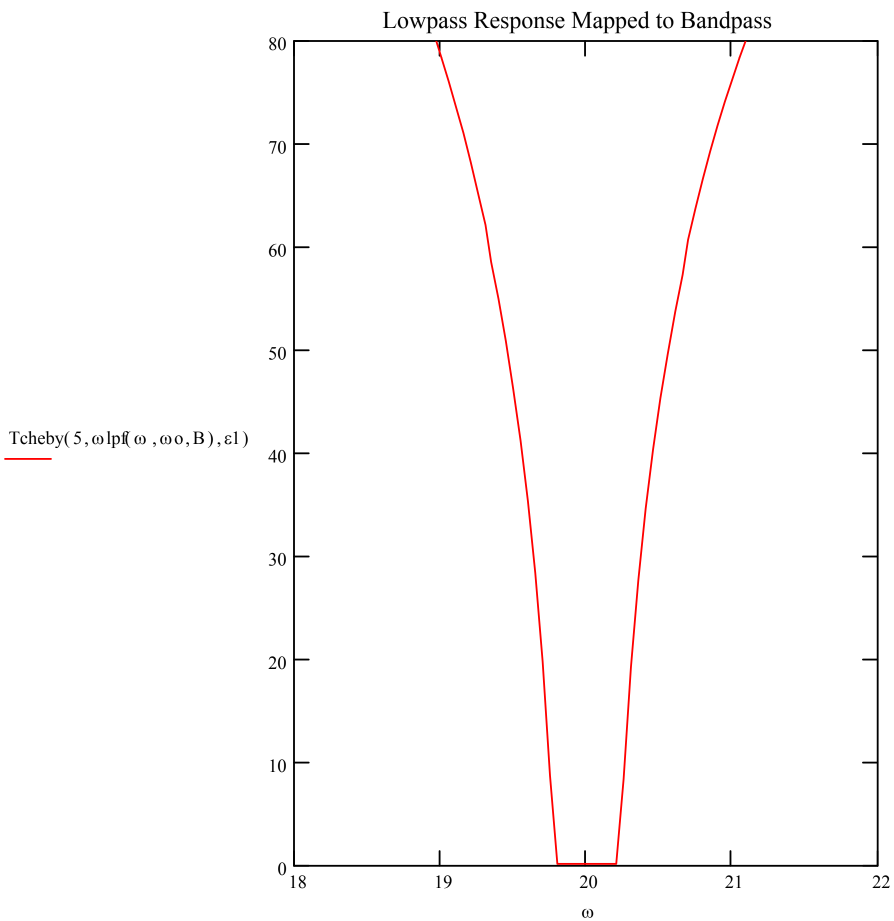
Lowpass to Bandpass Mapping

Filter Response Mapping

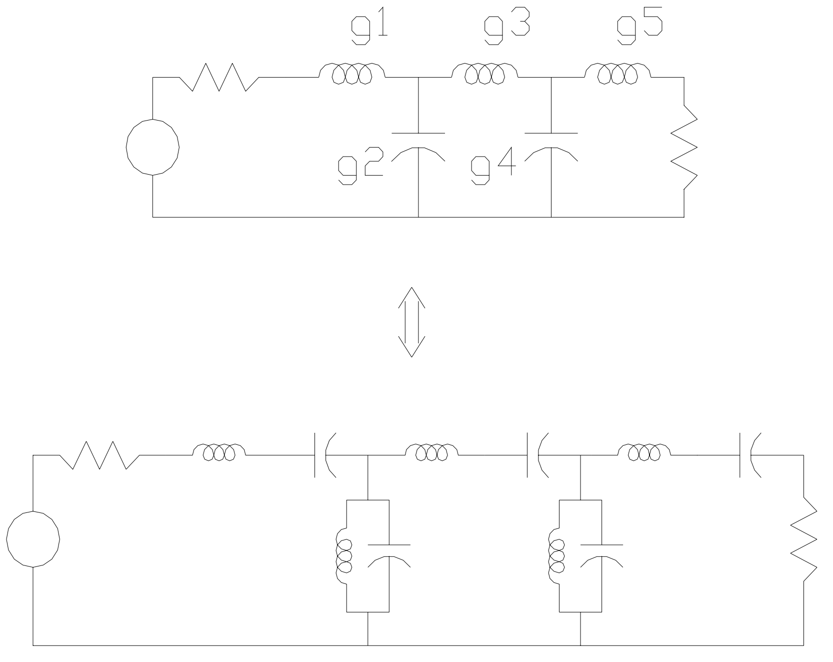
$$\omega lpf(\omega , \omega o, B) := \frac{1}{B} \cdot \left(\frac{\omega}{\omega o} - \frac{\omega o}{\omega} \right)$$

$\omega 1 := 19.8$ $\omega 2 := 20.2$ $\omega o := \sqrt{\omega 1 \cdot \omega 2}$ $B := \frac{\omega 2 - \omega 1}{\omega o}$

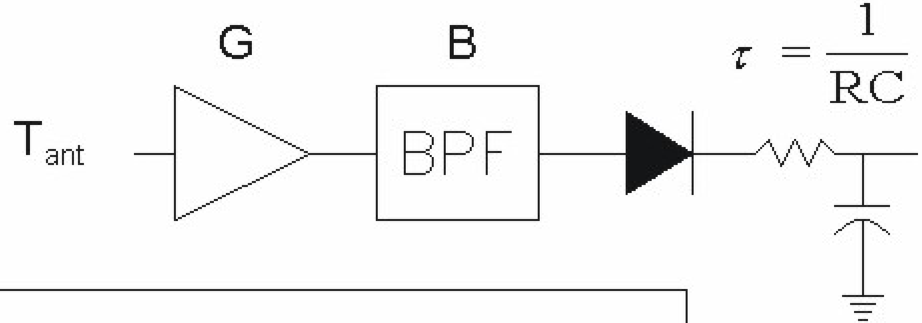
$\omega := 18, 18.05 .. 22$



Lowpass to Bandpass Mapping

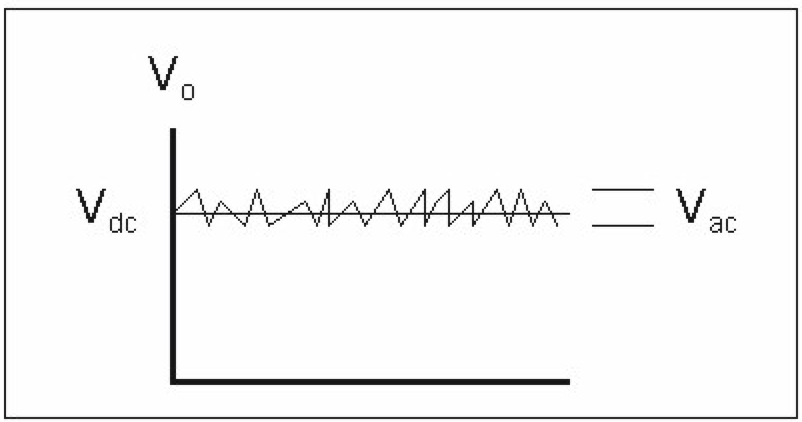


Radiometer Equation



$$\tau = \frac{1}{RC}$$

$$V_o \propto G\, T_{ant}$$

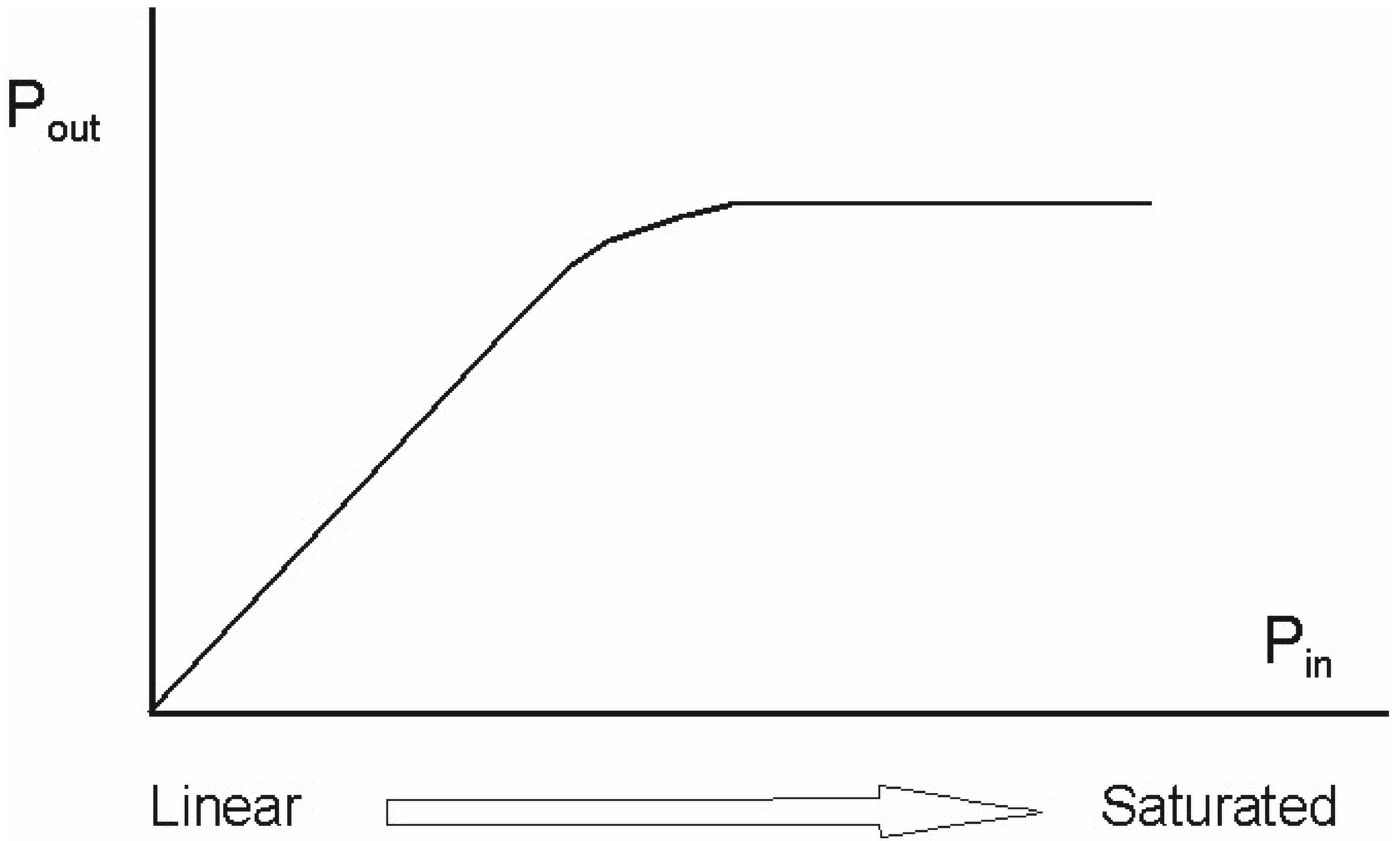


$$\frac{V_{ac,\,rms}}{V_{dc}} = \sqrt{\frac{1}{B\tau} + \left(\frac{\Delta G}{G}\right)^2}$$

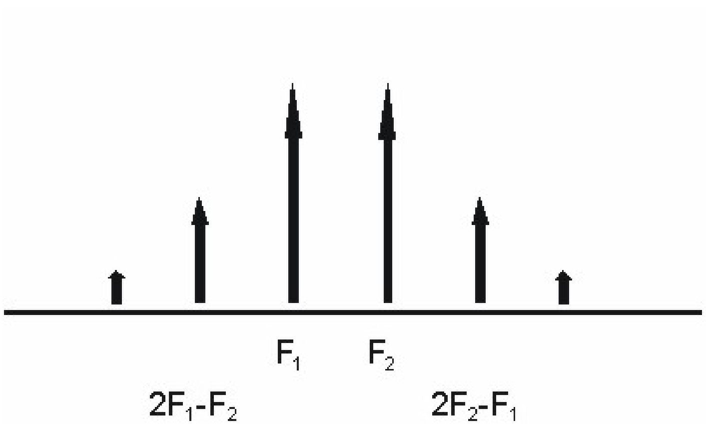
Example: B = 100 MHz, tau = 0.1 s, then
(Assuming constant gain)

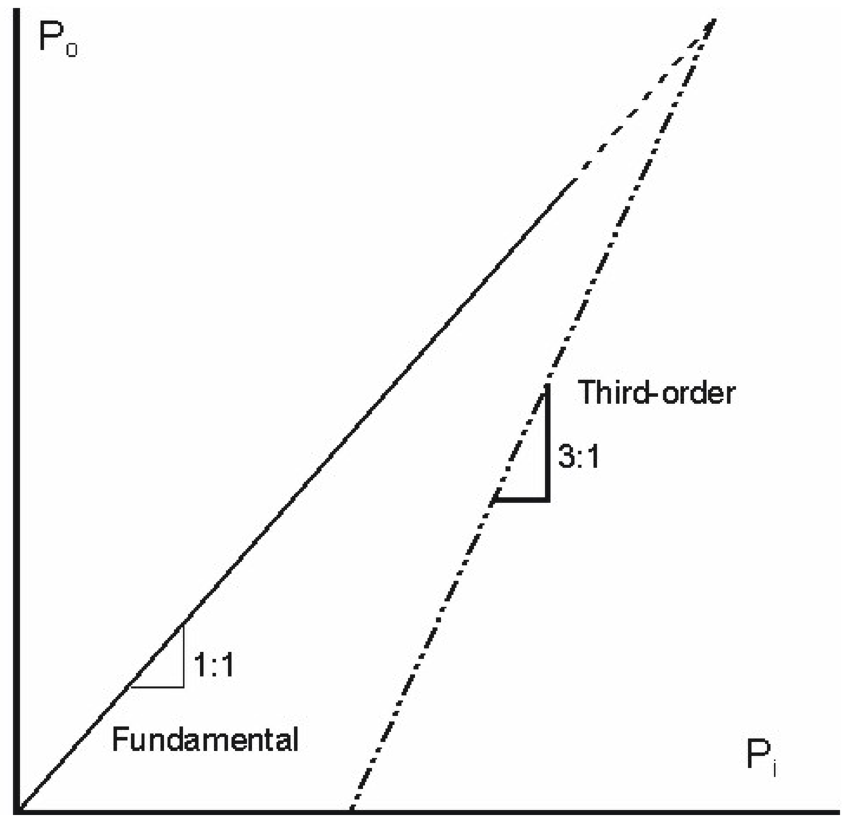
$$\frac{V_{ac,\,rms}}{V_{dc}} = 0.03\%$$

Linearity

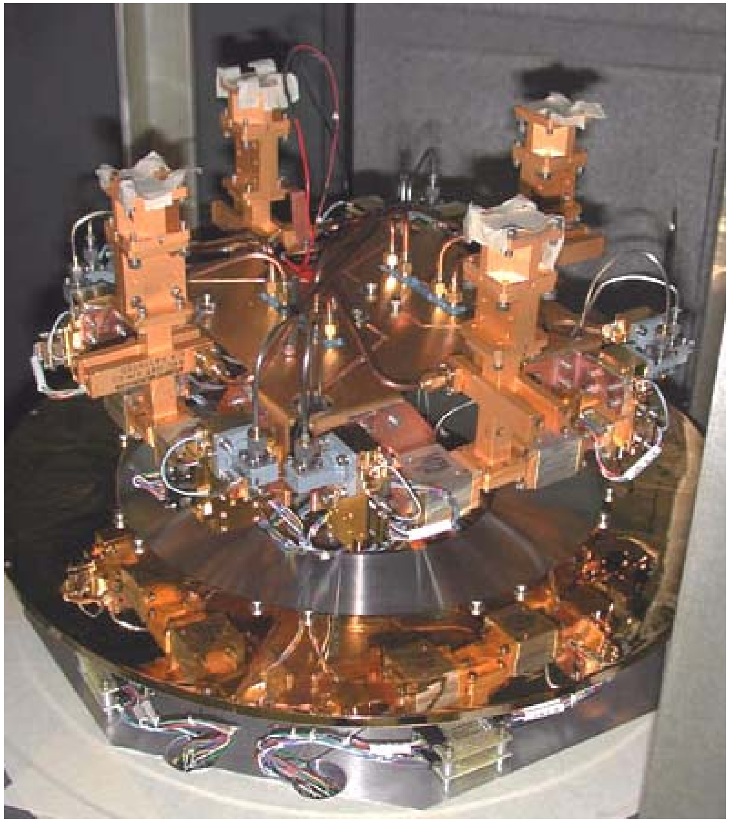


Intermodulation





Some GBT Receivers



Summary
An Introduction to:

- Critical Receiver Components
- Noise Theory
- Filters
- Non-linearity