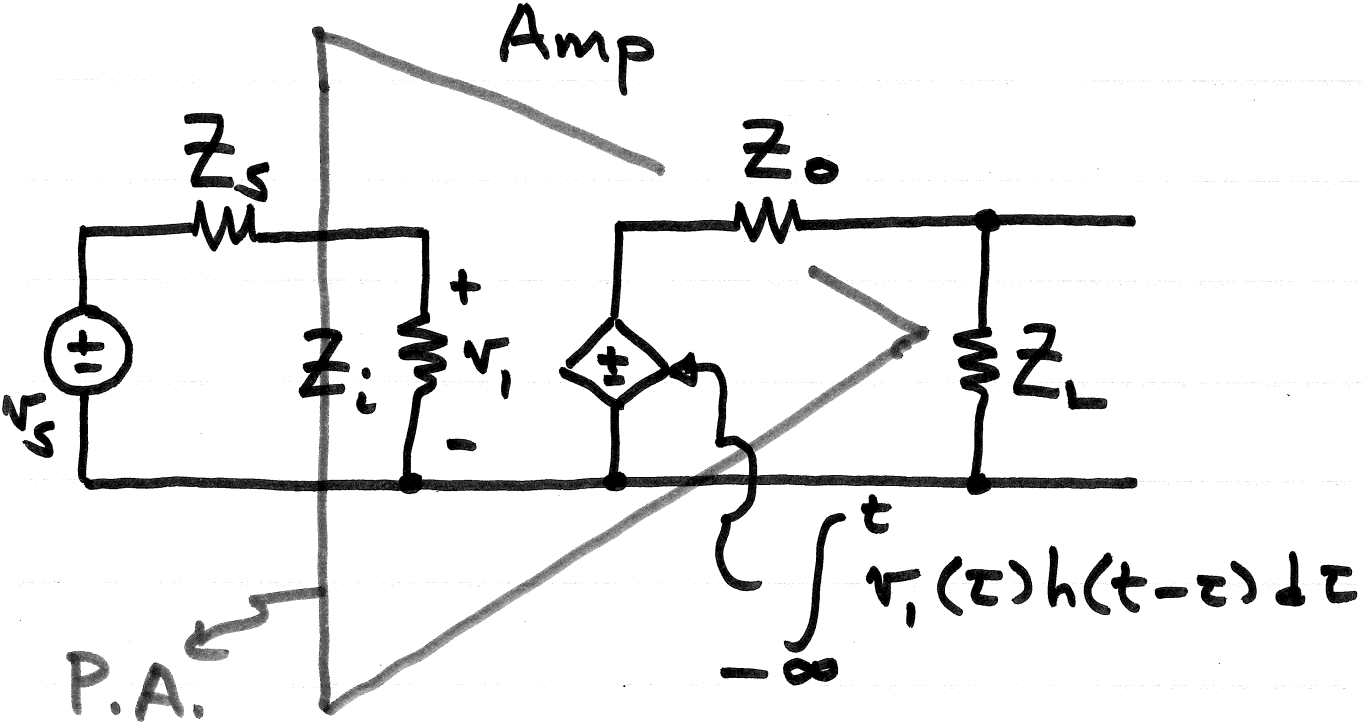
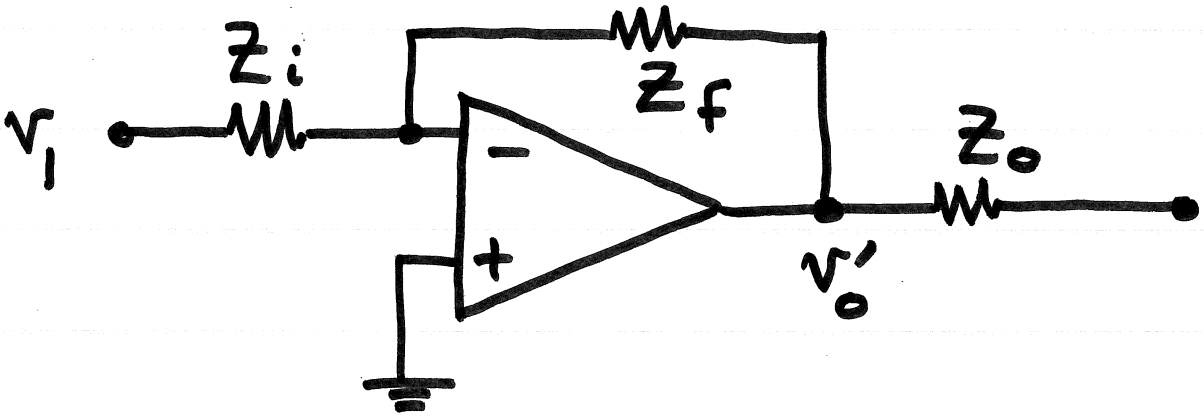
ECE 544 Digital Communications

Last Time: Working on $G_{available}$ for Power Amp



$$G_a = \frac{R_s(f)}{R_o(f)} \left| \frac{H(f)\, Z_i(f)}{Z_s(f) + Z_i(f)} \right|^2$$

A Model for $H(f)$ can be got from ideal OP AMP models of circuit theory:



Transf. Funct $v_1 \longmapsto v_o'$ is

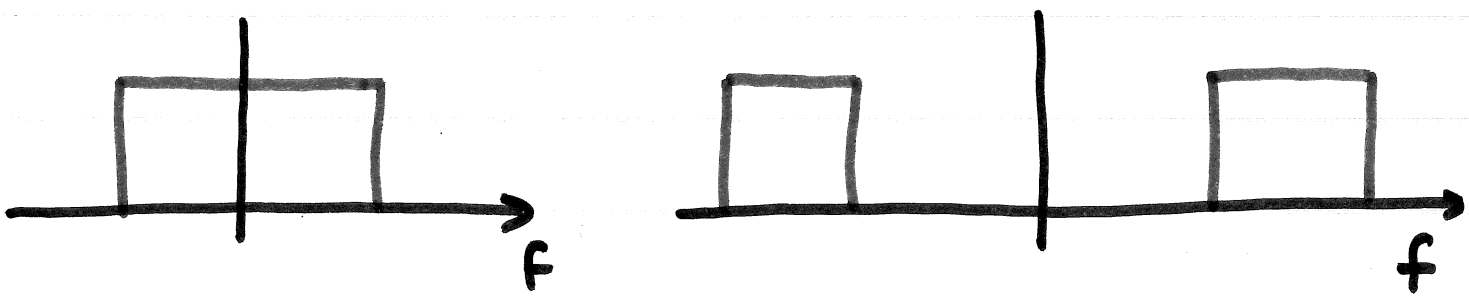
$$h(t) \longleftrightarrow H(f) = -\frac{Z_f(f)}{Z_i(f)}$$

<u>Conclude</u>: See how to use circuit theory with r.p.s. for comm. models.

Previous allows freq. dependent circuit models. Is useful.

But too complicated usually.

Freq dependence can often be modeled as "ideal" filtering functions, e.g.



That is "flat" over the band of interest.

Toward Simplest Models

- All freq. dependence is flat in band of interest.
- Therefore

  If in band $\Longrightarrow$ Transfer functions are just gains or losses.

  If out of band $\Longrightarrow$ No transmission

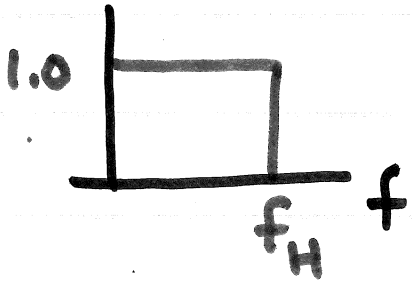
- Also assume all circuit/block impedances are matched .... or that gains account for mismatches.

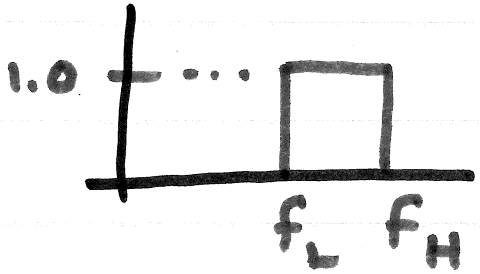
Start with Noiseless Components

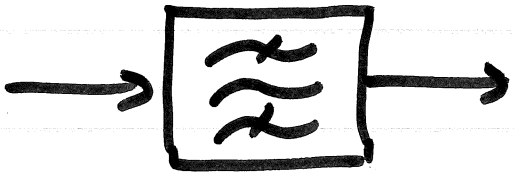
- Antenna  gain $G_{ant} = \dfrac{4\pi A_{ant}}{\lambda^2}$

  A_{ant} = effective area
  λ = wavelength at carrier freq.

- Filters 

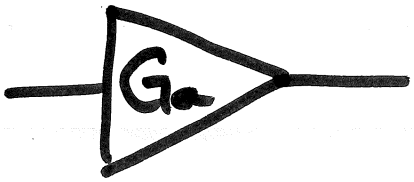






- Oscillator 

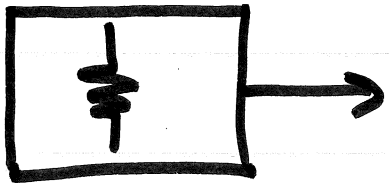
$$v_{osc}(t) = \sqrt{2P_{osc}}\cos\left(2\pi f_{osc} t + \Theta\right)$$

- Amp 

gain or loss.

Basic Noisy Components

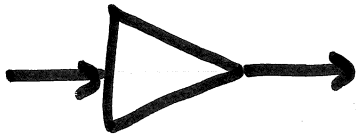
- Noise Source



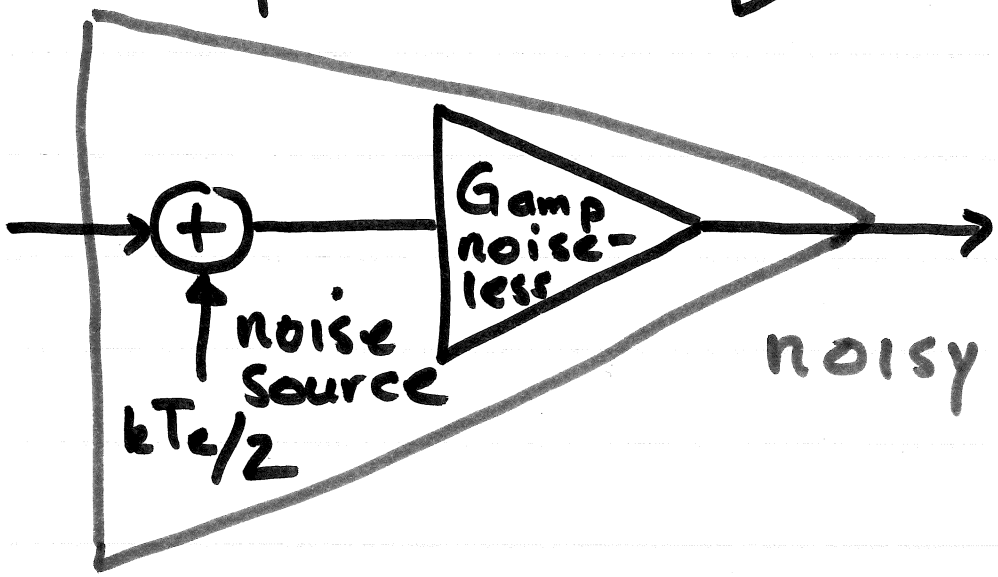
white Gaussian with psd $\frac{kT_e}{2}$

$T_e \triangleq$ equiv. noise temp

- Amplifier



T_e
G_{amp}, power gain



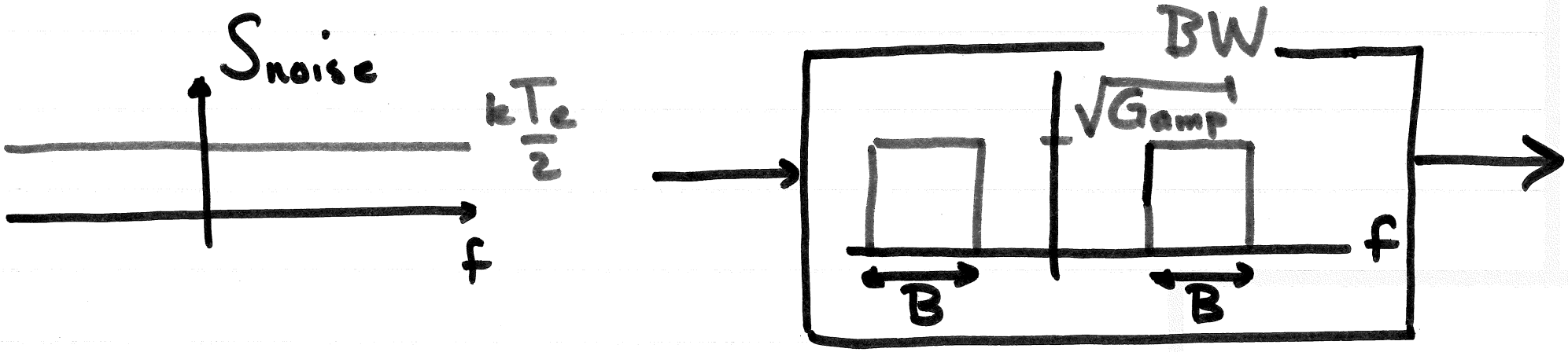
noisy amp

Noisy amp: Amplifies input <u>and</u> adds noise.

Noise power in amp. output due to amp. internal noise sources is

$$P_{out,\,internal} = k T_e G_{amp} B$$

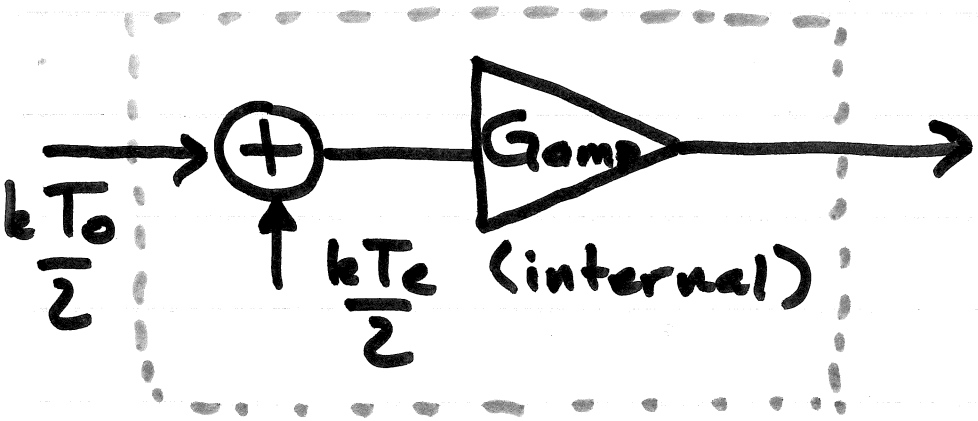
one-sided BW



Power in output above equals $P_{out,\,internal}$.

Standard Noise Figure

$\triangleq$ by comparing output noise power due to <u>internal</u> noise sources to that due to external noise sources



$$P_{out} = \underbrace{kT_o G_{amp} B}_{\text{external}} + \overbrace{kT_e G_{amp} B}^{\text{internal}}$$

Assumes external source is at standard temp $T_o = 290\,K$

$$F \triangleq \frac{P_{out}}{P_{out,\,external}} = \frac{P_{out,\,int} + P_{out,\,ext}}{P_{out,\,ext}}$$

$$= 1 + \frac{P_{out,\,int}}{P_{out,\,ext}} = 1 + \frac{T_e}{T_o} \geq 1.$$

Noise Figure in dB

$$F_{dB} = 10 \log_{10} F$$

Also note

$$T_e = T_o (F-1)$$

Note: Must Know T_o to understand F.

Attenuators

$L_{atten} = 1/G_{atten}$

T = physical temp

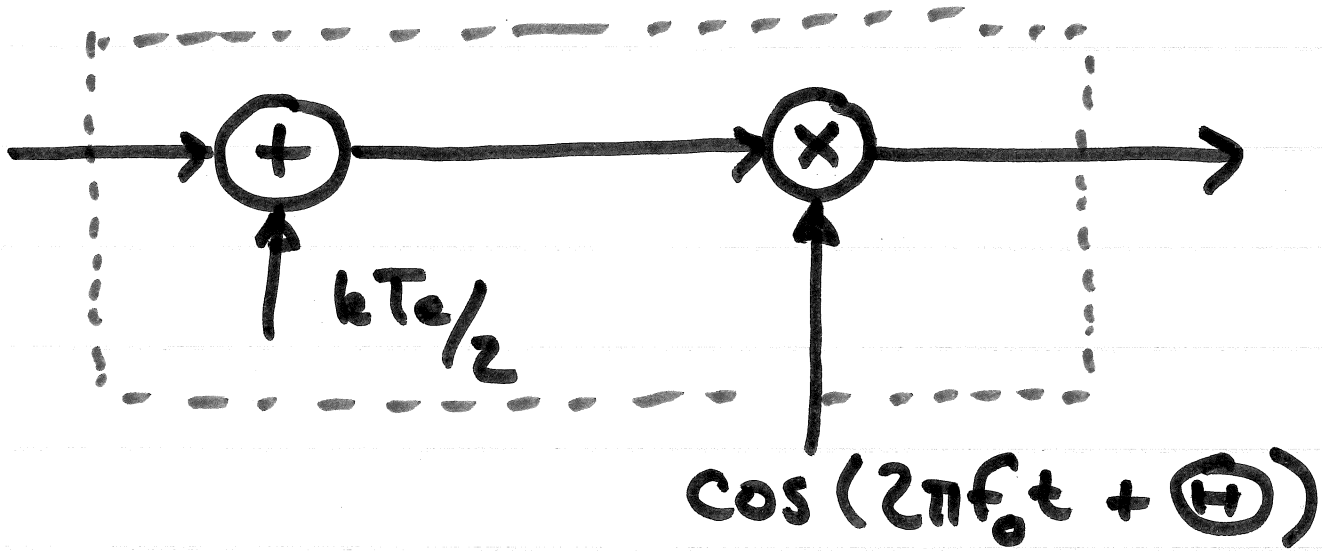
$$\Rightarrow \quad T_e = (L_{atten} - 1)\,T$$

$$F = 1 + (L_{atten} - 1)\,T/T_0$$

290K standard

(This is a resistive divider model).

Mixers



$G_{mixer} = 1/2$

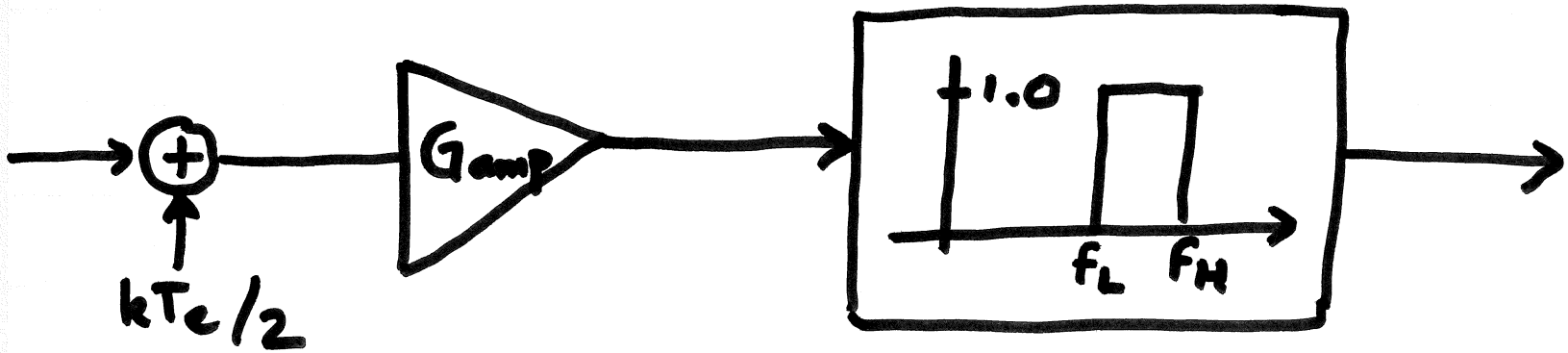
T_e equiv. noise temp.

mixer "looks like" noisy amp with power gain of 1/2.

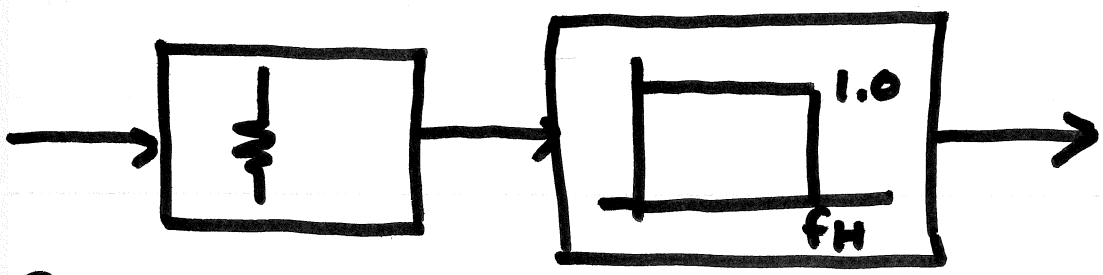
Combine Basic Blocks

(Can always make a block noiseless by setting $T_e = 0$)

Noisy Bandlimited Amplifier



Lossy Filter



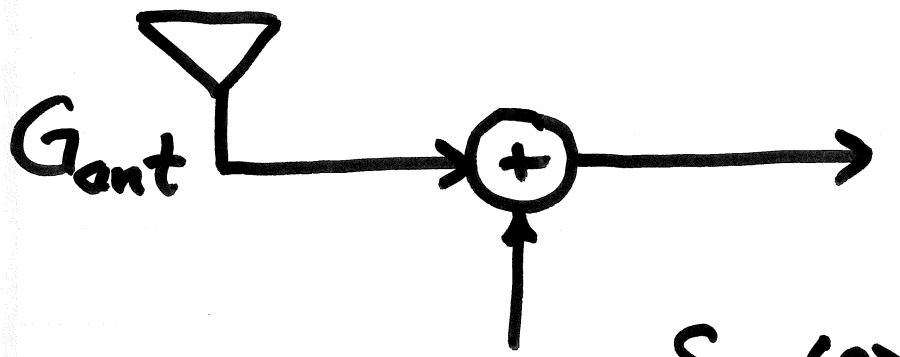
Gamp < 1 $\quad T_e = T$ physical temp

Receiver Antenna

Reciprocity holds : antenna props s.a. gain, pattern, impedance are same for it whether in receive or trans. mode.

But when in Rx mode sigs of inter. are orders of mag. smaller than in Tx mode.

In receive mode antenna receives background noise in addition to desired sig.



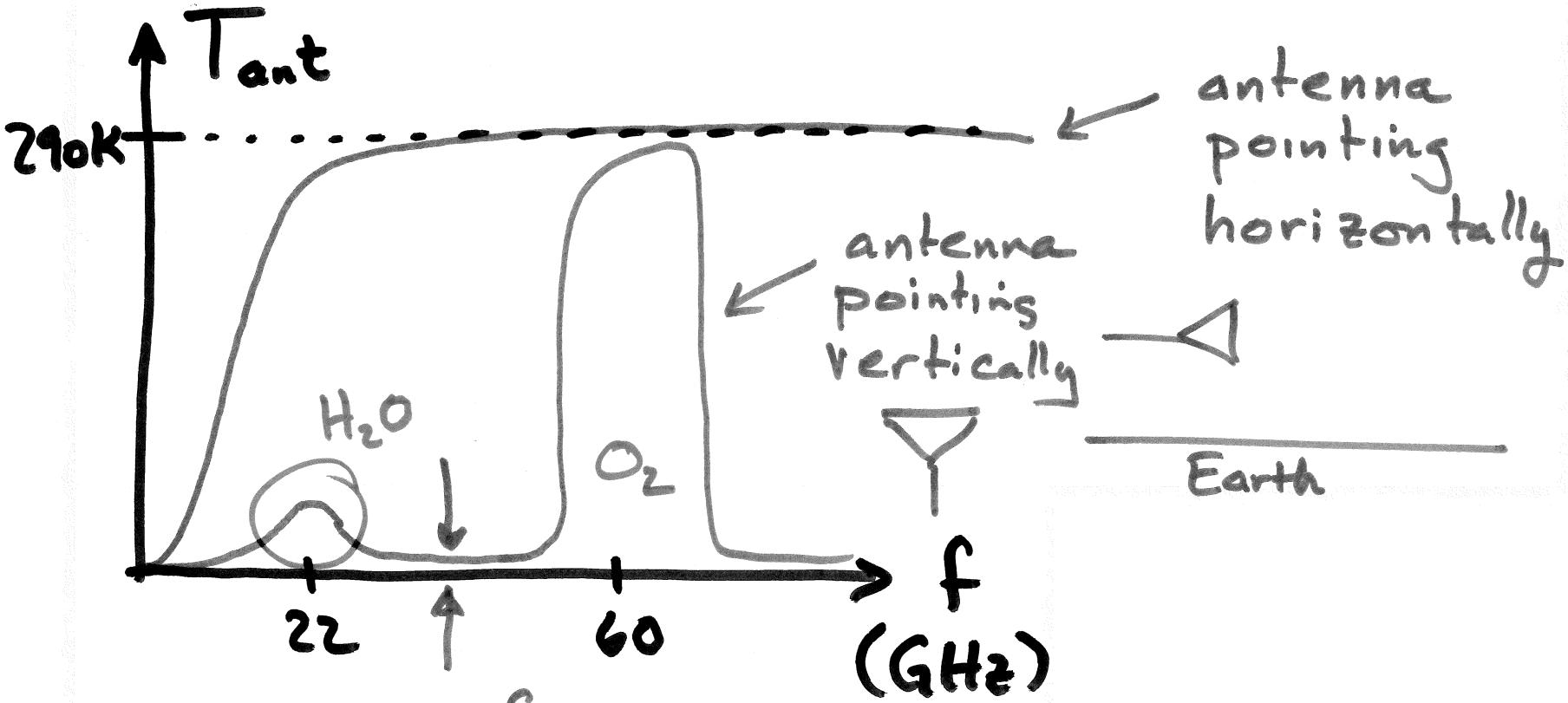
$$n_w(t) : S_{n_w}(f) = \frac{kT_{ant}}{2}$$

In a one-sided BW of B Hz this antenna with temp T_{ant} will give a noise power

$$kT_{ant}B$$

$$G_{ant}P_{signal} + kT_{ant}B$$

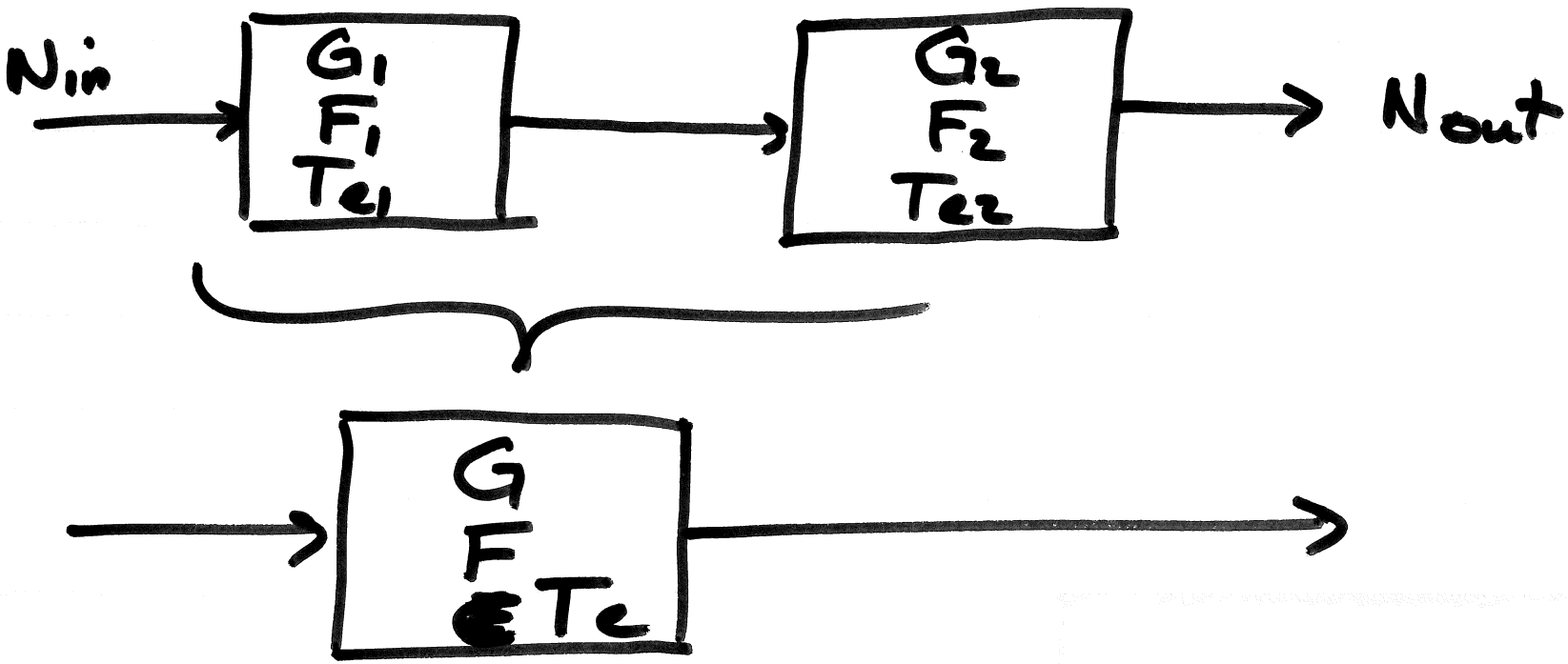
See text by Pozar have graphs of antenna temp:



≈ few Kelvin.

Penzias + Wilson: Nobel in physics

Noise Fig. of Comm Systems



$$F = F_1 + \frac{F_2 - 1}{G_1} \qquad G = G_1 G_2$$

$$T_e = T_{e1} + \frac{T_{e2}}{G_1}$$