

## Cascaded Noise Example

- Noise Temp. vs. voltage
- Build to Friis
- Attenuators
- SNR degrades in here

## Explicit Friis Formula

- LNA
- T/R switch or BPF
- SNR degrades

## Quantization Noise

- ↳ source
- ↳ statistics & value

- 1st & 2nd order
- noise formulas

• spectrum analyze

## Talking about noise

↳ purely random corruption of signals (not many common minimizers)

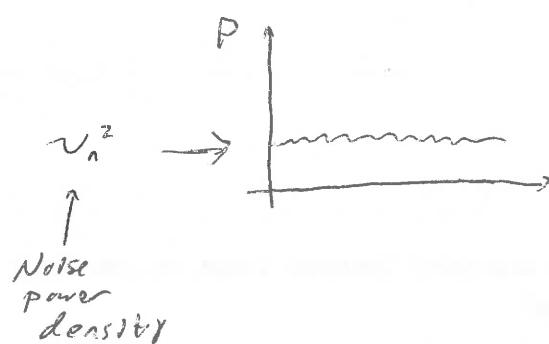
↳ so far we're focusing on thermal noise ... random  $e^-$  fluctuations  
 $\sim$  w/ avg E of  $kT$

↳ if noise is thermal it's distributed over wide f  $\sim$  Gaussian

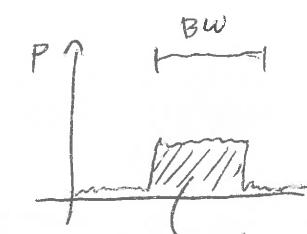
Creating a power spectral density: noise power per  $\Delta f$

↳ power  $\approx$  variance ... way of describing how wide noise is

↳ need language



$(Xfer \ \epsilon_n)^2$   
of  
BPF  
w/  
BW



- area is  $V_n^2$  total noise power

-  $\bar{V}_n = \sqrt{V_n^2}$  is std. dev of noise

- Affected by BW, so hard to add up.

~ sqrt is called noise voltage density  
 commonly reported for amplifiers

- One crucial metric we haven't covered is signal-noise ratio (SNR)

↳ ratio of signal power to noise power:

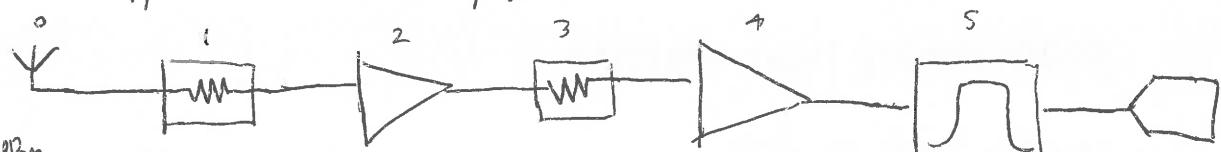
$$\frac{V_{sp}^2 / 2R}{\bar{V}_n^2}$$

↳ used in a figure of merit for amplifiers call noise figure/factor

- noise factor  $N_f = \frac{SNR_i}{SNR_o}$  is always  $> 1$

- noise figure  $NF = 10 \log N_f$

Let's look @ a typical noise example



$$\bullet N_{1A} = -50 \text{ dBm}$$

$$\bullet T_2 = \frac{1}{4\pi} D \cdot T_{\text{ant}}$$

-Night sky + k  
-Earth 290K

Tighter dB

$$T_N = \frac{P}{k \cdot \text{BW}} = \frac{\bar{N}_n^2}{k \cdot \text{BW}} = \frac{V_n^2}{k}$$

• T/R switch

• -1 dB ILH (~0.8)

• basically a res.

divider

• LNA

•  $S_{21} = 10 \text{ dB}$

• can about

power gain

• Attenuator

• -3 dB  
(Q.S power gain)

•  $T = \left(\frac{1}{0.5} - 1\right) \cdot T_A$

$= 2.90$

• Gain

•  $T = 245$

•  $BW = 100 \text{ kHz}$

$V_{n1}^2$  loop Hz

• IL = 2 dB (0.63)

•  $BW = 100 \text{ kHz}$

•  $T = 170$

$V_{n5}^2$

BW is narrowest BW in system  
for reasons that will become clear

•  $T = \left(\frac{1}{0.5} - 1\right) \cdot T_A$

$= 22.5$

•  $T = 58$

(based on loss  
in amp)

• BW 1 MHz

SIG

0

-50 dBm

max noise  $N_n^2$

$$N_{n0}^2$$

spectrum



Noise temp

$$\approx 290$$

$$SNR = \frac{V^2 / 50 \cdot 2}{T_N \cdot k \cdot BW}$$

(assuming no  
rest of chain)

1

-51 dBm

$$IL \cdot V_{n0}^2 + V_{n1}^2$$



$$= 0.8 \cdot 290 + 22.5$$

$$= 254.5$$

2

-41 dBm

$$G(IL \cdot V_{n0}^2 + V_{n1}^2) + V_{n2}^2$$



$$10(254.5) + 38$$

$$2603$$

$$2.2 \times 10^6$$

3

-44 dBm



$$2603 \cdot 0.5 + 290$$

$$1591.5$$

$$1.8 \times 10^6$$

4

-14 dBm



$$1000 - 159.5 + 145$$

$$1591.645$$

$$1.8 \times 10^6$$

5

-16 dBm



$$1.59 \times 10^6 \cdot 0.63 + 170$$

$$1.00 \times 10^6$$

$$1.8 \times 10^6$$

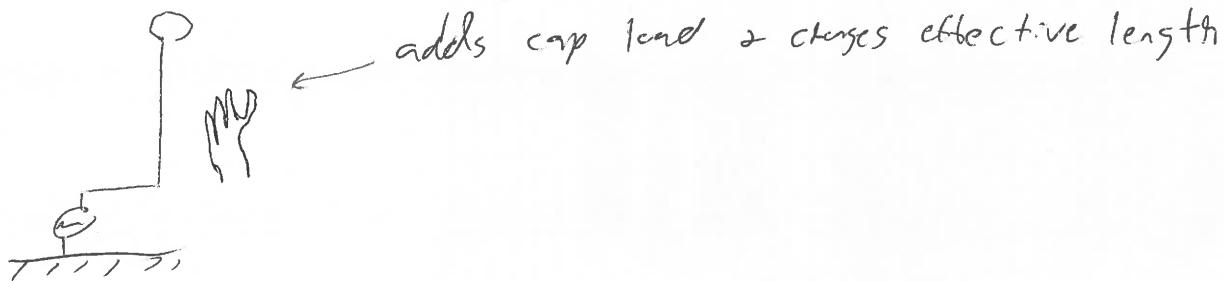


why use gain  
at 911?

- Noise at end matters much less!
- Capture by "referring" noise

$$F-1 = 1 + T_{\text{noise}}$$

- Anything in the near field can capacitively load an antenna



- Antenna is a lumped element.

↳ drive w/ ideal voltage src is possible

↳ if t.line here, adds src impedance

- L & C of antenna related to velocity &  $\lambda/2$  ... capacitive & inductive/length

↳ but  $\frac{1}{\sqrt{LC}}$  tells you resonant freq of antenna

$$\begin{aligned} \text{↳ so } \frac{1}{\sqrt{LC}} &\approx \omega_0 \text{ & } C = 2\pi\lambda\omega_0 \text{ so } \frac{C\sqrt{\mu_0}}{2\pi} = \lambda \\ \text{& } C &= \frac{1}{\sqrt{L'C'}} \end{aligned}$$