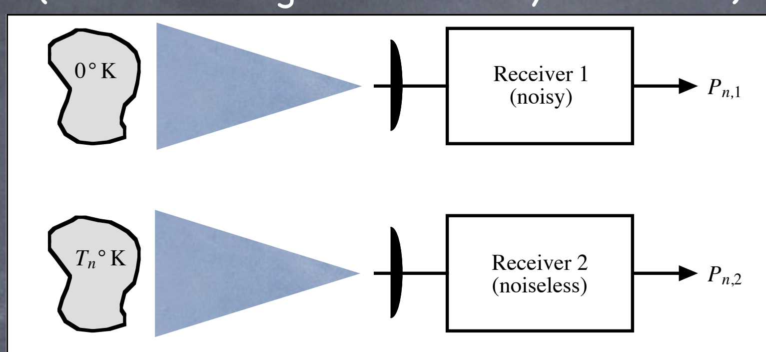
Session 10

Recall ... 10.1

Noise Temperature

(Characterizing Microwave System Noise)



Receiver 1 is an *actual* noisy receiver. Its antenna pointed at a black body of temperature $T = 0^\circ$ K.

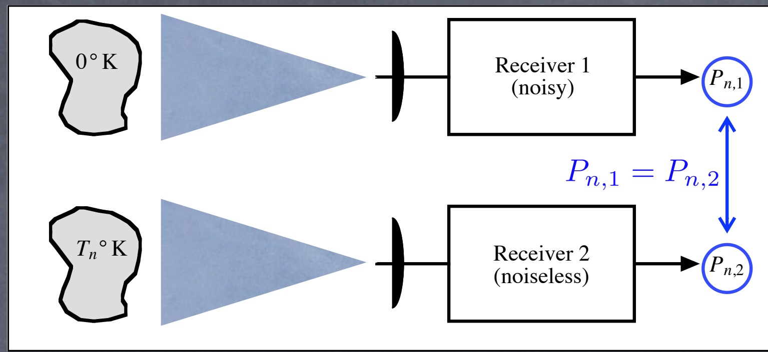
Receiver 2 is a *hypothetical* noiseless receiver. Its antenna is pointing at a black body of temperature T_n.

Assume we can adjust T_n in second scenario until

$$P_{n,1} = P_{n,2}$$

We call the T_N achieving this the *noise temperature* of Receiver 1.

Recall...



- When we quote a noise temperature for a real receiver, we are referring internal receiver noise to a hypothetical external noise source.

- This is a convenient accounting trick, as it allows us to look at all noise contributions at the same location—the input to the receiver.

Noise Figure or Noise Factor

The noise figure or noise factor NF of a receiver is

$$\text{NF} = \frac{T_n}{290^\circ\ \text{K}} + 1$$

It is often expressed in dB:

$$\text{NF}_{\text{dB}} = 10 \log_{10}\left(\frac{T_n}{290\ \text{K}} + 1\right) \qquad \text{(dB)}$$

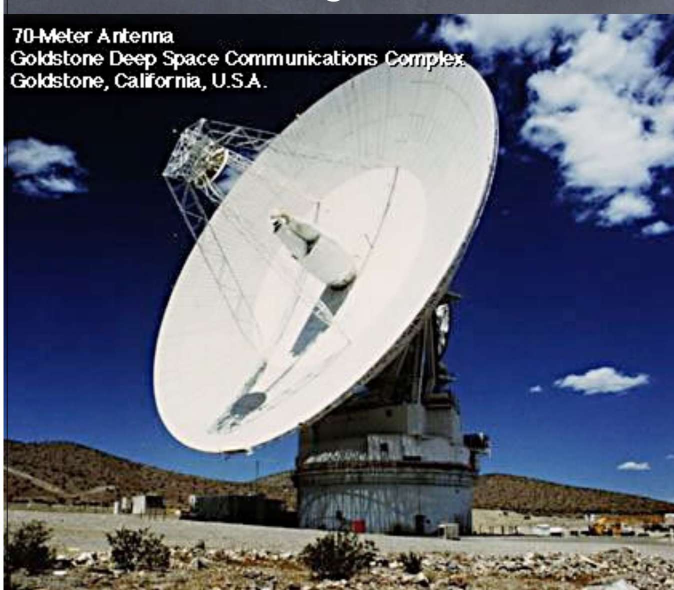
10.4

Typical Noise Figures

- Noise figures for typical microwave receivers used in satellite communications are in the range of 2–5 (3–7 dB).
- Radar systems are typically higher, because they are clutter—not thermal noise—limited.
- NASA DSN Stations have an overall system noise temperature of about 20°K. NF=1.069

Big Antennas, "Cool" Receivers

10.5

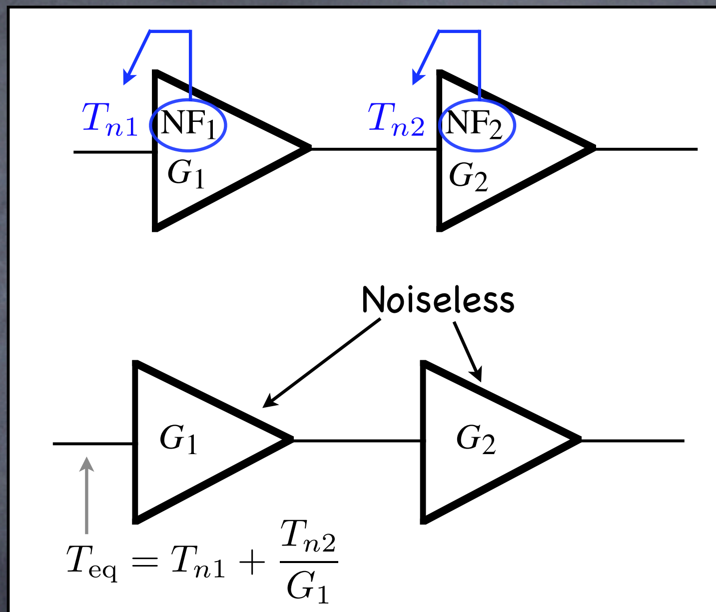


NASA DSN Antenna
70m diameter

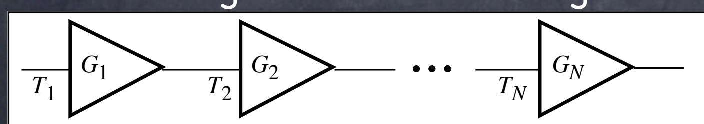
Arecibo (PR) Radio/Radar
Telescope Antenna
305m diameter

10.6

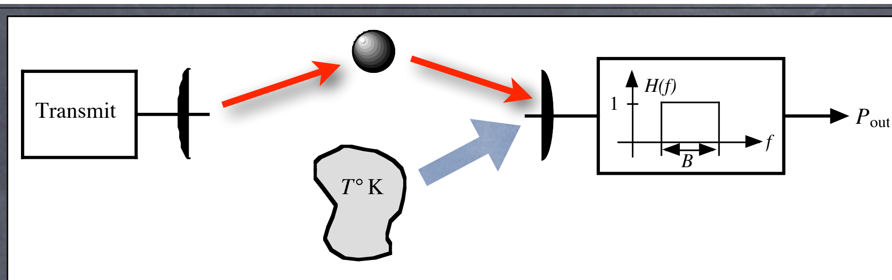
Noise Temperature/Figure of a Cascade



This can be generalized to N stages...



10.7



We transmit a pulse of bandwidth B at frequency f_0.

The received signal power is

$$P_r = \frac{P_t A^2 \sigma}{4\pi\lambda^2 R^4} \qquad \text{(Radar Equation)}$$

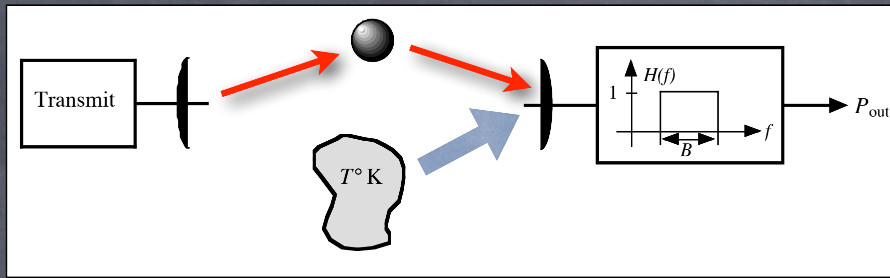
Assume ideal bandpass filter H(f) does not effect the signal

(*n.b.* We must carefully interpret P_t and P_r:
"Peak Power", "Average Power"?—more on this later.)

The received noise power is

$$P_n = kT_eB$$

10.8



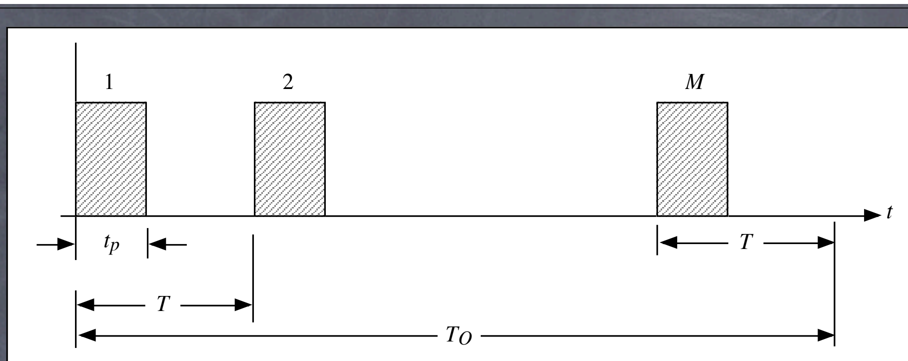
The signal-to-noise ratio is

$$\mathrm{SNR} = \frac{P_r}{P_n} = \frac{P_t A^2 \sigma}{4\pi\lambda^2 R^4 k T_e B} \quad \longleftarrow \text{Effective Aperture}$$

$$= \frac{P_t \lambda^2 G^2 \sigma}{(4\pi)^3 R^4 k T_e B} \quad \longleftarrow \text{Antenna Gain}$$

We can think of this as the SNR for a single pulse when the pulse is "on", but many radars transmit a sequence of pulses.

10.9



t_p = Pulse Width

T = Pulse Period (PRI~Pulse Repetition Interval)

T_O = Observation Time = MT

Similarly, we can define bandwidths/frequencies

$B = 1/t_p$ = Pulse Bandwidth (unmodulated)

$f_R = 1/T$ = Pulse Repetition Frequency (PRF)

$\Delta B_{\mathrm{Dop}} = 1/T_O$ = Doppler Resolution of Radar

If the source is not transmitting all of the time, we must be careful to note whether we are talking about Peak Power or Average Power.

Peak Power → P_T

Average Power → P_{AVE}

If P_T is the peak power (power when transmitter is on)

$$P_{\text{ave}} = \frac{P_T t_p}{T}$$

If a coherent detector and matched filter are used to process returns, the voltage received from each pulse adds coherently:

Signal power increases as M^2

Noise power increases as M

Thus we have

$$\text{SNR}_M = M \cdot \text{SNR}_1 = \frac{M P_T A^2 \sigma}{4\pi\lambda^2 R^4 k T_e B}$$

Because P_T is the peak power when the transmitter is "on" and the signal bandwidth $B \approx 1/t_p$, we have

$$\text{SNR}_M = \frac{M P_{\text{ave}} \frac{T}{t_p} A^2 \sigma}{4\pi\lambda^2 R^4 k T_e B} = \frac{P_{\text{ave}} \frac{B}{\triangle B_{Dop}} A^2 \sigma}{4\pi\lambda^2 R^4 k T_e B}$$

$$= \frac{P_{\text{ave}} A^2 \sigma}{4\pi\lambda^2 R^4 k T_e \triangle B_{Dop}}.$$

Typically, $\Delta B_{\text{Dop}} \ll B$ and it can be that $P_{\text{ave}} \ll P_T$. So, "who wins?"

$$\text{SNR}_M = \frac{P_{\text{ave}} A^2 \sigma}{4\pi\lambda^2 R^4 k T_e \triangle B_{Dop}}$$

Typically P_{ave} is constant.

Bounded from above by hardware limitations

Noise bandwidth varies as $1/M$

Thus, SNR_M is proportional to M.

$\triangle B_{Dop}$ becomes the effective noise bandwidth.
(We will see this later.)