More noise ---

(or --- what do these receiver specs really mean?)

Background ---

Noise in a resistor:

$$E_n = \sqrt{4 K T R \Delta f}$$

- Δf — Bandwidth – Hz $= \frac{1}{sec}$
- R — Resistance – ohms $= \frac{Volts}{amps}$
- T — Temperature – °K
- K — Boltzman's constant $= 1.38 \times 10^{-23} \frac{joules}{°K}$

Check the units ---

$$\frac{joules}{°K} \quad °K \quad \frac{Volts}{amps} \quad \frac{1}{sec.}$$

$$\frac{Volts}{amps} \rightarrow \frac{\frac{joule}{coul}}{\frac{coul}{sec}} \rightarrow \frac{joules \cdot sec}{coul^2}$$

$$\frac{joules}{\cancel{°K}} \quad \cancel{°K} \quad \frac{joules \cdot \cancel{sec}}{coul^2} \quad \frac{1}{\cancel{sec}}$$

$$\frac{joules^2}{coul^2} = volts^2 \Rightarrow E_N = \sqrt{volts^2}$$

HW:
12.2-1,2
12.3-1.

Noise power:

$$P_N = 4KT\,\Delta f \qquad E_N = \sqrt{P_N R}$$

$$\frac{\text{joules}}{{}^\circ K} \quad {}^\circ K \quad \frac{1}{\text{sec}}$$

$$= \frac{\text{joules}}{\text{sec}} = \text{watts}.$$

Example: at 300 °K ...

$$S_n(w) = (4)(1.38 \times 10^{-23})(300)$$

$$= 1.66 \times 10^{-20} \ \frac{\text{watts}}{\text{Hz}} \quad \text{or}$$

$$E_N = \sqrt{P_N R}$$

Noise voltage for a 75Ω antenna.

$$= \sqrt{(1.66 \times 10^{-20})(75)}$$

$$E_N = 1.11 \times 10^{-9} \ \frac{\text{Volts}}{\sqrt{\text{HZ}}}$$

For 5KHz bandwidth...

$$V_N = (1.11 \times 10^{-9}) \cdot (\sqrt{5000})$$

$$= 7.88 \times 10^{-8} \ \text{volts}.$$

Example

We live in a city.

For a carrier frequency of 100 MHz

signal bandwidth of 15 KHz.

Received signal strength of 1 millivolt on $75\,\Omega$.

What is the received signal to noise ratio?

SSB-SC, DSB-SC ? (like baseband)

AM, $\mu = 1$

FM, $\beta = 1$ with -- no premphasis

$\beta = 5$ and 2 kHz preemphasis.

Solution: Signal power is: $\frac{V^2}{R} = \frac{(10^{-3})^2}{75} = 1.33 \times 10^{-8}$ watts

Noise power is: 40 dB above thermal (from the chart). (10^4 X thermal)

Thermal noise:

$$S_n(\omega) = 4KT$$

$$= (4)(1.38 \times 10^{-23})(300)$$

$$= 1.66 \times 10^{-20}$$

$$P_{\text{Thermal Noise}} = \int_0^B S_n(\omega)\,df = \int_0^{15000} 1.66 \times 10^{-20}\,df$$

$$= 2.49 \times 10^{-16} \text{ watts.}$$

Actual $P_N = (2.49 \times 10^{-16})(10^4) = 2.49 \times 10^{-12}$ watts.

$$\frac{\text{Signal}}{\text{Noise}} = \frac{1.33 \times 10^{-8}}{2.49 \times 10^{-12}} = 5.34 \times 10^{3}$$

in dB: $10 \log \frac{P_S}{P_N} = 37$ dB

For AM:

$$\frac{S}{N} = \frac{\gamma}{3} = \frac{5.34 \times 10^{3}}{3} = 1.78 \times 10^{3}$$

32.5 dB.

For FM: mult BB by $\frac{3}{2}\beta^2$

No preemphasis

$\beta = 1$: $(5.34 \times 10^{3})\left(\frac{3}{2}\right) = 8.01 \times 10^{3}$

$\Rightarrow$ 39 dB.

$\frac{3}{2}(1)^2 = 1.5 \Rightarrow 1.76$ dB. improvement

$\Rightarrow$ 39 dB.

$\beta = 5$ -- $\frac{3}{2}(5)^2 = 37.5 \Rightarrow 15.7$ dB improvement

$\Rightarrow$ 53 dB.

With 2 KHz preemphasis.

Multiply BB by $\frac{1}{2}\beta^2\left(\frac{B}{f_1}\right)^2$ $\qquad \frac{B}{f_1} = \frac{15}{2} = 7.5$

$\beta = 1$. $(5.34 \times 10^{3})\left(\frac{1}{2}\right)(1)^2(7.5)^2 = 1.5 \times 10^{5}$

$\Rightarrow$ 51 dB

$\beta = 5$ -- $(5.34 \times 10^{3})\left(\frac{1}{2}\right)(5)^2(7.5)^2 = 37.5 \times 10^{6}$

$\Rightarrow$ 65.7 dB