

Performance with noise (overview)

(really glossing over it!)

Baseband systems (for reference).

Assume the channel is distortionless.

Actually, it is filtered to control bandwidth,
but the input signal is also filtered,
so the channel is distortionless.

Send a signal -- S_i

Receive a signal -- S_o

but it has noise added -- N_o

Simply, noise can be categorized...

Random noise: - Uniformly distributed over 'B'.

(It might be nonuniform, but we won't deal with that.)

Interference: - someone else's "signal",
but to us, it is noise.

For random noise --

$$N_o = \int_0^B S_n(u) df$$

↑ Power spectral density
of channel noise.

This tells us that noise power proportional to bandwidth
-- noise voltage is proportional to square root of bandwidth.
→ often specified in $\frac{\text{Volts}}{\sqrt{\text{Hz}}}$

Define:

$$\gamma = \frac{S_o}{N_o}$$

Signal
noise → "Signal to noise ratio"

8B-1

AM systems

8B-2

SSB-SC - Synchronous detection is required.
Bandwidth is the same as baseband.

$$\Rightarrow \frac{S}{N} = \text{Same as baseband.}$$

DSB-SC - with synchronous detection.

RF bandwidth is twice baseband,
but signal is doubled also.

$$\Rightarrow \frac{S}{N} = \text{Same as baseband.}$$

AM - with synchronous detection.

Same as DSB-SC except for addition of carrier.

Output noise (N_o) is same as DSB-SC.

Received signal is $K [A + m(t)] \cos \omega_c t$

K = some constant, $A = \text{carrier}$, $m(t) = \text{modulation}$

Modulation level is lower -

For sine wave -- $\frac{1}{3}$ of total power
best case $\frac{1}{2}$ of total power.

$$\text{So } \frac{S}{N} = \frac{\gamma}{2} \text{ -- best case, } \mu=1 \text{ (3dB worse)}$$

$$\frac{S}{N} = \frac{\gamma}{3} \text{ -- sine wave modulation, } \mu=1 \text{ (4.7 dB worse)}$$

AM - envelope detection

When noise is high —

carrier is multiplied by the noise,
so it is worse.

(so far, we assumed noise was only added).

→ Threshold effect.

Phase modulation —

(using limiter and phase detector) (synchronous)

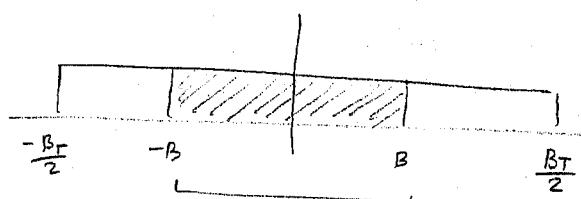
Presence of unmodulated carrier suppresses noise.

→ Quieting effect.

With no signal, noise is very high,
it goes down with increasing signal strength
(input S/N ratio).

Baseband Signal output is independent of RF level.

Detector output spectrum:



Bandwidth of
original signal

$B_T = \text{transmission bandwidth.}$
(use Carson's rule).

$$= 2(B_p + 1)B$$

Large transmission bandwidth → more noise.

Large deviation → more signal.

$\beta_p = \text{peak phase deviation}$

Comparison to baseband —

$$\frac{S/N_{\text{out}}}{S/N_{\text{baseband}}} = \beta_p^2 \left(\frac{m}{V_p} \right)^2$$

$m = \text{the signal level}$
 $V_p = \text{peak signal level}$

mean square value of modulation
relative to its peak ≈ 0.5

8B-3

For typical signal — $\frac{m^2}{V_p^2} = 0.5$

Max phase without wrapping = π

$$\text{improvement} = (\pi^2)(0.5) \Rightarrow 6.9 \text{ dB.}$$

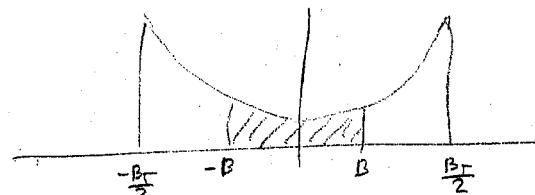
8B-4

Frequency modulation

Same as PM except detector output

is $\frac{d\theta(t)}{dt}$ instead of $\theta(t)$

→ Emphasizes high frequency noise.



$B_f = \text{bandwidth of}$
 modulated signal.

$B = \text{baseband bandwidth.}$

$$\beta_p = \frac{B_f}{B}$$

Compare to baseband —

$$\frac{S/N_{\text{out}}}{S/N_{\text{baseband}}} = \frac{3}{2} \beta_p^2$$

(assuming sinusoidal
modulation).

Example $B = 15 \text{ kHz}$

$$\Delta f = 75 \text{ kHz}$$

$$\Rightarrow \beta = \frac{\Delta f}{B} = 5, \quad B_T = 2(75+15) = 180 \text{ kHz}$$

$$\text{Improvement} = \frac{3}{2}(5)^2 = 37.5 \Rightarrow 15.7 \text{ dB}$$

$$3 \beta_p^2 \left(\frac{m}{V_p} \right)^2$$

sinusoidal mod.
signal

$= \frac{1}{2}$ for

FM / PM - Threshold -

$\frac{S}{N}$ must be above a threshold
to get this improvement.

Near the threshold, analysis is more complicated.

$$\frac{S}{N}_{\text{out}} = \frac{\frac{3}{2} \beta_f^2 \left(\frac{S}{N}_{\text{baseline}} \right)}{1 + \left(\frac{12}{\pi} \beta_f \right) \left(\frac{S}{N}_{\text{baseline}} \right) e^{-\frac{1}{2(\beta_f+1)} \left(\frac{S}{N}_{\text{baseline}} \right)}}$$

see graph - Couch p. 522

Actually -- it is a little worse --

Need to use receiver filter bandwidth as B_f
which is a little wider.

Using De-emphasis -

S/N can be improved by using
preemphasis on transmit,
deemphasis on receive.

$$\frac{S/N_{\text{out}}}{S/N_{\text{baseline}}} = \frac{\frac{1}{2} \beta_f^2 \left(\frac{B}{f_1} \right)^2}{1 + \beta_f^2 \left(\frac{B}{f_1} \right)^2 \left(\frac{m}{V_p} \right)^2}$$

for sinusoidal modulation.
in general
 $\left(\frac{m}{V_p} \right)^2 = .5$ for sinusoidal mod

for $\frac{B}{f_1} \gg 1$



$$\left(\frac{B}{f_1} \right)^2 = 3 \rightarrow \frac{B}{f_1} \approx 1.73$$

8B-5

Example - $f_1 = 2 \text{ kHz}$

8B-6

$$\text{improvement} = (5)^2 \left(\frac{15}{2} \right)^2 (.5)$$

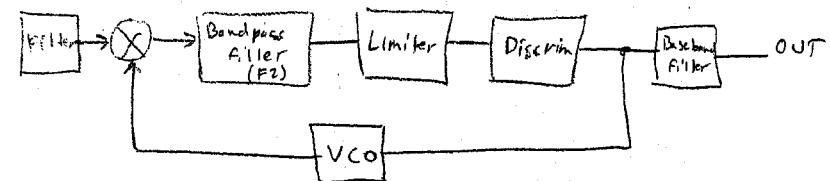
$$= (25)(56.25)(.5)$$

$$\text{improvement} = 70.3 \Rightarrow 28.4 \text{ dB}$$

(25 dB S/N in
gives us 53 dB)

FM Threshold extension -

Use a feed back loop to make a narrow filter
track the modulation.



VCO tracks the input signal,
so a narrower filter (F2) can be
used.

leads to phase locked loop.
in practice -- $\approx 3-6 \text{ dB}$ improvement.

Attach graphs - Couch p. 526, 522

Need $\frac{B}{f_1} > 1.73$ for any benefit.

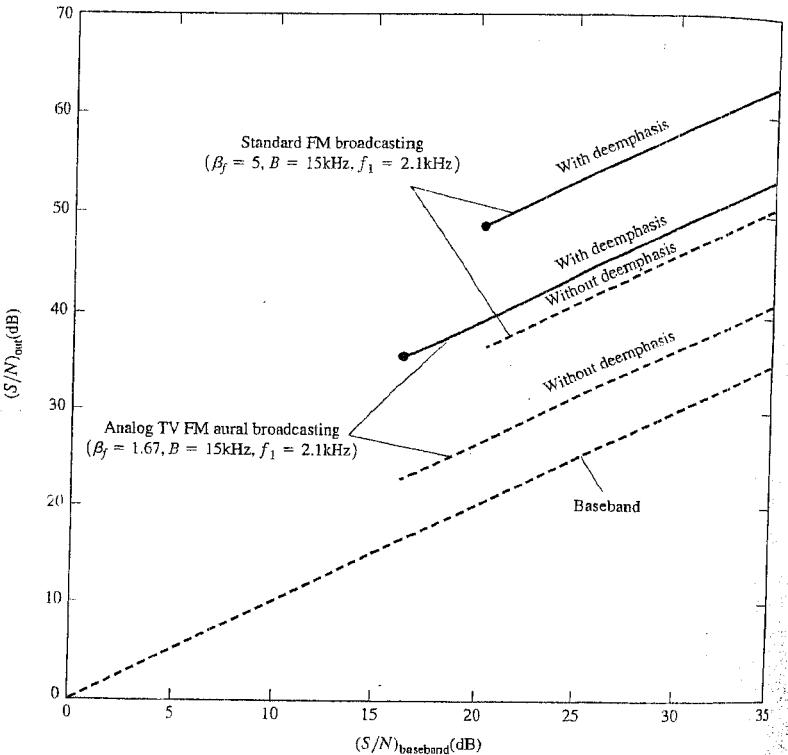
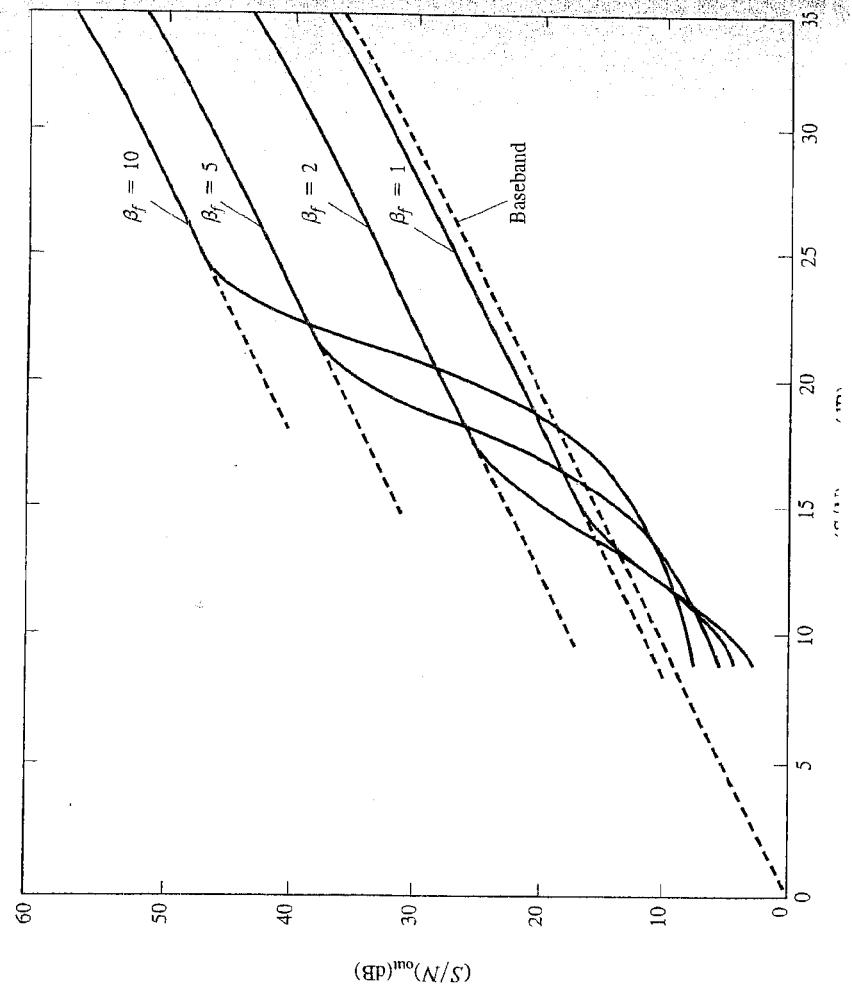


Figure 7-26 Noise performance of standard FM systems for sinusoidal modulation.

It is interesting to compare the noise performance of commercial FM systems. As shown in Table 5-4, for standard FM broadcasting $\beta_f = 5$, $B = 15$ kHz, and $f_1 = 2.1$ kHz. Using these parameters in Eq. (7-141), we obtain the noise performance of an FM broadcasting system, as shown in Fig. 7-26 by a solid curve. The corresponding performance of the same system, but without preemphasis-deemphasis, is shown by a dashed curve [from Eq. (7-131)]. Similarly, the results are shown for the performance of the conventional analog TV FM aural transmission system where $\beta_f = 1.67$, $B = 15$ kHz, and $f_1 = 2.1$ kHz.

Figure 7-26 also illustrates that the FM noise performance with deemphasis can be substantially better than that of FM without deemphasis. For example, for standard FM broadcasting ($\beta_f = 5$, $B = 15$ kHz, and $f_1 = 2.1$ kHz) with $(S/N)_{baseband} = 25$ dB, the FM

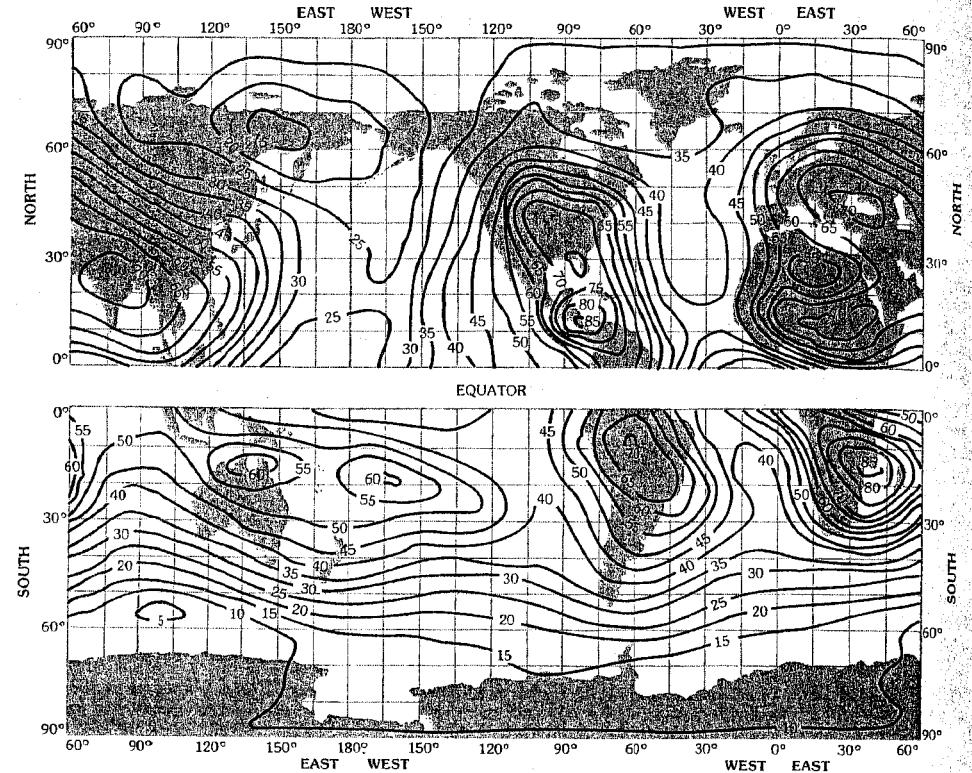


Fig. 2. Atmospheric noise levels in northern and southern hemispheres, summer, 1200–1600 hours local time. The maps show the expected values of F_a at 1 MHz, in decibels above kT_0B . (From CCIR Report 322, 10th Plenary Assembly, Geneva; 1963.)

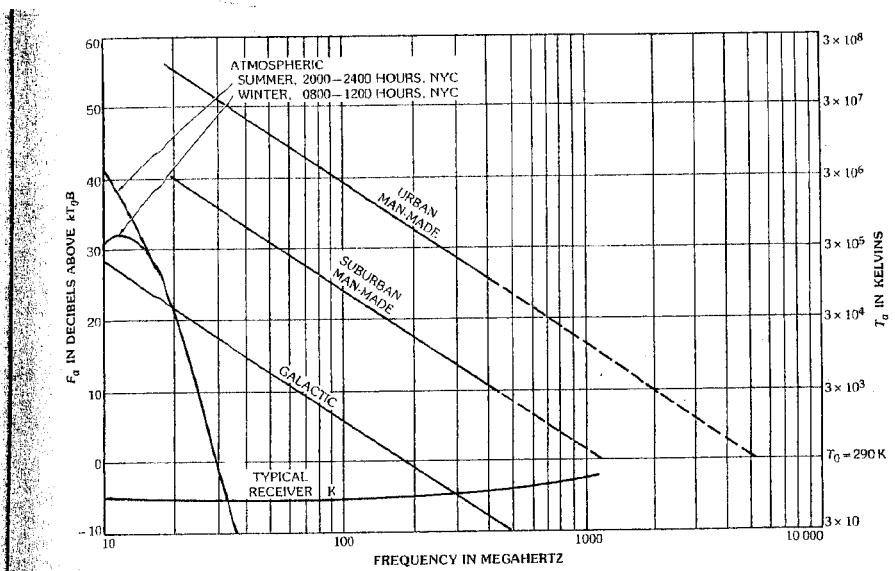


Fig. 9. Median values of average noise power expected from various sources (omnidirectional antenna near surface).

..... ESD components of the noise source.

distances, the ratio of E to H is no longer equal to 377

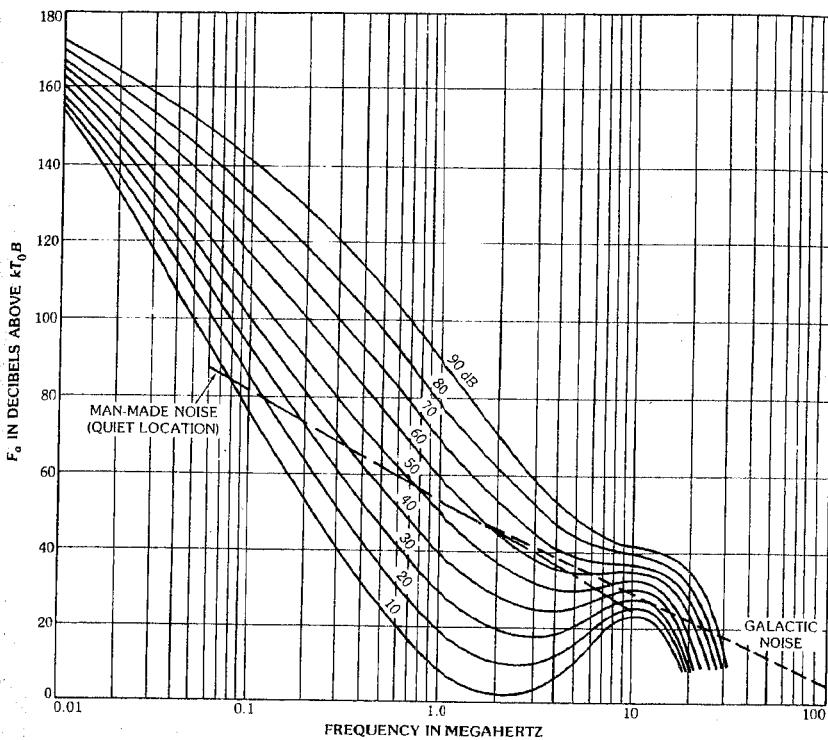


Fig. 3. Variation of radio noise with frequency, for data given in Fig. 2 legend. (From CCIR Report 322, 10th Plenary Ass

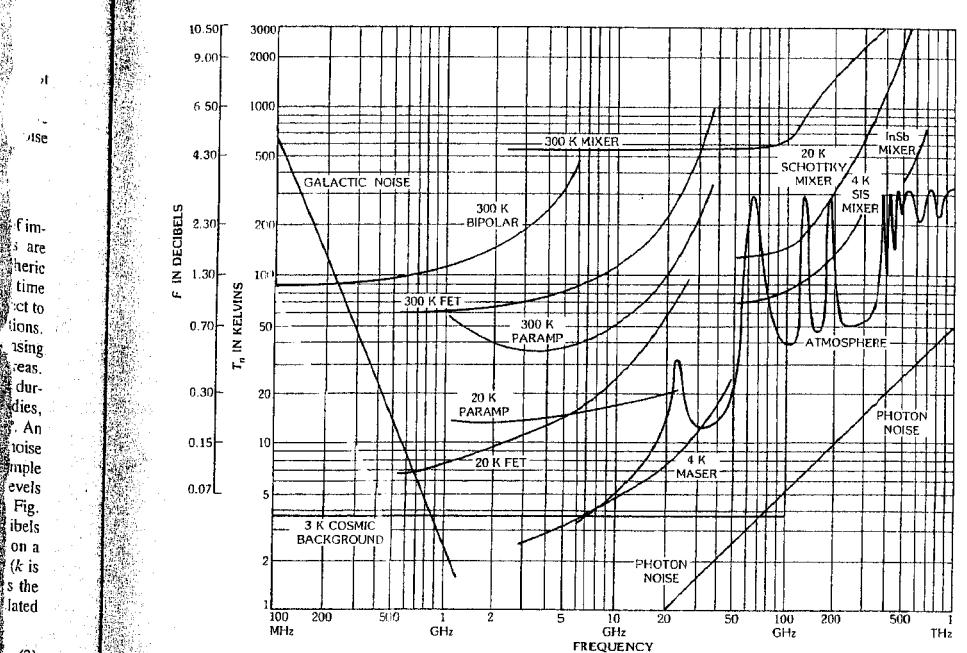


Fig. 1. Noise figure (F) and noise temperature (T_n) for various devices and natural limits—1984. (From S. Weinreb, "Low Noise GaAsFET Amplifiers," IEEE Trans. on MTT, Vol. MTT-28, No. 10, October 1980, pp. 1041–1054. Material updated, 1984 by Weinreb.)