Noise Figure, Noise Factor and Sensitivity

Wireless Systems Instructional Design

Noise

- "Any unwanted input"
- Limits systems ability to process weak signals
- Sources:
  1. Random noise in resistors and transistors
  2. Mixer noise
  3. Undesired cross-coupling noise
  4. Power supply noise
- Dynamic range – capability of detecting weak signals in presence of large-amplitude signals

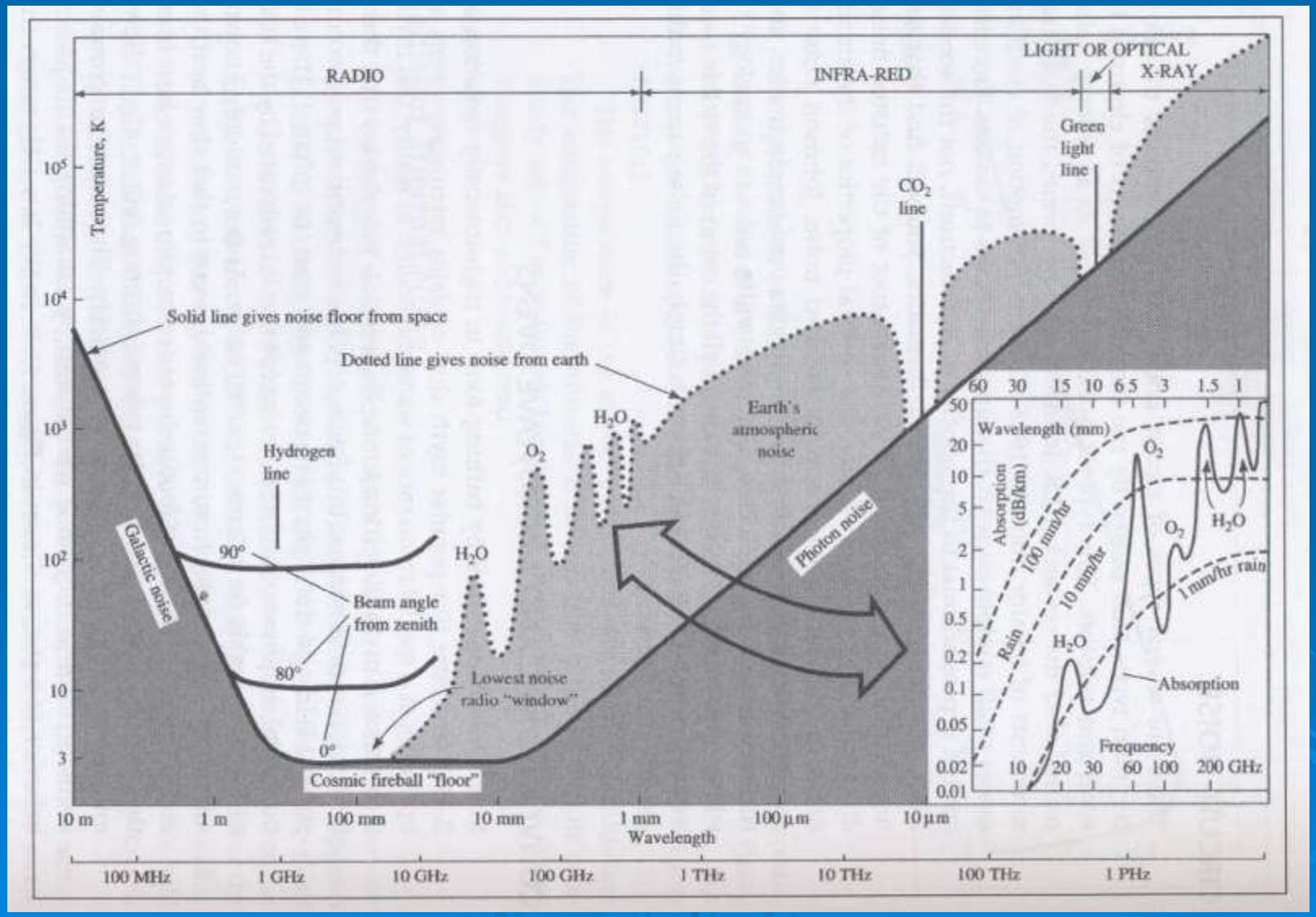
Noise (contd.)

- "noisiness" of the signal measure = signal-to-noise ratio (frequency dependant)

$$SNR = \frac{S(f)}{N(f)} = \frac{average - signal - power}{average - noise - power}$$

- Random noise
  - External
    - Atmospheric
    - Interstellar
  - Receiver internal
    - Thermal
    - Flicker noise (low frequency)
    - Shot noise

“Sky” Noise


RADIO
INFRA-RED
LIGHT OR OPTICAL
X-RAY
Temperature, K
10^5
10^4
10^3
10^2
10
3
Green light line
CO_2 line
Solid line gives noise floor from space
Dotted line gives noise from earth
Earth's atmospheric noise
H_2O
O_2
Hydrogen line
Galactic noise
90°
80°
0°
Beam angle from zenith
Lowest noise radio "window"
Photon noise
Cosmic fireball "floor"
10 m
1 m
100 mm
10 mm
1 mm
100 µm
10 µm
Wavelength
100 MHz
1 GHz
10 GHz
100 GHz
1 THz
10 THz
100 THz
1 PHz
60 30 15 10 6 5 3 1.5 1
Wavelength (mm)
Absorption (dB/km)
50
20
10
5
2
1
0.5
0.2
0.1
0.05
0.02
0.01
Rain
100 mm/hr
10 mm/hr
1 mm/hr rain
Absorption
Frequency
10 20 30 60 100 200 GHz

Noise factor

- IEEE Standards: "The noise factor, at a specified input frequency, is defined as the ratio of (1) the total noise power per unit bandwidth available at the output port when noise temperature of the input termination is standard (290 K) to (2) that portion of (1) engendered at the input frequency by the input termination."

$$F = \frac{available - output - noise - power}{available - output - noise - due - to - source}$$

Noise factor (cont.)

$$F=\frac{(N_i G(f)+N_a)S_i}{N_i S_o}=\frac{S_i}{N_i}\frac{N_o}{S_o}=1+\frac{N_a}{G(f)N_i}$$

- It is a measure of the degradation of SNR due to the noise added - $F=\frac{SNR_i}{SNR_o}\geq 1$
- Implies that SNR gets worse as we process the signal
- Spot noise factor $F=1+\frac{N_a}{kT}$
- The answer is the bandwidth

Noise factor (cont.)

- Quantitative measure of receiver performance wrt noise for a given bandwidth
- Noise figure $NF = 10\log(F)$
  - Typically 8-10 db for modern receivers
- Multistage (cascaded) system

$$F = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2} + \ldots + \frac{F_n - 1}{G_1 G_2 \cdots G_{n-1}}$$

Sensitivity

- Minimum detectable input signal level for a given output SNR (also called *noise floor*)
- Not necessarily related to required output SNR
- Example