APECE-302: Radio & Television Engineering

Applied Physics, Electronics & Communication Engineering

Lecture # 05

University of Dhaka | APECE DU

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- ❑ Noise figure
- ❑ Calculation of noise figure
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Noise Figure and Calculation

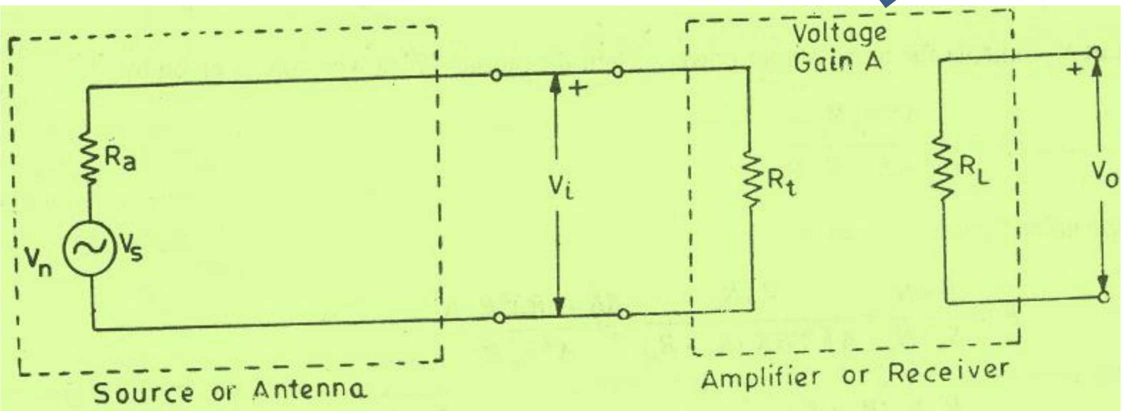
- Noise Figure

Noise Figure:

$$F = \frac{S/N \text{ at the input}}{S/N \text{ at the output}}$$

- Calculation of Noise Figure

(i) Determine the input signal power S_i
(ii) Determine the input noise power N_i
(iii) Calculate the input signal-to-noise power ratio S_i/N_i
(iv) Determine the output signal power S_o
(v) Determine the output noise power N_o
(vi) Calculate the output signal-to-noise power ratio S_o/N_o
(vii) From steps (iii) and (vi) calculate the noise figure F.



$$V_{si} = \frac{V_s R_t}{R_a + R_t}$$

$$S_i = \frac{V_{si}^2}{R_t} = \left(\frac{V_s \cdot R_t}{R_a + R_t}\right)^2 \frac{1}{R_t} = \frac{V_s^2 R_t}{(R_a + R_t)^2}$$

Calculation of Noise Figure

Input noise voltage is given by, $V_{ni}^2 = 4\bar{k}TB\dfrac{R_a R_t}{R_a + R_t}$

Hence input noise power is, $N_i = \dfrac{V_{ni}^2}{R_t} = \dfrac{4\bar{k}TBR_a}{R_a + R_t}$

The input signal-to-noise power ratio is given by,

$$\frac{S_i}{N_i} = \frac{V_s^2 R_t}{(R_a + R_t)^2} \cdot \frac{(R_a + R_t)}{4\bar{k}TBR_a} = \frac{V_s^2 R_t}{4\bar{k}TBR_a(R_a + R_t)}$$

The output signal power is given by,

$$S_o = \frac{V_{so}^2}{R_L} = \frac{(A\ V_{si})^2}{R_L} = \left(\frac{A\ V_s R_t}{R_a + R_t}\right)^2 \cdot \frac{1}{R_L}$$

$$= \frac{A^2 V_s^2 R_t^2}{(R_a + R_t)^2 R_L}$$

Calculation of Noise Figure

$$\frac{S_o}{N_o} = \frac{A^2 V_{s^2} R_{t^2}}{(R_a + R_t)^2 R_L N_o}$$

Hence the noise figures is given by,

$$F = \frac{S_i / N_i}{S_o / N_o} = \frac{V_{s^2} R_t}{4 \bar{k} TBR_a(R_a + R_t)} \cdot \frac{(R_a + R_t)^2 R_L N_o}{A^2 V_s^2 R_t^2}$$

$$= \frac{R_L N_o (R_a + R_t)}{4 \bar{k} TBA^2 R_a T_t}$$

Noise Figure in terms of Noise Resistance

Equivalent noise resistance

$$R_{eq} = R_1 + R_2' = R_1 + \frac{R_2}{A_1^2} + \frac{R_3}{A_1^2 A_2^2}$$

I/P resistance of the first stage

Eq. noise resistance of the first stage

Noise resistance of the subsequent stages referred to the I/P of the first stage

$$R_{eq}' = R_{eq} - R_t$$

$$R = R_{eq}' + \frac{R_a R_t}{R_a + R_t}$$

$$V_{ni} = \sqrt{4 k T B R}$$

Noise Figure in terms of Noise Resistance

Substitute N_0

$$N_o = \frac{V_{no}^2}{R_L} = \frac{(A V_{ni})^2}{R_L} = \frac{A^2 4 \bar{k} TBR}{R_L}$$

$$F = \frac{R_L (R_a + R_t)}{4 \bar{k} TBA^2 R_a R_t} \cdot \frac{A^2 4 \bar{k} TBR}{R_L}$$

$$= R \frac{R_a + R_t}{R_a R_t} = \left(R_{eq}' + \frac{R_a R_t}{R_a + R_t} \right) \cdot \frac{R_a + R_t}{R_a R_t} = 1 + R_{eq}' \frac{R_a + R_t}{R_a . R_t}$$

$R_t >> R_a$

$$F = 1 + \frac{R_{eq}'}{R_a}$$

Noise Temperature

- Noise Figure is a good indicator of noise performance
  - However, UHF, microwave low noise antenna, Rx or devices!
  - Noise temp << addition of noise power from several sources

$$P_t = \bar{k} T_t B$$

$$P_t = P_1 + P_2 = \bar{k} B T_1 + \bar{k} B T_2$$

$$\bar{k} B T_t = \bar{k} B (T_1 + T_2)$$

$$T_t = T_1 + T_2$$

Greater variation than F

where P_1 and P_2 are the two individual noise powers which may respectively be the noise powers received by the antenna and the power generated by the antenna.
T_1 and T_2 are the individual noise temperatures corresponding to P_1 and P_2 respectively and T_t is the *total* noise temperature.

Noise Temperature

- We introduce equivalent noise temperature, $\mathbf{T_{eq}}$, like Eq. noise resistance

$$F = 1 + \frac{R_{eq}'}{R_a} = 1 + \frac{\bar{k}\, T_{eq}\, BR_{eq}'}{\bar{k}\, T_o\, BR_a} = 1 + \frac{T_{eq}}{T_a}$$

where $R_{eq}' = R_a$ as assumed in the definition of T_{eq},

$$T = 27°\text{C} = 300°\ \text{K}$$

T_{eq} = equivalent noise temperature of the receiver or amplifier under consideration.

$$T_o F = T_o + T_{eq}$$

Hence

$$T_{eq} = T_o (F - 1)$$

Noise Temperature

A receiver having equivalent noise resistance of 2500 Ω and input resistance of 500 Ω is connected to an antenna of resistance 50 Ω. Compute the noise figure (in dBs) and equivalent noise temperature for the receiver.

Solution.

$$F = 1 + \frac{R_{eq}'}{R_a}$$

$$R_{eq}' = R_{eq} - R_t = 2500 - 500 = 2000\ \Omega$$

Hence

$$F = 1 + \frac{2000}{50} = 41$$

$$F \text{ in dB} = 10 \log_{10} 41 = 16.12 \text{ dB}$$

$$T_{eq} = T_o (F - 1) = 300\,(41 - 1) = 1200°\text{K}.$$

Q & A