CHAPTER 3

Noise

(Part 2 of 2)

3.2 Noise expression

<u>Common noise expressions</u>

1. **Signal to Noise ratio, SNR**

2. **Noise factor, F and noise figure**

3. **Noise Temperature (not in syllabus)**

3.2 Noise expression

Signal to noise ratio (SNR)

- The ratio of the signal power to the noise power at a specific point in a communication system

$$\text{SNR} = \frac{\text{Signal Power, } P_s \text{ at a point in a communication system}}{\text{Noise Power, } P_n \text{ at a the same point}}$$

$$\boxed{\text{SNR} = \frac{P_s}{P_n}}$$

3.2 Noise expression

Signal to noise ratio (SNR)

- **SNR defined in decibels**

SNR(in dB) = 10 log SNR

e.g. if SNR = 1000,
then SNR (expressed in dB) = 10 $\log_{10}$1000 = 30 dB

3.2 Noise expression

Signal to noise ratio (SNR)

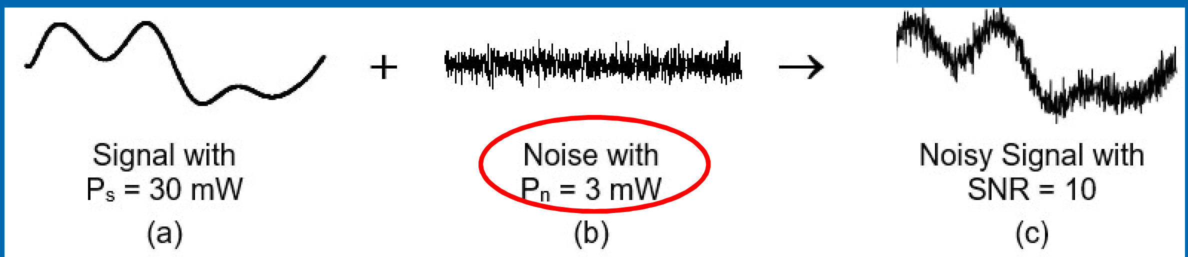
- Indicate how noisy a signal is.

The noisiness of a signal is NOT determined by how much noise it contains but rather the amplitude of this noise compared with the signal amplitude.

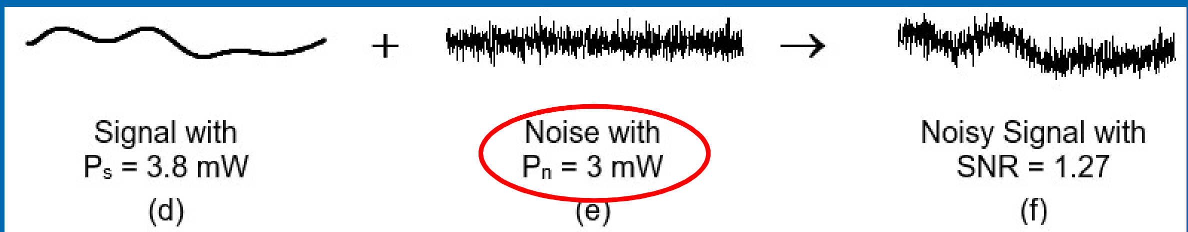
Low SNR means $P_s \approx$ or $< P_n \rightarrow$ signal is noisy

High SNR means $P_s >> P_n \rightarrow$ signal is not noisy

Same noise power



If the signal is stronger (a), the noise effect will not be serious (c).



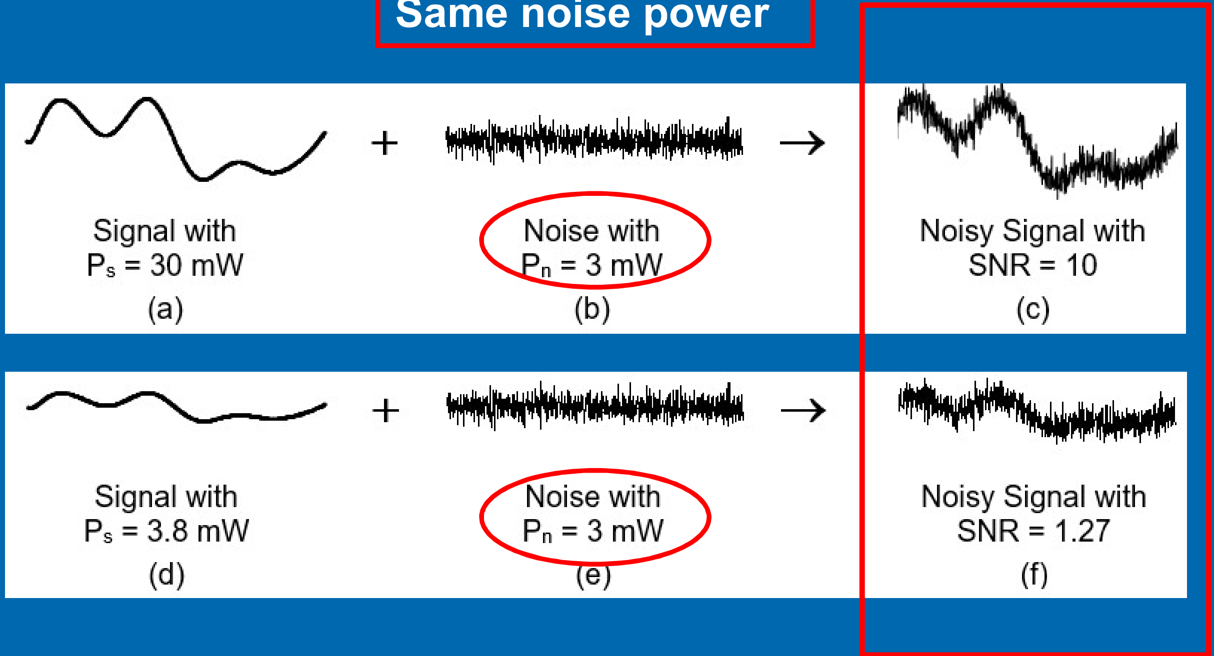
If the signal is weak (d), the noise effect will be serious (f);

3.2 Noise expression

Signal to noise ratio (SNR)

SNR is the correct indicator of signal noisiness, not noise power

Same noise power



signal in (c) is less noisy than signal in (f).

3.2 Noise expression

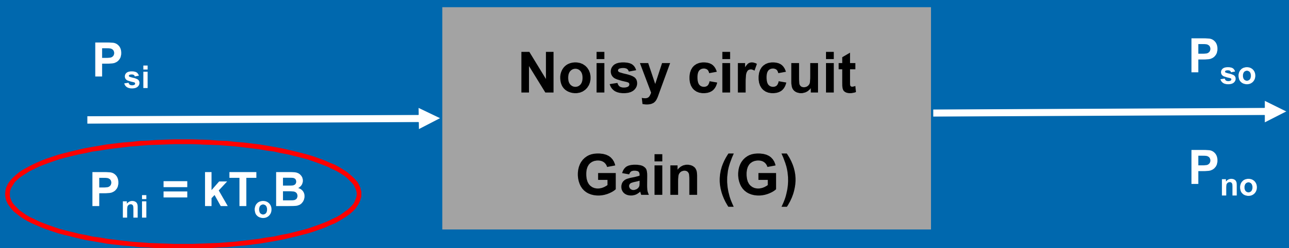
Noise Factor, F

$$F = \frac{SNR_i}{SNR_o}$$

(with P_{ni} set to kT_oB Watts, where T_o=290 Kelvin)

When measuring F, the input noise power, P_{ni} **must** be set at a value equal to kT_oB watts.

- Signal picks up noise from the noisy circuit, e.g. amplifier
- Hence, $SNR_o < SNR_i$
- i.e. F >1, in practice
- If circuit is NOISELESS → $SNR_o = SNR_i$ → F =1 (the best value for F)



3.2 Noise expression

Noise Factor, F

- **The higher the F, the noisier the circuit**

High F means $SNR_o << SNR_i$

→ **Output signal is much more noisy than the input signal**

→ **Signal picks up a lot of noise from the amplifier as it travels through it**

→ **The circuit is noisy**

3.2 Noise expression

Noise Figure

Noise factor expressed in decibels (dB):

Noise Figure (NF) = $10 \log_{10} F$ dB

e.g. if F = 100,
then NF = $10 \log_{10} 100 = 20$ dB

Example 3.2

With the available noise power at the input standardised at kT_0B, the measurements performed on Amplifiers A and B produce the following results:

Amplifier A	-	SNR at input = 40
		SNR at output = 10
Amplifier B	-	SNR at input = 75
		SNR at output = 15

(a) Which output signal is noisier?

(b) Why does SNR reduces as the signal travels from the input to the output of each amplifier?

(c) Does amplifying a signal make the signal less noisy?

(d) Which amplifier is noisier?

Solution

Amplifier A: SNR at input, SNR_i = 40

SNR at output, SNR_o = 10

Amplifier B: SNR at input, SNR_i = 75

SNR at output, SNR_o = 15

(a) Which output signal is noisier?

Output from amplifier A is noisier because SNR_o is lower.

Solution

(b) Why does SNR reduces as the signal travels from the input to the output of each amplifier?

All electronic circuits produce noise.

The signal picks up noise from the amplifier as it travels through it.

Amplifier A: SNR at input, $SNR_i = 40$

SNR at output, $SNR_o = 10$

Amplifier B: SNR at input, $SNR_i = 75$

SNR at output, $SNR_o = 15$

Solution

(c) Does amplifying a signal make the signal less noisy?

No. In fact amplifying a signal makes it noisier

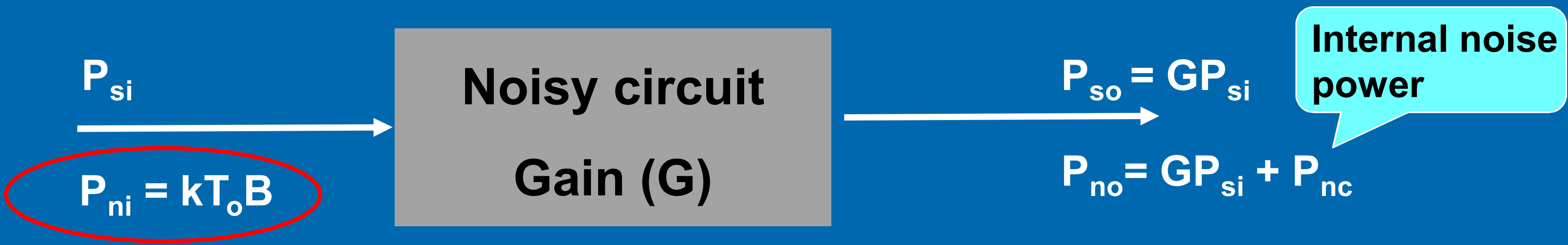
Amplifiers CANNOT be used to reduce noise!

Amplifier A: SNR at input, $SNR_i = 40$

SNR at output, $SNR_o = 10$

Amplifier B: SNR at input, $SNR_i = 75$

SNR at output, $SNR_o = 15$



Solution

(d) If all the SNR values were measured with $P_{ni} = kT_oB$ which amplifier is noisier?

F is most appropriate unit to use for this comparison.

Since $P_{ni} = kT_oB$, the formula, $F = \dfrac{SNR_i}{SNR_o}$ can be used.

Amplifier A: SNR at input, $SNR_i = 40$

SNR at output, $SNR_o = 10$

$\boxed{F_A = 4}$

Amplifier B: SNR at input, $SNR_i = 75$

SNR at output, $SNR_o = 15$

$\boxed{F_B = 5}$

Since $F_B > F_A \rightarrow$ Amplifier B is noisier.

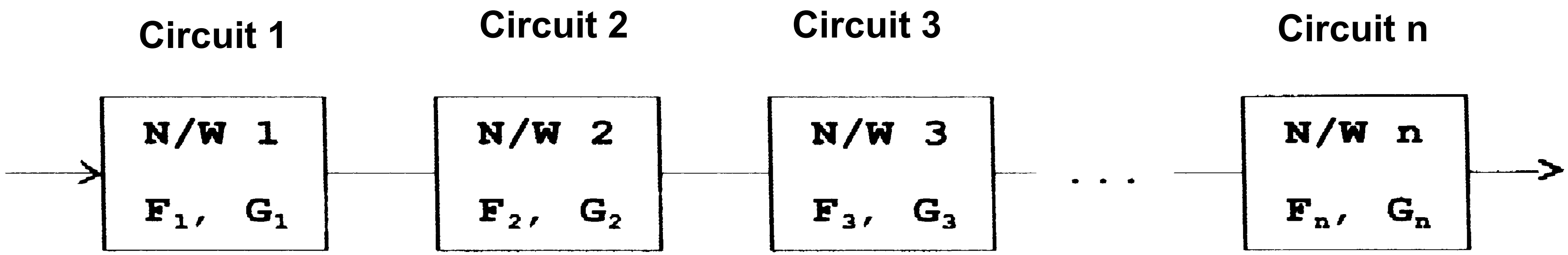
3.3 Total Noise Factor of Cascaded Circuits

When stages of circuits are cascaded, total noise factor, F_t is given by the Friiss' formula:

$$F_t = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2} + \frac{F_4 - 1}{G_1 G_2 G_3} + \ldots.. + \frac{F_n - 1}{G_1 G_2 G_3 \ldots G_{(n-1)}}$$

Where G_n and Fn are s the Power Gain and noise factor of circuit n, i.e.

$$G_1 = \frac{\text{Signal power at the output of Circuit1}}{\text{Signal power at the input of Circuit1}} \qquad G_2 = \frac{\text{Signal power at the output of Circuit2}}{\text{Signal power at the input of Circuit2}}$$ etc.



3.4 Improvement of overall noise factor

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Re-arrange the amplifiers in a cascaded network can obtain lowest F_t

$$F_t = F_1 + \boxed{\frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2} + \frac{F_4 - 1}{G_1 G_2 G_3} + \dots\dots + \frac{F_n - 1}{G_1 G_2 G_3 \dots G_{(n-1)}}}$$

For best noise performance F_t must be lowest.

The noise contribution are reduced by the power gain G_1

$F_t > F_1$

$F_{t\,(min)} = F_1$

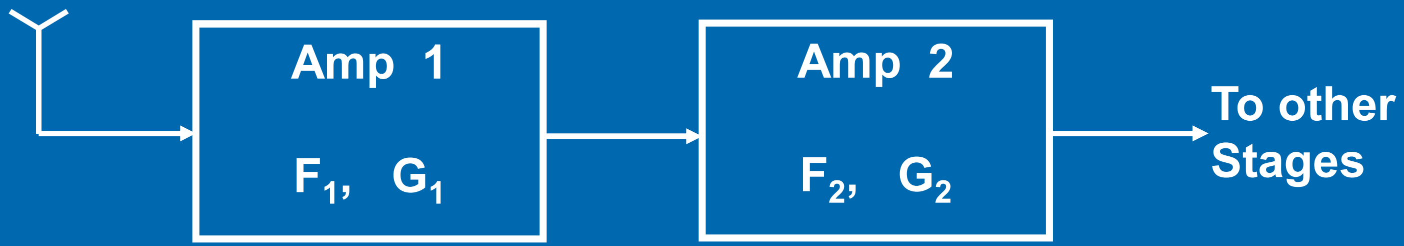
If $G_1 \gg (F_2 - 1)$ then $F_t \approx F_1$

If F_1 is low, then F_t will also be low.

low noise factor and high power gain amplifier should be used as first stage.

Example 3.3

Figure below is the front end of a radio receiver consisting 2 amplifiers to amplify the weak signal received by the antenna. Show that an amplifier 1 with high power gain and low noise factor is necessary in order to achieve a low overall noise factor F_t of the two cascade amplifier connection.



Solution

The overall noise factor F_t of the two amplifiers is given by

$$F_t = F_1 + \frac{F_2 - 1}{G_1}$$

$$F_t > F_1$$

$$F_{t(min)} = F_1$$

If $G_1 \gg (F_2 - 1)$ then, $F_t \approx F_1 = F_{t(min)}$

If F_i is low, then F_t will also be low.

low noise factor and high power gain amplifier is used as first stage.

End

CHAPTER 3

(Part 2 of 2)