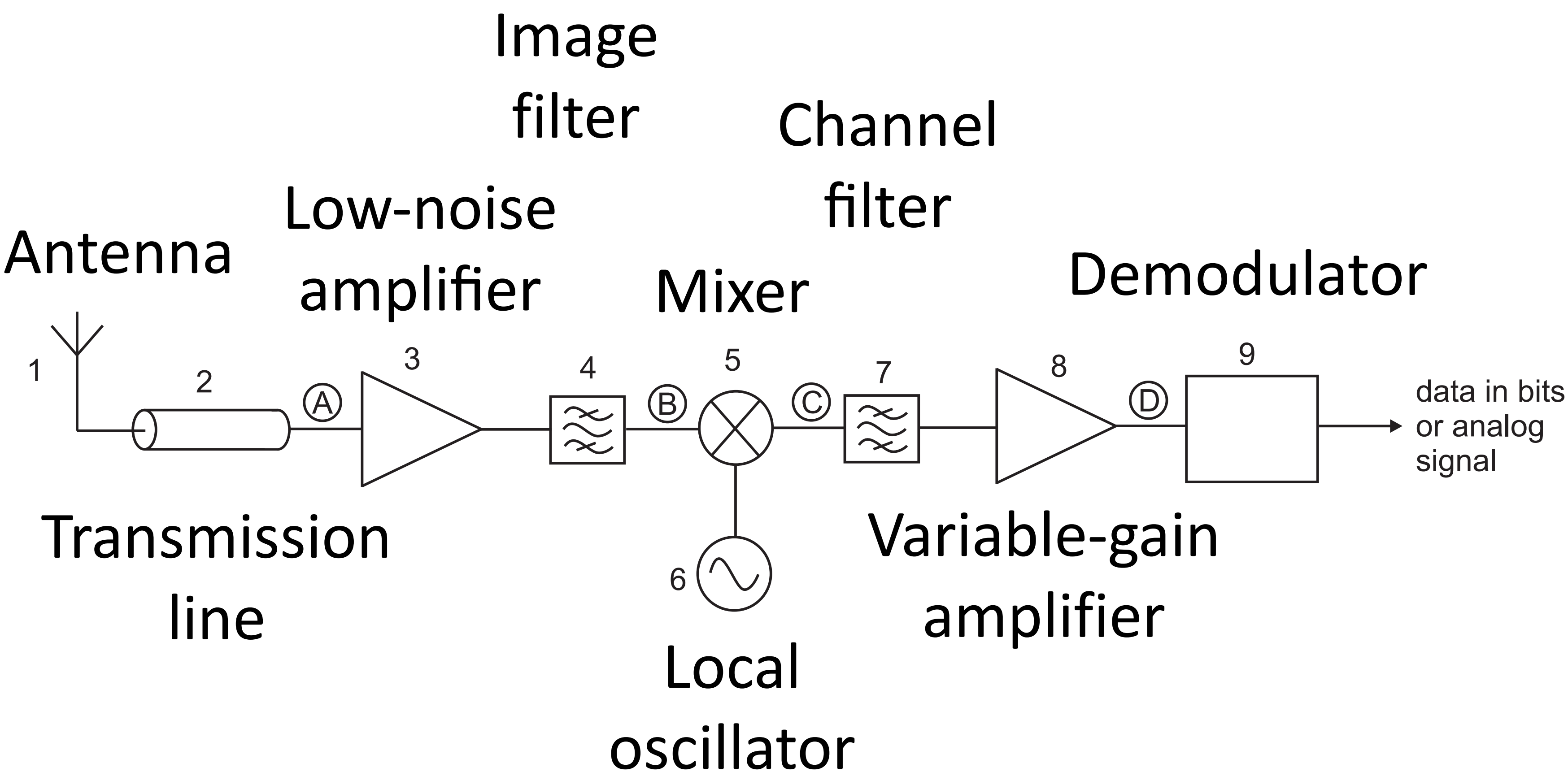
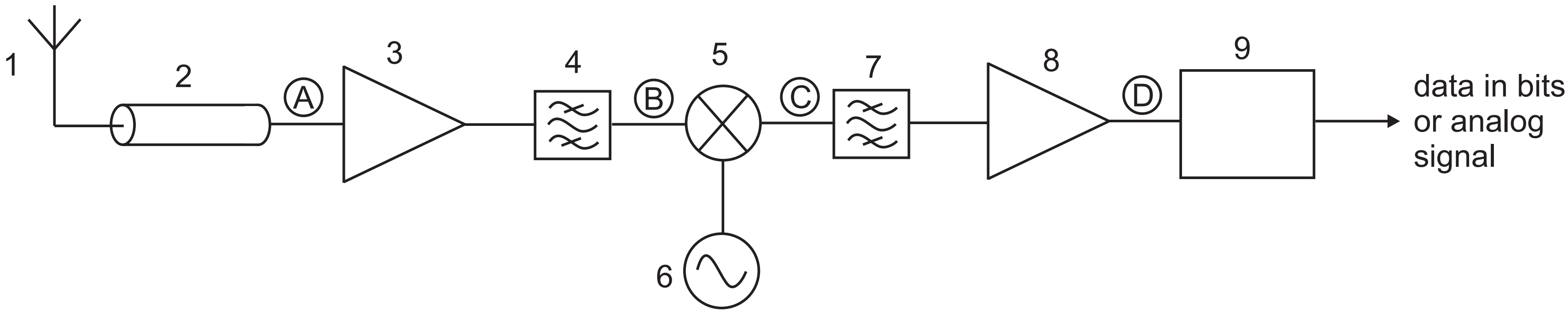
First lecture of Topic 4: Receiver and noise

February 21, 2019

Super-Heterodyne Receiver (Example Structure)

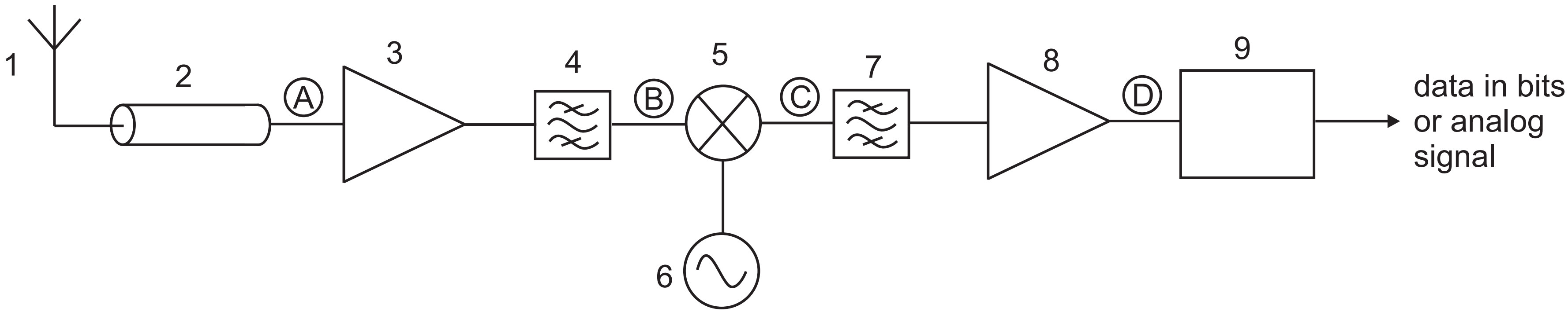


Q1a: Choose an **incorrect explanation**. What are the reasons to use super-heterodyne receiver? Choose 5. if you do not know which one to choose.



1. Increasing the signal-to-noise ratio at the demodulator input than at the antenna.
2. Reducing interference that antennas inevitably receive from environments.
3. Analog-to-digital converter at the demodulation works at sufficiently slow speed.
4. The dynamic range of the analog-to-digital converter is fully exploited.
5. I do not know which item is incorrect.

Q1b: Choose an **incorrect explanation**. What are the reasons to use super-heterodyne receiver?



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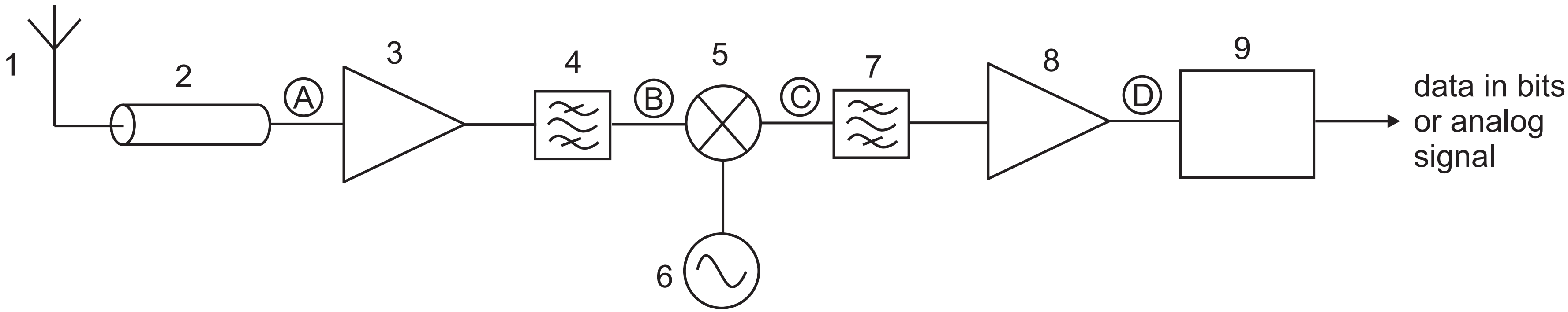
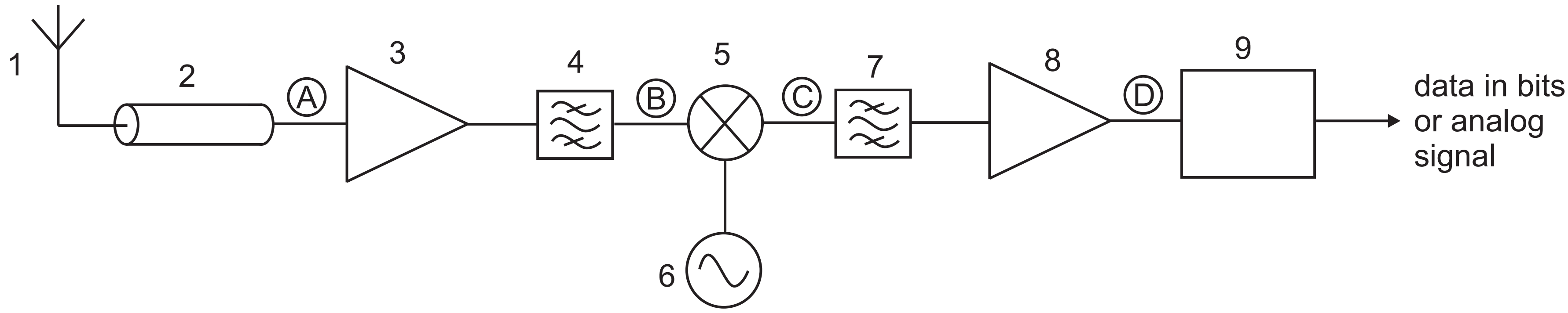
Q2a: Choose an **incorrect explanation**. The following explains each component of the super-heterodyne receiver. Choose 5. if you do not know what to choose.



1. The image filter removes the mirror frequency spectrum of the signal of interest.
2. The channel filter is usually implemented at the radio frequency stage for ease of implementation.
3. The low-noise amplifier is operated either in linear or saturation regions in practical radio systems.
4. The local oscillator can tune frequencies to select a frequency of interest with a fixed band-pass filter.
5. I do not know which explanation is incorrect.

Q2b: Choose an **incorrect explanation**. The following explains each component of the super-heterodyne receiver.



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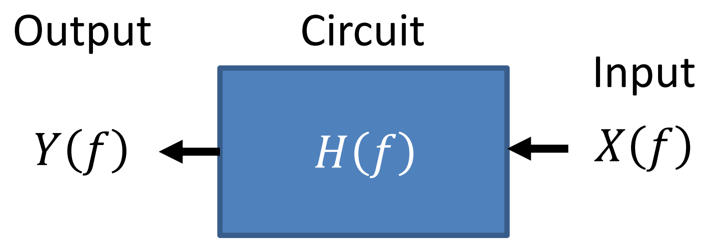
Linear and Non-Linear Circuits



$$Y(f) = a_0 + a_1 X(f) + a_2 X^2(f) + \ldots$$

Linear response Non-linear response

- Linear circuits
  - E.g., resistance, inductance and capacitance, i.e., passive components
  - Output is always proportional to inputs at any frequency
  - Scattering parameter does NOT change depending on input power level
  - $Y(f) = X(f)H(f) \rightarrow aX(f)H(f) = aY(f)$
- Non-linear circuits
  - E.g., diodes, operational amplifiers and transistors, i.e., active components
  - Scattering parameter depends on input power level
  - $Y(f) = X(f)H(f) \rightarrow aX(f)H(f) \neq aY(f)$

Q3a: Non-linear components, e.g., diodes, are usually **not** used as the following microwave circuits. Choose 5. if you do not know what to choose.

1. Mixer.
2. Amplifier.
3. Filter.
4. Rectifier.
5. I do not know which one to choose.

$$v_{\mathrm{o}} = a_0 + a_1 v_{\mathrm{i}} + a_2 v_{\mathrm{i}}^2 + a_3 v_{\mathrm{i}}^3 + \ldots$$

$$v_{\mathrm{i}} = V_0 \cos \omega_1 t$$

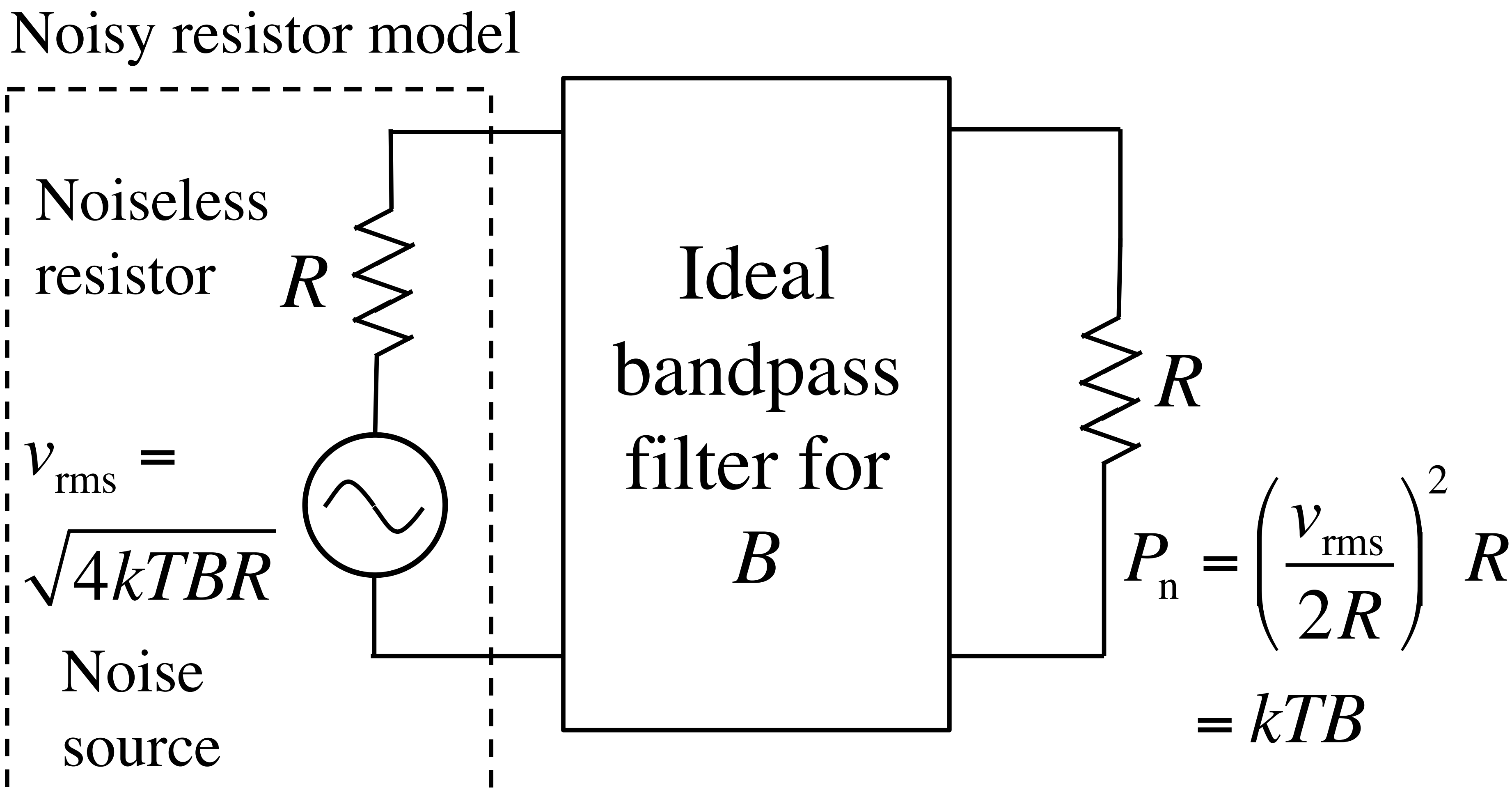
Q3b: Non-linear components, e.g., diodes, are usually **not** used as the following microwave circuits.

1. Mixer.
2. Amplifier.
3. Filter.
4. Rectifier.
5. I do not know which one to choose.

$$v_o = a_0 + a_1 v_i + a_2 v_i^2 + a_3 v_i^3 + \ldots$$

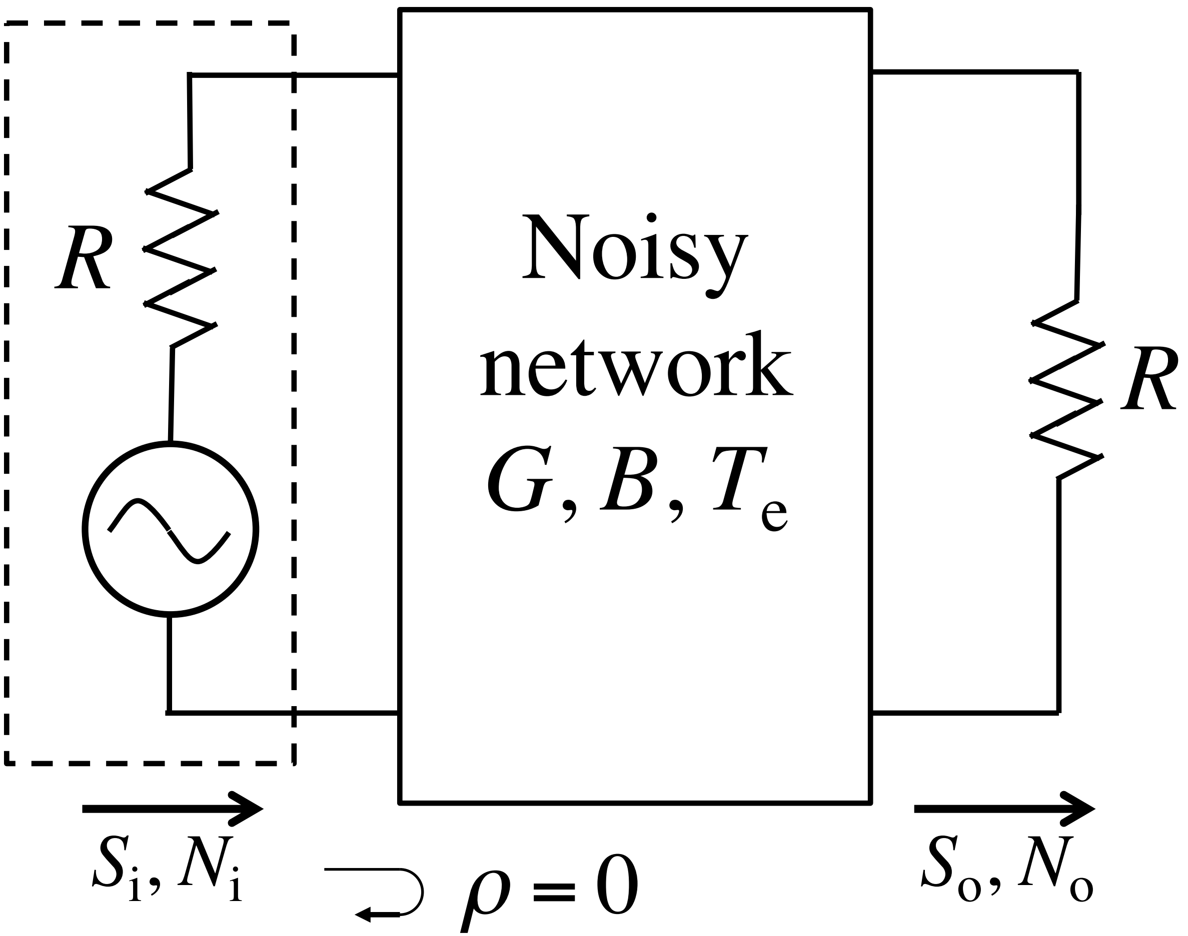
$$v_i = V_0 \cos \omega_1 t$$

Equivalent Circuit Model of a Resistor



Noise Figure and Temperature: Definition

$T_0 = 290\text{K}$ as a reference!



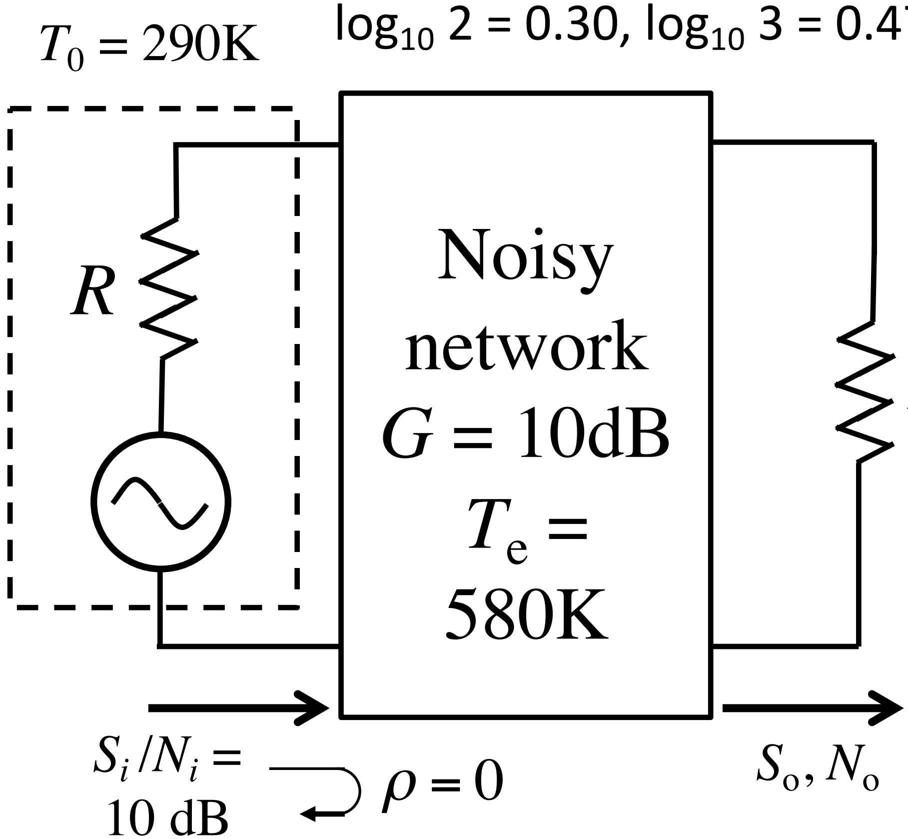
$$F = \frac{S_i / N_i}{S_o / N_o}$$

$$= 1 + \frac{T_e}{T_0}$$

Q4a: What is the output signal-to-noise ratio S_o / N_o of the two port network?

1. 7.0 dB.
2. 15.3 dB.
3. 17.0 dB.
4. 5.3 dB.
5. I do not know.

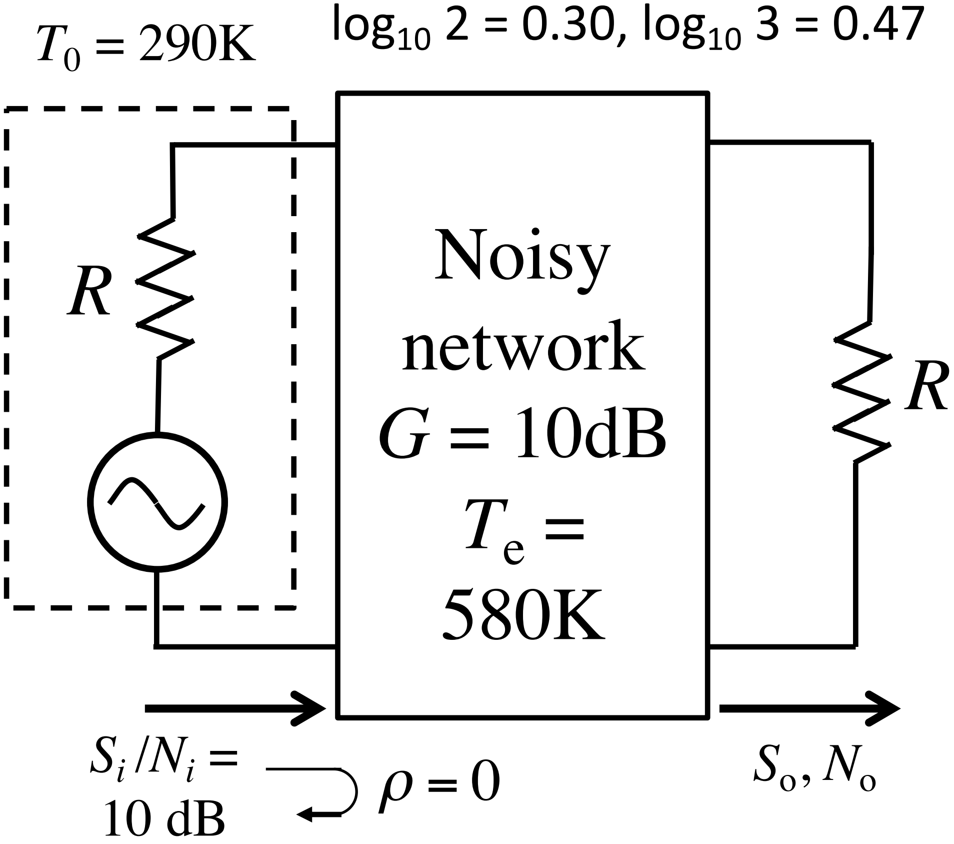
$\log_{10} 2 = 0.30$, $\log_{10} 3 = 0.47$



Q4b: What is the output signal-to-noise ratio S_o / N_o of the two port network?

1. 7.0 dB.
2. 15.3 dB.
3. 17.0 dB.
4. 5.3 dB.

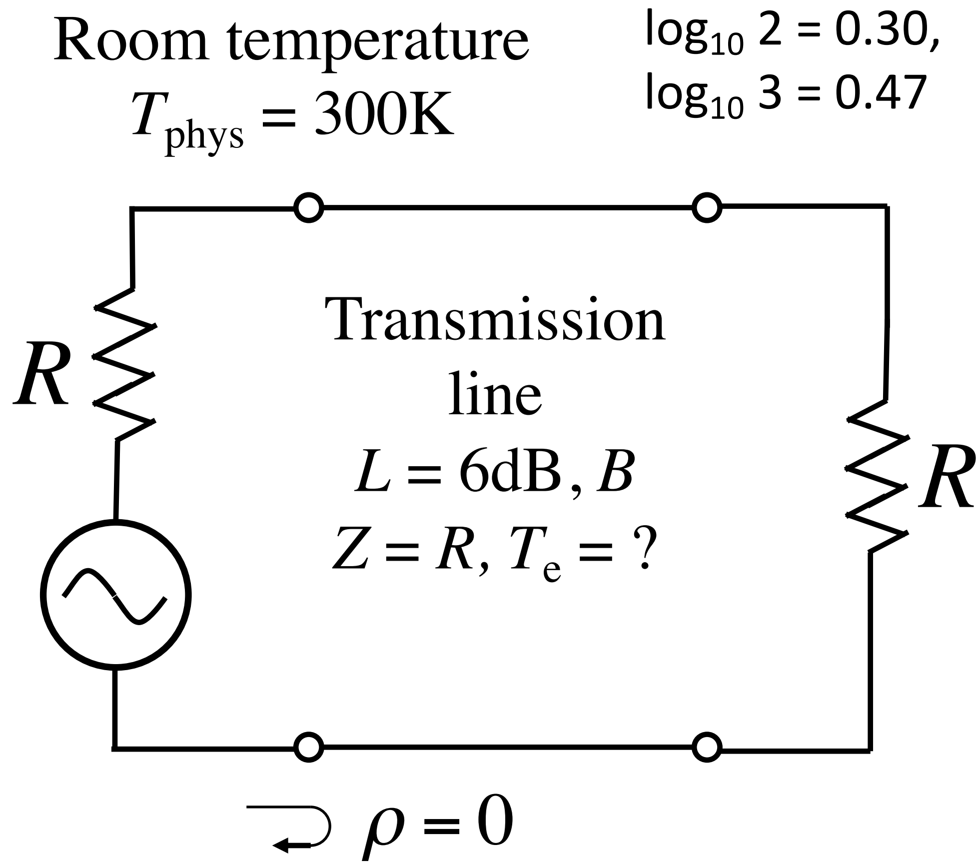
$\log_{10} 2 = 0.30$, $\log_{10} 3 = 0.47$



Q5a: What is the equivalent noise temperature of a transmission line, T_e?

1. 300 K.
2. 600 K.
3. 900 K.
4. 1200 K.
5. I do not know.

$\log_{10} 2 = 0.30$,
$\log_{10} 3 = 0.47$



Q5b: What is the equivalent noise temperature of a transmission line, T_e?

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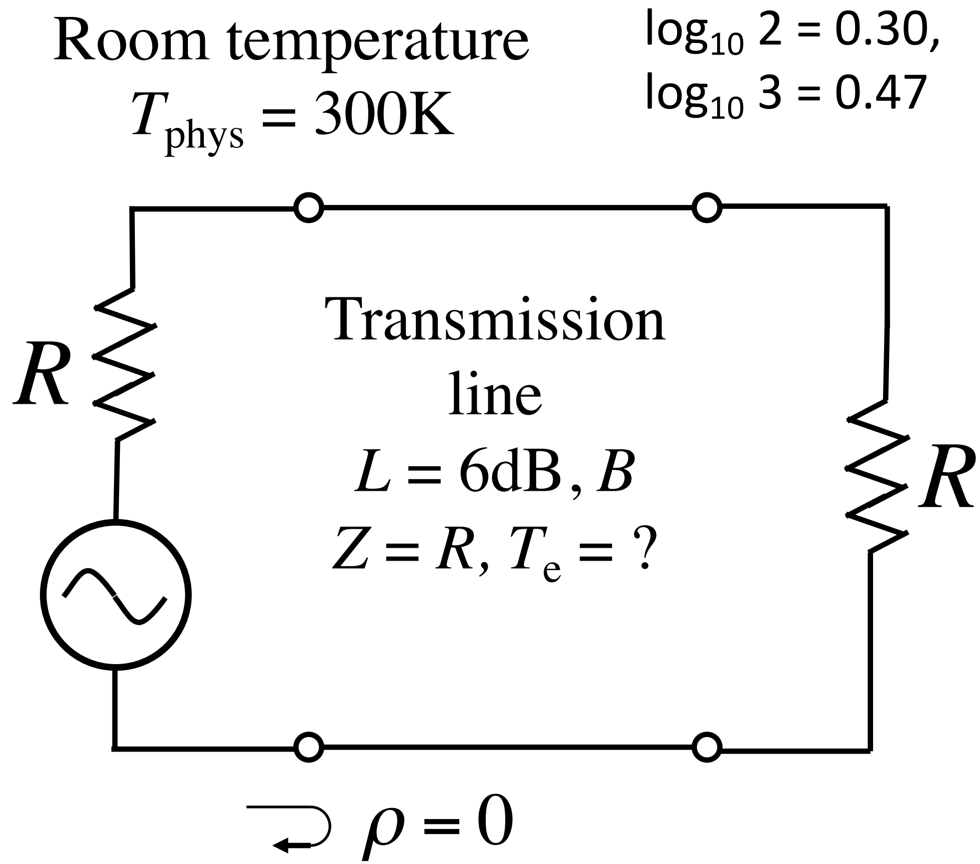
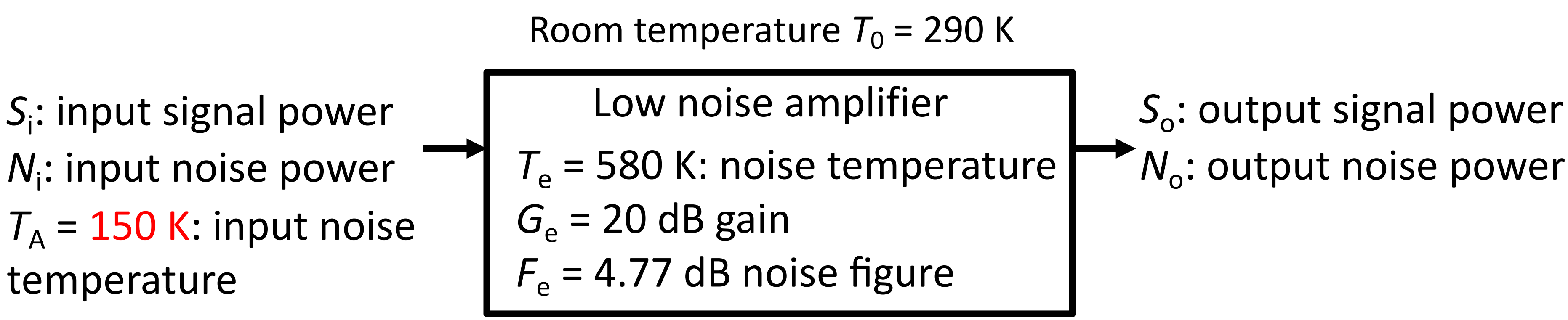
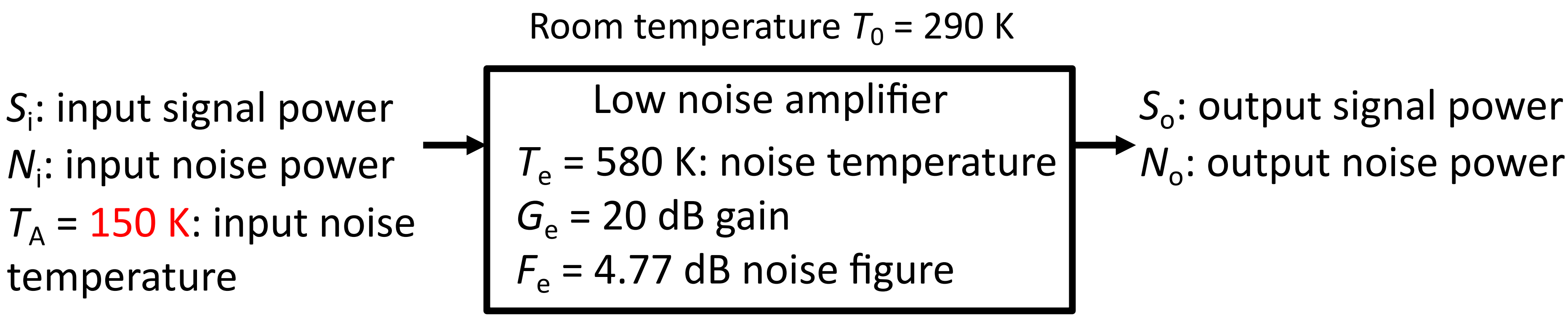


Q6a: There is a low noise amplifier of the following input, output and component parameters. Choose **an incorrect formula or explanation**. Choose 5. if you do not know what to choose.



1. $(S_o / N_o) = (S_i / N_i) - F_e$ in dB.
2. $F_e = 1 + T_e / T_0$.
3. $N_o = kT_A BG_e + kT_e BG_e$.
4. (S_o / N_o) does not depend on G_e.
5. I do not know.

Q6b: There is a low noise amplifier of the following input, output and component parameters. Choose **an incorrect formula or explanation**.



1. $(S_o / N_o) = (S_i / N_i) - F_e$ in dB.
2. $F_e = 1 + T_e / T_0$.
3. $N_o = kT_A B G_e + kT_e B G_e$.
4. (S_o / N_o) does not depend on G_e.

First Pre-Task for Topic 4

Read the course book chapter 10.2 (Noise figure) and 14.2 (Wireless communication). Answer the following tasks.

A receiver system consists of the following components:

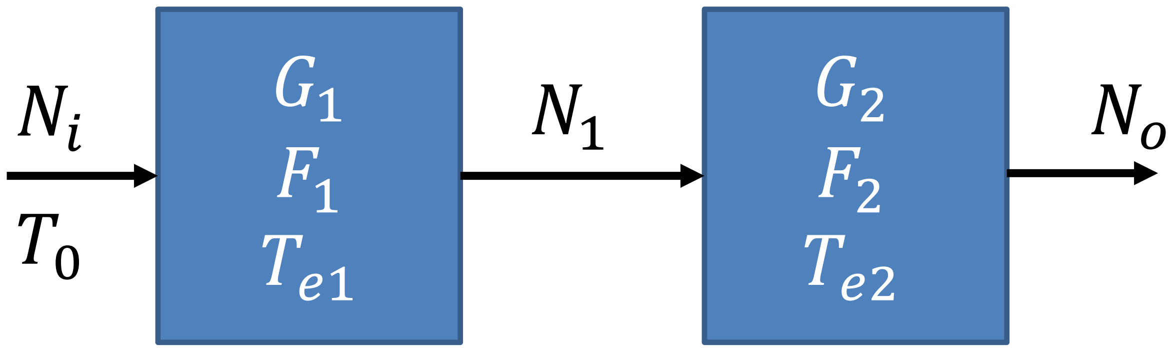
- lossy cable (a cable is needed because the antenna and receiver cannot be in the same location)
- band-selection filter (band-pass filter)
- receiver RX unit
- antenna
- low-noise amplifier

a. In which order the components (between the antenna and the receiver unit) should be placed in order to maximize the signal-to-noise ratio in the receiver? Justify your answer.

b. Which of the components (in the order of your selection in a.) has the relatively biggest effect on the signal-to-noise ratio of the whole receiver system? Justify your answer.

Noise Temperature of Receiver

- The first component at the RF front-end is most influential to total noise of the receiver.
  - We therefore use "low-noise" amplifier in the receiver.



$$T_{cas} = T_{e1} + \frac{T_{e2}}{G_1}$$

Towards the End of the Course

- Monday, 25th February at 10:15 am
  - Exercise return session until noon
- Thursday, 28th February at 9:00 am
  - Deadline of second pre-task for topic 4
- Thursday, 28th February at 9:15 am
  - Second lecture for topic 4 (Noise temperature, antenna gains, Friis' formula and link budget)
- Monday, 4th March at 10:15 am
  - Exercise return session until noon
- Thursday, 7th March at 9:00 am
  - Deadline of pre-task for topic 5
- Thursday, 7th March at 9:15 am
  - Lecture for topic 5 (radio propagation)