Noise Figure of Passive Devices

Recall that passive devices are typically **lossy**. Thus, they have a **"gain"** that is **less than one**—we can define this in terms of device **attenuation** A:

$$A = \frac{1}{G}$$

where for a lossy, passive device $G < 1$, therefore $A > 1$.

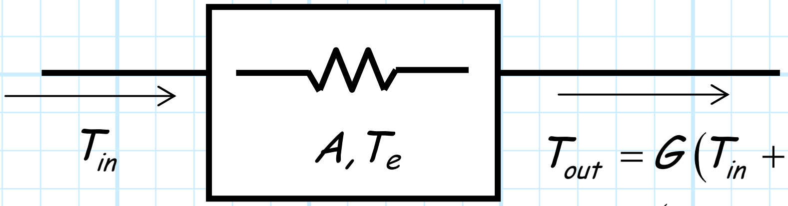
Q: *What is the equivalent noise temperature T_e or noise figure F of a **passive** device (i.e., **not** an amplifier) ?*

A: The **equivalent noise temperature** of a **passive** device can be shown to be approximately (trust me!):

$$T_e = (A - 1)\,T$$

where T is the **physical** temperature of the passive device. Typically we assume this physical temperature to be $290\,K^\circ$, so that:

$$T_e = (A - 1)\,290K^\circ$$



Thus, we find that the **output** noise temperature of a **passive** device is:

$$\begin{aligned} T_{out} &= G(T_{in} + T_e) \\ &= \frac{T_{in} + T_e}{A} \\ &= \frac{T_{in}}{A} + \frac{(A-1)290\,K^\circ}{A} \\ &= \frac{T_{in}}{A} - \frac{290\,K^\circ}{A} + 290\,K^\circ \end{aligned}$$

This result is **very** interesting, and **makes sense** physically. As attenuation A approaches the **lossless** case $A = 1$, we find that $T_{out} = T_{in}$. In other words the noise passes through the device **unattneuated**, and the device produces **no** internal noise!

→ Just like a length of lossless transmission line!

On the other hand, as A gets **very large**, the input noise is completely **absorbed** by the device. The noise at the device output is entirely generated **internally**, with a noise temperature $T_{out} = 290\,K^\circ$ equal to its physical temperature.

→ Just like the output of a **resistor** at physical temperature $T = 290\,K^{\circ}$

Q: *So, what is the **noise figure** F of a **passive** device?*

Now, we determined earlier that the **noise figure** of a two-port device is related to its equivalent noise temperature as:

$$F = 1 + \frac{T_e}{290\,K^{o}}$$

Therefore, the noise figure of a **passive** device is:

$$\begin{aligned} F &= 1 + \frac{(A-1)290K^{\circ}}{290K^{\circ}} \\ &= 1 + (A-1) \\ &= A \end{aligned}$$

Thus, for a **passive** device, the noise figure is **equal** to its attenuation!

$$F = 1/G = A$$

So, for an **active** two-port device (e.g., an amplifier), we find that two important and **independent device parameters** are gain G and noise figure F—**both** values must be specified.

However, for **passive** two-port devices (e.g., an attenuator), we find that attenuation *A* and noise figure *F* are not only completely **dependent**—they are in fact **equal**!

Finally, we should not that the value *A* represents the attenuation (i.e., loss) of **any** passive device—**not** just an attenuator.

For example, *A* would equal the **insertion loss** for a switch, filter, or coupler. Likewise, it would equal the **conversion loss** of a mixer.

Thus, **you** should now be able to specify the noise figure and equivalent noise temperature of each and **every** two-port device that we have studied!