RF Design - Cascaded Stages

Noise Temperature

Since the thermal noise power is proportional to the temperature of a device, we can treat the noise added by a device as an equivalent increase in temperature. This "equivalent noise temperature" can be computed from the noise figure as:

$$T_e = T_0(F-1)$$

where T_0 is 290K and F is the noise figure in linear units. For example, a noise figure of 3dB would correspond to an equivalent noise temperature of $T_e = 290(2-1) = 290K$.

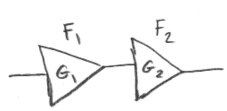
Cascade Noise Figure

We define the noise figure for a device such as an amplifier (or receiver) that affects both the signal and noise powers as the ratio of the SNR at the input to the SNR at its output.

Exercise 1: What is the noise figure of a 3dB attenuator?

When multiple devices (amplifiers, attenuators, mixers, etc) are connected in series (cascade) both the signal and noise generated by each state are amplified by subsequent stages. Thus the impact of noise added by later stages has less impact on the overall SNR and thus has less impact on the overall noise figure.

It is possible to show that when several devices (amplifiers, attenuators, mixers, etc) with gains $G_1, G_2, \ldots$ and noise figures $F_1, F_2, \ldots$ (both in linear units) are connected in series (cascade):



the overall (or "system" or "cascade") noise figure is given by:

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

and the equivalent noise temperature is given by:

$$T_e = T_1 + \frac{T_2}{G_1} + \frac{T_3}{G_1 G_2} + \ldots$$

Exercise 2: A What is the system noise figure of a receiver that consists of a 10dB amplifier with 3 dB noise figure followed by a mixer with a 6dB loss and an IF amplifier with a 20dB gain?

Cascade IP3

When multiple amplifiers are connected in series (cascade) the signal level at the input to the second amplifier is higher than the level at the input to the first stage. We would thus expect that the IP3 of the cascade would be determined primarily by the IP3 of the final amplifier.

It is possible to show that the input IP3 (in linear units) of a cascade of amplifiers with gains $G_1, G_2, \ldots$ and input IP3's $I_1, I_2 \ldots$ is:

$$\frac{1}{IIP3} = \frac{1}{I_1} + \frac{G_1}{I_2} + \frac{G_1 G_2}{I_3} + \ldots$$

When the gains are significant, the IIP3 of the last stage predominates.