How are gain and noise figure related for low noise RF amplifiers?

In low noise RF amplifiers, gain and noise figure share an inverse relationship. Depending on the parameter of interest, circuit design trade-offs can be made to optimize either one. Although gain and noise figure are distinct characteristics, implementing high gain in the first amplifier stage reduces the relative impact of the noise figure in all subsequent stages, improving overall system performance.

How does gain compare to noise figure on a single-stage LNA design?

The noise figure (NF) of an amplifier is defined as the ratio of input signal-to-noise ratio (SNR) to output SNR. One way to achieve a lower noise figure is by driving the amplifier's transistors at maximum current capacity. This raises the signal level relative to the amplifier's own internal noise sources, thereby improving the output SNR.

As amplifier gain increases, any noise added by the RF amplifier is amplified along with the signal. However, when gain is sufficiently high, the noise already present in the input signal dominates, offsetting the amplifier's internal noise contribution. This principle is captured by the Friis formula (or Friis equation), which defines the relationship between gain and noise in cascaded systems.

In practical terms, a high-gain low-noise amplifier (LNA) at the front end of a system, such as one positioned directly at the antenna, minimizes the impact of noisier downstream stages. For this reason, the cleanest and lowest-noise LNAs are typically located as close to the antenna as possible.