Let's review what we have discovered! The noise power at the output of a receiver (i.e., the input of the demodulator) is:

\[ P_n^{\text{out}} = F_{Rx} G_{Rx} k T_o B_{IF} \]

while the signal power at the receiver output is:

\[ P_s^{\text{out}} = G_{Rx} P_{s}^{\text{in}} \]

Thus, the SNR at the receiver output (the detector input) is:

\[
\begin{align*}
    \text{SNR}_{RX}^{\text{out}} &= \frac{P_{s}^{\text{out}}}{P_n^{\text{out}}} \\
    &= \frac{G_{Rx} P_{s}^{\text{in}}}{F_{Rx} G_{Rx} k T_o B_{IF}} \\
    &= \frac{P_{s}^{\text{in}}}{F_{Rx} k T_o B_{IF}} = \text{SNR}_{D}^{\text{in}}
\end{align*}
\]
Q: OK, so the expression above provides a method for determining the value of $\text{SNR}^\text{out}_{\text{Rx}}$; but what should this value be? What value is considered to be sufficiently large for accurate signal detection/demodulation?

A: It depends! It depends on modulation type, demodulator design, and system accuracy requirements.

From all these considerations we can determine the minimum required $\text{SNR}$ (i.e., $\text{SNR}^\text{min}_D$)—a value that must be exceeded at the detector/demodulator input in order for an sufficiently accurate demodulation to occur. I.E.,

$$\text{SNR}^\text{out}_{\text{Rx}} > \text{SNR}^\text{min}_D$$

for accurate demodulation

The value of this minimum $\text{SNR}$ can be as small as -20 dB (or even lower), or as large as 40 dB (or even greater), depending on the application and its requirements.

Q: How can we insure that $\text{SNR}^\text{out}_{\text{Rx}} > \text{SNR}^\text{min}_D$?

A: Of course, we do need to make the noise figure of the receiver as small as possible. However, the value $\text{SNR}^\text{out}_{\text{Rx}}$ ultimately depends on the signal power $P^\text{in}_s$—if this signal power drops toward zero, so too will $\text{SNR}^\text{out}_{\text{Rx}}$!

Thus, the requirement $\text{SNR}^\text{min}_D$ ultimately translates into a minimum signal power—any signal above this minimum can be accurately detected, but signal power below this value cannot.
We call this minimum input signal power the **Minimum Detectable Signal (MDS)**—a.k.a the Minimum Discernable Signal. I.E.,

\[
P_s^{in} > MDS \quad \text{for accurate demodulation}
\]

This Minimum Discernable Signal thus determines the **sensitivity** of the receiver.

**Q:** What is the value of MDS? How can we determine it?

**A:** We know that for **sufficiently** accurate demodulation:

\[
SNR_{Rx}^{out} = \frac{P_s^{in}}{F_{Rx} kT_0 B_{IF}} > SNR_D^{min}
\]

Thus:

\[
P_s^{in} > F_{Rx} kT_0 B_{IF} SNR_D^{min}
\]

And so it is evident that:

\[
MDS = F_{Rx} kT_0 B_{IF} SNR_D^{min}
\]
Radio engineers often express MDS as dBm! The above expression can be written logarithmically as:

\[
\text{MDS (dBm)} = 10 \log_{10} \left[ \frac{F_R \cdot kT_o \cdot B_{IF}}{1 \text{mW}} \cdot \frac{\text{SNR}_D^{\text{min}}}{\text{1 Hz}} \right]
\]

\[
= 10 \log_{10} \left[ \frac{F_R \cdot kT_o \cdot B_{IF}}{1 \text{mW}} \cdot \frac{\text{SNR}_D^{\text{min}}}{\text{1 Hz}} \right]
\]

\[
= 10 \log_{10} \left[ F_R + 10 \log_{10} \left( kT_o \cdot \frac{1 \text{ Hz}}{1 \text{ mW}} \right) \right]
\]

\[
+ 10 \log_{10} \left( \frac{B_{IF}}{1 \text{ Hz}} \right) + 10 \log_{10} \text{SNR}_D^{\text{min}}
\]

Recall that we earlier determined that:

\[
10 \log_{10} \left[ kT_o \cdot \frac{1 \text{ Hz}}{1 \text{ mW}} \right] = -174
\]

And so the sensitivity of a receiver can be determined as:

\[
\text{MDS (dBm)} = -174 + F_R \text{ (dB)} + \text{SNR}_D^{\text{min}} \text{ (dB)} + 10 \log_{10} \left( \frac{B_{IF}}{1 \text{ Hz}} \right)
\]
Now, let’s do an example!

Say a receiver has a noise figure of 4.0 dB and an IF bandwidth of 500 kHz. The detector at the receiver output requires an SNR of 3.0 dB. What is the sensitivity of this receiver?

\[
MDS (dBm) = -174 + F_{R_s} (dB) + SNR_D^{min} (dB) + 10 \log_{10} \left( \frac{B_{IF}}{1Hz} \right)
\]

\[
= -174 + 4.0 + 3.0 + 10 \log_{10} \left( \frac{5 \times 10^3}{1Hz} \right)
\]

\[
= -174 + 4.0 + 3.0 + 57.0
\]

\[
= -110.0
\]

Q: Yikes! The value -110 dBm is 10 femto-Watts! Just one percent of one billionth of one milli-Watt! Could this receiver actually detect/demodulate a signal whose power is this fantastically small?
**A:** You bet! The values used in this example are fairly **typical**, and thus an MDS of -110 dBm is **hardly unusual**.

It’s a **good** thing too, as the signals delivered to the receiver by the antenna are **frequently** this tiny!