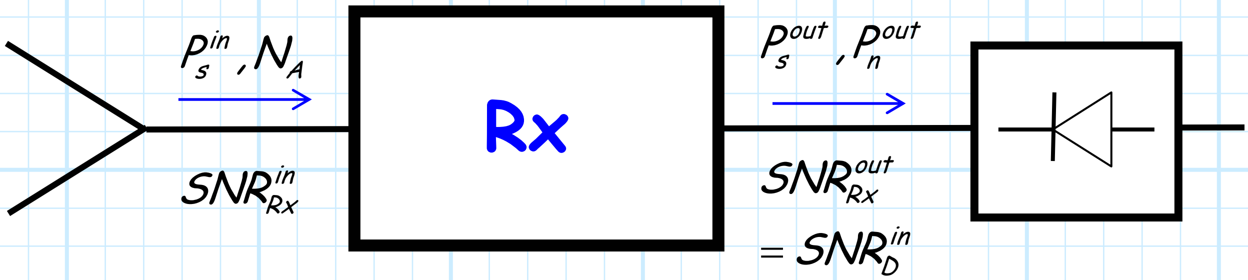
Minimum Detectable Signal



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

$$P_n^{out} = F_{Rx}\, G_{Rx}\, kT_o\, B_{IF}$$

while the **signal power** at the receiver **output** is:

$$P_s^{out} = G_{Rx}\, P_s^{in}$$

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

$$\begin{aligned} SNR_{Rx}^{out} &= \frac{P_s^{out}}{P_n^{out}} \\ &= \frac{G_{Rx}\, P_s^{in}}{F_{Rx}\, G_{Rx}\, kT_o\, B_{IF}} \\ &= \frac{P_s^{in}}{F_{Rx}\, kT_o\, B_{IF}} = SNR_D^{in} \end{aligned}$$

Q: *OK, so the expression above provides a method for determining the value of SNR_{Rx}^{out}; 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 *SNR*** (i.e., SNR_D^{min})—a value that **must** be exceeded at the detector/demodulator input in order for an **sufficiently accurate** demodulation to occur. I.E.,

$$SNR_{Rx}^{out} > SNR_D^{min} \qquad \text{for accurate demodulation}$$

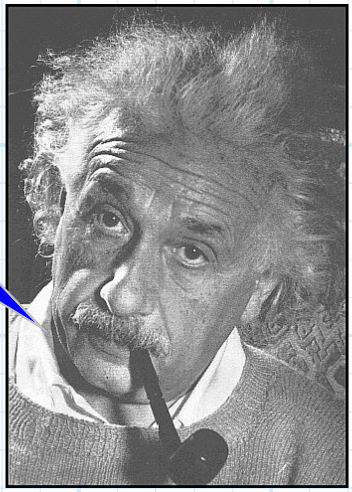
The value of this minimum SNR can be as small as -20 dB (or even lower), or as large as 40 dB (or even greater), depending on the application and its requirements.

Q: *How can we insure that* $SNR_{Rx}^{out} > SNR_D^{min}$ *??*

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

Thus, the requirement SNR_D^{min} ultimately translates into a **minimum signal power**—any signal above this minimum can be accurately detected, but signal power **below** this value **cannot**.

*Makes sense! If the input signal power is too small, it will be **"buried"** by the receiver noise.*



We call this minimum input signal power the **Minimum Detectable Signal** (MDS)—a.k.a the Minimum Discernable Signal. I.E.,

$$P_s^{in} > MDS \qquad \text{for accurate demodulation}$$

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:

$$SNR_{R_x}^{out} = \frac{P_s^{in}}{F_{R_x}\, kT_o\, B_{IF}} > SNR_D^{min}$$

Thus:

$$P_s^{in} > F_{R_x}\, kT_o\, B_{IF}\, SNR_D^{min}$$

And so it is evident that:

$$MDS = F_{R_x}\, kT_o\, B_{IF}\, SNR_D^{min}$$

Radio engineers often express MDS as **dBm**! The above expression can written **logarithmically** as:

$$MDS(dBm) = 10\,log_{10}\left[\frac{F_{R_x}\,kT_o\,B_{IF}\,SNR_D^{min}}{1\,mW}\right]$$

$$= 10\,log_{10}\left[\frac{F_{R_x}\,kT_o\,B_{IF}\,SNR_D^{min}}{1\,mW}\,\frac{1\,Hz}{1\,Hz}\right]$$

$$= 10\,log_{10}\,F_{R_x} + 10\,log_{10}\left[kT_o\,\frac{1\,Hz}{1\,mW}\right]$$

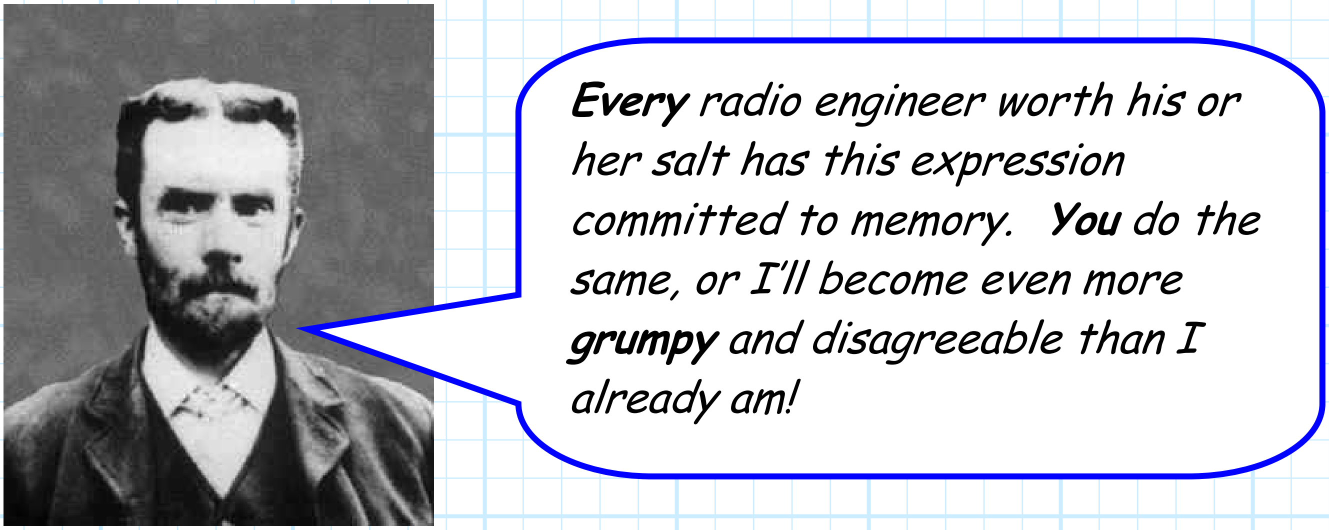
$$+10\,log_{10}\left[\frac{B_{IF}}{1\,Hz}\right] + 10\,log_{10}\,SNR_D^{min}$$

Recall that we earlier determined that :

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

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

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



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?

$$
\begin{aligned}
MDS(dBm) &= -174 + F_{R_x}(dB) + SNR_D^{min}(dB) + 10\log_{10}\left[\frac{B_{IF}}{1\,Hz}\right] \\
&= -174 + 4.0 + 3.0 + 10\log_{10}\left[5\times 10^{3}\right] \\
&= -174 + 4.0 + 3.0 + 57.0 \\
&= -110.0
\end{aligned}
$$

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!