What Do We Mean By Minimum Detectable Signal?

This sounds like an obvious question, but in fact there is more to this than you might have imagined. First, a little review of quantum physics. The fundamental factor limiting the minimum detectable signal is Boltzmann's Constant, which is 1.3807×10^{-23} Joules/K. In other words, at absolute zero there is an energy of 1.3807×10^{-23} Joules.

Now, Joules per second is a power, watts, so, we can also say that this is the power every second. We would really like to deal in familiar units, so we can turn this into dBW by saying:

$$Np = 10 \times \log_{10}(1.3807\times10^{-23})$$

and this is −228.6dBW, or −198.6dBm/Hz/K.

In other words, for every degree K, and for every Hz of bandwidth, there will be a noise power increment of −198.6dBm.

Now we usually operate our receivers at room temperature, which is typically 20°C. This is also 293°K, so, to account for the room temperature noise contribution we have to add this noise power, which is:

$$10 \times \log_{10}(293) = 24.4\text{dB}.$$

Thus, in every Hz of bandwidth at room temperature there is a fundamental noise power of −198.6 + 24.4 = −174.2dBm.

So, what about bandwidth? Well, if we are using a good SSB filter with a 6dB B/W of, say, 2.4kHz that too will increase the received noise power. What we really need to know is not the 6dB B/W but the effective noise bandwidth, which is wider.

Let's say, for the sake of argument, that the shape factor is 1.5:1 then the effective noise bandwidth is roughly 3kHz. This would add:

$$10 \times \log_{10}(3000) = 34.8\text{dB},$$

so the noise power would then be −174.2 + 34.8 = −139.5dBm, again, in round figures let's call this −140dBm.

OK, what this means is that in a perfect receiver – note, a perfect receiver – the minimum detectable signal cannot be lower than −140dBm as this is the intrinsic noise floor.

In practice of course every receiver has a noise figure, and this can be anything from about 3dB to 15dB depending upon its design. With modern low-noise FETs and low-noise local oscillators the figure might well be about 6dB or so. Thus the noise floor of such a receiver would be about −134dBm.

Right, at this point let's see what typical receivers manage. The FT-450D is specified to have a sensitivity of 0.25uV in a 2.4kHz bandwidth. Assuming that the input impedance is 50 ohms, this corresponds to an input power of:

$0.25 \times 10^{-6} \times 0.25 \times 10^{-6} / 50 = 1.25 \times 10^{-12}$ mW or −119dBm.

This specification also states that the signal to noise ratio is 10dB. In this case that means the noise floor is at −119 − 10 = −129dBm. This suggests that the FT-450D has a noise figure of 11dB. (−140 − −129 = 11dB)

What about the Icom IC-756 Pro III? This transceiver is specified to have a sensitivity of 0.16uV for 10dB S/N in a 2.4kHz B/W. This equates to an input power of:

$0.16 \times 10^{-6} \times 0.16 \times 10^{-6} / 50 = 5.12 \times 10^{-13}$mW or −123dBm.

As the output S/N ratio is specified as 10dB, this suggests that the Icom 756 Pro-III has a noise figure of 7dB.

What about the Elecraft KX3? Here Elecraft are being somewhat cagey about their specs. They suggest that the minimum detectable signal in a 500Hz B/W is about −138dBm but they do not specify what the output S/N ratio is.

Well, in order to use the same bandwidth, we have to add $10\log_{10}(3000 / 500)$ = 8dB, so the minimum detectable signal in a 3kHz noise B/W would be −138 + 8 = −130dBm suggesting that the noise figure is about 10dB.

What about the JRC NRD-525? The manufacturers have given a specification of 0.5uV for 10dB S/N ratio using the INTERMEDIATE filter which has a 3:1 shape factor.

In this case the noise bandwidth is wider, and would be roughly 5kHz. We will therefore have to subtract $10 \times \log_{10}(5 / 3)$ dB or 2.2dB because the bandwidth is wider.

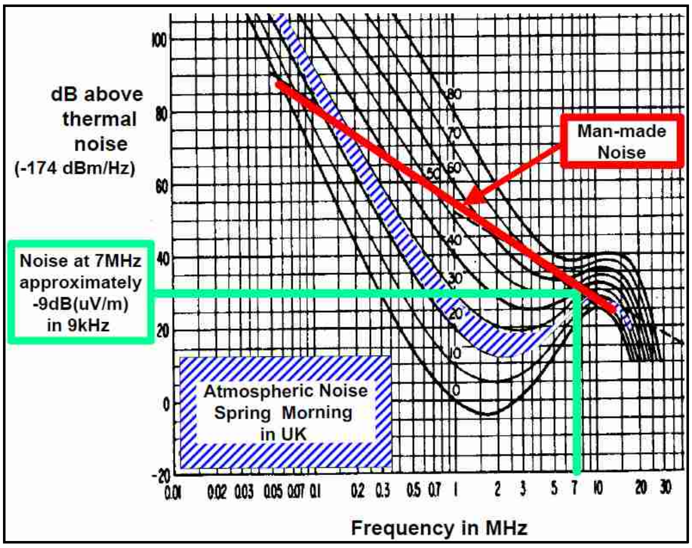
The input power is therefore $0.5 \times 10^{-6} \times 0.5 \times 10^{-6} / 50$ = −113dBm for a 10dB S/N ratio. In the same noise bandwidth as the other receivers the power would be about −115dBm, suggesting that the noise figure is about 15dB.

We can see therefore how receivers have improved in the last 20 years or so.

Now for the Elad FDM-DUO. Well, in this case the manufacturer's have not given any specification! So, I'm going to have to try it out for myself.

Now, how do these sensitivity figures relate to actual use? The actual noise limit for HF receivers between about 1.5MHz and 15MHz is determined by atmospheric noise pickup rather than receiver noise figure or sensitivity.

The following graph shows the atmospheric noise level versus frequency above thermal background (−174dBm) for various bandwidth related in dB. For example, a 1kHz bandwidth is the 30 curve, meaning 30dB.



From this you can see that actually man-made noise dominates, and so absolute sensitivity is not particularly important for frequencies below about 15MHz – 20MHz.

For the higher HF bands, and for 6m however then absolute sensitivity and more importantly receiver noise figure are the determining factors.

This of course implies the use of a wide-band antenna system such as a dipole or vertical. If you are using a magnetic loop antenna then this changes everything.

These antennas respond primarily to the H vector rather than the E vector as do dipoles and verticals, and as most man-made noise tends to have a large E vector then these loop antennas inherently do not respond well and thus the noise is rejected.

Equally, as they have a very high ‘Q’ their effective bandwidth is very narrow, roughly 0.2% and thus they also reject large amounts of atmospheric noise, which is why they sound so quiet. Thus, a good receiver having a really low MDS coupled to a loop antenna would out-perform many a beam or dipole connected system.

OK, probably more than you ever wanted to know about Minimum Detectable Signal specs.

73, Adrian, 5B4AIY