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Signal level and S-Meter

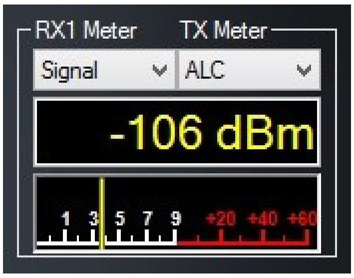
Every radio amateur knows them, the units of measurement "dB" or "dBm", otherwise he would have survived the technical part of the amateur radio test only with a lot of luck.

On shortwave, S9 is defined as the input voltage 50µV at 50Ohm, which corresponds to the level -73dBm (for ultra shortwave one refers to −93dBm or 5µV).

The present program establishes the connection between S-Meter display and voltage levels at the receiver input and thus saves cumbersome calculations.

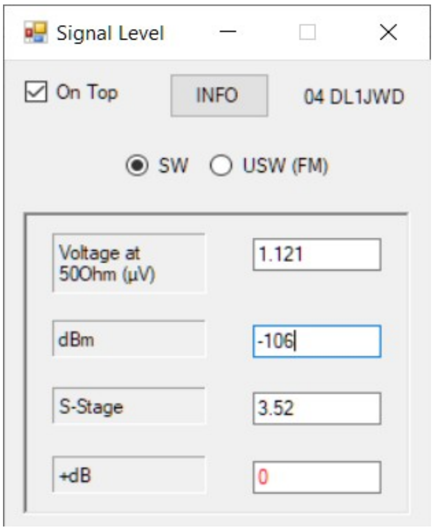
Example 1:

The S-Meter display of my SDR transceiver Flex-1500 shows me the following:



What is the voltage at the receiver input?

The program gives the answer: 1.12µV
Whether you enter the dBm value or the value of the S-meter, the voltage is updated instantly:

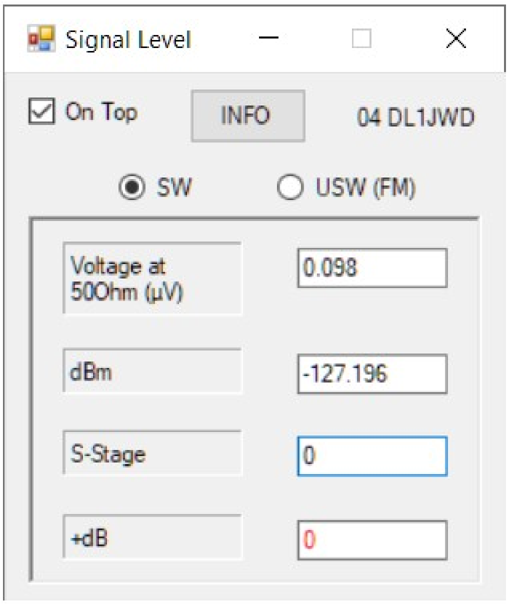


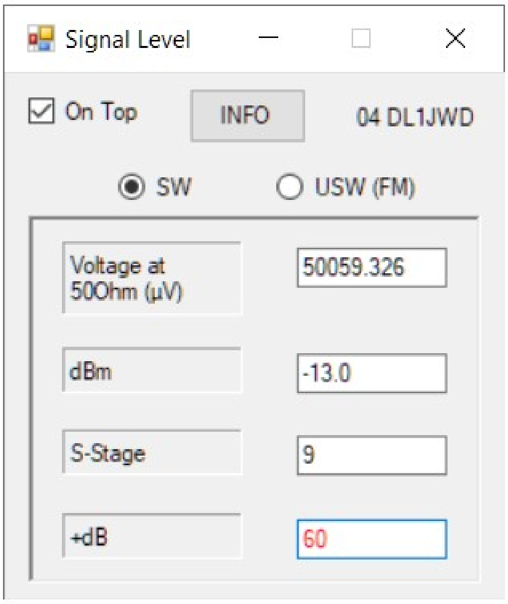
Example 2:

From the scale of my S-meter I can read values between S0 and S9+60dB.
It shows the change in signal strength in 6dBm steps. These 6dBm are exactly one S-stage.

What display range does my S-Meter offer me for the input voltage of the receiver?

You have to enter for both extrem cases the values for S-Stage and +dB:





In the left picture you see, that an S-value of 0 corresponds to a measly signal of approx. 0.1µV (-127dBm).
The right picture shows, that an S-value of 9 + 60dB corresponds to a very strong signal of approx. 50 mV (-13dBm).
With my S-Meter, I can therefore see at a glance the huge range of 0.1µV to 50mV.
Now you understand, if the S-Meter were replaced by a normal voltage meter, this would not be possible without many range switchings.

The entire dynamic range of the display is therefore 127 - 13 = 114dB, this value can be reached after some thought even if you calculate 6 * 9 + 60.

Example 3:

The picture shows a section of the panorama display of my Flex-1500 (80m band, CW):

What is the SNR (signal noise relationship) of the marked signal?

I read: the noise or interference carpet is about -110dBm, the useful signal about -85dBm.
The signal-to-noise ratio (SNR) is the difference and is therefore

SNR = -85 - (-110) = 25dB,
or 25 / 6 = approx. 4 S-stages.

The report "you come in here with S4 over the noise" is thus the result of simple mental arithmetic (division by 6).

Unfortunately, many OMs give a report that only refers to the S-Meter display for the useful signal, which in our above example would be the value S = 7 for -85dBm, which is simply wrong and becomes more and more wrong when the noise level approaches the order of magnitude of the useful signal.

The program calculates the corresponding values for useful and noise voltage (based on 50Ohm):

U_{noise} = 0.71µV and U_{sig} = 12.51µV

Theory

What exactly is meant by dB?
It is the decadal logarithm of the ratio of two physical quantities multiplied by a factor of 10.
In communications engineering, this is the ratio of a power P to a reference power Po:

$$a[dB] = 10\,lg\left(\frac{P}{P_o}\right)$$

The so-called signal-to-noise ratio can be defined as the ratio of a useful to an interference or noise power:

$$dst[dB] = 10\,lg\left(\frac{P_{nutz}}{P_{stör}}\right)$$

Why do you logarithmic the P_{sig}/P_{noise} ratio?
For many other physical quantities, as well as for the power levels at the receiver input, the value ranges extend over several orders of magnitude.
The indication as a logarithmic ratio allows a clear comparison of very small with very large values.
For example, instead of saying "the useful power is 1000 times greater than the noise power", it is better to say "the signal-to-noise ratio is 30dB".

What does dBm mean?
Because a fixed value of 1mW is set for the reference power Po, the unit of measurement is dBm.
A signal power of 1mW at a 50Ohm receiver input then corresponds to a voltage of

$$U = \sqrt{P_o * 50} \;=\; 0{,}2236\,V \;=\; 223{,}6\,mV$$

It should be clear that such a high input voltage hardly occurs in receiver practice, the radio amateurs have therefore introduced the S-system for signal strength.

On shortwave, S9 is defined as the input voltage 50µV at 50Ohm, which corresponds to the level -73dBm based on 1mW:

$$a[dBm] = 10\,lg\left(\frac{50\,\mu V^2/50\,Ohm}{1\,mW}\right) \;=\; -73\,dBm$$

For ultra shortwave (FM), this refers to −93 dBm or 5 microvolts.

What is the relationship between the input voltage and the S-Meter display?
One step on the S-meter corresponds to a level difference of 6dB, which corresponds to a halving or doubling of the input voltage (or quartering or quadrupling of the input power):

$$U_S[\mu V] = \frac{50}{2^{9-S}}$$

By changing the above equation, the signal report S is obtained as a function of the input voltage:

$$S = 9 - \frac{lg\left(\frac{50}{U_S[\mu V]}\right)}{\log 2} = 9 - 3{,}32 * lg\left(\frac{50}{U_S[\mu V]}\right)$$

Values above S9 are specified additively. For example, −53 dBm on shortwave is rendered as S9 + 20 dB.

How to determine the SNR?
Decisive for the readability of a signal is not its absolute level, but the relationship to the interference level.
Simplified (assuming appropriate narrowband size), the signal-to-noise relationship of a useful signal to an interfering signal results from the difference of the corresponding dBm values:

$$SNR[dB] = dBm_{U_{nutz}} - dBm_{U_{stör}}$$

Since a level difference of 6dB corresponds to one S-stage, the SNR can also be expressed as an "S-value over noise":

$$SNR[S] = \frac{dBm_{U_{nutz}} - dBm_{U_{stör}}}{6}$$