

AMATEUR HOUR with VK4PQ

Hi, VK4PQ Peter in Townsville, this time we look at the signal report you read from the S Meter on your HF Transceiver and give to a dx contact on SSB, 59 +10 dB for example.

I will try and explain the signal report with respect to the antenna input of your transceiver, and derive what **V**oltage and **P**ower levels you could measure at this point, by using **dB** , **dBm** and I will try and show you their relationship along the way.

*I will not be explaining the RST (**R**eadability, **S**ignal strength and **T**one) reporting methodology, I expect you to know this.*



Most signal strength meters will look similar to this.

IARU Standards:

On an RF scale, the voltage that corresponds to an **S9** signal depends on the frequency range:

- For frequencies **below 30 MHz (HF bands)**, **S9** is defined as **50 microvolts (μV)** at the receiver antenna input, into a 50 ohm impedance.
- For frequencies **above 30 MHz (VHF/UHF bands)**, **S9** is defined as **5 microvolts (μV)** into 50 ohms.

The International Amateur Radio Union (IARU) Region 1 standardized these values in a 1981 recommendation. In terms of power, **S9** is equivalent to **-73 dBm** on HF and **-93 dBm** on VHF/UHF.

Note: Each **S** unit is equal to **6dB** which gives a **x2 voltage ratio**. EG: $S_8 = 25 \mu\text{V}$, $S_9 = 50 \mu\text{V}$.

It is worth noting that S-meters on commercial amateur radio equipment are often not precisely calibrated to this standard and may vary from one manufacturer or band to another.

Understanding dB, dBm, and Voltage in the RF Spectrum - Simplified Explanation

What is a Decibel (dB) ?

A decibel (dB) is a way to compare two power levels. It tells you how much bigger or smaller one signal is compared to another. In radio, it's used to show increases or decreases in signal strength.

What is dBm ?

dBm measures the actual power of a signal, compared to 1 milliwatt (mW). If a signal is 0 dBm, it means it's exactly 1 mW. If it's -10 dBm, it's less than 1 mW; if it's +10 dBm, it's more than 1 mW.

Worked example.

Now let's work the HF signal report example of S9 +10 dB and determine what that means in real voltage and power terms at our receiver's antenna input with an input impedance of 50 ohms.

IARU For HF, S9 = 50μV

A 10 dB gain is going to be more than twice the voltage of an S9 signal (50 μV) because remember a 6 dB increase is twice the voltage ratio so we will be expecting over 100 μV in our answer.

Let's work out the ratio increase of 10 dB.

- Every 6 dB = x2 in voltage

Calculation: Calculate the multiplication ratio.

$$\text{Multiplier} = 2^{\left(\frac{dB}{6dB \text{ steps}}\right)} = 2^{\left(\frac{10}{6}\right)} = 2^{1.66} = \mathbf{3.16}$$

Calculation: Calculate the voltage seen at the input of the transceiver.

$$S9 + 10dB = 50\mu V \times 3.16 = \mathbf{158\mu V}$$

Summary:

So, an S9 +10 dB signal corresponds roughly to 158μV at the receiver input, which 3.16 times that of an S9 (50μV) signal.

Let's do a dBm calculation and confirm that voltage, by converting the dBm values to μV.

IARU standard for HF, S9 = -73 dBm

Calculation: Calculate total dBm

$$S9 + 10dB = -73 + 10 = \mathbf{-63dBm}$$

Next we need to convert -63 dBm to mW, then to Watts.

$$\text{Formula: } P_{mW} = 10^{\left(\frac{dB}{10}\right)}$$

Calculation: Calculate Watts

$$P_{mW} = 10^{\left(\frac{dBm}{10}\right)} = 10^{\left(\frac{-63}{10}\right)} = 5.01 \times 10^{-7} \mathbf{mW}$$

$$\text{Convert to Watts } P_W = 5.01 \times 10^{-7} \times 10^{-3} = 5.01 \times 10^{-10} \mathbf{W}$$

$$\text{Formula: } P = \frac{V^2}{R}$$

Calculation: Calculate and confirm the above voltage result.

$$V_{rms} = \sqrt{P \times R} = \sqrt{5.01 \times 10^{-10} \times 50} = 1.58 \times 10^{-4} \mathbf{V}$$

Which gives, $V_{rms} = 158 \mu V$, this proves the above calculation and table below is correct.

Formula and reference data.

Formula: for power ratios $dB = 10 \log_{10} \left(\frac{P_2}{P_1} \right)$ $Antilog \left(\frac{P_2}{P_1} \right) = 10^{\left(\frac{dB}{10} \right)}$

This equation is used to calculate the ratio of two power levels (P_2 and P_1) in decibels (dB). Decibels are a logarithmic unit that expresses the relative difference between two quantities, commonly used in electronics, acoustics, and communications.

Formula: for voltage ratios $dB = 20 \log_{10} \left(\frac{V_2}{V_1} \right)$ $Antilog \left(\frac{V_2}{V_1} \right) = 10^{\left(\frac{dB}{10} \right)}$

This equation calculates the ratio of two voltage levels (V_2 and V_1) in decibels (dB). The factor of 20 is used instead of 10 because power in a resistive circuit is proportional to the square of the voltage ($P \propto V^2$), so the logarithmic relationship doubles.

Formula: for power to dBm $P_{dBm} = 10 \log_{10} \left(\frac{P}{1mW} \right)$ $Antilog P_{mW} = 10^{\left(\frac{P_{dBm}}{10} \right)}$

This equation is used to express a power level, P , in decibels relative to 1 milliwatt (mW). The unit "dBm" stands for "decibels relative to one milliwatt." System impedance 50 Ohms.

Table: Comparison of S1 to S9+n dB signals, showing the voltage and power at the input of a transceiver with a 50ohm antenna input impedance.

Level	ΔdB relative to S9	Voltage (μV rms)	Power (dBm)
S1	-48 dB	0.195 μV	-121 dBm
S2	-42 dB	0.39 μV	-115 dBm
S3	-36 dB	0.78 μV	-109 dBm
S4	-30 dB	1.56 μV	-103 dBm
S5	-24 dB	3.13 μV	-97 dBm
S6	-18 dB	6.25 μV	-91 dBm
S7	-12 dB	12.5 μV	-85 dBm
S8	-6 dB	25 μV	-79 dBm
S9	0 dB	50 μV	-73 dBm
S9 +10	+10	158 μV	-63 dBm
S9 +20	+20	500 μV	-53 dBm
S9 +30	+30	1.58 mW	-43 dBm
S9 +40	+40	5 mV	-33 dBm

Note: Mathematics has given us the permission to add two different units of measure together dB + dBm we can do this because dB is just a ratio.

Final Word.

You may well ask , **WHY** did you do this article and what is it all about.

Great question , well I was listening to a tech net on the air the other day and a question came from a relatively new HAM (2+ years) who was logged into the net and he explained, that when he was a new ham and he asked the question “can someone please explain to me what dB and dBm means and their relationship”, he went on to say that he had never had anyone volunteer an answer, and he was still asking this same question, on this net, silence, nothing from the net.

Well I thought I would have a go at explaining what dB and dBm is. This will be easy I thought, so what you see above is an attempt to show the relationship between dB and dBm with respect to an Amateur Radio Transceiver S-Meter readings.

You can see from the above workings as to why it would be a little hard and messy trying to answer that question on air, it took a while to actually put it all together too I might add.

In the early days of amateur radio, transceivers were mostly constructed by hams and the receiver antenna input be it either 50 ohms or 600 ohms may have had a voltmeter to measure the incoming signal, and it would read Volts. The above article uses 50 ohms as a standard input impedance reference.

The humble S-Meter didn't appear until around 1930(*Wikipedia*).

Caveat: This is written by a Ham for Hams and is my research, findings and interpretation, any errors or omissions passed back to me would be greatly received and appreciated.

So if an old timer gives you a signal report of R5 and S -6.25 μ V, what is your signal strength ?? , you give him a report back, “thanks for the R5 S6, your report is R5 S9 (*read from your receivers S-Meter, and also add*), your old boat anchor is working nicely OM”.

Best 73's de VK4PQ Peter @ Townsville Nth Queensland.