Decibel & S-meter

dBm as a power level

dBm (sometimes dBmW or decibel-milliwatts) is unit of level used to indicate that a power ratio is expressed in decibels (dB) with reference to one milliwatt (mW). It is used in radio, microwave and fiber-optical communication networks as a convenient measure of absolute power because of its capability to express both very large and very small values in a short form compared to dBW, which is referenced to one watt (1,000 mW).

Since it is referenced to the watt, it is an absolute unit, used when measuring absolute power. By comparison, the decibel (dB) is a dimensionless unit, used for quantifying the ratio between two values, such as signal-to-noise ratio. The dBm is also dimensionless but since it compares to a fixed reference value the dBm rating is an absolute one.

A power level of 0 dBm corresponds to a power of 1 milliwatt. A 10 dB increase in level is equivalent to a 10-fold increase in power. A 3 dB increase in level is approximately equivalent to doubling the power, which means that a level of 3 dBm corresponds roughly to a power of 2 mW. Similarly, for each 3 dB decrease in level, the power is reduced by about one half, making −3 dBm correspond to a power of about 0.5 mW.

dBm as a power level		
dBm	**P out**	**Typical for**
60	1kW	typical radiated RF power of a microwave oven
50	100W	typical maximum output RF power from a ham radio HF transceiver
40	10W	
37	5W	typical maximum output RF power from a handheld ham radio VHF/UHF transceiver
33	2W	maximum output from a GSM 850/900 mobile phone
30	1W	DCS or GSM 1 800/1 900 MHz mobile phone
20	100mW	EIRP for a IEEE 802.11b/g 20 MHz-wide channel in the 2.4 GHz ISM band (5 mW/MHz)
10	10mW	
0	1mW	Bluetooth class 3 radio with 1 m range
-10	100µW	IEEE 802.11 maximal signal strength
-60	1nW	power received per m2 of a magnitude +3.5 star
-73	50pW	S9 signal strength on S-meter
-100	100fW	IEEE 802.11b/g minimal signal strength
-101	83fW	noise floor of a IEEE 802.11b/g 20 MHz channel at 300 K
-134	41aW	noise floor of a 10 kHz wide FM signal at 300 K
-140	12aW	noise floor of a 2.7 kHz wide SSB signal at 300 K

HF S-meter

Many amateur radio and shortwave broadcast receivers feature a signal strength meter (S-meter). In 1981, the International Amateur Radio Union (IARU) Region 1 agreed on a technical recommendation for S-meter calibration of HF and VHF/UHF transceivers.

IARU Region 1 Technical Recommendation R.1 defines S9 for the HF bands to be a receiver input power of -73 dBm. This is a level of 50 µV at the receiver's antenna input assuming the input impedance of the receiver is 50 Ω.

The recommendation defines a difference of one S-unit corresponds to a difference of 6 dB, equivalent to a voltage ratio of two, or a power ratio of four. Signals stronger than S9 are given with an additional dB rating, thus "S9 + 20 dB", or, verbally, "20 decibel over S9", or simply "20 over 9" or even the simpler "20 over".

Conversion between power and HF S-units			
S-reading	**P out @ 50Ω**	**V out @ 50Ω**	**(V out / 1µV) @ 50Ω**
S9 + 40 dB	-33 dBm	5 mV	74 dBµV
S9 + 30 dB	-43 dBm	1.6 mV	64 dBµV
S9 + 20 dB	-53 dBm	0.5 mV	54 dBµV
S9 + 10 dB	-63 dBm	0.16 mV	44 dBµV
S9	-73 dBm	50 µV	34 dBµV
S8	-79 dBm	25 µV	28 dBµV
S7	-85 dBm	12.6 µV	22 dBµV
S6	-91 dBm	6.3 µV	16 dBµV
S5	-97 dBm	3.2 µV	10 dBµV
S4	-103 dBm	1.6 µV	4 dBµV
S3	-109 dBm	800 nV	-2 dBµV
S2	-115 dBm	400 nV	-8 dBµV
S1	-121 dBm	200 nV	-14 dBµV

The noise floor for a ▯=2700 Hz wide SSB signal at ▯=300 K is −139.5dBm

VHF/UHF S-meter

The same IARU Region 1 recommendation defines S9 for VHF/UHF to be a receiver input power of -93 dBm. This is the equivalent of 5 µV in 50 Ω. Again, one S-unit corresponds to a difference of 6 dB, equivalent to a voltage ratio of two, or a power ratio of four.

Conversion between power and VHF/UHF S-units			
S-reading	**P out @ 50Ω**	**V out @ 50Ω**	**(V out / 1µV) @ 50Ω**
S9 + 40 dB	-53 dBm	0.5 mV	54 dBµV
S9 + 30 dB	-63 dBm	0.16 mV	44 dBµV
S9 + 20 dB	-73 dBm	50 µV	34 dBµV
S9 + 10 dB	-83 dBm	16 µV	24 dBµV
S9	-93 dBm	5 µV	14 dBµV
S8	-99 dBm	2.5 µV	8 dBµV
S7	-105 dBm	1.26 µV	2 dBµV
S6	-111 dBm	630 nV	-4 dBµV
S5	-117 dBm	320 nV	-10 dBµV
S4	-123 dBm	160 nV	-16 dBµV
S3	-129 dBm	80 nV	-22 dBµV
S2	-135 dBm	40 nV	-28 dBµV

Conversion between power and VHF/UHF S-units			
S-reading	**P out @ 50Ω**	**V out @ 50Ω**	**(V out / 1μV) @ 50Ω**
S1	-141 dBm	20 nV	-34 dBμV

The noise floor for a 10 kHz wide FM signal at 300 K is −134dBm

The term noise floor refers to the calculated thermal noise, also known as the Johnson–Nyquist noise.
$P = k_b*T*B$
Where $k_b = 1.3806488*10^{-23}$ J/K (Boltzmann's constant)

Johnson–Nyquist noise (thermal noise, Johnson noise, or Nyquist noise) is the electronic noise generated by the thermal agitation of the charge carriers (usually the electrons) inside an electrical conductor at equilibrium, which happens regardless of any applied voltage. Thermal noise is present in all electrical circuits, and in sensitive electronic equipment such as radio receivers can drown out weak signals, and can be the limiting factor on sensitivity of an electrical measuring instrument. Thermal noise increases with temperature. Some sensitive electronic equipment such as radio telescope receivers are cooled to cryogenic temperatures to reduce thermal noise in their circuits. The generic, statistical physical derivation of this noise is called the fluctuation-dissipation theorem, where generalized impedance or generalized susceptibility is used to characterize the medium.

Thermal noise in an ideal resistor is approximately white, meaning that the power spectral density is nearly constant throughout the frequency spectrum. When limited to a finite bandwidth, thermal noise has a nearly Gaussian amplitude distribution.

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