measuring RF: dB math

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relative concept

- decibels are a ***relative*** measurement unit unlike the *absolute* measurement of milliwatts
- the decibel (dB) is an expression of the relationship between a variable quantity and a known reference quantity
- the calculation of decibels uses a *logarithm* to allow very large or very small relations to be represented with a conveniently small number

from *dB* to *dBm*

- on the logarithmic scale, the reference cannot be zero because the log of zero does not exist!
- the reference point that relates the logarithmic decibel scale to the linear watt scale is:

1 mW = 0 dBm

- the m in dBm refers to the fact that the reference value is **1 mW** and therefore *a dBm measurement is a measurement of absolute power*

the math

- to convert power [mW] to power [dBm]:

$$\mathbf{P[dBm] = 10 \log_{10} P[mW]}$$

- to convert dBm to mW:

$$\mathbf{P[mW] = \log_{10}^{-1} (P[dBm]/10) = 10^{(P[dBm]/10)}}$$

why log?

The dB is used rather than arithmetic ratios or percentages because:

- when circuits are connected in chain, expressions of power level, in dB, may be arithmetically added and/or subtracted
- logarithmic units preserve relative errors (in contrast to linear units that preserve absolute errors)

gains and losses

- gain or loss of signal power in an RF system may be referred to by *absolute* power measurement (i.e. 1W or 30dBm of power) or by a *relative* power measurement (i.e. half of its power, or -3dB)
- gains and losses in dB are ***additive***

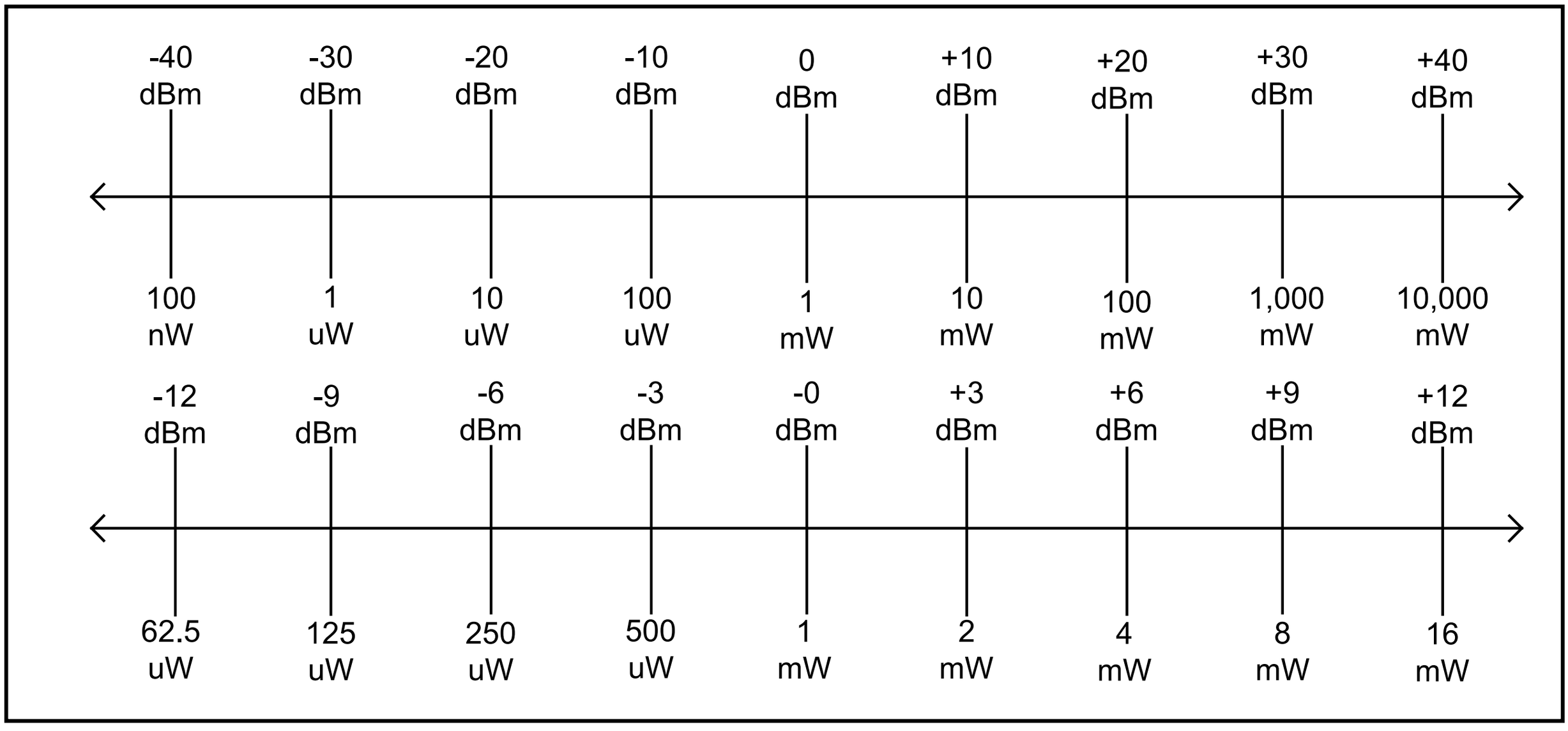
examples

- **-3dB = half** the power in mW
- **+3dB = double** the power in mW
- **-10dB = one tenth** the power in mW
- **+10dB = ten times** the power in mW

examples (2)

- 10 mW + 3 dB = 20 mW
- 100 mW - 3dB = 50 mW
- 10 mW + 10 dB = 100 mW
- 300 mW - 10 dB = 30 mW

dB math


-40 dBm
-30 dBm
-20 dBm
-10 dBm
0 dBm
+10 dBm
+20 dBm
+30 dBm
+40 dBm
100 nW
1 uW
10 uW
100 uW
1 mW
10 mW
100 mW
1,000 mW
10,000 mW
-12 dBm
-9 dBm
-6 dBm
-3 dBm
-0 dBm
+3 dBm
+6 dBm
+9 dBm
+12 dBm
62.5 uW
125 uW
250 uW
500 uW
1 mW
2 mW
4 mW
8 mW
16 mW

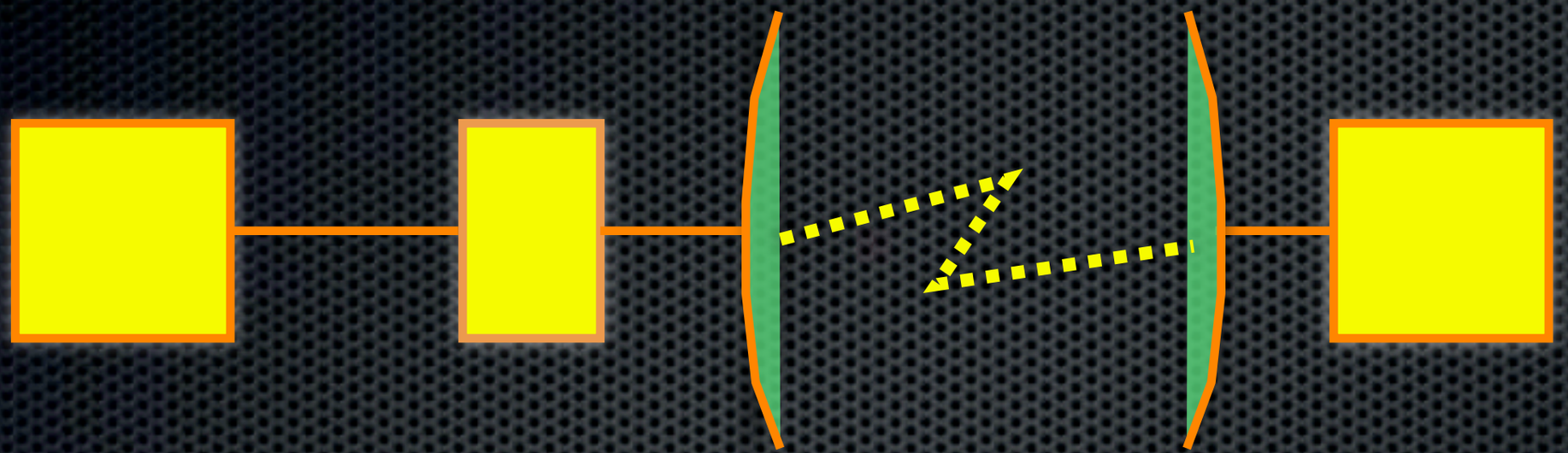
from dBm to W

- +43 dBm = ?
- +43dBm is 43dB relative to 1mW
- 43dB = 10dB + 10dB + 10dB + 10dB + 3dB
- 1 mW x 10 = 10 mW
- 10 mW x 10 x 10= 1000 mW
- 1000 mW x 10 = 10000 mW
- 10000 mW x 2 = 20000 mW = 20 W

negative doesn’t man bad ;-)

- -26 dBm = ?
- it’s 1mW (0dBm) “minus” 26dB
- -26dB = - 10dB - 10dB - 3dB - 3dB
- 1 mW / 10 = 100 µW
- 100 µW / 10 = 10 µW
- 10 µW / 2 = 5 µW
- 5 µW / 2 = 2.5 µW (it’s 2.5 x 10^{-6} W)

example: RF power budget



- Transmitter power (dBm)
- Cable loss (dB)
- Power Amplifier gain (dB)
- Cable loss (dB)
- Antenna gain (dB)
- Free Space Path loss (dB)
- Antenna gain (dB)
- Cable loss (dB)
- Result: power at receiver

origin of deciBel

- The name decibel comes from the unit “Bel” and it is in honor of Alexander Graham Bell (1847-1922), a Scottish-born teacher of the deaf and American inventor of the telephone