

## Decibels start with logarithms

- What's a logarithm (abbreviated "log")? A shorthand way to represent very small or very large numbers.
- Consider the numbers $100,1,000,10,000$ and 0.001 , and the different ways in which they can be represented:

| Number: |  |  |
| :--- | :--- | :--- |
| 100 | $=10 * 10$ | $=10^{2}$ |
| 1,000 | $=10 * 10 * 10$ | $=10^{3}$ |
| 10,000 | $=10 * 10 * 10 * 10$ | $=10^{4}$ |
| 0.001 | $=\frac{1}{(10 * 10 * 10)}$ | $=10^{-3}$ |

## Logarithms

- What do the previous numbers have in common? Each number can be represented as 10 raised to some power.
- The base 10 exponent - that is, the power to which 10 is raised - is the logarithm!



## Logarithms

- $\log _{10}(100)=2$

That is, $10^{2}=100$

- $\log _{10}(1,000)=3$

That is, $10^{3}=1,000$

- $\log _{10}(10,000)=4$

That is, $10^{4}=10,000$

- $\log _{10}(0.001)=-3$

That is, $10^{-3}=0.001$

- $\log _{10}(523)=2.7185$

That is, $10^{2.7185}=523$

## The decibel

- $d B$ is an abbreviation for decibel

Decibels express the logarithmic ratio of two power
levels:
$d B=10 \log _{10}(P 1 / P 2)$

- Here's an example of the decibel at work. Let's say you have a 50 watt stereo, and your neighbor has a 100 watt stereo. How much more power, in decibels, does your neighbor's stereo have than yours?

$$
\begin{aligned}
& \mathrm{dB}=10^{*}\left[\log _{10}(100 \text { watts/50 watts })\right] \\
& \mathrm{dB}=10^{*}\left[\log _{10}(2)\right] \\
& \mathrm{dB}=10^{*}[0.301] \\
& \mathrm{dB}=3.01 \mathrm{~dB} \text { higher power }
\end{aligned}
$$



## The decibel

- $\quad d B$ is an abbreviation for decibel

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Decibels express the logarithmic ratio of two power
levels:
dB = 10log
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- Here's another example. Assume a local FM radio station installs a new 40,000 watt transmitter to replace an old 20,000 watt transmitter. How much more powerful is the new transmitter than the old one?

$$
\begin{aligned}
& \mathrm{dB}=10^{*}\left[\log _{10}(40,000 \text { watts/20,000 watts) }]\right. \\
& \mathrm{dB}=10^{*}\left[\log _{10}(2)\right] \\
& \mathrm{dB}=10^{*}[0.301] \\
& \mathrm{dB}=3.01 \mathrm{~dB} \text { higher power }
\end{aligned}
$$



## The decibel

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Decibels express the logarithmic ratio of two power
levels:
$d B=10 \log _{10}(P 1 / P 2)$

- How can that be? In the first example, the power difference was 50 watts, and in the second example the power difference was 20,000 watts! Why does 3.01 dB apply to both examples?

The absolute difference between the two power levels isn't what matters, it's the ratio of the two power levels. In both examples the ratio is 2 (one power level is twice as much as the other).

## The decibel

- By itself, the decibel cannot be used to express absolute signal levels
- For instance, one can correctly say that an amplifier has 20 dB of gain, or a splitter has 4 dB of loss

- It's incorrect to say that the RF signal level at the input to a modem is -2 dB , or the RF signal level at a line extender output is +48 dB . For that, the decibel must be appended with a reference, such as dBmV , or decibel millivolt. The two examples here are correctly stated as -2 dBmV and +48 dBmV respectively.


## The decibel

- dBmV expresses power in terms of voltage:

0 dBmV defines the power produced when a voltage of 1 millivolt ( mV ) root mean square (rms) is applied across a defined impedance: 75 ohms in the case of the cable industry. That is, 1 mV in a 75 ohm impedance is 13.33 nanowatts ( nW ), which we call 0 dBmV .

- Other signal levels in dBmV are technically ratios of those levels' voltages to the 0 dBmV 1 mV "reference":

$$
d B m V=20 \log _{10}\left(\frac{\text { level in } \mathrm{mV}}{1 \mathrm{mV}}\right)
$$



## Correct usage of the decibel

| dB | dBmV $^{*}$ |
| :--- | :---: |
| $\checkmark$ Gain | $\checkmark$ Signal level (RF power) |
| $\checkmark$ Loss (attenuation) | X |
| $\checkmark$ Signal-to-noise ratio (SNR) | X |
| $\checkmark$ Carrier-to-noise ratio (CNR) | X |
| $\checkmark$ Modulation error ratio (MER) | X |
| $\checkmark$ Return loss | X |
| $\checkmark$ Noise power ratio (NPR) |  |
| $\checkmark$ Carrier-to-distortion ratio (e.g., <br> composite triple beat, <br> composite second order, <br> common path distortion) |  |

*Note: Other examples of absolute values include decibel microvolt ( $\mathrm{dB} \mu \mathrm{V}$ ), decibel milliwatt ( dBm ), decibel watt (dBW), decibel volt (dBV), and decibel microvolt per meter ( $\mathrm{dB} \mu \mathrm{V} / \mathrm{m}$ )

For more about the decibel, see my Broadband Library article, "The Wise and Mighty Decibel," at:
https://broadbandlibrary.com/wi se-and-mighty-decibel/

## Correct usage of the decibel

Is this statement correct? "The signal level at the modem input increased by 2 $d B m V$, going from +3 dBmV to +5 dBmV "

- This statement is incorrect! Why? Because signal levels cannot increase or decrease in increments of dBmV , only dB .
- Here's the correct statement: "The signal level at the modem input increased by $2 d B$, going from $+3 d B m V$ to $+5 d B m V$."
Here's another example:
- Assume you measure the output of an amplifier, and find that Ch. 2's signal level is 40 dBmV and Ch. 117's signal level is 48 dBmV . Is the tilt 8 dBmV or 8 dB ?
- The answer is 8 dB , because the difference between 48 dBmV and 40 dBmV is 8 dB Changes in decibel-related values are done by adding or subtracting dB , not dBmV.


