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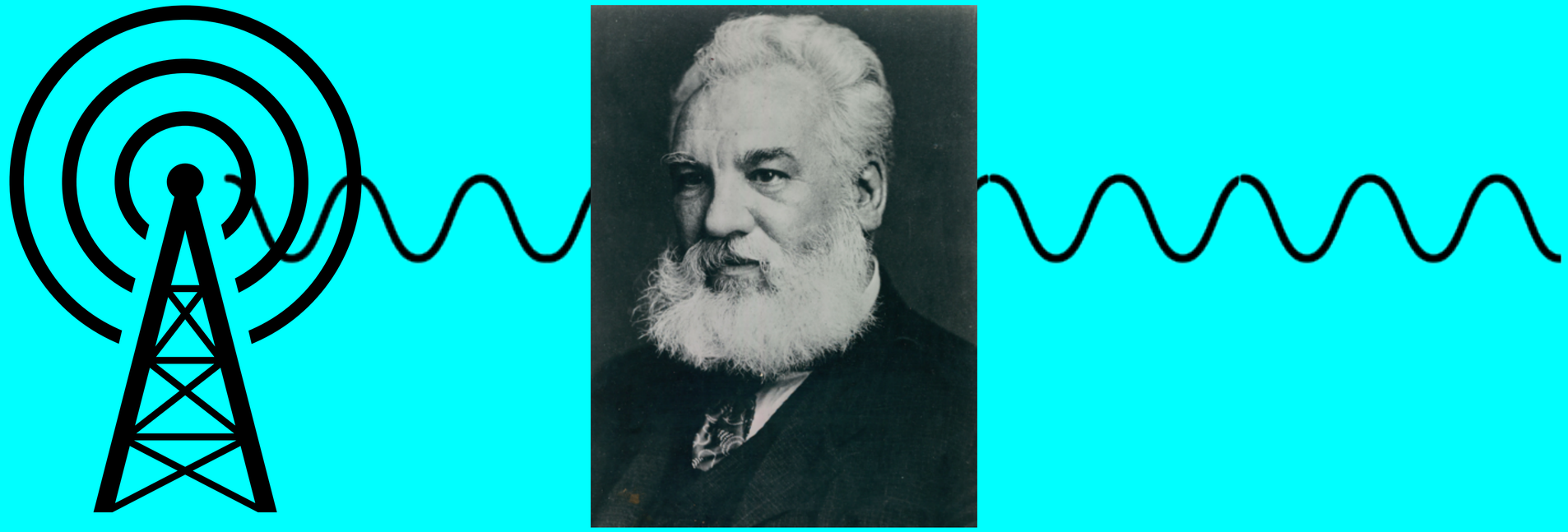
LORA / LORAWAN TUTORIAL 5

Decibel, dBm, dBi, dBd



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INTRO

- In this tutorial I will explain what the decibel is and what the purposes are of the units dBm, dBi and dBd.

DECIBEL: dB

- A deciBel (dB) is a unit of measurement used to express the ***ratio*** of powers, sound pressures or others things on a logarithmic scale. The deciBel was invented by Bell Labs and named after Alexander Graham Bell.
  In this tutorial the deciBel is used to express the ***ratio* of electrical powers** (meaning Watts).
  $A = 10 \times \log_{10}(P_o / P_i)\ dB$
  Where P_i is the input power and P_o the output power.

$$A(gain) = 10 \times \log_{10}(6/2) = 4.7\ dB$$

$$A(loss) = 10 \times \log_{10}(8/10) = -0.96\ dB$$

- Convert deciBel to power ratio: $P_o/P_i = 10^{(A/10)}$

DECIBEL: dB

- The logarithmic scale is used to avoid very big or very small numbers, meaning the ratios. Using decibels is easier to work with.

- For example:
  A power ratio of 1,000,000 (1 million) can be expressed by 60 dB.
  A power ratio of 0,000001 can be expressed by -60 dB.

- A power ratio of 1,000,000,000,000,000 (1 quadrillion) can be expressed by 150 dB.
  A power ratio of 0,000000000000001 can be expressed by -150 dB.

- A power ratio of 1,000,000,000,000,000,000,000,000 (1 septillion) can be expressed by 240 dB.
  A power ratio of 0,000000000000000000000001 can be expressed by -240 dB.

DECIBEL: dB

- Remember: The unit dB is a ratio, it does not represent an absolute value.

The only thing you know about this device is that it has a gain of 3dB.

- Question: If P_i = 1 mW. Do you know what P_o is?

- Answer:

$$P_o/P_i = 10^{(A/10)}$$

$$P_o/1 = 10^{(3/10)}$$

$$P_o = 10^{(3/10)} = 1.995 \text{ mW}$$

DECIBEL: dBm

- dB is a **ratio** it does not represent an absolute value.

- If we use a reference input power of 1mW (P_i = 1 mW) the unit is expressed as dBm.

$$A = 10 \times \log_{10}(P_o / 1) \text{ dBm}$$

$$P_o/P_i = 10^{(A/10)} \quad P = 10^{(A/10)} \text{ mW}$$

- Unit dBm represents an absolute value because it uses a fixed reference value 1mW.

Transmitter 80dBm

$$P=10^{(80/10)} = 10^8 \text{ mW} = 10^5 \text{ W} = 100 \text{ kW}$$

Transmitter 27dBm

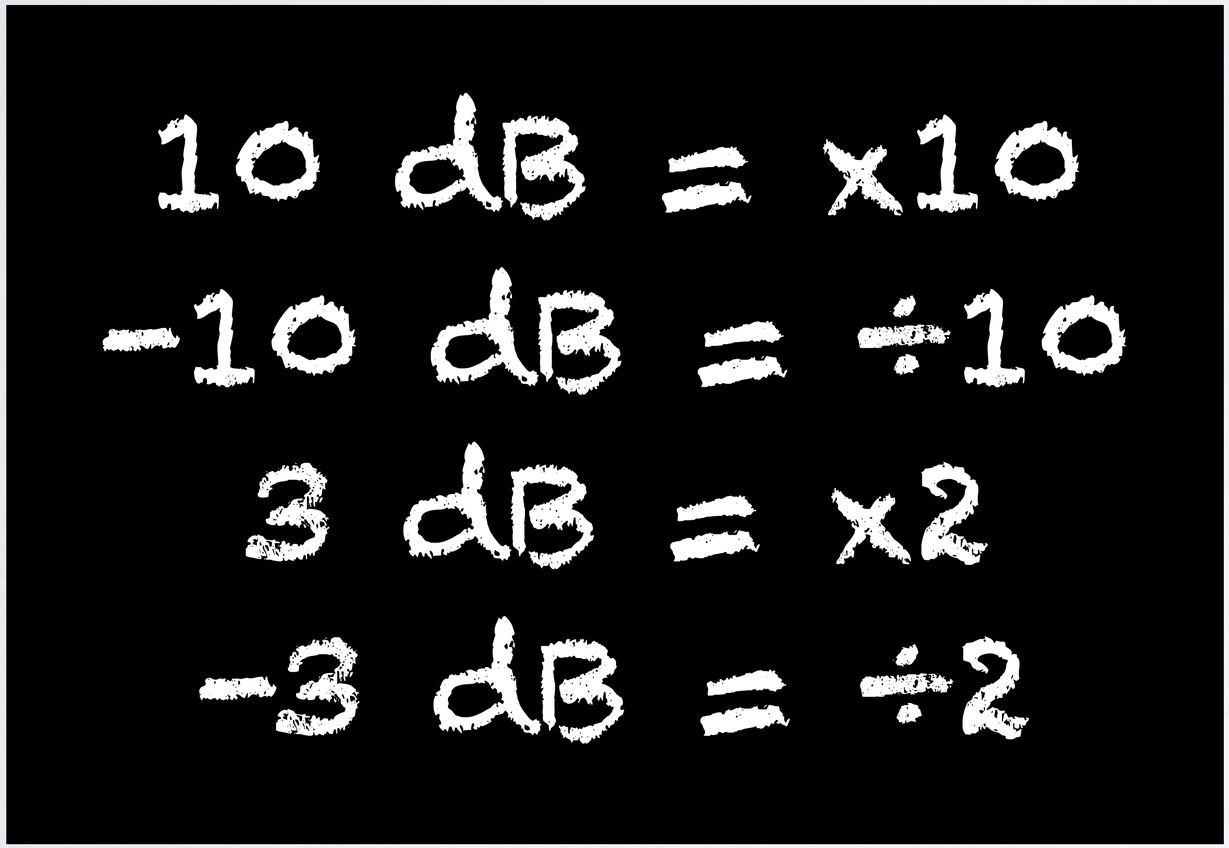
$$P=10^{(27/10)} = 501.18 \text{ mW} \approx 500 \text{ mW}$$

Receiver -73dBm

$$P=10^{(-73/10)} = 5.01 \times 10^{-8} \text{ mW} \approx 5 \times 10^{-8} \text{ mW}$$

DECIBEL: dBm

- There is an easy way to convert dBm values to its absolute power value (P_o). Remember this:



The rule of 10s and 3s

DECIBEL: dBm

dB	Power ratio (P_o/P_i)	Power ratio (P_o/P_i)
50	100000	x100000
40	10000	x10000
30	1000	x1000
20	100	x100
10	10	x10
3	**1.995 ≈ 2**	x2
1	1.259	x1.259
0	1	x1
-3	**0.501 ≈ 0.5**	÷2
-10	0.1	÷10
-20	0.01	÷100
-30	0.001	÷1000
-40	0.0001	÷10000
-50	0.00001	÷100000
-60	0.000001	÷1000000

$$A = 10 \times \log_{10}(P_o/P_i) \text{ dB}$$

$$P_o/P_i = 10^{(A/10)}$$

← watch out

← watch out

DECIBEL: dBm

- You can calculate any number by only using the values 10 and 3.

```
1 = 10 - 3 - 3 - 3
2 = 3 + 3 + 3 + 3 - 10
3 = 3
4 = 10 - 3 - 3
5 = 3 + 3 + 3 + 3 + 3 - 10
6 = 3 + 3
7 = 10 - 3
8 = 10 + 10 - 3 - 3 - 3 - 3
9 = 3 + 3 + 3
```

DECIBEL: dBm

```
10 = 10
11 = 10 + 10 - 3 - 3 - 3
12 = 3 + 3 + 3 + 3
13 = 10 + 3
14 = 10 + 10 - 3 - 3
15 = 3 + 3 + 3 + 3 + 3
16 = 10 + 3 + 3
17 = 10 + 10 - 3
18 = 10 + 10 + 10 - 3 - 3 - 3 - 3
19 = 10 + 3 + 3 + 3
20 = 10 + 10
```

DECIBEL: dBm

```
 41 = 10 + 10 + 10 + 10 + 10 - 3 - 3 - 3
-25 = -3 - 3 - 3 - 3 - 3 - 10
-28 = -10 - 10 - 10 - 10 + 3 + 3 + 3 + 3
```

- Rules:
  Only use a multiple of 10's and 3's (positive and negative) to represent a value.
  If possible avoid using 3's and never use more than five 3's!

- Incorrect:
  8 = 3 + 3 + 3 + 3 + 3 + 3 - 10
  Correct:
  8 = 10 + 10 - 3 - 3 - 3 - 3

DECIBEL: dBm

- If a transmitter has 6 dBm, how much power does it generates?
  Answer:
  P_i is always 1 mW (remember the m in dB**m**)

```
6dB = 3dB + 3dB
1mW     x2      x2
6dBm ≈ 4mW
```

10 dB = x10
-10 dB = ÷10
3 dB = x2
-3 dB = ÷2

- If a transmitter has 17 dBm, how much power does it generates?
  Answer:

```
17dB = 10dB + 10dB - 3dB
1mW     x10     x10     ÷2
17dBm ≈ 50mW
```

DECIBEL: dBm

- The receiver has a sensitivity of -138 dBm, how much power is this?
  Answer:

```
-138dB = -10 -10 -10 -10 -10 -10 -10 -10 -10 -10   (-100)
         -10 -10 -10                               (-30)
         -10 -10 +3 +3 +3 +3 dB                    (-8)

  1mW    ÷10 ÷10 ÷10 ÷10 ÷10 ÷10 ÷10 ÷10 ÷10 ÷10
         ÷10 ÷10 ÷10
         ÷10 ÷10 x2 x2 x2 x2
```

$-138dBm \approx 1mW \times 10^{-10} \times 10^{-3} \times 10^{-2} \times 16 \approx 16 \times 10^{-15}\ mW$

$-138dBm \approx 16 \times 10^{-15}\ mW = 16 \times 10^{-15} \times 10^{-3}\ W \approx 16 \times 10^{-18}\ W$

PREFIXES USED WITH SI UNITS

Symbol	Prefix	Scientific notation
E	exa	10^{18}
P	peta	10^{15}
T	tera	10^{12}
G	giga	10^{9}
M	mega	10^{6}
k	kilo	10^{3}
h	hecto	10^{2}
da	deka	10^{1}
-	-	10^{0}
d	deci	10^{-1}
c	centi	10^{-2}
m	milli	10^{-3}
μ	micro	10^{-6}
n	nano	10^{-9}
p	pico	10^{-12}
f	femto	10^{-15}
a	atto	10^{-18}

SI is French for Systeme Internationale which means International System of Units

For example:
Powers (Watt), distance (meter), time (seconds) etc.

DECIBEL: dBm

$-138dBm \approx 16 \times 10^{-18} W \approx 16\ aW$

- The receiver has a sensitivity of -14 dBm, how much power is this?
  Answer:

$-14dB = -10\ -10\ +3\ +3\ db$

$1mW \quad \div 10\ \div 10\ \times 2\ \times 2$

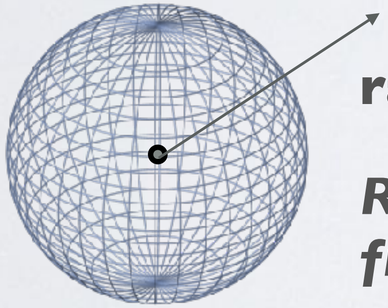
$-14dBm \approx 1mW \div 10 \div 10 \times 2 \times 2 \approx 4 \times 10^{-2} mW \approx 0.04\ mW$

DECIBEL: dBi, dBd

- Other notable deciBel notations are: dBi and dBd (these also represents ratios)

- Antenna manufacturers are using these units to measure antenna performance and is useful for comparison purpose.
  Manufacturer A has an 868MHz antenna, its gain is 3 dBi
  Manufacturer B has an 868MHz antenna, its gain is 2.5 dBi

- dBi refers to the antenna gain with respect to an isotropic antenna. This is an hypothetic point source antenna, that radiates its power uniformly in all directions.

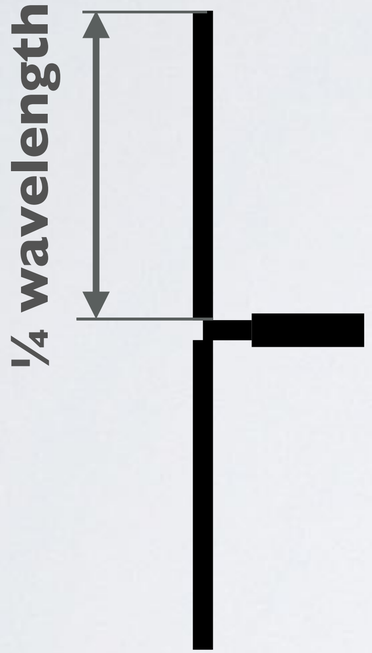


radiation pattern point source

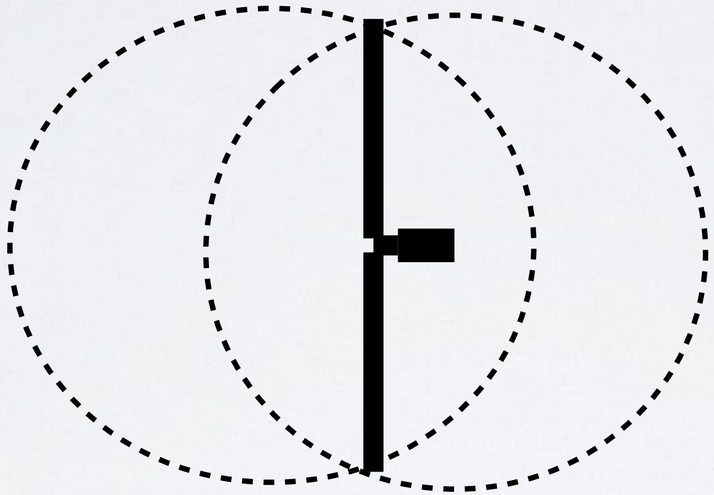
Radiation or antenna pattern reflects the strength of the radio waves from the antenna in different directions.

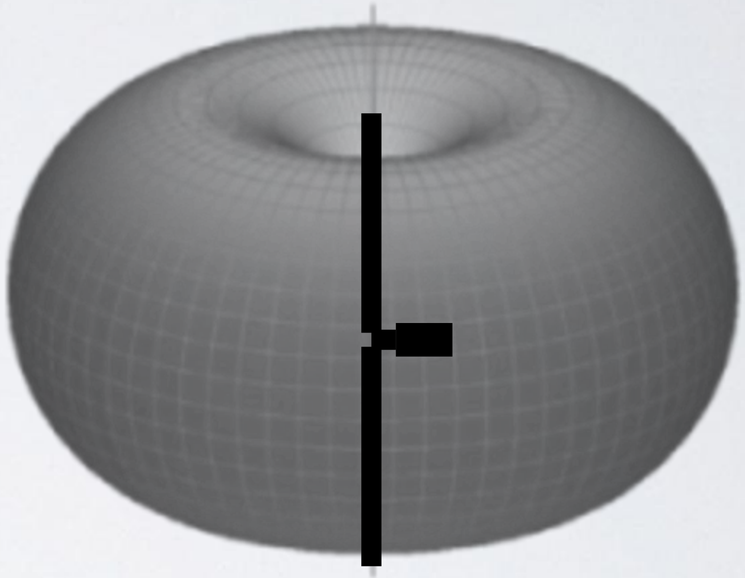
DECIBEL: dBi, dBd

- dBd refers to the antenna gain with respect to a reference dipole antenna.



dipole antenna





radiation pattern dipole looks like a “donut”

DECIBEL: dBi, dBd

- The relationship between dBd and dBi

```
dBi = dBd + 2.15
```