dB math

Training materials for wireless trainers

The Abdus Salam
International Centre
for Theoretical Physics

Goals

- To understand why we use dB to make calculations on wireless links.
- To learn dB math.
- To be able to solve some simple exercises.
- To understand what regulatory boards consider in their rules.

Why do we use dB?

- The signal strength does not fade in a linear manner, but inversely as the square of the distance.

- You move by **x** and the signal decreases by $\mathbf{1/x^2}$; hence, the **“inverse square law.”**

$$2 \rightarrow \tfrac{1}{4}$$
$$4 \rightarrow 1/16$$
$$8 \rightarrow 1/64$$

- The fact that exponential measurements are involved in signal strength measurement is one reason why we use a logarithmic scale.

Intro to dB

- 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.
- On the logarithmic scale, the reference cannot be zero because the log of zero does not exist!

dB and mW

- The reference point that relates the logarithmic dB scale to the linear watt scale is:

$$1 \text{ mW} \rightarrow 0 \text{ dBm}$$

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

dB and mW

- To convert mW to dBm:

$$P_{dBm} = 10 \log_{10} P_{mW}$$

10 times the *logarithm in base 10* of "P in mW"

- To convert dBm to mW:

$$P_{mW} = 10^{P_{dBm}/10}$$

10 *to the power of* ("P in dBm" divided by 10)

- Gains and losses are ***additive***.

dB and mW

- To convert mW to dBm:

100mw

$\log_{10}$ 100 = 2 and 10^2=100

20dBm → 100mW

50mw

$\log_{10}$ 50 = 1.698 and 10^1.698 = 50

16.9dBm → 50 mW

Using dB

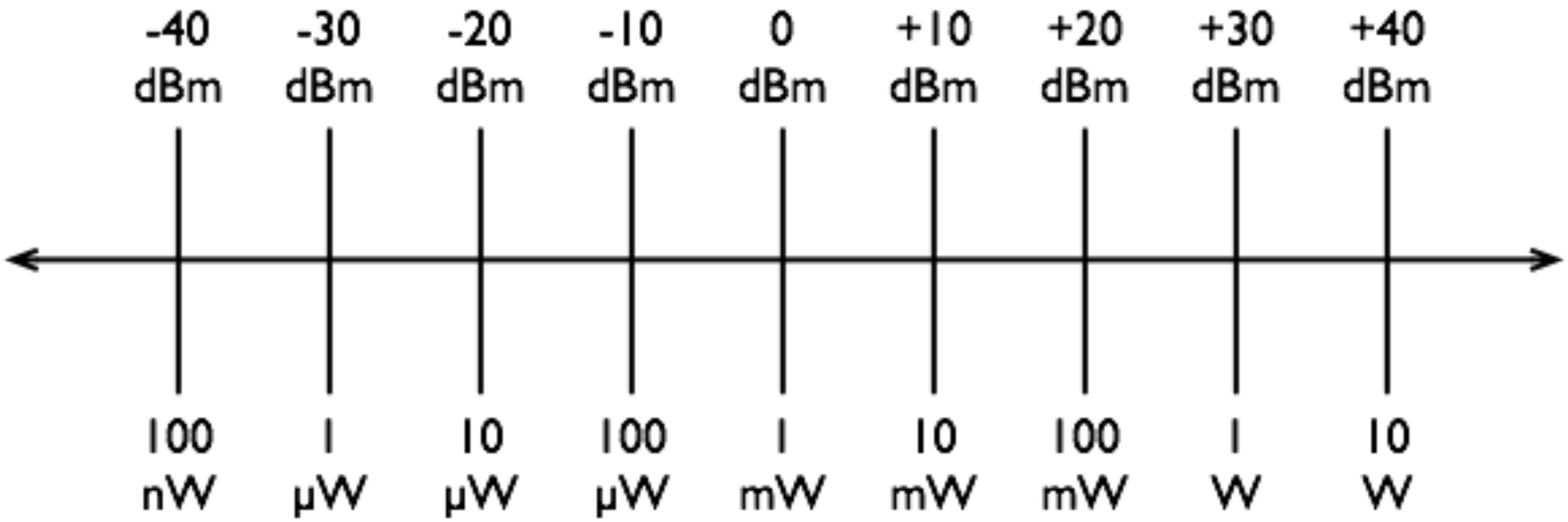
Commonly used (and easy to remember) dB values:

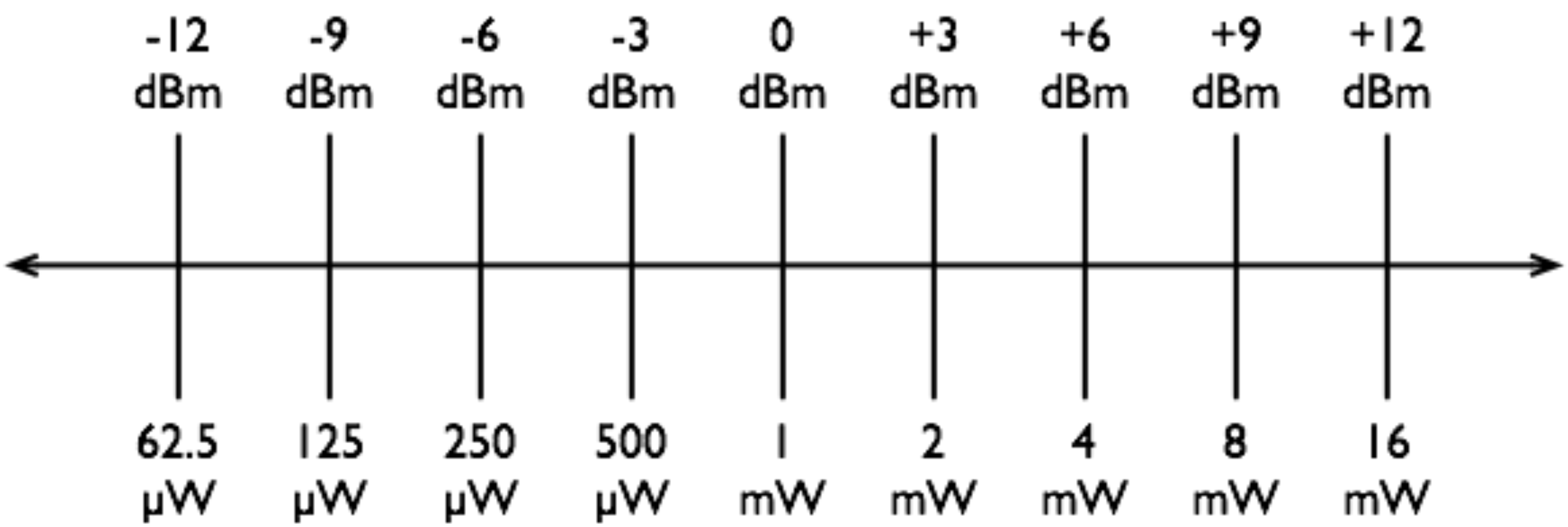
```
 +3 dB     = double power
 -3 dB     = half the power
+10 dB     = 10 times the power
-10 dB     = one tenth power
```

For example:

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

Using dB


-40 dBm
-30 dBm
-20 dBm
-10 dBm
0 dBm
+10 dBm
+20 dBm
+30 dBm
+40 dBm
100 nW
1 μW
10 μW
100 μW
1 mW
10 mW
100 mW
1 W
10 W


-12 dBm
-9 dBm
-6 dBm
-3 dBm
0 dBm
+3 dBm
+6 dBm
+9 dBm
+12 dBm
62.5 μW
125 μW
250 μW
500 μW
1 mW
2 mW
4 mW
8 mW
16 mW

dB and milliwatts

It is easy to use dB to simplify the addition of gains and losses, then convert back to milliwatts when you need to refer to the absolute power.

```
   1 mW          = 0 dBm
   2 mW          = 3 dBm
   4 mW          = 6 dBm
   8 mW          = 9 dBm
  10 mW          = 10 dBm
 100 mW          = 20 dBm
1000 mW (1W)     = 30 dBm
```

Simple dB math

How much power is 43 dBm?

- +43 dBm is 43 dB relative to 1 mW
- 43 dB = 10 dB + 10 dB + 10 dB + 10 dB + 3 dB
- 1 mW x 10 = 10 mW x 10 = 100 mW x 10 = 1000 mW x 10 = 10 000 mW x 2 = 20 000 mW = 20 W
- Therefore, +43 dBm = ***20 W***

What about negative values?

Negative doesn't mean bad. ;-)

How much power is -26 dBm?

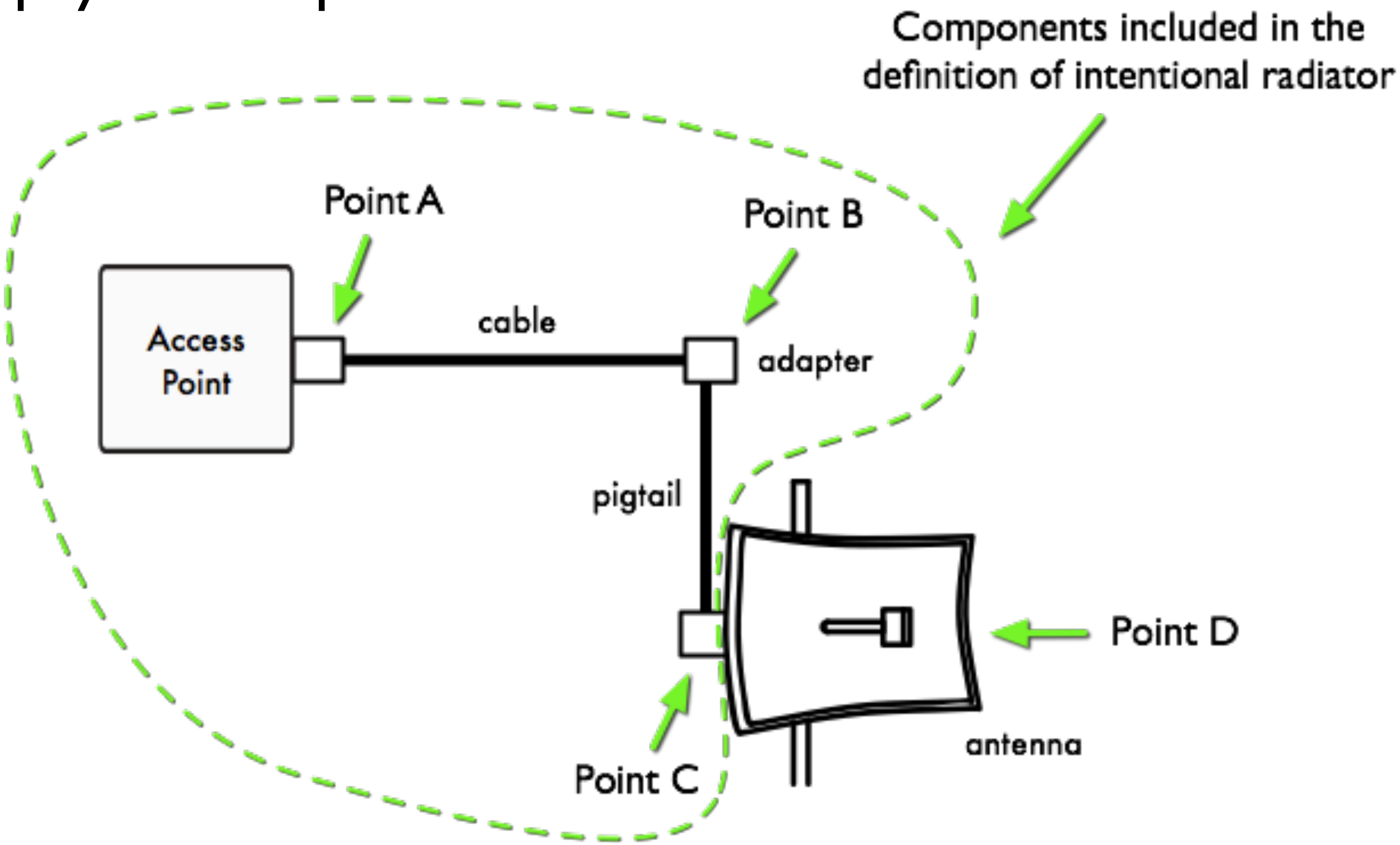
- -26 dBm is 1mW (0dBm) "minus" 26 dB
- -26 dB = -10 dB - 10 dB - 3 dB - 3 dB
- 1 mW / 10 = 100 µW
- 100 µW / 10 = 10 µW
- 10 µW / 2 = 5 µW
- 5 µW / 2 = ***2.5 µW*** (2.5 x 10^{-6} W)
- -26 dBm = 2.5 µW

dB and antennas

- When quantifying the gain of an antenna, the decibel units are represented by ***dBi***
- The **i** stands for ***isotropic***, which means that the change in power is referenced against an isotropic radiator.
- An isotropic radiator is a theoretical ideal transmitter that produces an electromagnetic field in all directions with equal intensity at 100% efficiency.

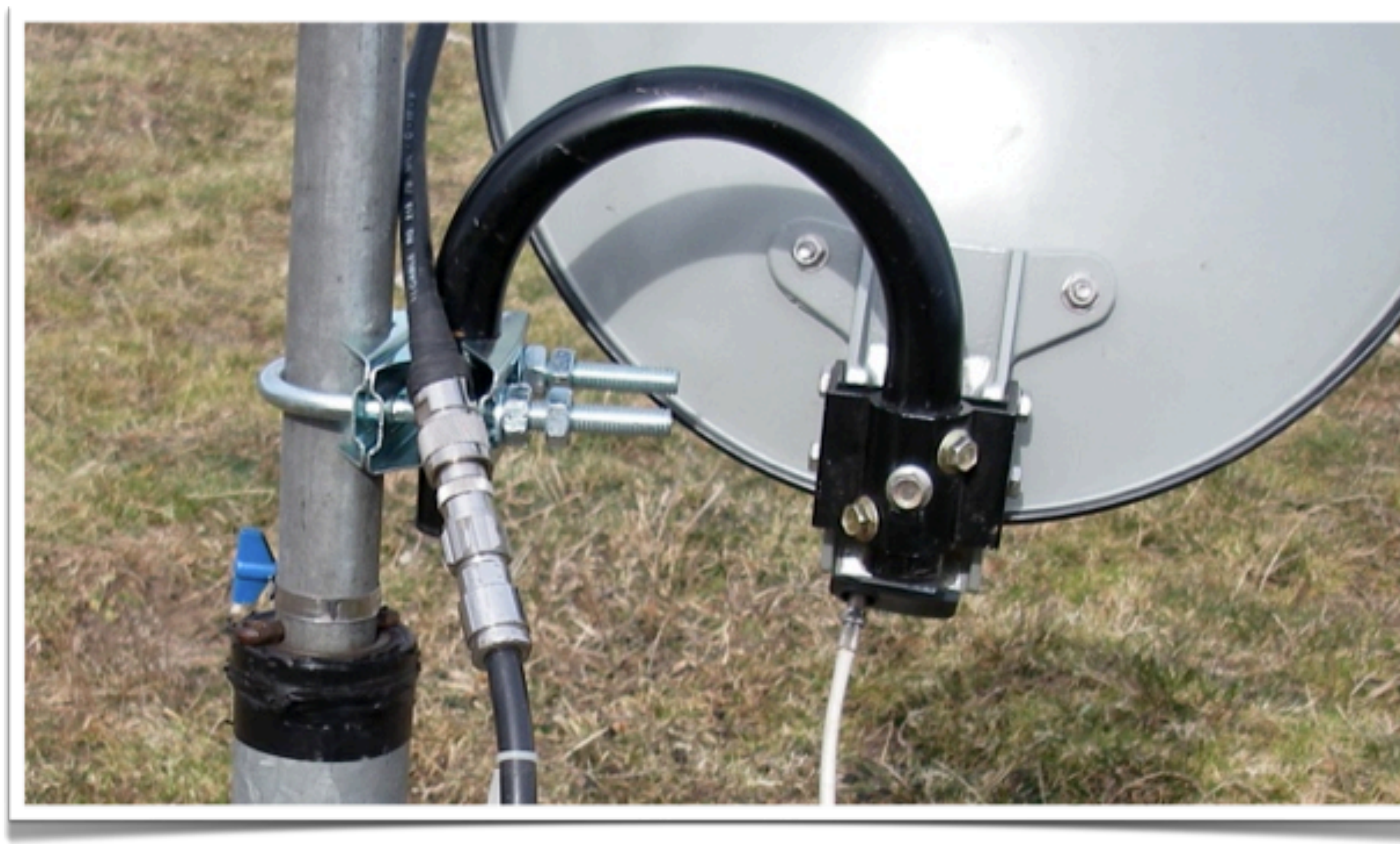
Intentional radiator

- An antenna element is a passive device: it cannot add power!
- The antenna can create the effect of amplification by virtue of its physical shape.



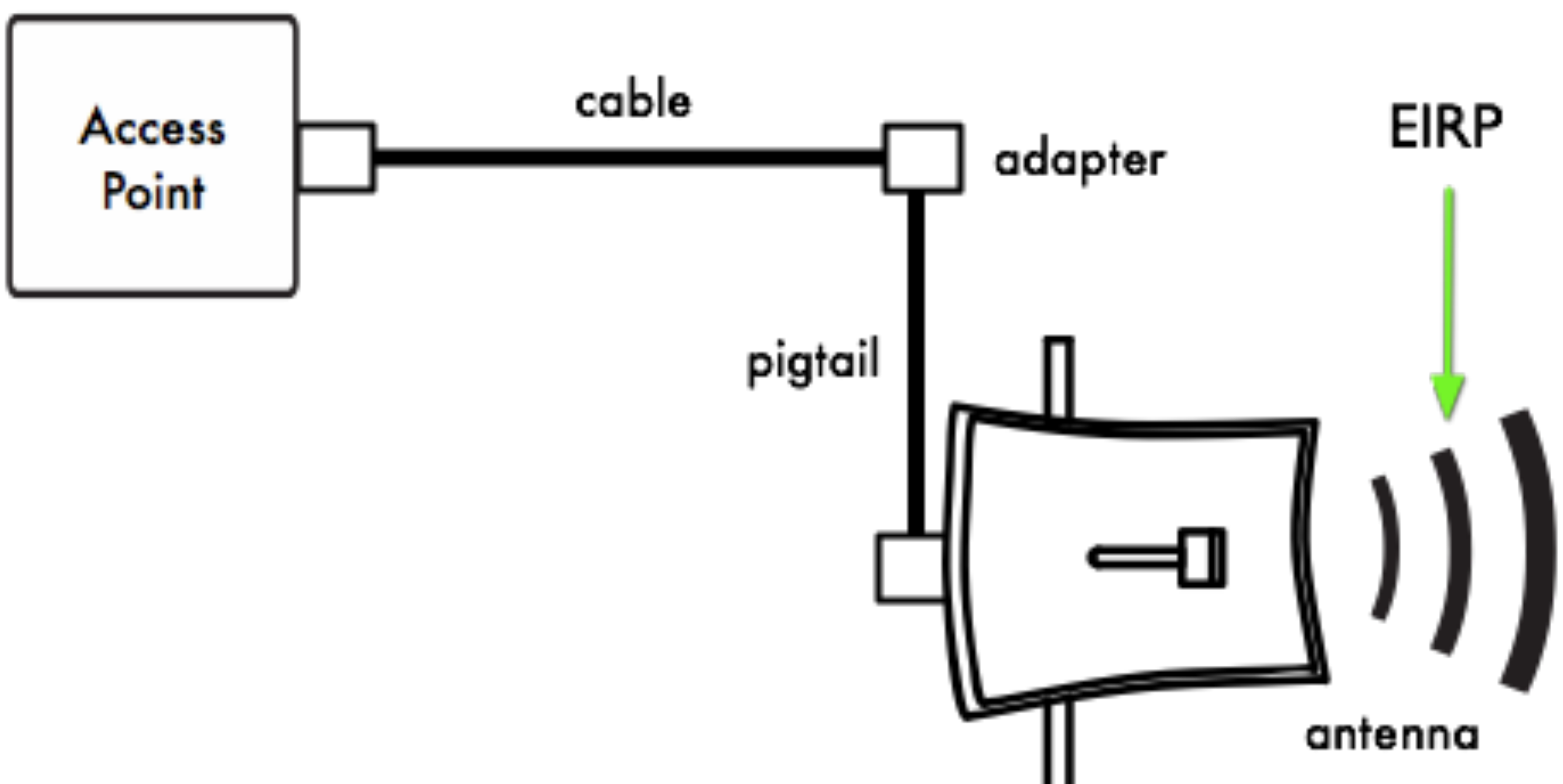
Intentional radiator

- Any reference to "power output of the intentional radiator" refers to the power output at the end of the last cable or connector before the antenna.
- If a 100 mW radio loses 50 mW of power in the cable and another 25 mW from connectors, the power of the intentional radiator is ***25 mW***.

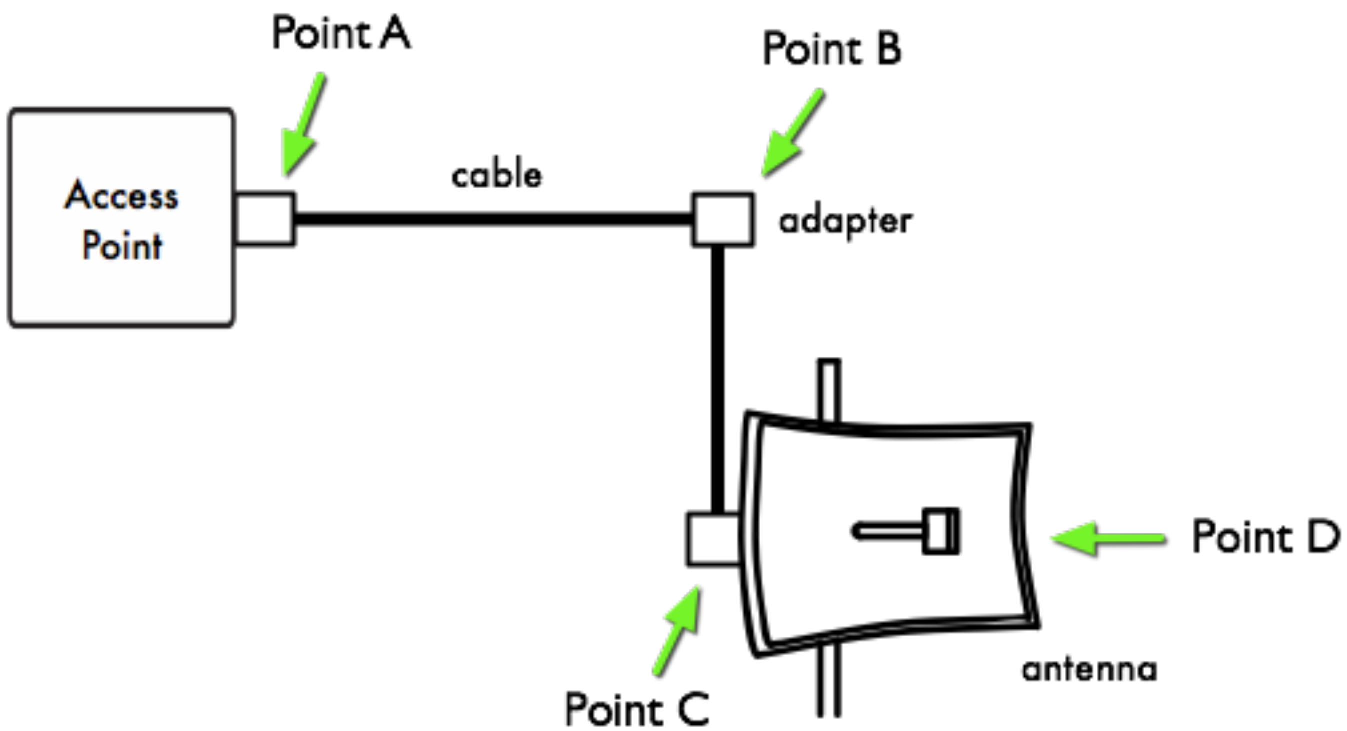


Equivalent Isotropically Radiated Power (EIRP)

- ***EIRP*** is the ***Equivalent Isotropically Radiated Power***
- EIRP is the power actually radiated by the antenna element and is important because it is regulated by the regulatory agencies.
- EIRP is used to calculate whether or not a wireless link is viable.
- EIRP takes the gain of the antenna into account.



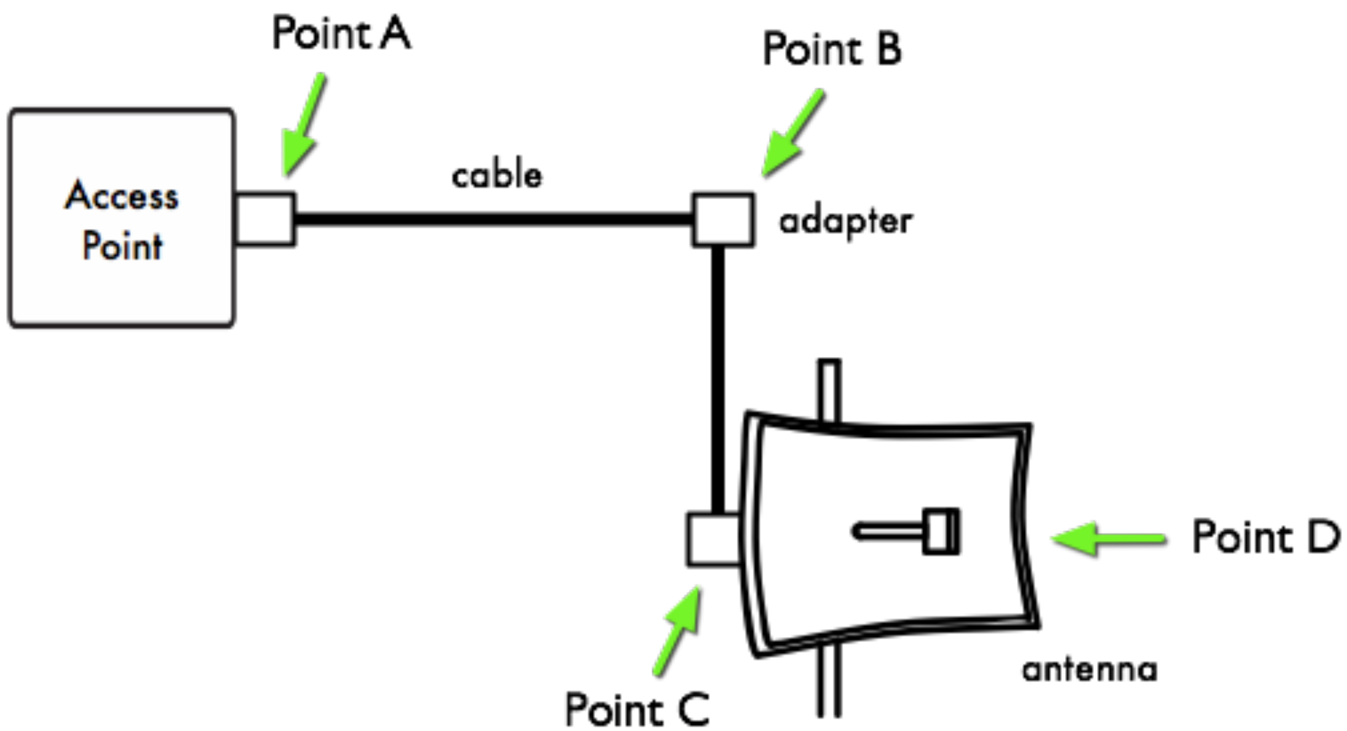
Example



Using mW

Power in A	Loss of cable	Power in B	Loss of adapter + cable	Power in C	Gain of antenna	Power in D
100 mW	half *(-3 dB)*		half *(-3 dB)*		16 times *(+12 dBi)*	
	100 mW / 2	50 mW				
			50 mW / 2	25 mW		
					25 mW x 16	400 mW

Example



Using dB

Power in A	Loss of cable	Power in B	Loss of adapter + cable	Power in C	Gain of antenna	Power in D
20 dBm	-3 dB		-3 dB		+12 dBi	
	-3 dB	17 dBm				
			- 3 dB	14 dBm		
					+ 12 dBi	26 dBm

Regulations

- The regulators have rules defining both the power output at the intentional radiator and at the EIRP.
- The FCC (Federal Communications Commission - USA) enforces certain rules regarding the power radiated by the antenna element, depending on whether the implementation is point-to-multipoint or point-to-point.
- For example, the FCC limits the EIRP of PtMP links to ***4 watts***, with the power limit for the intentional radiator set to ***1 watt.***

Conclusions

- dB provide an easier way to make calculations on wireless links.
- The main advantage of using dB is that gains and losses are ***additive***.
- Use the Intentional Radiator and the EIRP when checking that your system complies to the regulation of your country.

Thank you for your attention

For more details about the topics presented in this lecture, please see the book ***Wireless Networking in the Developing World***, available as free download in many languages at:

http://wndw.net