Link Budget Calculation

Goals

- To be able to calculate how far we can go with the equipment we have
- To understand why we need high poles for long links

Free space loss

- Signal power is diminished by geometric spreading of the wavefront, commonly known as ***Free Space Loss***.
- The power of the signal is spread over a wave front, the area of which increases as the distance from the transmitter increases. Therefore, the power density diminishes.

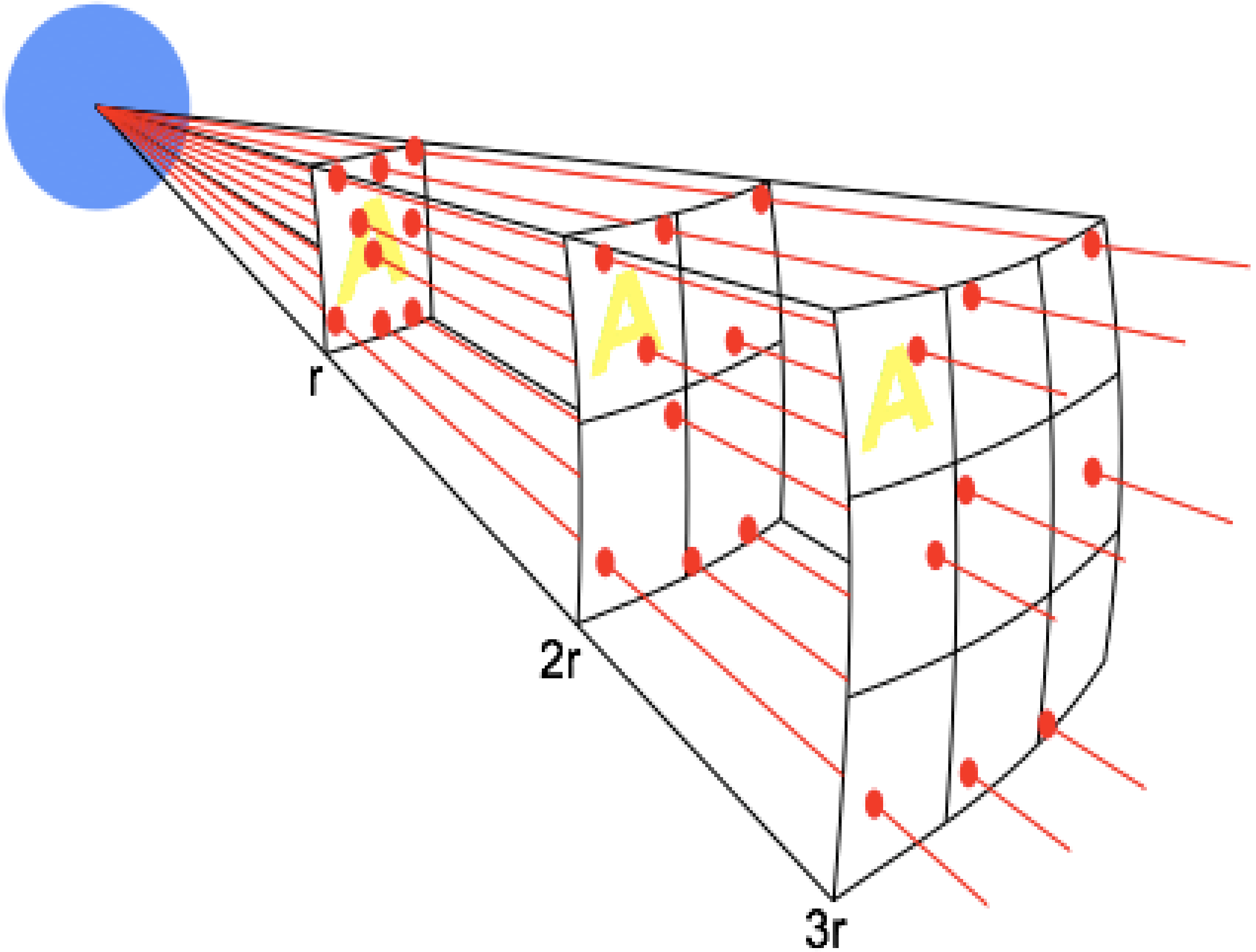


Figure from *http://en.wikipedia.org/wiki/Inverse_square*

Free Space Loss (any frequency)

- Using decibels to express the loss and using a generic frequency f, the equation for the Free Space Loss is:

$$L_{fs} = 92.4 + 20*\log_{10}(D) + 20*\log_{10}(f)$$

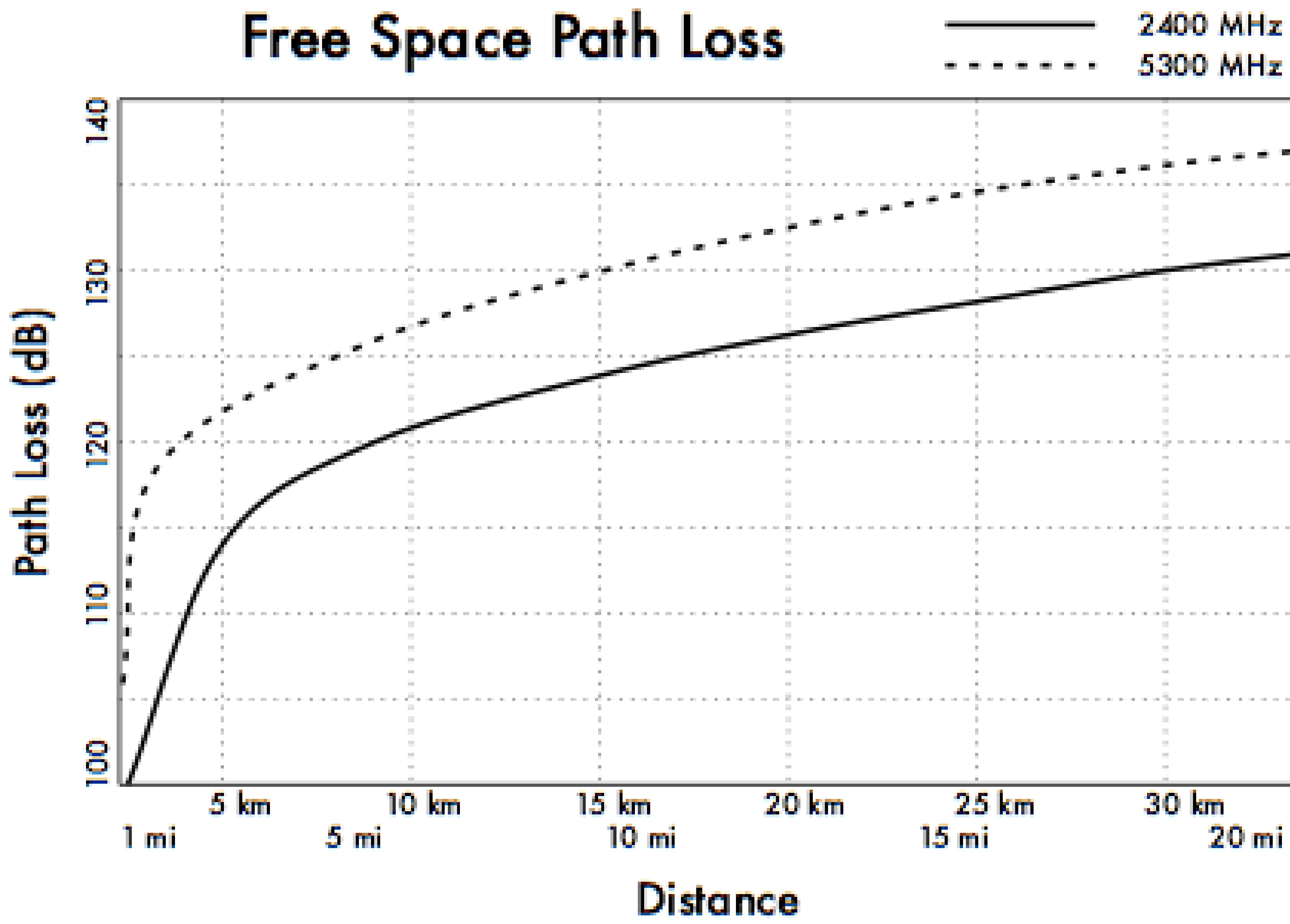
- ...where $\boldsymbol{L_{fs}}$ is expressed in dB, ***D*** is in kilometers and **f** is in GHz.

Free Space Loss (@2.45 GHz)

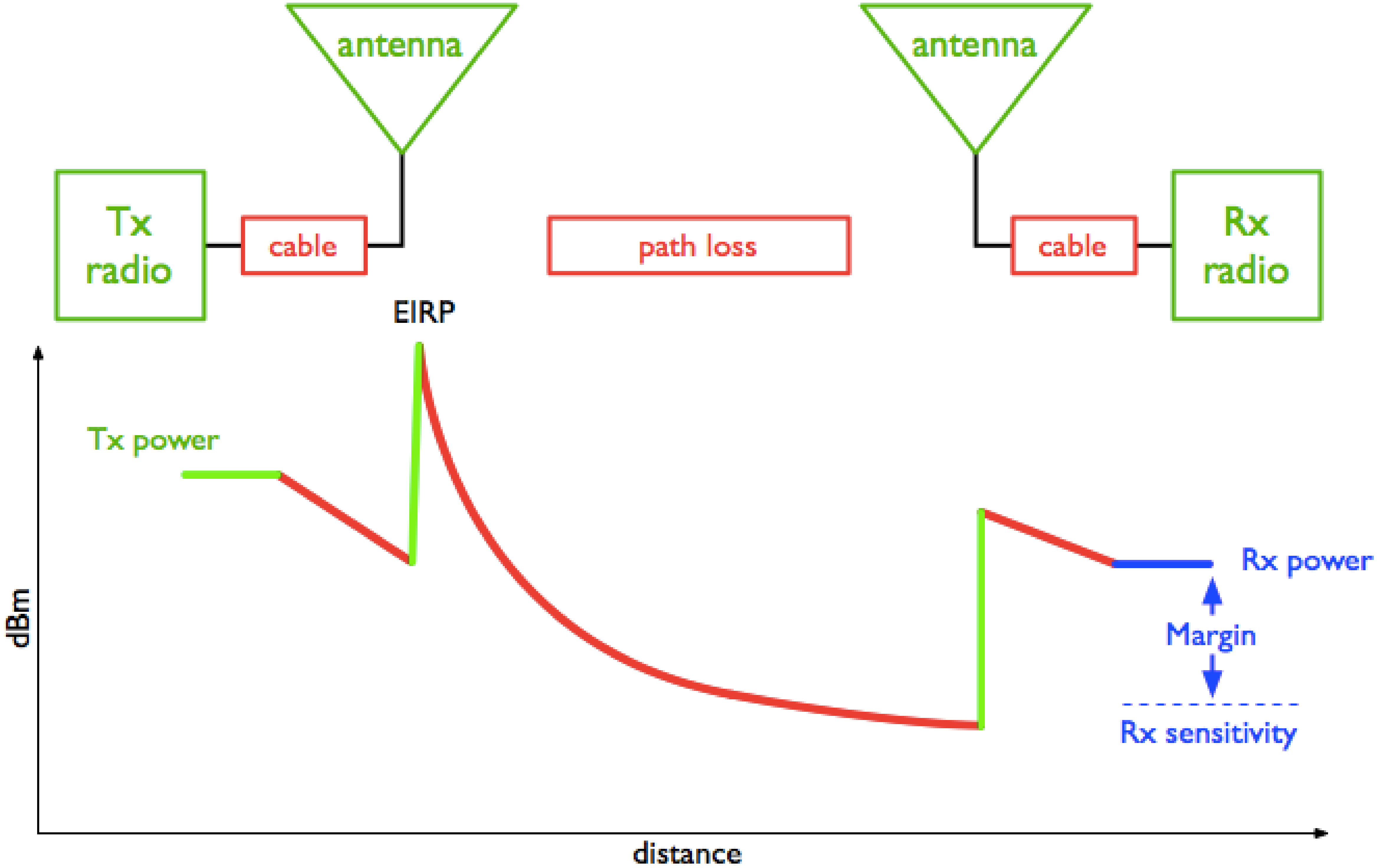
- Using decibels to express the loss and using 2.4 GHz as the signal frequency, the equation for the Free Space Loss is:

$$L_{fs} = 100 + 20*\log_{10}(D)$$

- ...where $\boldsymbol{L_{fs}}$ is expressed in dB and $\boldsymbol{D}$ is in kilometers.


Free Space Path Loss
2400 MHz
5300 MHz
Path Loss (dB)
140
130
120
110
100
5 km
10 km
15 km
20 km
25 km
30 km
1 mi
5 mi
10 mi
15 mi
20 mi
Distance

Power in a wireless system



Link budget

- The performance of any communication link depends on the quality of the equipment being used.
- ***Link budget*** is a way of quantifying the link performance.
- The received power in an 802.11 link is determined by three factors: ***transmit power***, ***transmitting antenna gain***, and ***receiving antenna gain***.
- If that power, minus the ***free space loss*** of the link path, is greater than the ***minimum received signal level*** of the receiving radio, then a link is possible.
- The difference between the minimum received signal level and the actual received power is called the ***link margin***.
- The link margin must be positive, and should be maximized (should be at least 10dB or more for reliable links).

Example link budget calculation

Let’s estimate the feasibility of a **5 km** link, with one access point and one client radio.

The access point is connected to an antenna with **10 dBi** gain, with a transmitting power of **20 dBm** and a receive sensitivity of **-89 dBm**.

The client is connected to an antenna with **14 dBi** gain, with a transmitting power of **15 dBm** and a receive sensitivity of **-82 dBm**.

The cables in both systems are short, with a loss of **2dB** at each side at the 2.4 GHz frequency of operation.

dB cheats

$$P_{dBm} = 10 \cdot \log_{10} \left(\frac{P}{1mW}\right)$$

$$P_{dBW} = 10 \cdot \log_{10} \left(\frac{P}{1W}\right)$$

$$P_{dBm} = P_{dBW} + 30$$

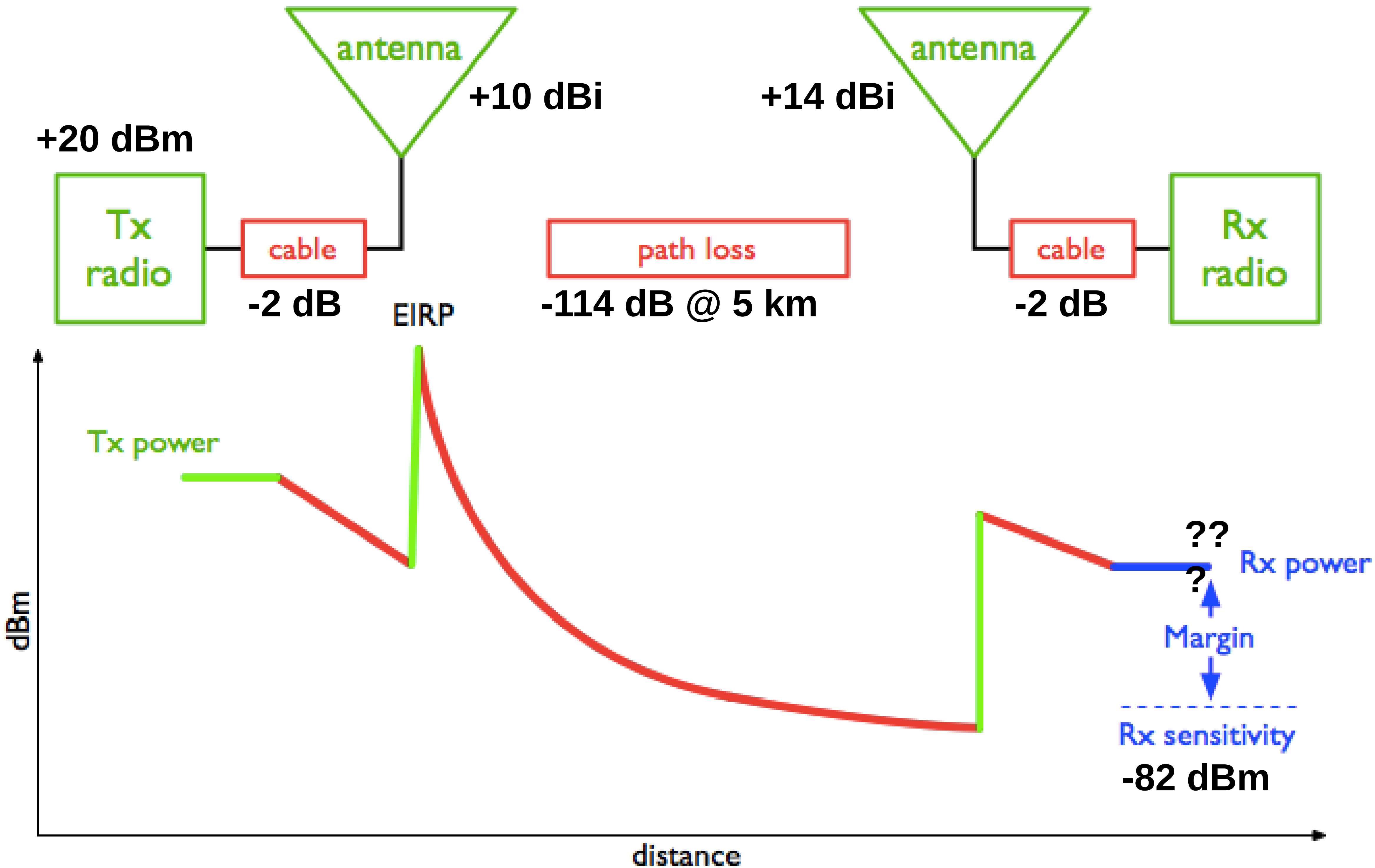
dBW ± dB = dBW

dBm ± dB = dBm

dBW - dBW= dB

dBm - dBm= dB

AP to Client link



Link budget: AP to Client link

20 dBm (TX Power AP)
+ 10 dBi (Antenna Gain AP)
- 2 dB (Cable Losses AP)
+ 14 dBi (Antenna Gain Client)
- 2 dB (Cable Losses Client)

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40 dBm Total Gain
-114 dB (free space loss @5 km)

-74 dBm (expected received signal level)
--82 dBm (sensitivity of Client)

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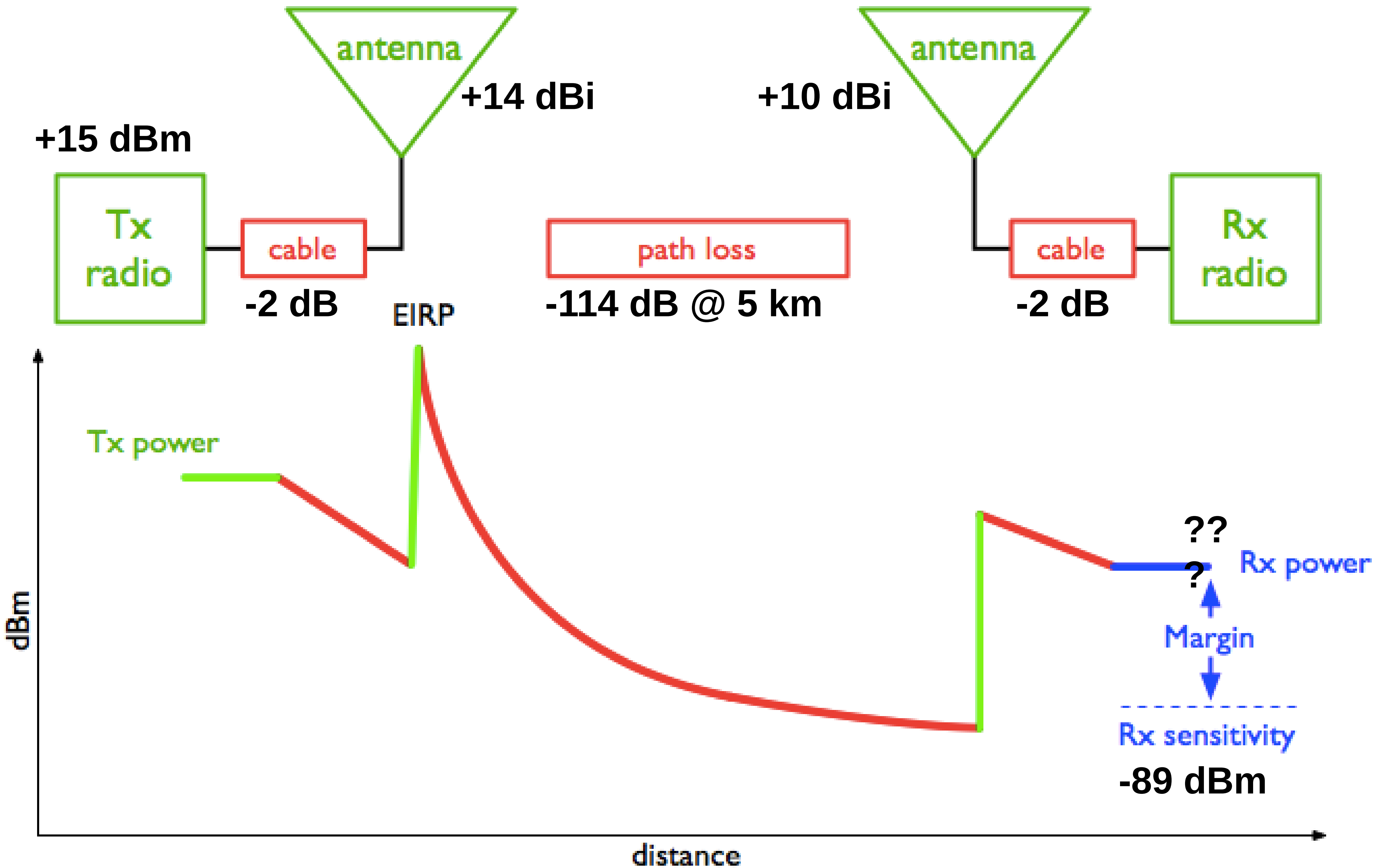
8 dB (link margin)

Opposite direction: Client to AP



Link budget: Client to AP link

15 dBm (TX Power Client)
+ 14 dBi (Antenna Gain Client)
- 2 dB (Cable Losses Client)
+ 10 dBi (Antenna Gain AP)
- 2 dB (Cable Losses AP)

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35 dBm Total Gain
-114 dB (free space loss @5 km)

-79 dBm (expected received signal level)
--89 dBm (sensitivity of AP)

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10 dB (link margin)