Planning IoT wireless links

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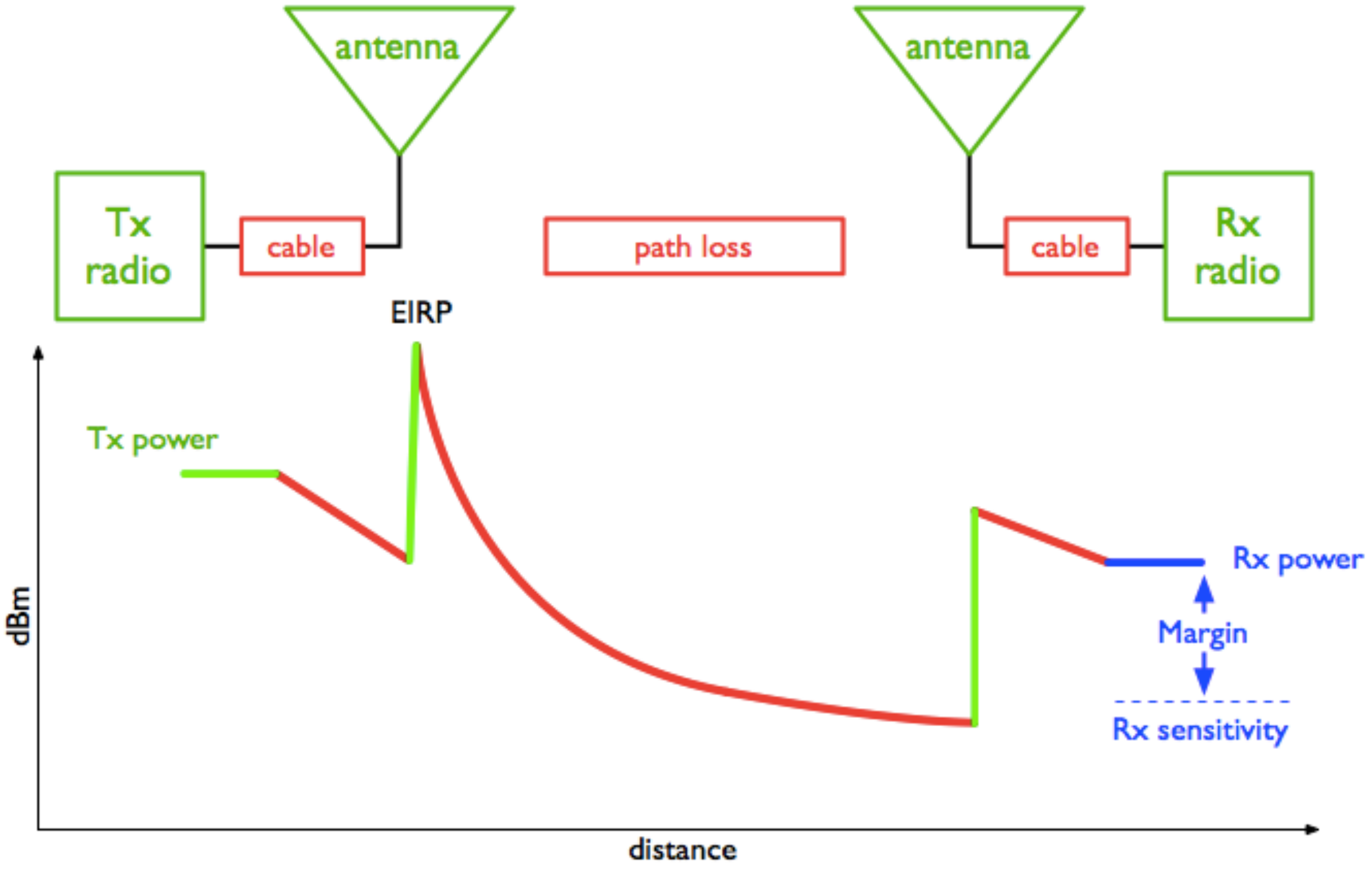
The great performance of LoRa in all these 3 features (good sensitivity, low path loss, good obstacle penetration) makes LoRa a disruptive technology enabling really long range links. This is specially important in urban scenarios, with very difficult transmission conditions. To sum up, LoRa can get long ranges in Smart Cities deployments, so it reduces dramatically the size of the backbone network (repeaters, gateways or concentrators).

As shown in the section 7, Libelium performed long range tests, getting the awesome distance of 22 km (13.6 miles) in LOS configurations and +2km (1.2 miles) in urban scenarios (going through buildings). The margin in those conditions would allow even more distance (x2, x3), the only problem was to keep the line-of-sight condition.

Goals

- To be able to calculate how far we can go with the equipment we have
- To understand why we need high masts for long links
- To learn about software that help the process of planning radio links

Power in a wireless system

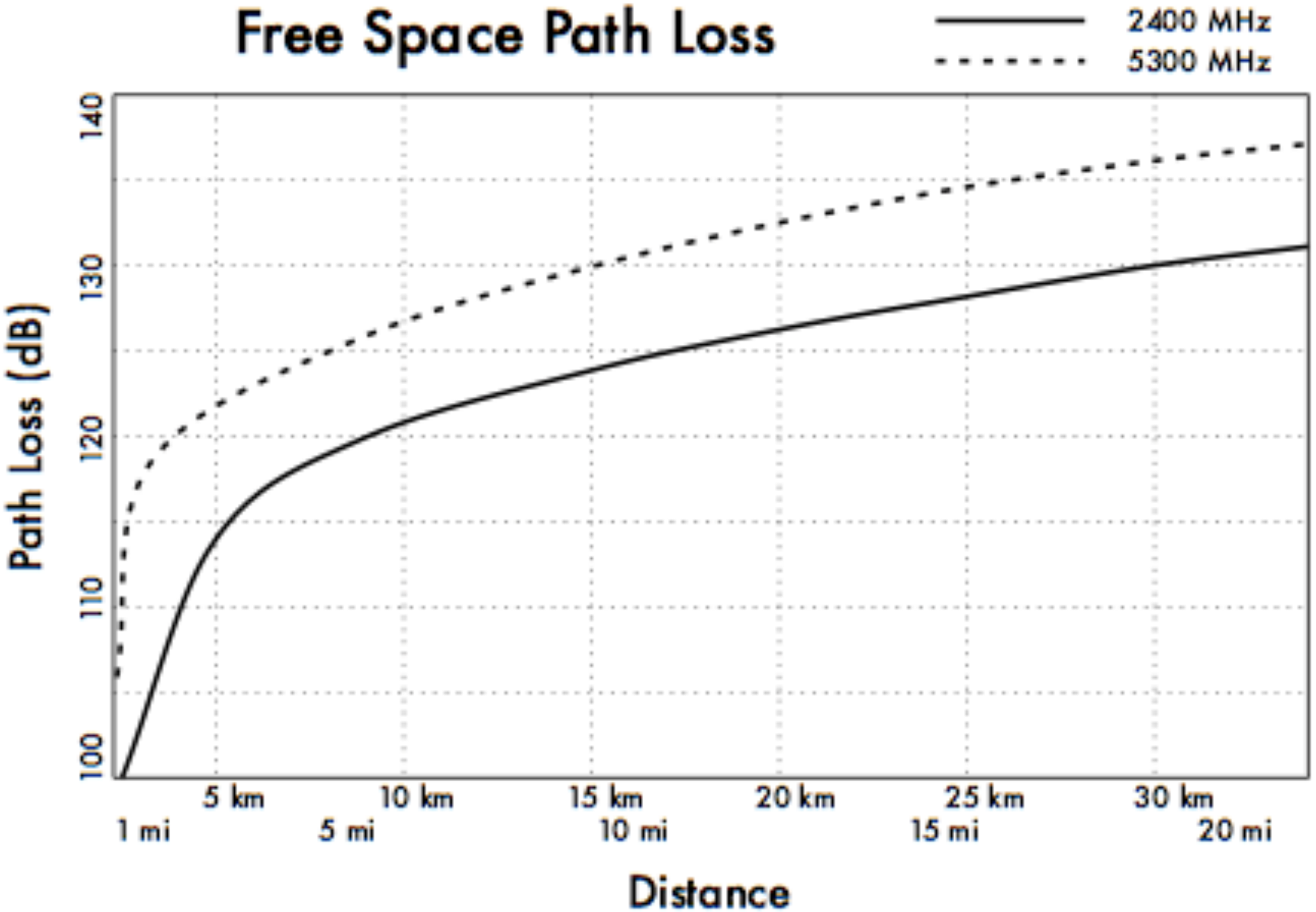


Free Space Loss (any frequency)

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

$$L_{fs} = 32,45 + 20*\log(D) + 20*\log(f)$$

- ...where L_{fs} is expressed in dB, D is in kilometers and **f** is in MHz.


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

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).

UBIQUITI NETWORKS

BULLET2

UBIQUITI NETWORKS

Zero Variable Outdoor Wireless Deployment

SYSTEM INFORMATION	
Processor Specs	Atheros MIPS 4KC, 180MHz
Memory Information	16MB SDRAM, 4MB Flash
Networking Interface	1 X 10/100 BASE-TX (Cat. 5, RJ-45) Ethernet Interface

REGULATORY / COMPLIANCE INFORMATION	
Wireless Approvals	FCC Part 15.247, IC RS210, CE
RoHS Compliance	YES

RADIO OPERATING FREQUENCY 2412-2462 MHz

TX SPECIFICATIONS

	DataRate	TX Power	Tolerance
802.11b	1Mbps	20 dBm	+/-1dB
	2Mbps	20 dBm	+/-1dB
	5.5Mbps	20 dBm	+/-1dB
	11Mbps	20 dBm	+/-1dB
802.11g OFDM	6Mbps	20 dBm	+/-1dB
	9Mbps	20 dBm	+/-1dB
	12Mbps	20 dBm	+/-1dB
	18Mbps	20 dBm	+/-1dB
	24Mbps	20 dBm	+/-1dB
	36Mbps	18 dBm	+/-1dB
	48Mbps	16 dBm	+/-1dB
	54Mbps	15 dBm	+/-1dB

RX SPECIFICATIONS

	DataRate	Sensitivity	Tolerance
802.11b	1Mbps	-95 dBm	+/-1dB
	2Mbps	-94 dBm	+/-1dB
	5.5Mbps	-93 dBm	+/-1dB
	11Mbps	-90 dBm	+/-1dB
802.11g OFDM	6Mbps	-92 dBm	+/-1dB
	9Mbps	-91 dBm	+/-1dB
	12Mbps	-89 dBm	+/-1dB
	18Mbps	-88 dBm	+/-1dB
	24Mbps	-84 dBm	+/-1dB
	36Mbps	-81 dBm	+/-1dB
	48Mbps	-75 dBm	+/-1dB
	54Mbps	-72 dBm	+/-1dB

Example link budget calculation

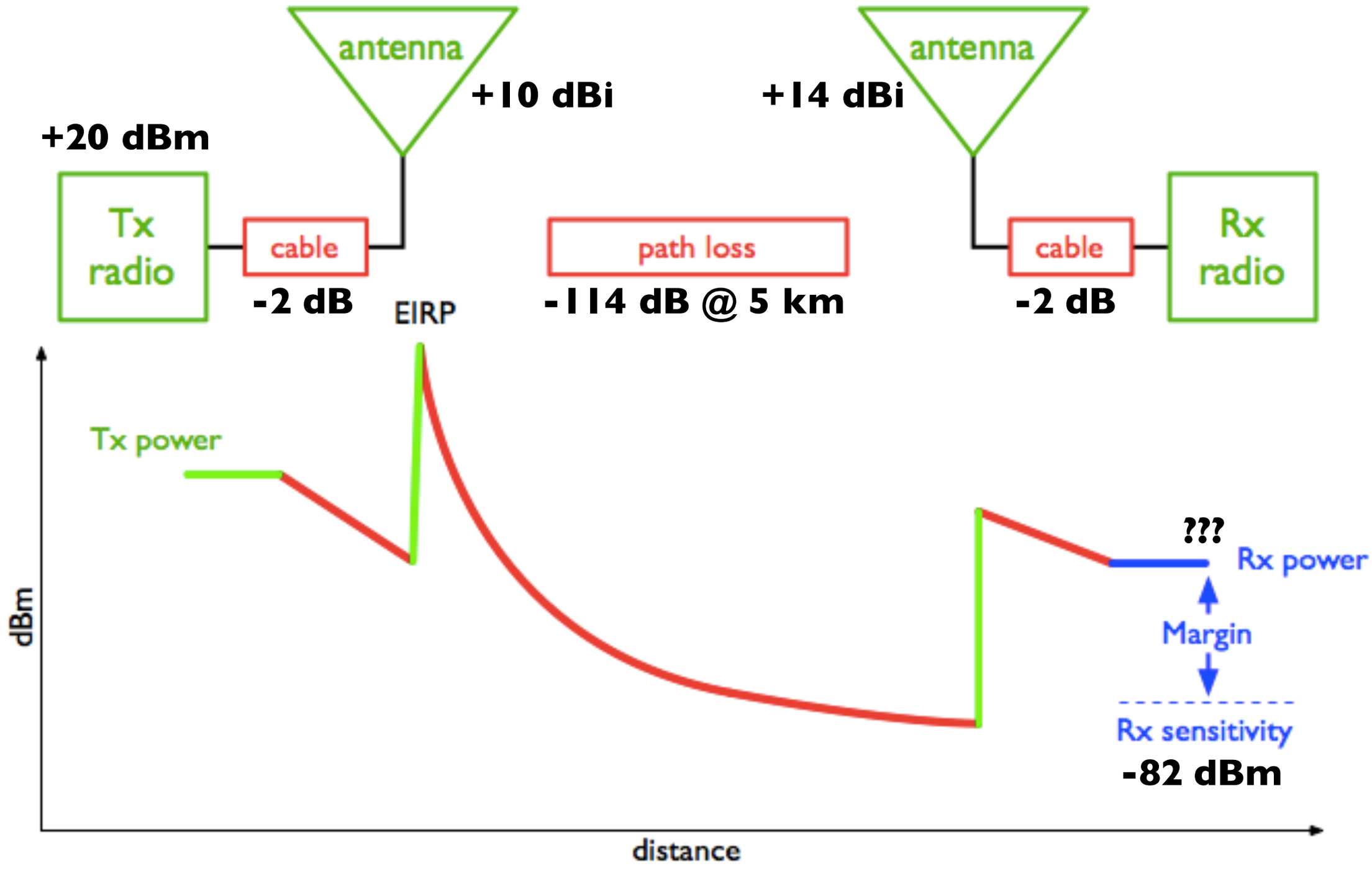
Let's estimate the feasibility of a **5 km** link, with one access point and one client radio.

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.

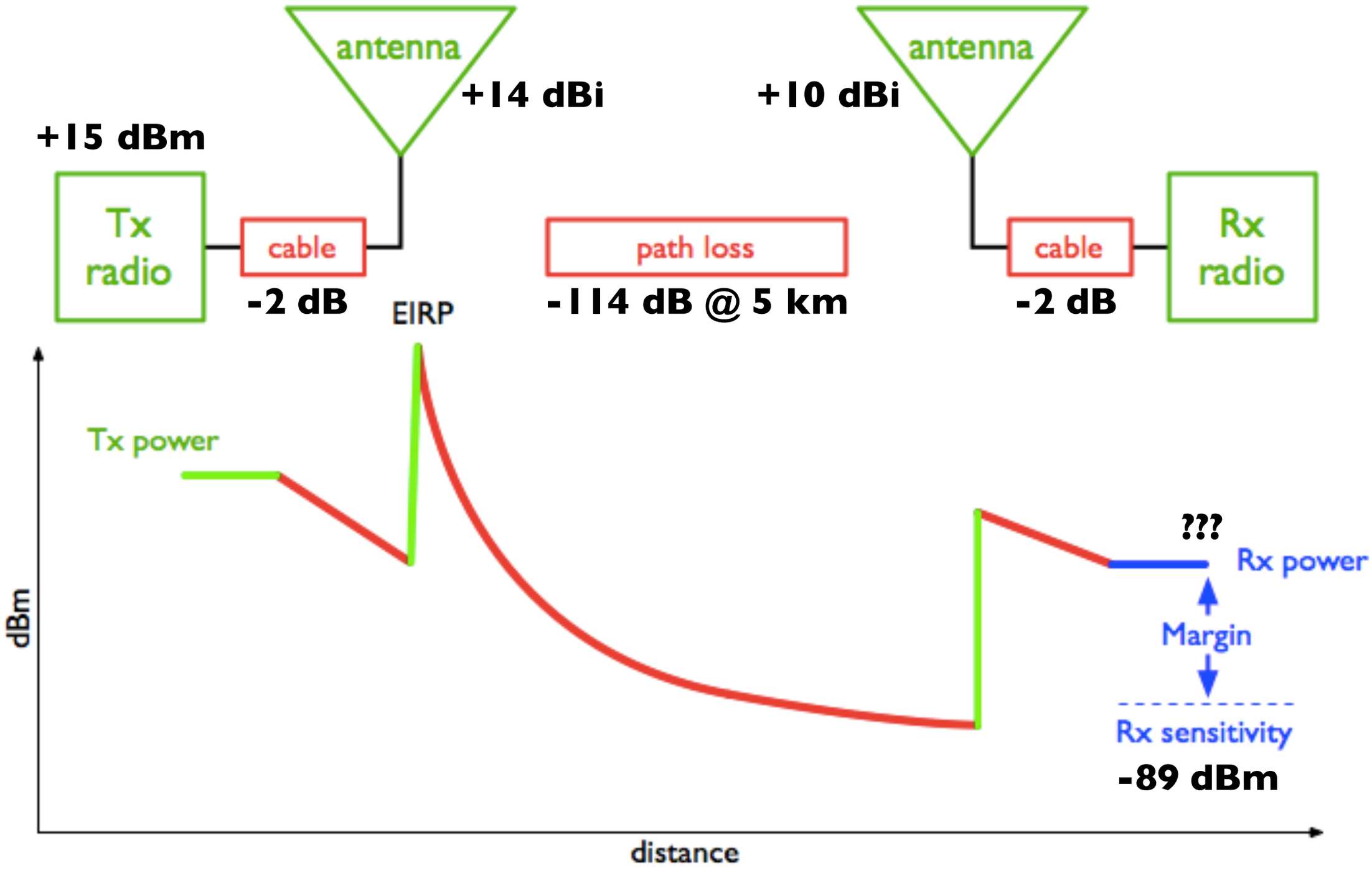
AP to Client link



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)
---------------
  40 dB  Total Gain
-114 dB  (free space loss @5 km)
---------------
 -73 dBm (expected received signal level)
--82 dBm (sensitivity of Client)
---------------
   9 dB  (link margin)
```

Opposite direction: Client to AP



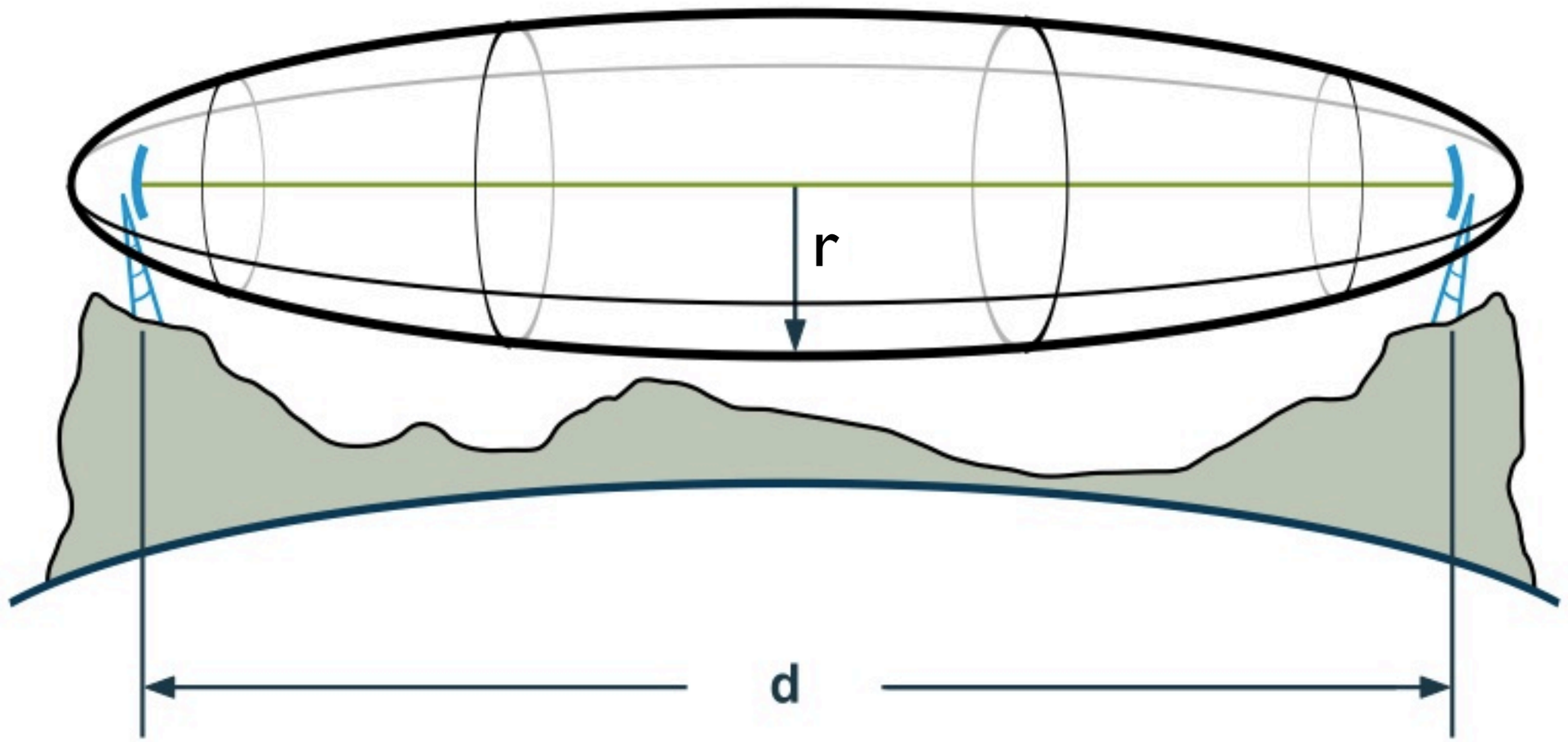
Link budget: Client to AP link

```
  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)
---------------

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

 -78 dBm (expected received signal level)
--89 dBm (sensitivity of AP)
---------------

  10 dB  (link margin)
```

Fresnel Zone

- The First Fresnel Zone is an ellipsoid-shaped volume around the Line-of-Sight path between transmitter and receiver.
- The Fresnel Zone is important to the integrity of the RF link because it defines a volume around the LOS that must be clear of any obstacle for the the maximum power to reach the receiving antenna.
- Objects in the Fresnel Zone as trees, hilltops and buildings can considerably attenuate the received signal, even when there is an unobstructed line between the TX and RX.

Line of Sight and Fresnel Zones



a free line-of-sight **IS NOT EQUAL TO** a free Fresnel Zone

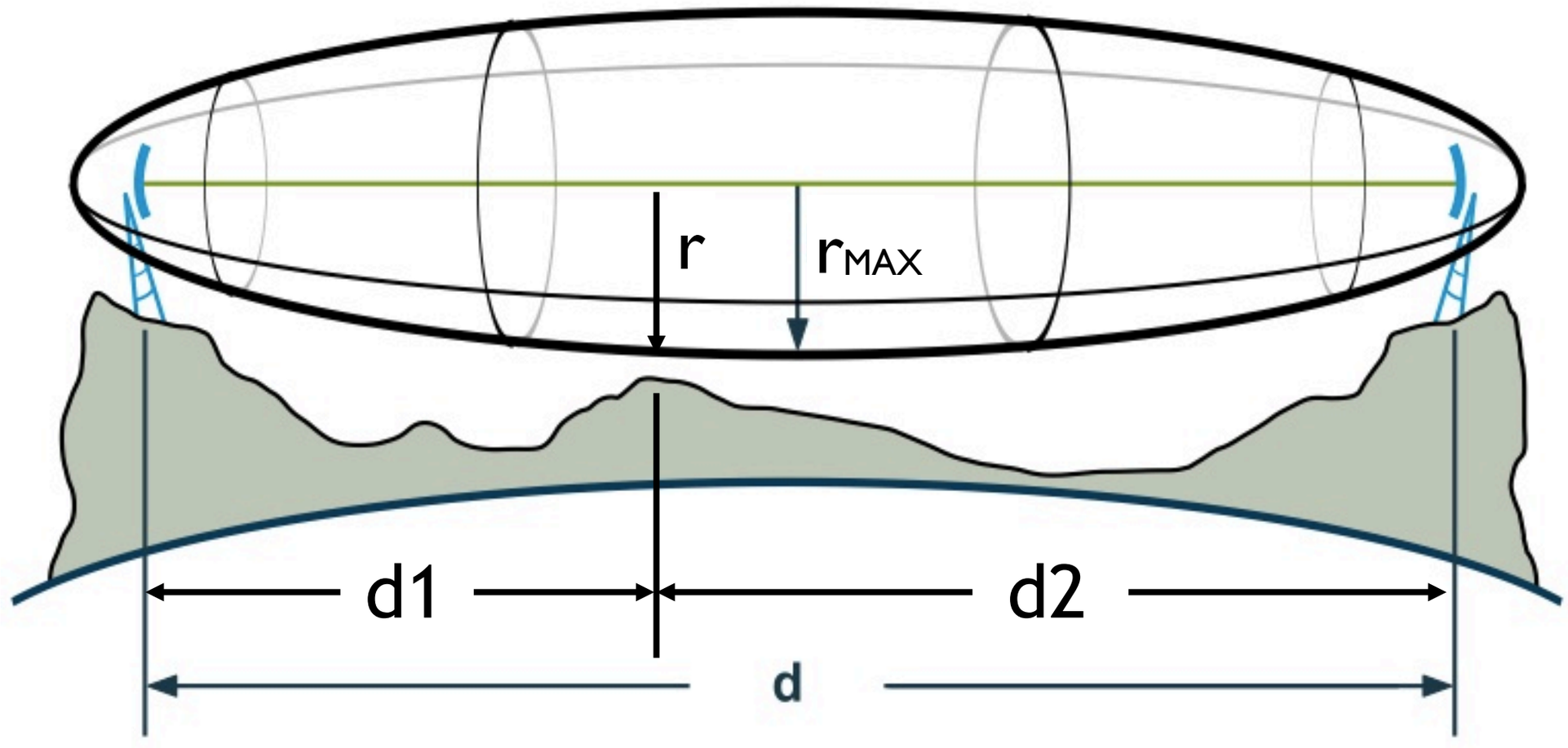
Fresnel Zone

- The radius of the first Fresnel Zone at a given point between the transmitter and the receiver can be calculated as:

```
r = 17.31 * sqrt((d1*d2)/(f*d))
```

- ...where **r** is the radius of the zone in meters, **d1** and **d2** are distances from the obstacle to the link end points in meters, **d** is the total link distance in meters, and **f** is the frequency in MHz.
- Note that this gives you the radius of the zone, not the height above ground. To calculate the height above ground, you need to subtract the result from a line drawn directly between the tops of the two towers.

Line of Sight and Fresnel Zones



$$r = 17.31 * \sqrt{((d1 * d2) / (f * d))}$$

Clearance of the Fresnel Zone and earth curvature

This table shows the minimum height above flat ground required to clear 70% of the first Fresnel zone for various link distances at 2.4 GHz.

Notice that earth curvature plays a small role at short distances, but becomes more important as the distance increases.

Distance (km)	1st zone (m)	70% (m)	Earth curvature (m)	Required height (m)
1	5.5	3.9	0.0	3.9
5	12.4	8.7	0.4	9.1
10	17.5	12.2	1.5	13.7
15	21.4	15.0	3.3	18.3
20	24.7	17.3	5.9	23.2
25	27.7	19.4	9.2	28.6
30	30.3	21.2	13.3	34.5

Fresnel Zone

- Considering the importance of the Fresnel Zone, it is important to quantify the degree to which it can be blocked.

- Typically, 20% - 40% Fresnel Zone blockage introduces little to no interference into the link.

- It is better to err to the conservative side allowing no more than 20% blockage of the Fresnel Zone.

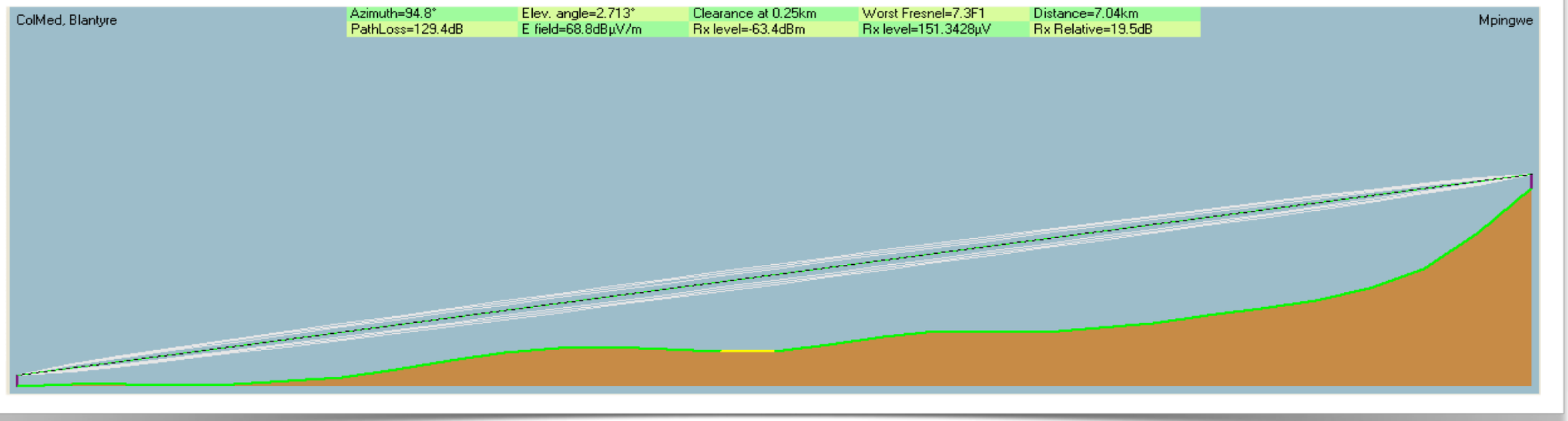
Radio Mobile

- Radio Mobile is a free tool to aid in the design and simulation of wireless systems.
- It can automatically calculate the power budget of a radio link, calculating the Fresnel zone clearance. It can use digital maps, GIS (Geographical Information Systems), or any other digital map, including maps provided by yourself.
- Runs on Windows 95, 98, ME, NT, 2000 and XP.

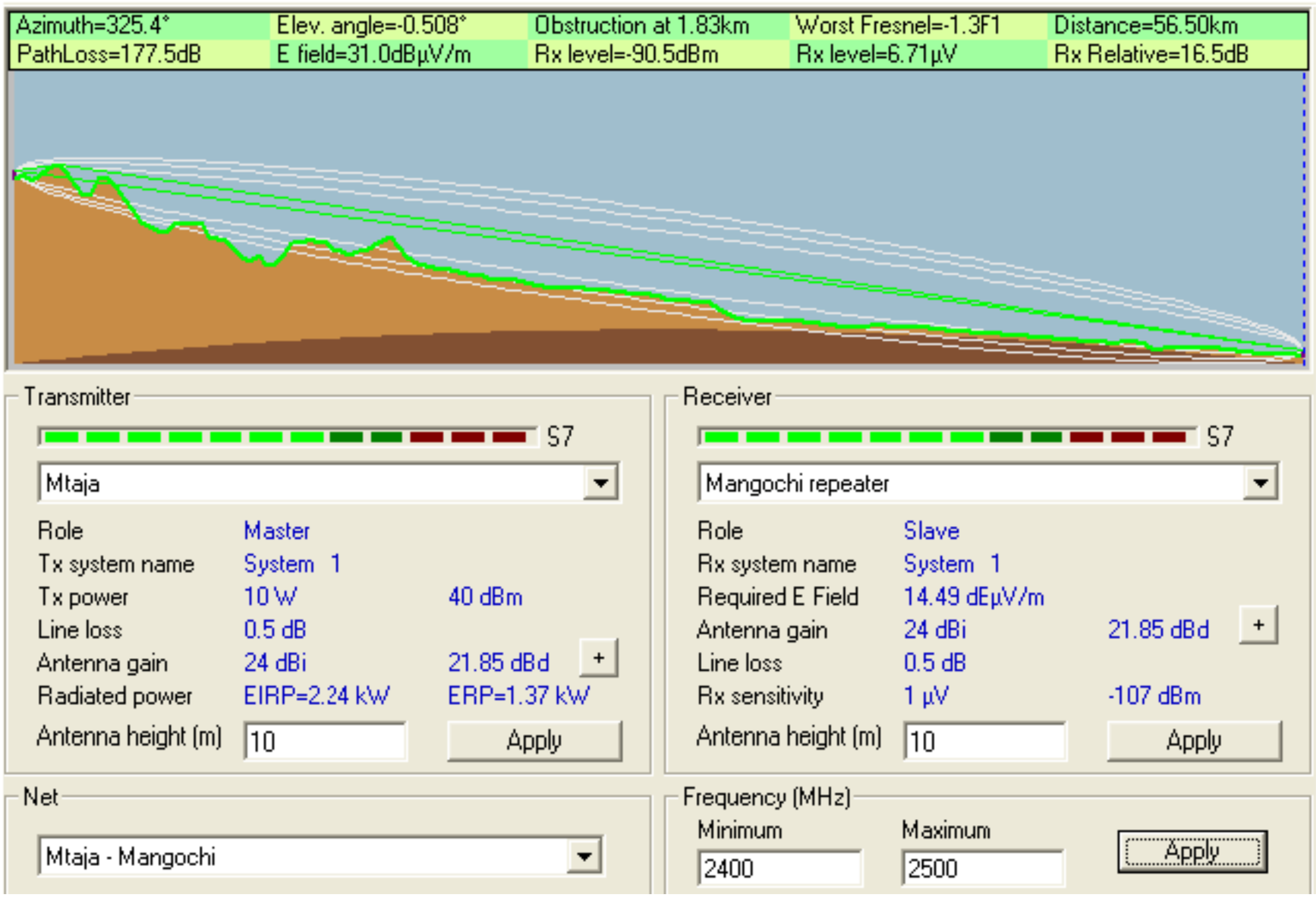
http://www.cplus.org/rmw/english1.html

Radio Mobile

- Uses Digital terrain Elevation Model for the calculation of coverage, indicating received signal strength at various point along the path.
- Radio Mobile automatically builds a profile between two points in the digital map showing the coverage area and 1st Fresnel zone.
- Different antenna heights can be tried to achieve optimum performance.



Radio Mobile



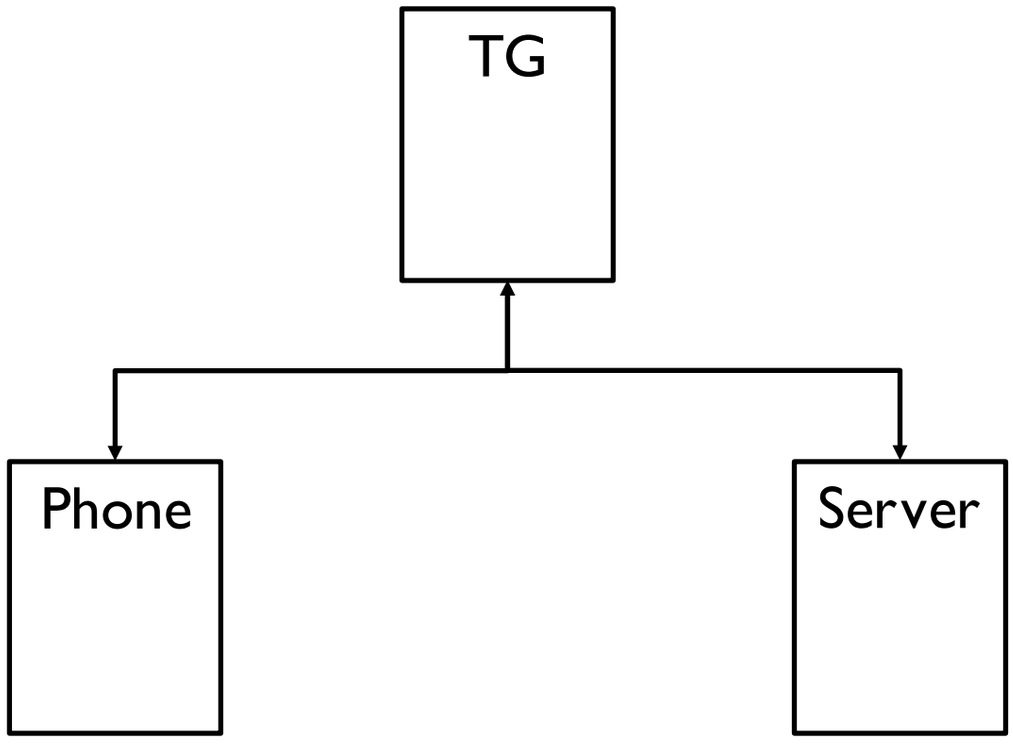
Telegram Bot: BotRf

- Telegram is an instant messaging service. Telegram clients exist for both mobile (Android, iOS, Windows Phone, Ubuntu Touch) and desktop systems (Windows, OS X, Linux). Users can send messages and exchange photos, videos, stickers and files of any type. Telegram also provides optional end-to-end encrypted messaging.

https://telegram.org/

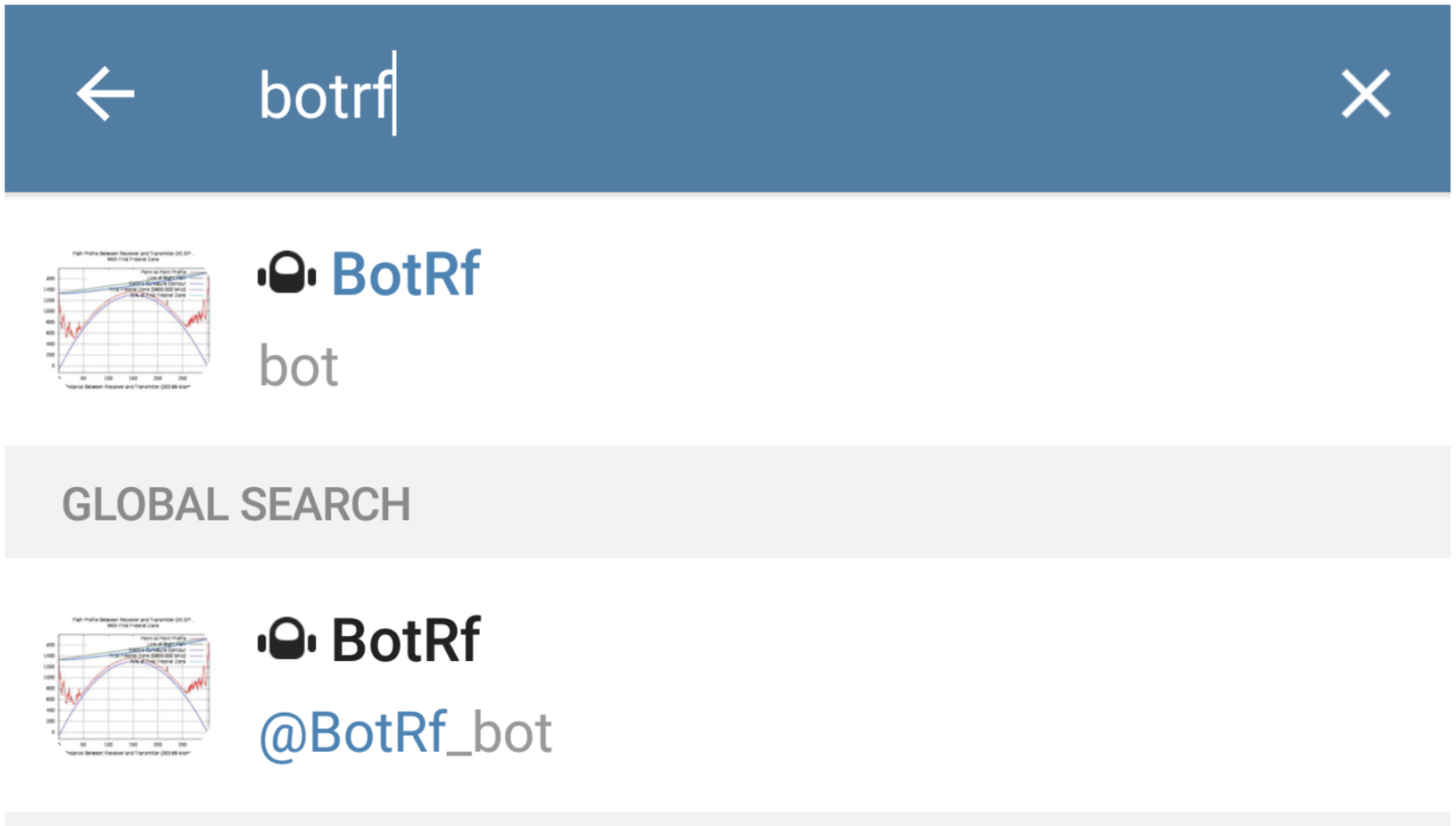
Telegram Bot: BotRf

- Telegram Bots are special accounts that do not require an additional phone number to set up. These accounts serve as an interface for code running somewhere on your server.



Telegram Bot: BotRf

- Start by installing Telegram on your smartphone (works on iOS, Android and Microsoft) or PC.
- Choose **BotRf** as a contact



Telegram Bot: BotRf

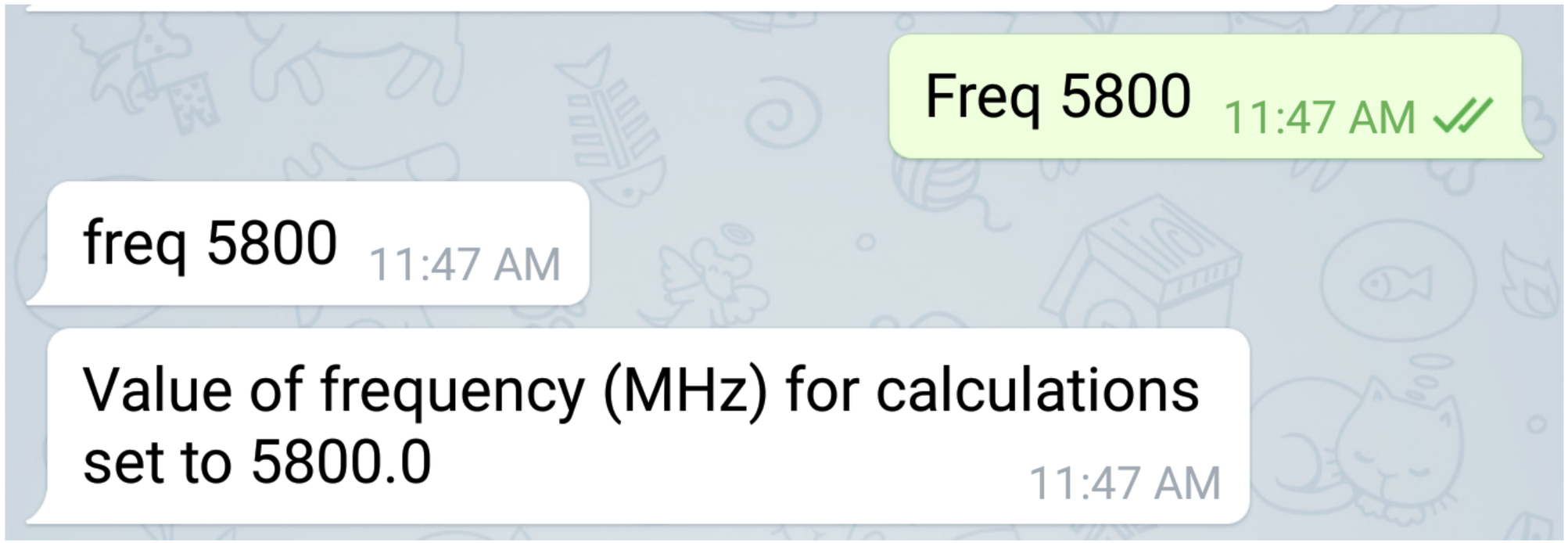
- There are three main commands:

- **Freq**: to change the frequency
- **Site**: to insert information about the sites (you need at least two sites for a link!)
- **Calc**: to check if the sites are in line of sight

- **Hlp** will give you a help about all the commands.

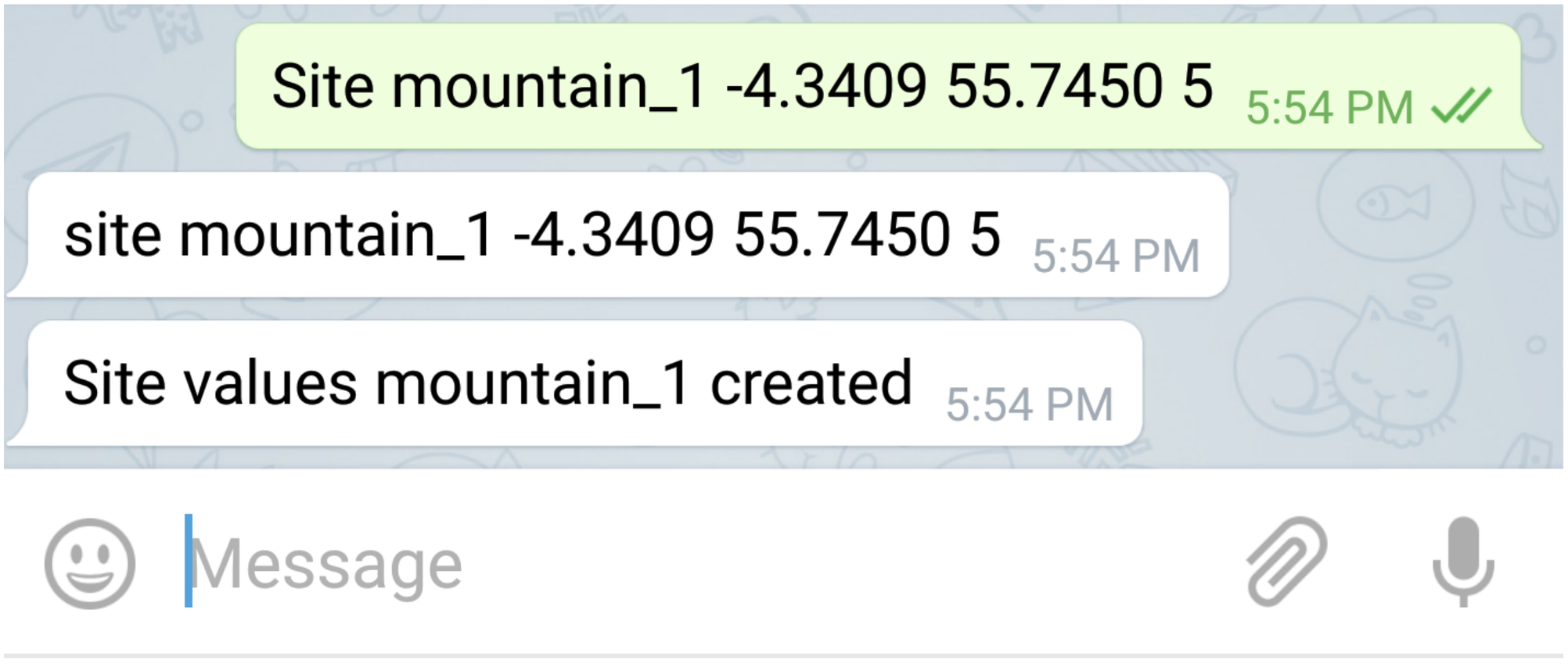
Telegram Bot: BotRf

- Let's start by setting the frequency to 5.8 Ghz



Telegram Bot: BotRf

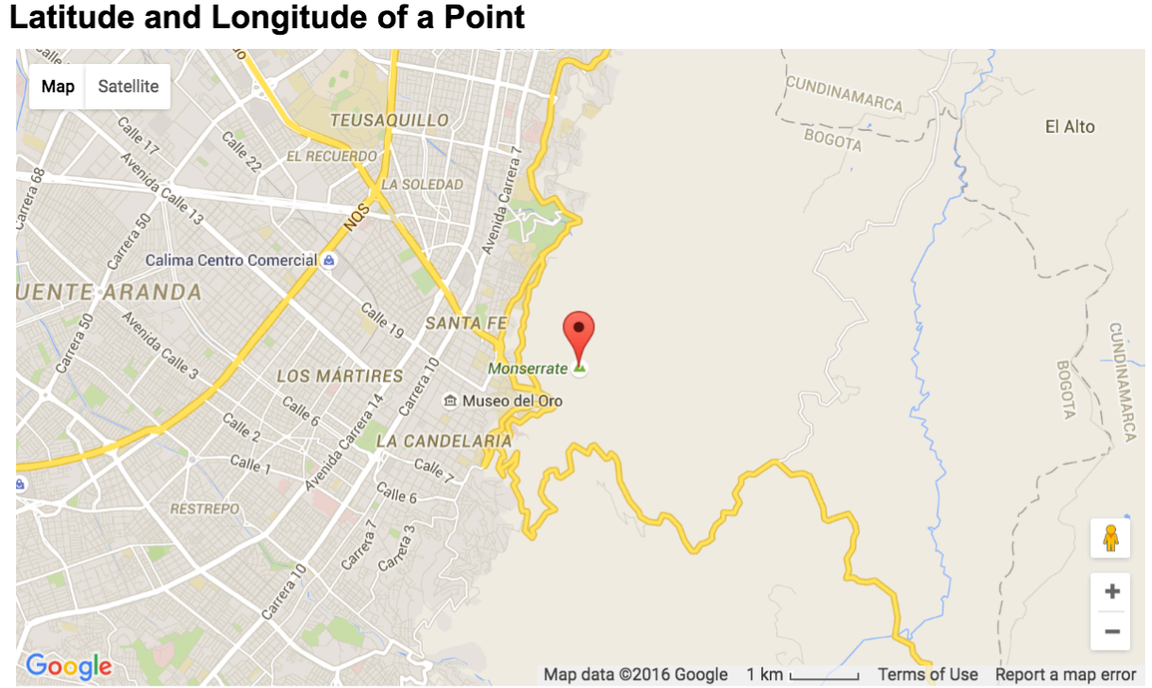
- Now let's create one site called mountain_1, with latitude -4.3409, latitude 55.7450 and antenna height 5 meters above the ground



Telegram Bot: BotRf

- You can find positions of sites using a GPS or by using this site:

- http://itouchmap.com/latlong.html



Clear / Reset | Remove Last Blue Marker | Center Red Marker

Get the Latitude and Longitude of a Point

When you click on the map, move the marker or enter an address the latitude and longitude coordinates of the point are inserted in the boxes below.

Latitude: 4.605896
Longitude: -74.056349

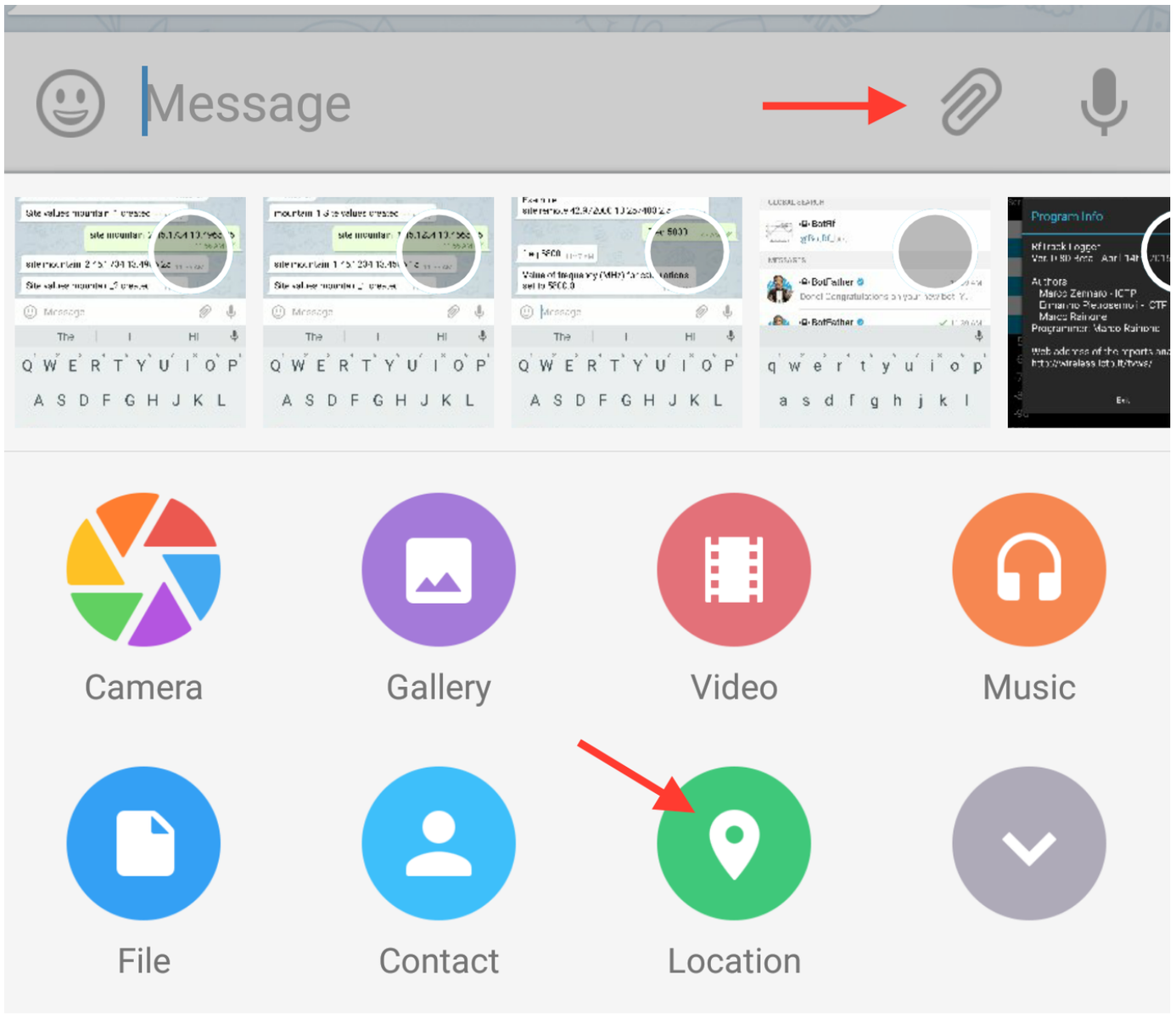
Show Point from Latitude and Longitude

Use this if you know the latitude and longitude coordinates of a point and want to see where on the map the point is.
Use: + for *N* Lat or *E* Long - for *S* Lat or *W* Long.
Example: +40.689060 -74.044636
Note: Your entry should not have any embedded spaces.

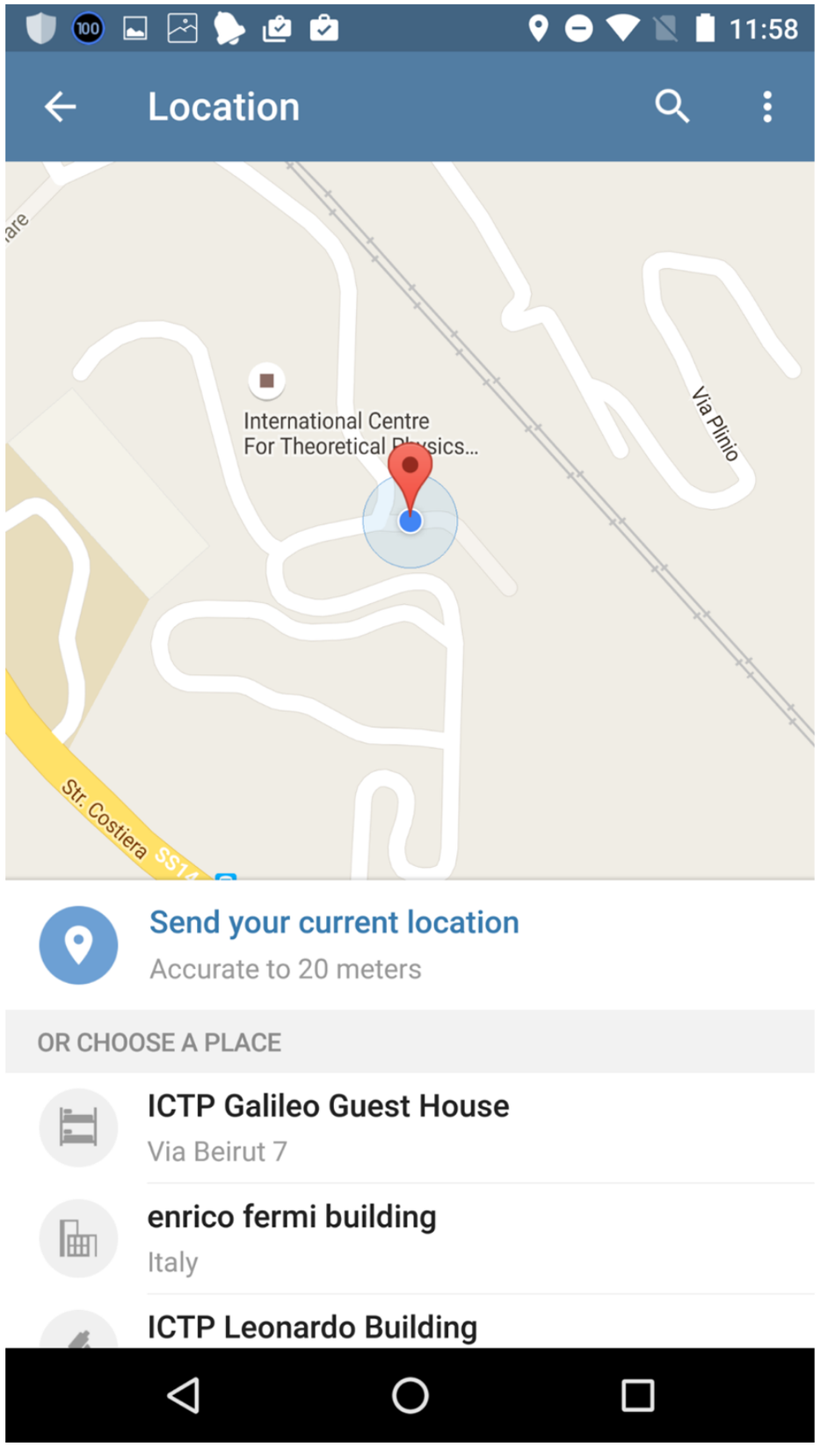
Decimal Deg. Latitude:
Decimal Deg. Longitude:
Show Point

Telegram Bot: BotRf

- If you are using your smartphone, you can use it to get the position of the site

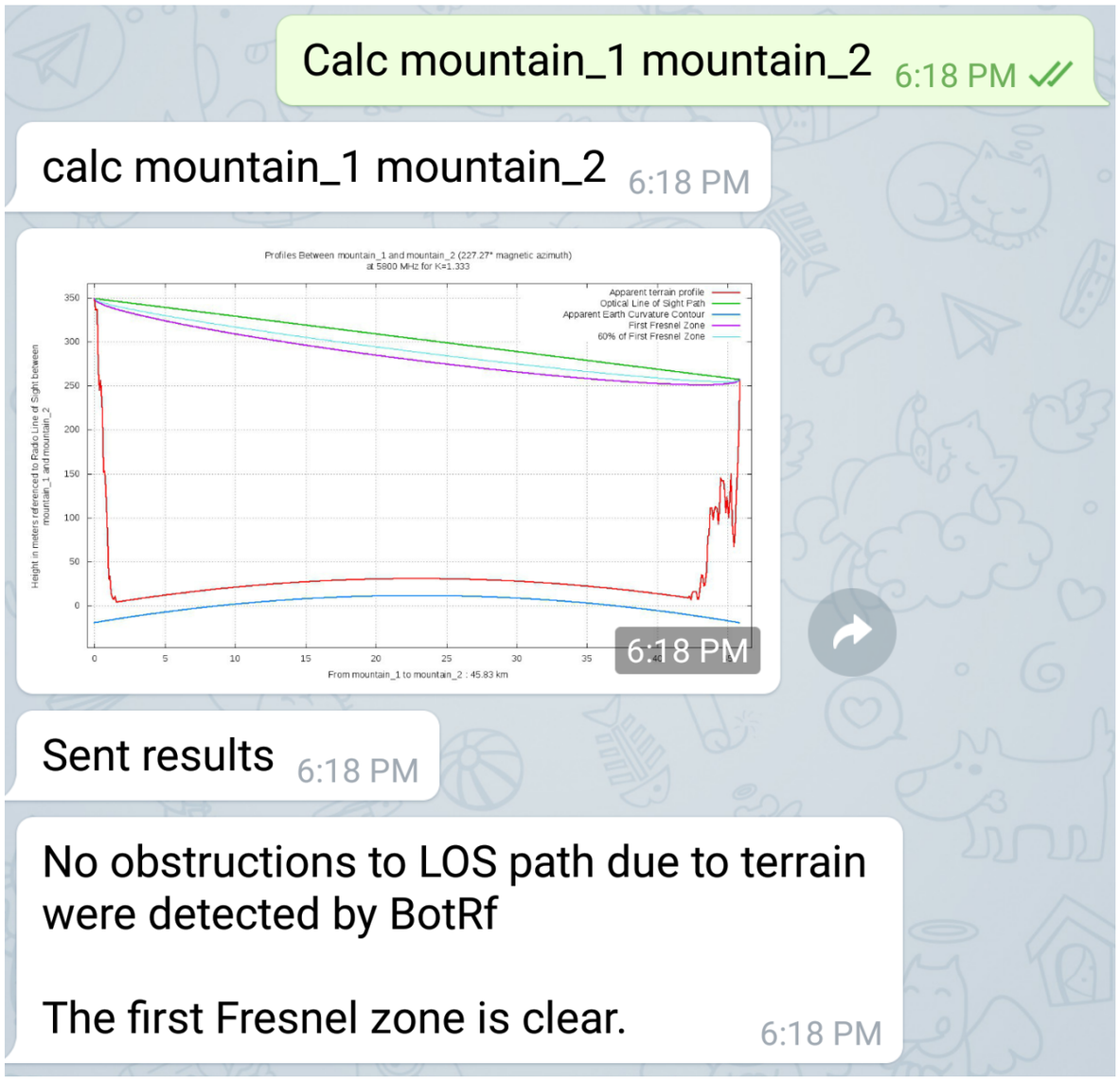


Telegram Bot: BotRf

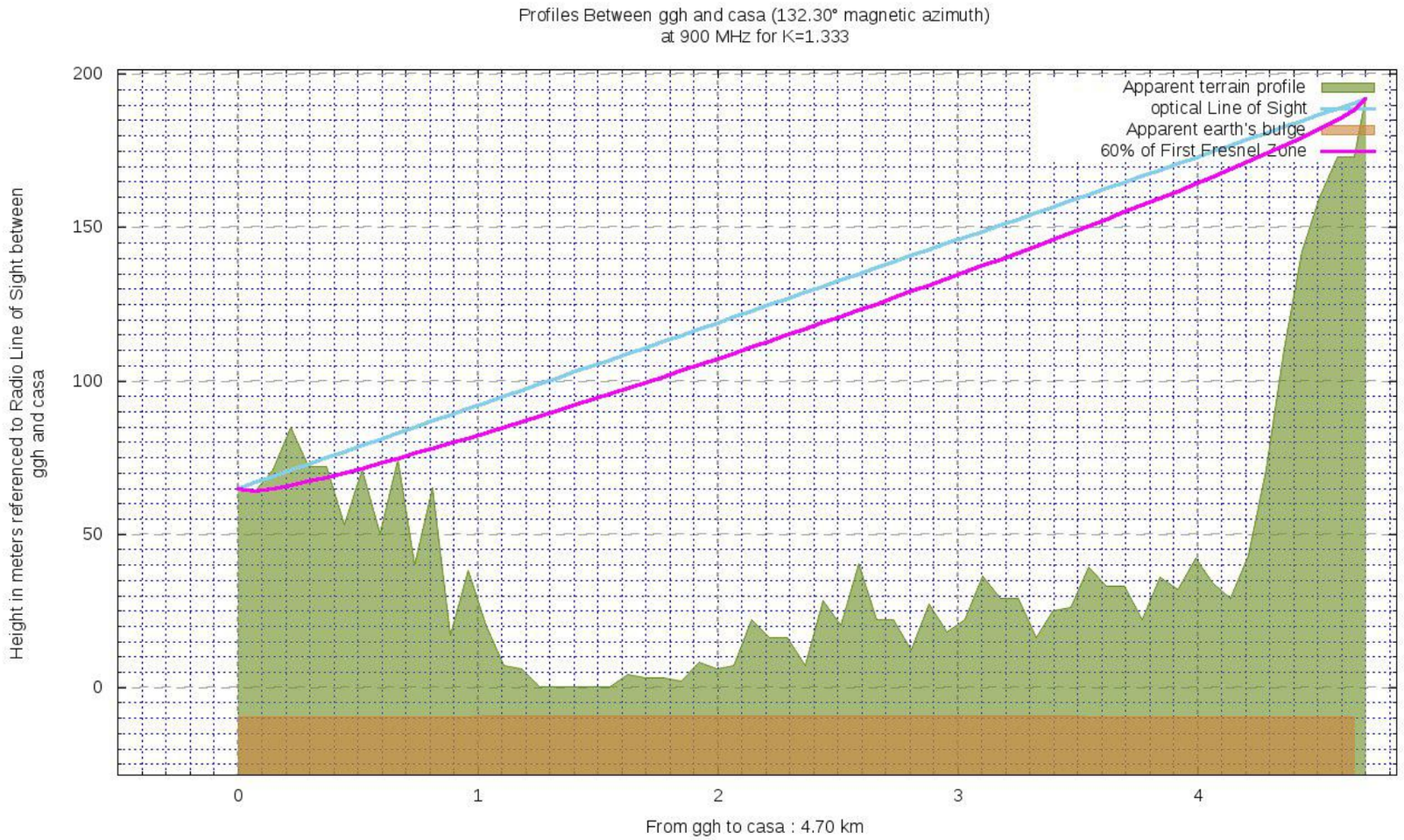


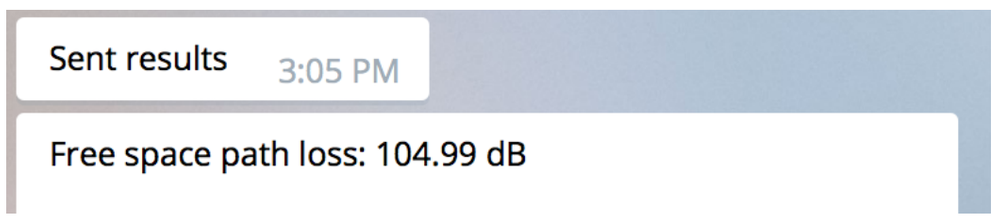
Telegram Bot: BotRf

- Once you have two sites (let's say they are called mountain_1 and mountain_2), you can check the profile between them with **Calc**



Telegram Bot: BotRf





Telegram Bot: BotRf

- **Excercise**
- Can you deploy an IoT link from Javeriana to Monserrate at 900 MHz?
- How far are they?
- How high do you have to raise the antennas?

- Calculate the link budget using RE-Mote devices