Planning IoT wireless links

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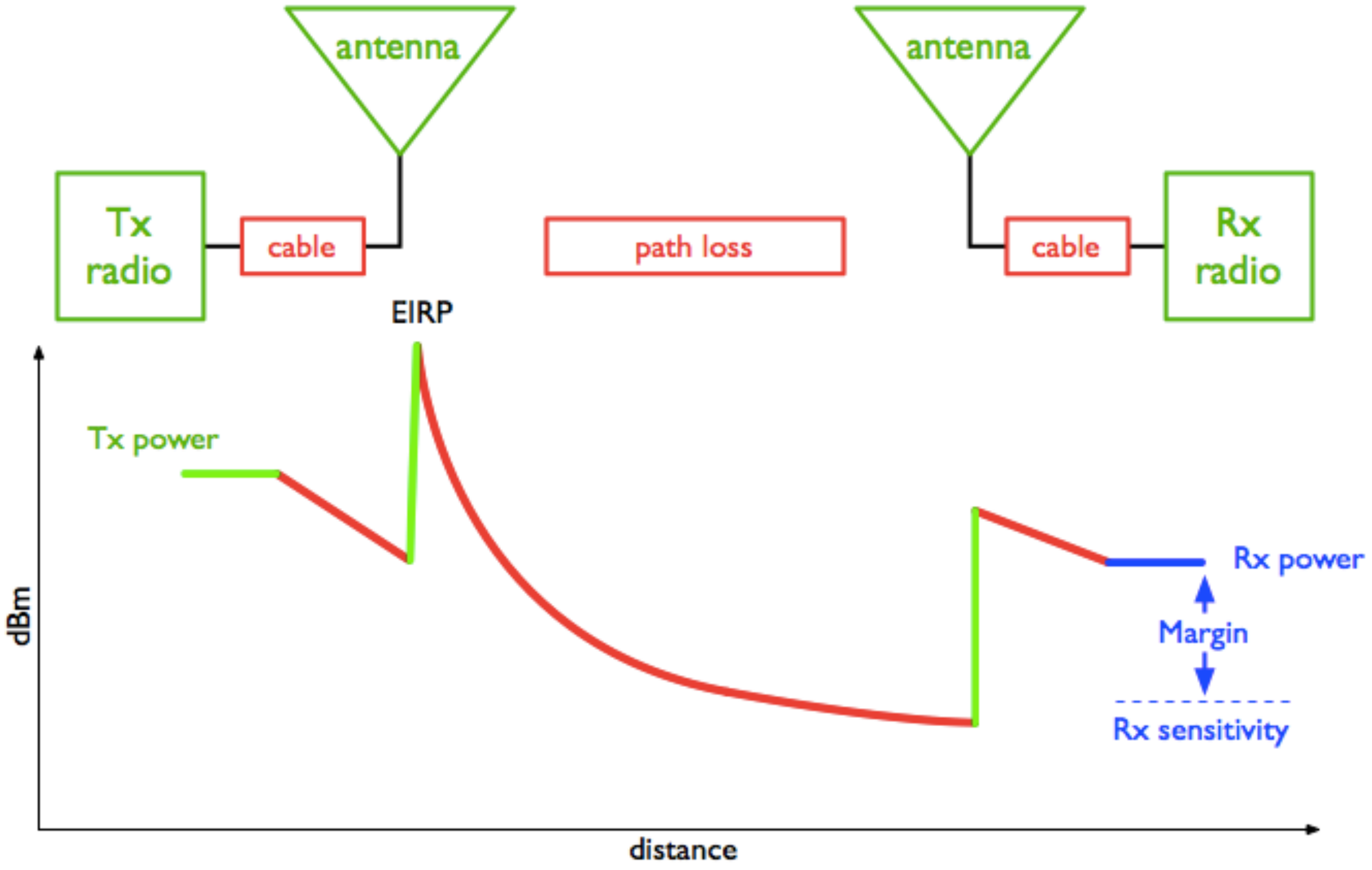
MATAJUR
CROCE ARCANA
(316 Km)
Merano
Meran
Brixen
Bolzano
Bozen
Ortisei
Sankt Ulrich
Misurina
Cortina
d'Ampezzo
Villach
Klagenfurt
Tarvisio
Bled
Kranj
Kamnik
Ljubljana
St Moritz
Livigno
Parco
Nazionale
dello Stelvio
Parco Naturale
Adamello
Brenta
Sondrio
Tirano
Park
Parco delle
Orobie
Bergamasche
Trento
Belluno
Udine
Gorizia
Pordenone
Conegliano
Levico Terme
Riva del Garda
Rovereto
Limone
Sul Garda
Bassano
del Grappa
Treviso
Castelfranco
Veneto
Vicenza
Padua
Venice
Lido di Jesolo
Caorle
Lignano
Sabbiadoro
Grado
Trieste
Koper
Postojna
Brescia
Sirmione
Verona
Desenzano
del Garda
Mantua
Cremona
Piacenza
Chioggia
Rovigo
Park
Parco
Regionale
Veneto del
Delta del Po
Rijeka
Opatija
Poreč
Crikvenica
Rovinj
Pula
Medulin
Krk
Baška
Cres
Mali Losinj
Parma
Carpi
Ferrara
Modena
Sassuolo
Bologna
Imola
Ravenna
Forlì
Cesena
Rimini
San Marino
Pesaro
Senigallia
Ancona
Iesi
La Spezia
Forte dei
Marmi
Viareggio
Pistoia
Prato
Florence
Pisa
Livorno
San Gimignano
Arezzo
Citta di
Castello
A10
A2
A22
A34
A28
E70
E45
E35
E33
A4
A35
A31
A13
E751
E65
A14
E76

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

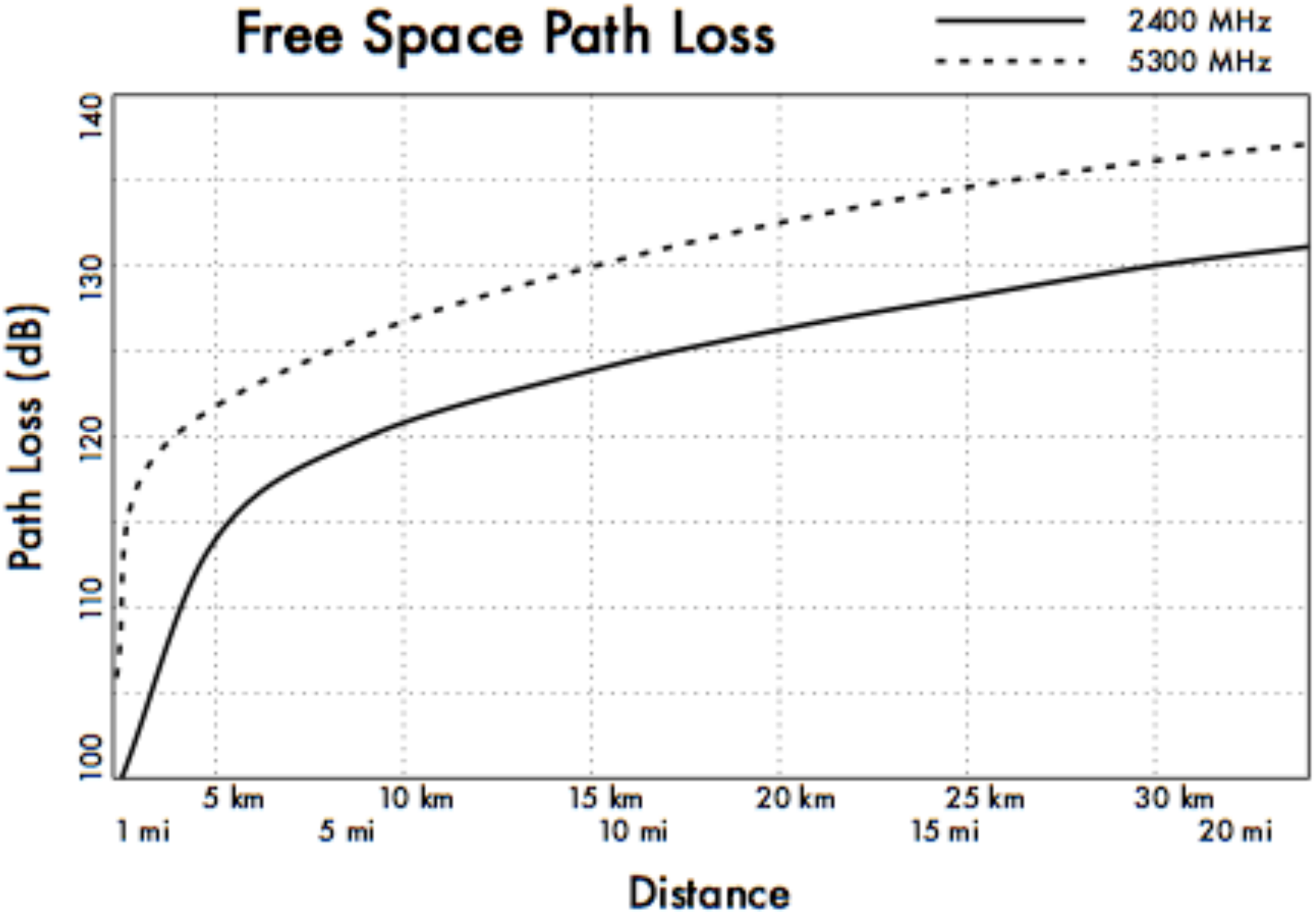


Free Space Loss (any frequency)

- 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 radio 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).

12.2 Specifications

Table 8 – WiFi specifications

Description	Min	Typ.	Max	Unit
Input Frequency	2412	–	2484	MHz
Tx power Output power of PA for 72.2 Mbps	13	14	15	dBm
Output power of PA for 11b mode	19.5	20	20.5	dBm
		Sensitivity		
DSSS, 1Mbps	–	–	98	dBm
CCK, 11 Mbps	–	–	91	dBm
OFDM, 6 Mbps	–	–	93	dBm
OFDM, 54 Mbps	–	–	75	dBm
HT20, MCS0	–	–	93	dBm
HT20, MCS7	–	–	73	dBm
HT40, MCS0	–	–	90	dBm
HT40, MCS7	–	–	70	dBm
MCS32	–	–	89	dBm

Example link budget calculation

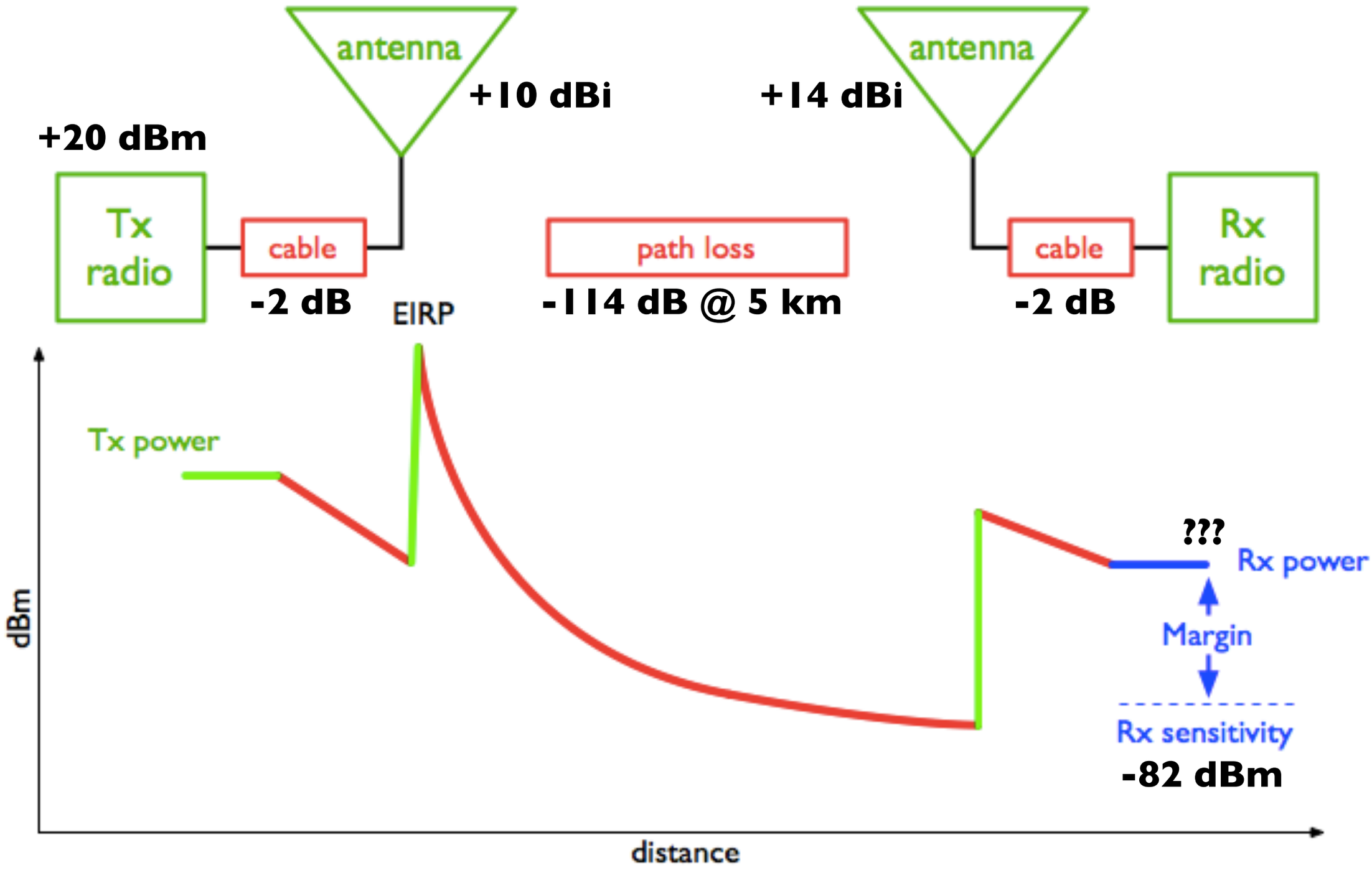
Let's estimate the feasibility of a **5 km** link, with two radios that we will call Radio1 and Radio 2.

Radio 1 is connected to an antenna with **10 dBi** gain, with a transmitting power of **20 dBm** and a receive sensitivity of **-89 dBm**.

Radio 2 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.

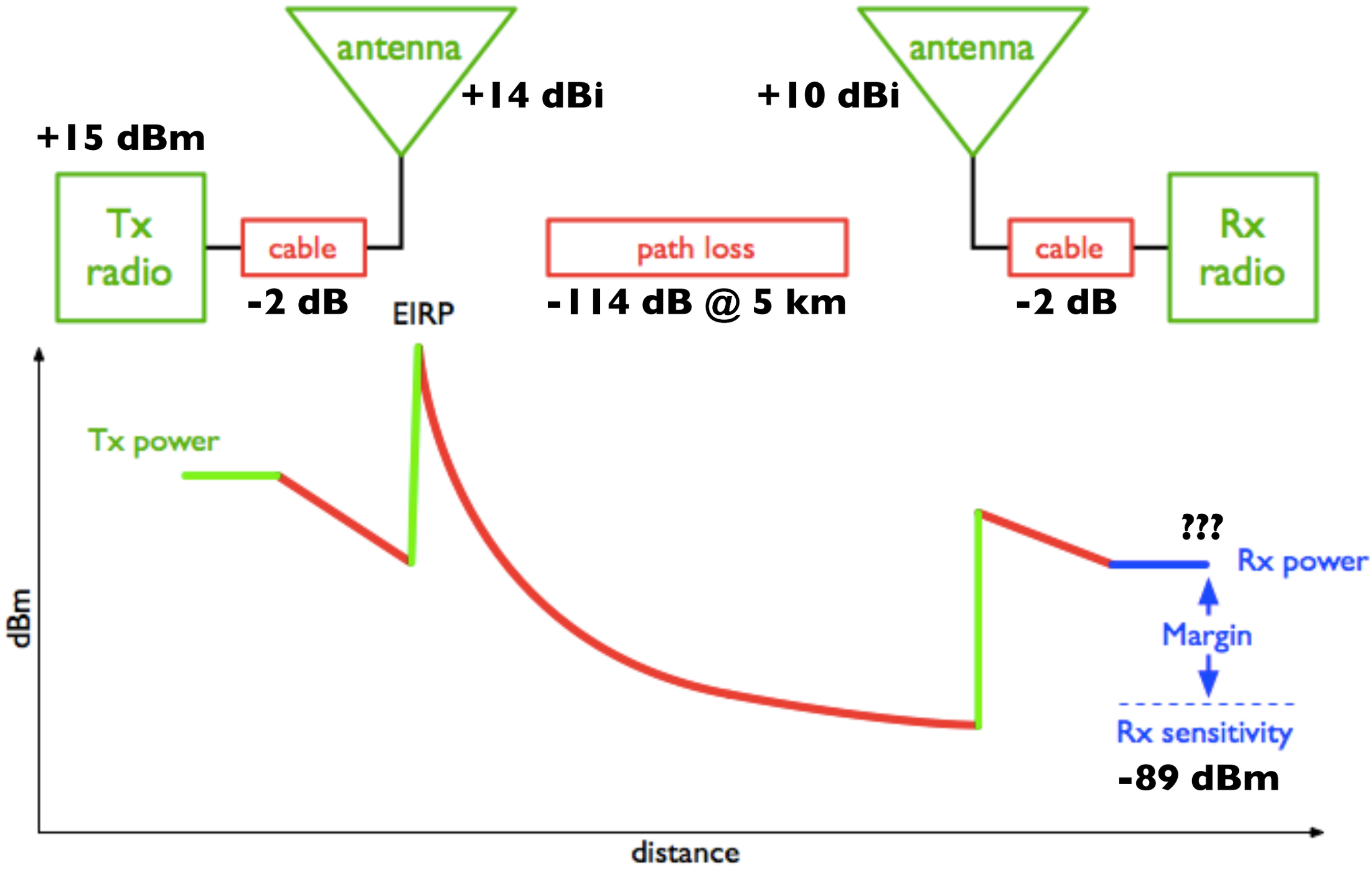
Radio 1 to Radio 2 link



Link budget: Radio 1 to Radio 2

```
  20 dBm (TX Power Radio 1)
+ 10 dBi (Antenna Gain Radio 1)
-  2 dB  (Cable Losses Radio 1)
+ 14 dBi (Antenna Gain Radio 2)
-  2 dB  (Cable Losses Radio 2)
---------------

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

 -73 dBm (expected received signal level)
--82 dBm (sensitivity of Radio 2)
---------------

   9 dB  (link margin)
```

Opposite direction: Radio 2 to Radio 1



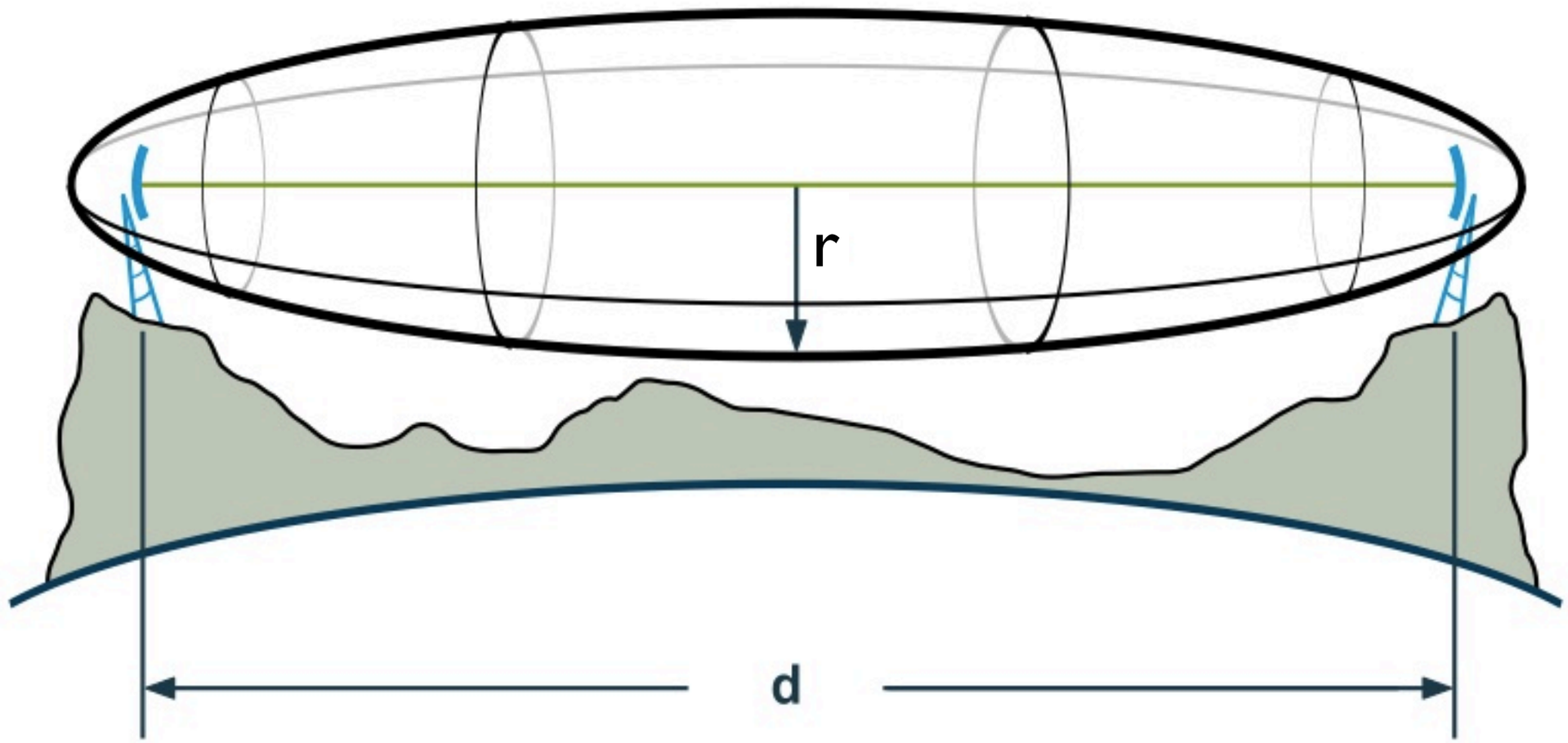
Link budget: Radio 2 to Radio 1

```
   15 dBm (TX Power Radio 2)
+  14 dBi (Antenna Gain Radio 2)
-   2 dB  (Cable Losses Radio 2)
+  10 dBi (Antenna Gain Radio 1)
-   2 dB  (Cable Losses Radio 1)
---------------

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

  -78 dBm (expected received signal level)
 --89 dBm (sensitivity of Radio 1)
---------------

   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

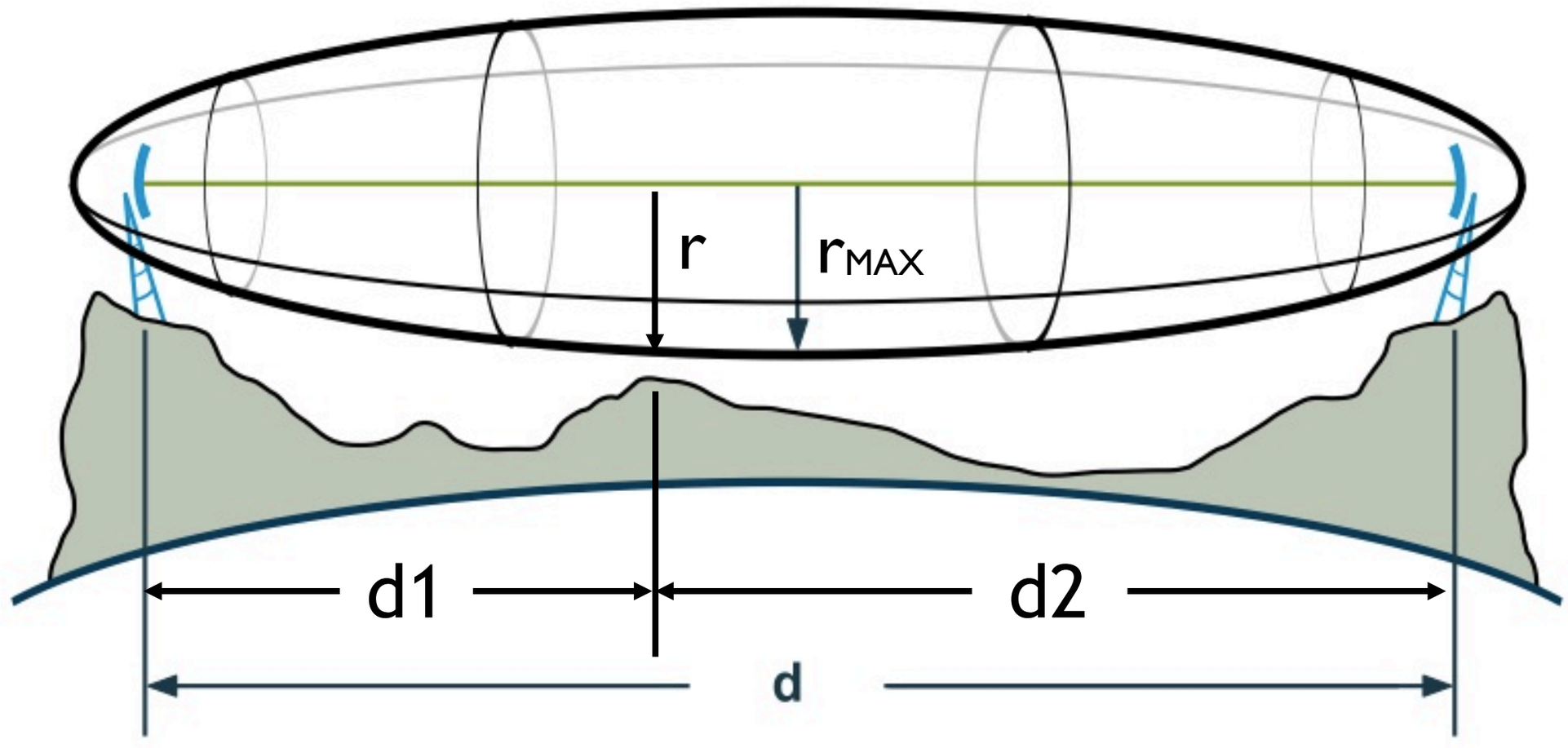
Fresnel Zone

- 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.

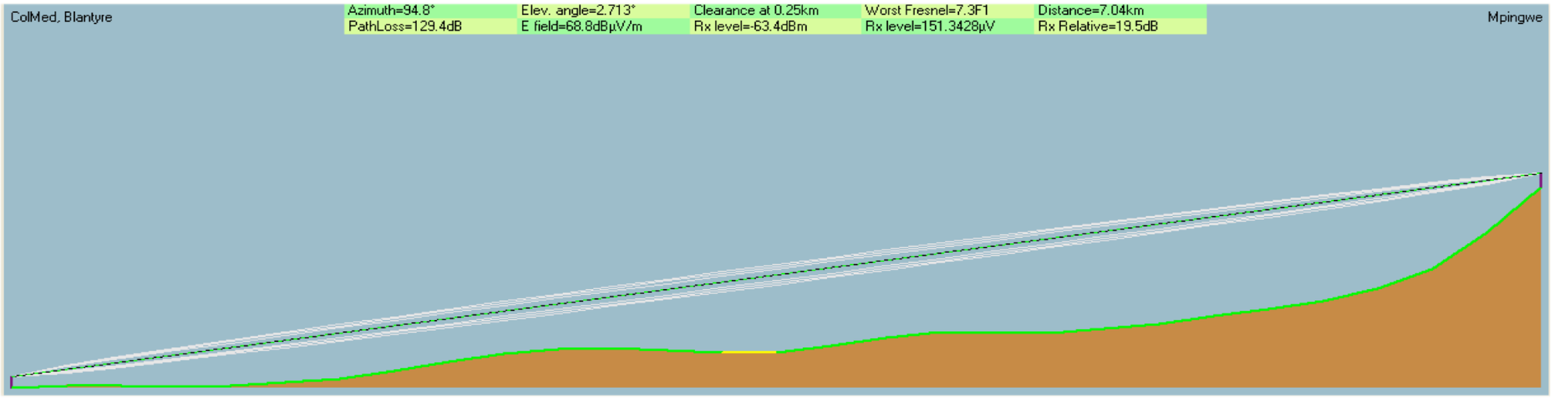
Radio Mobile

- 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.

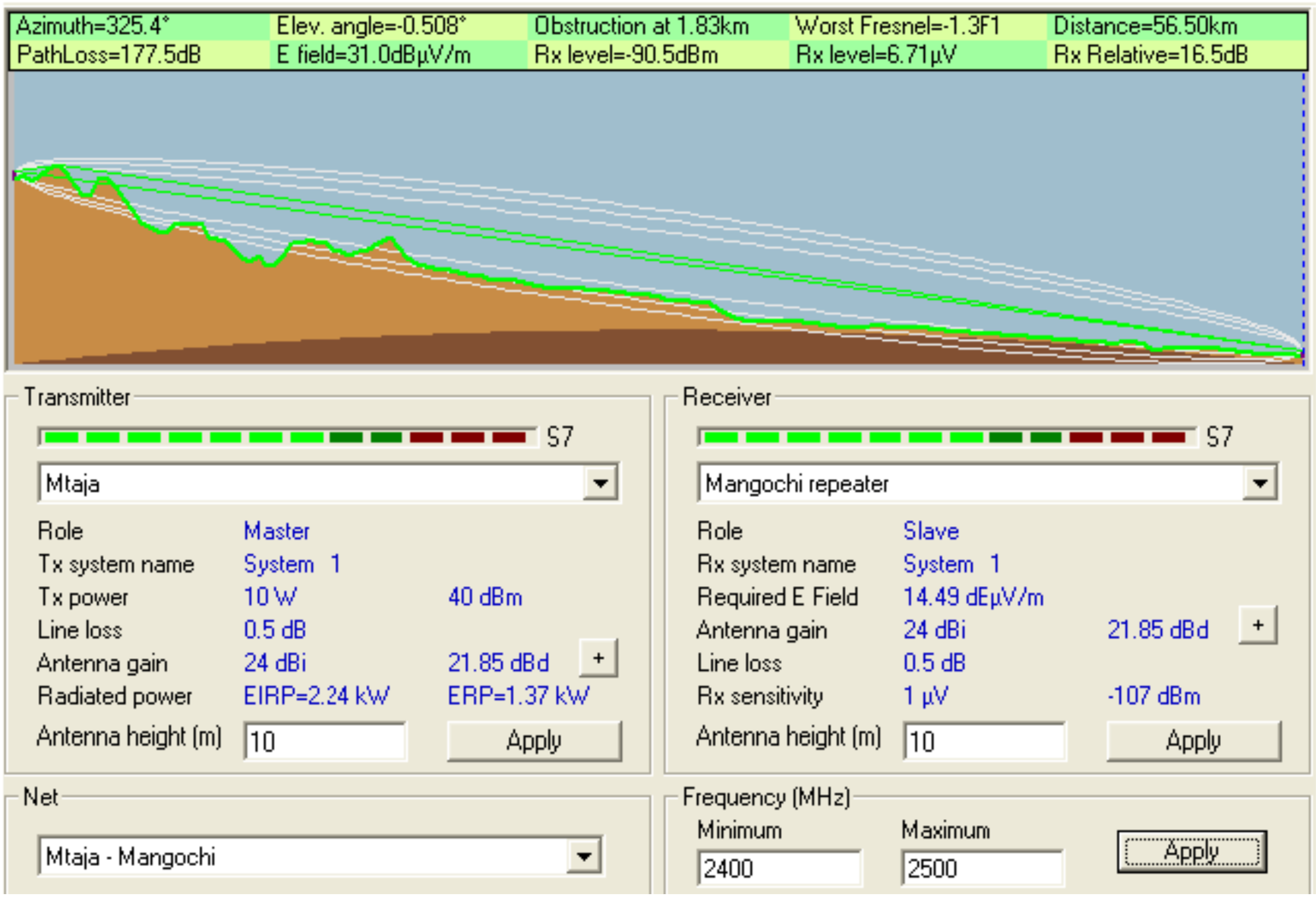
http://www.cplus.org/rmw/english1.html

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



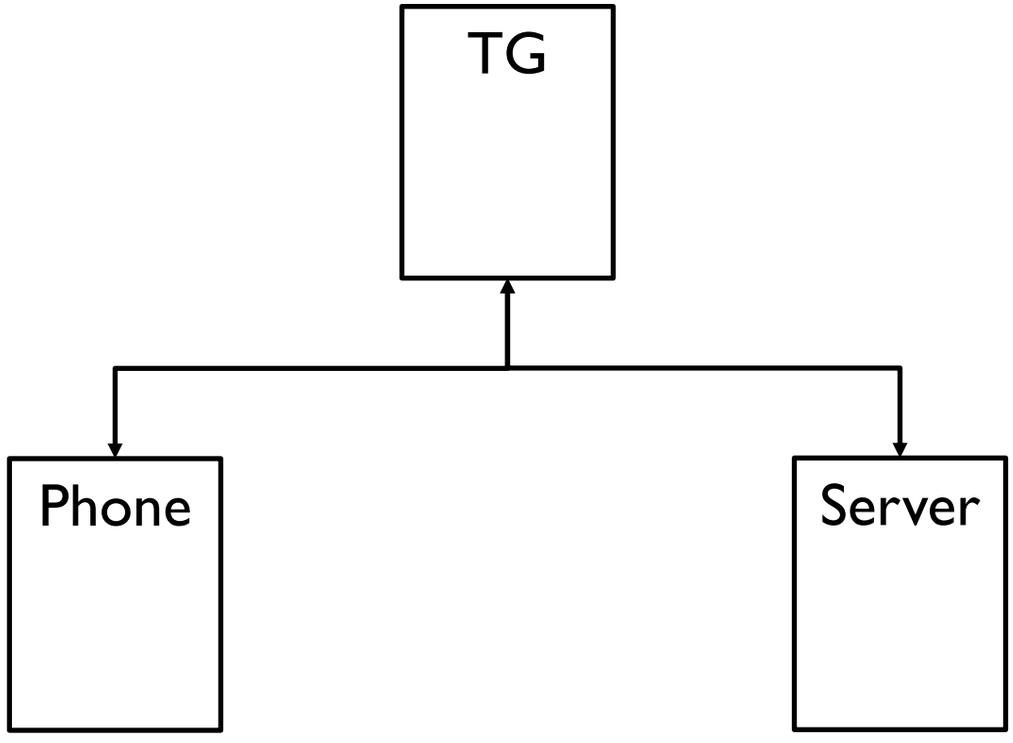
Telegram Bot: BotRf

- 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/

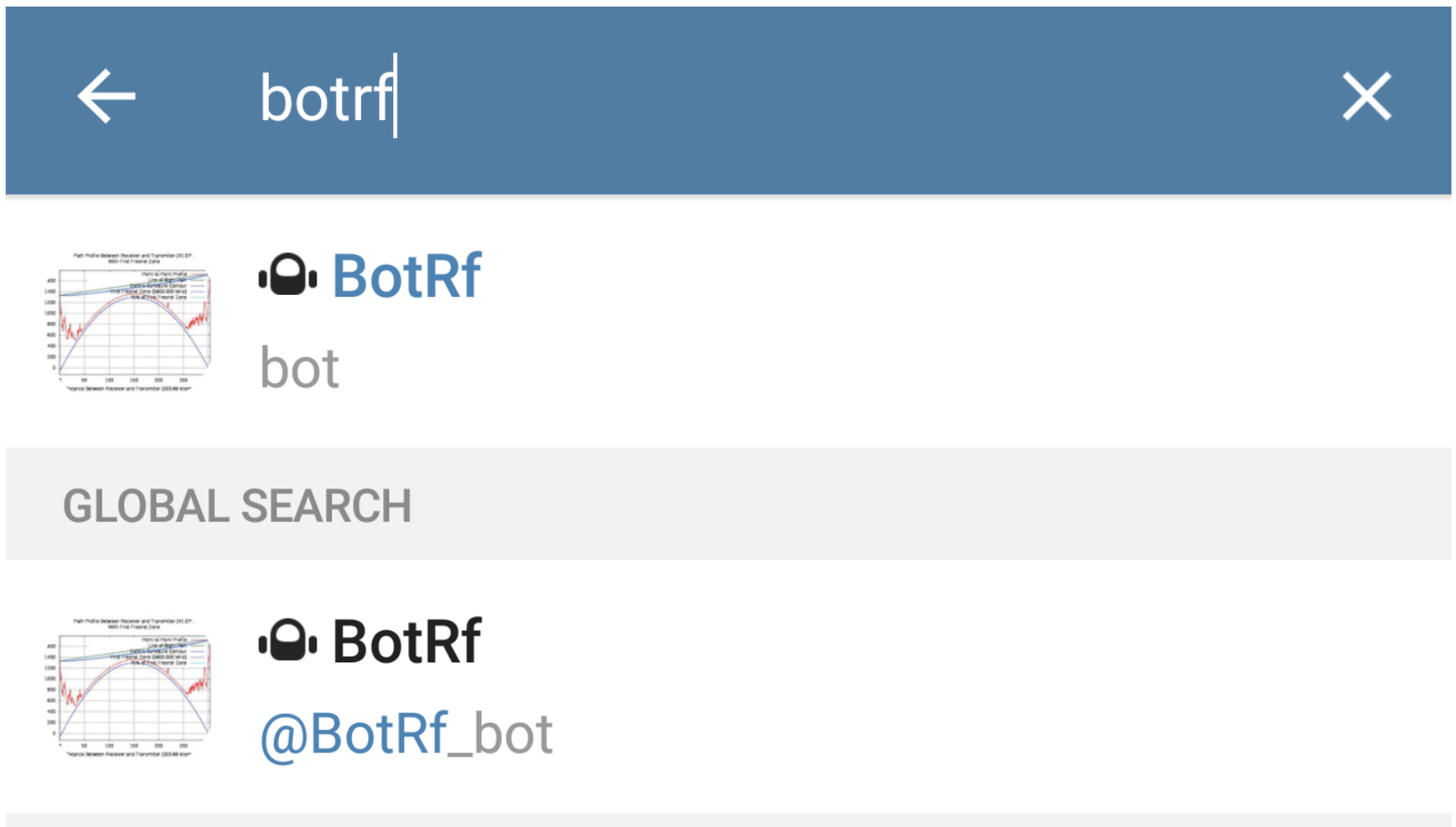
Telegram Bot: BotRf

- 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

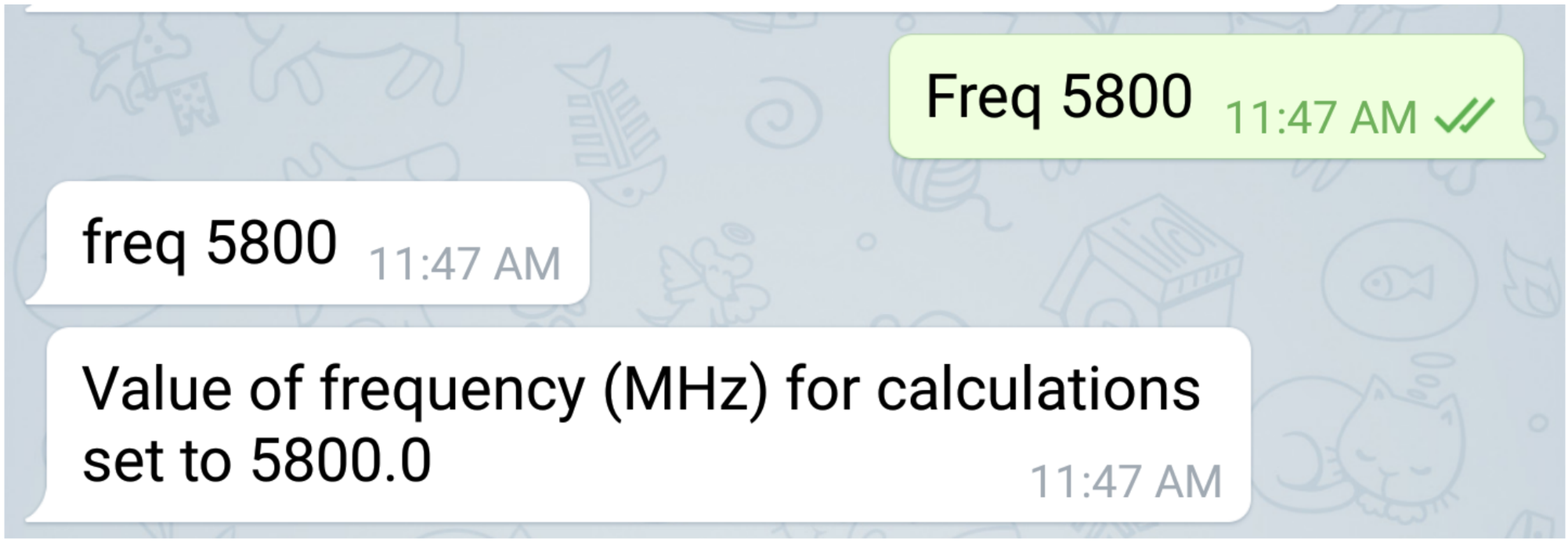
- There are three main commands:

- **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.

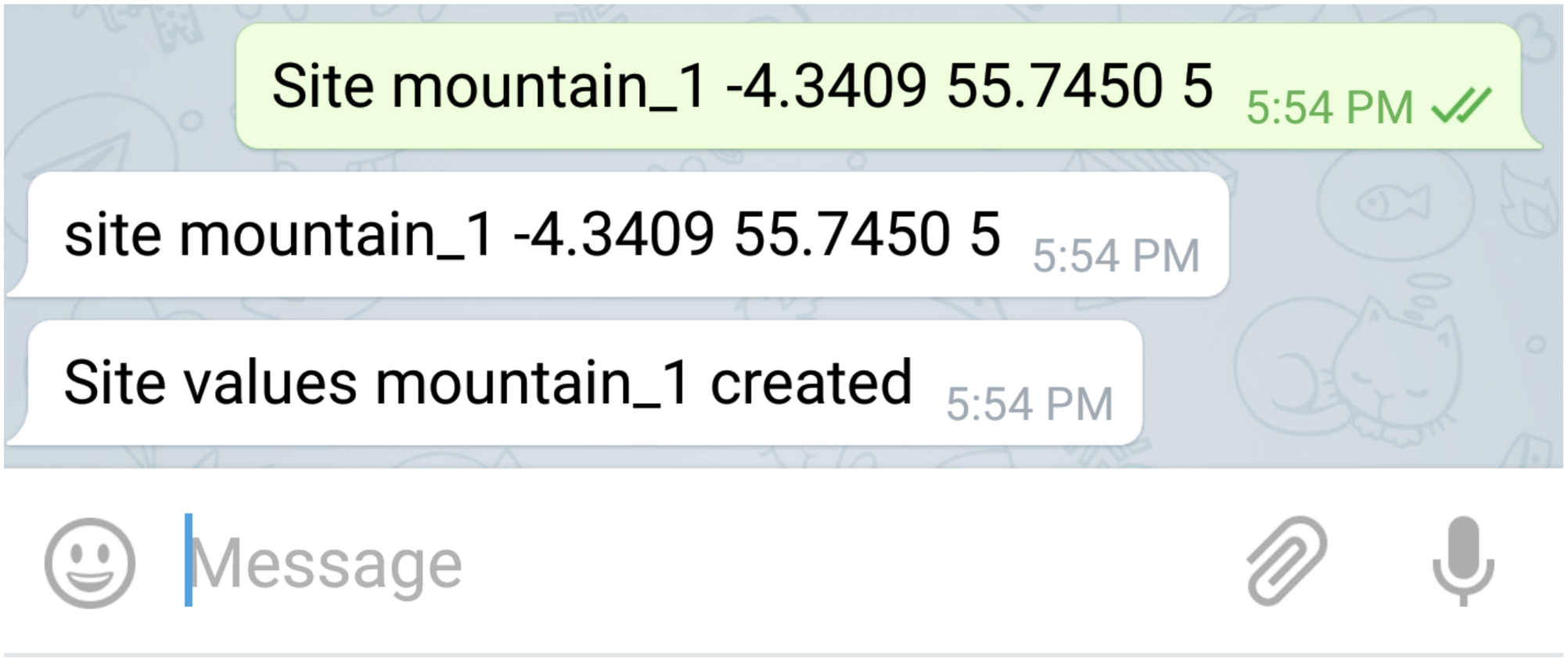
Telegram Bot: BotRf

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



Telegram Bot: BotRf

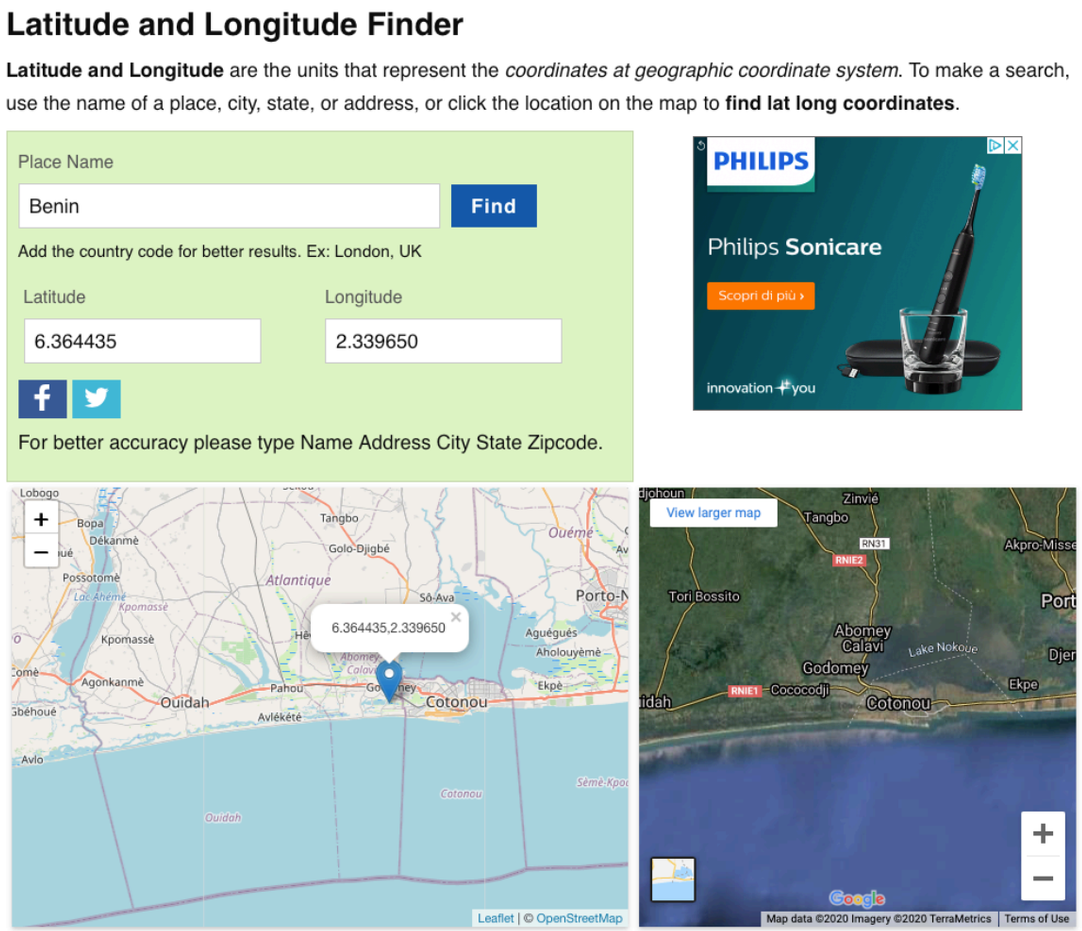
- Now let's create one site called mountain_1, with latitude -4.3409, latitude 55.7450 and antenna height 5 meters above the ground



Telegram Bot: BotRf

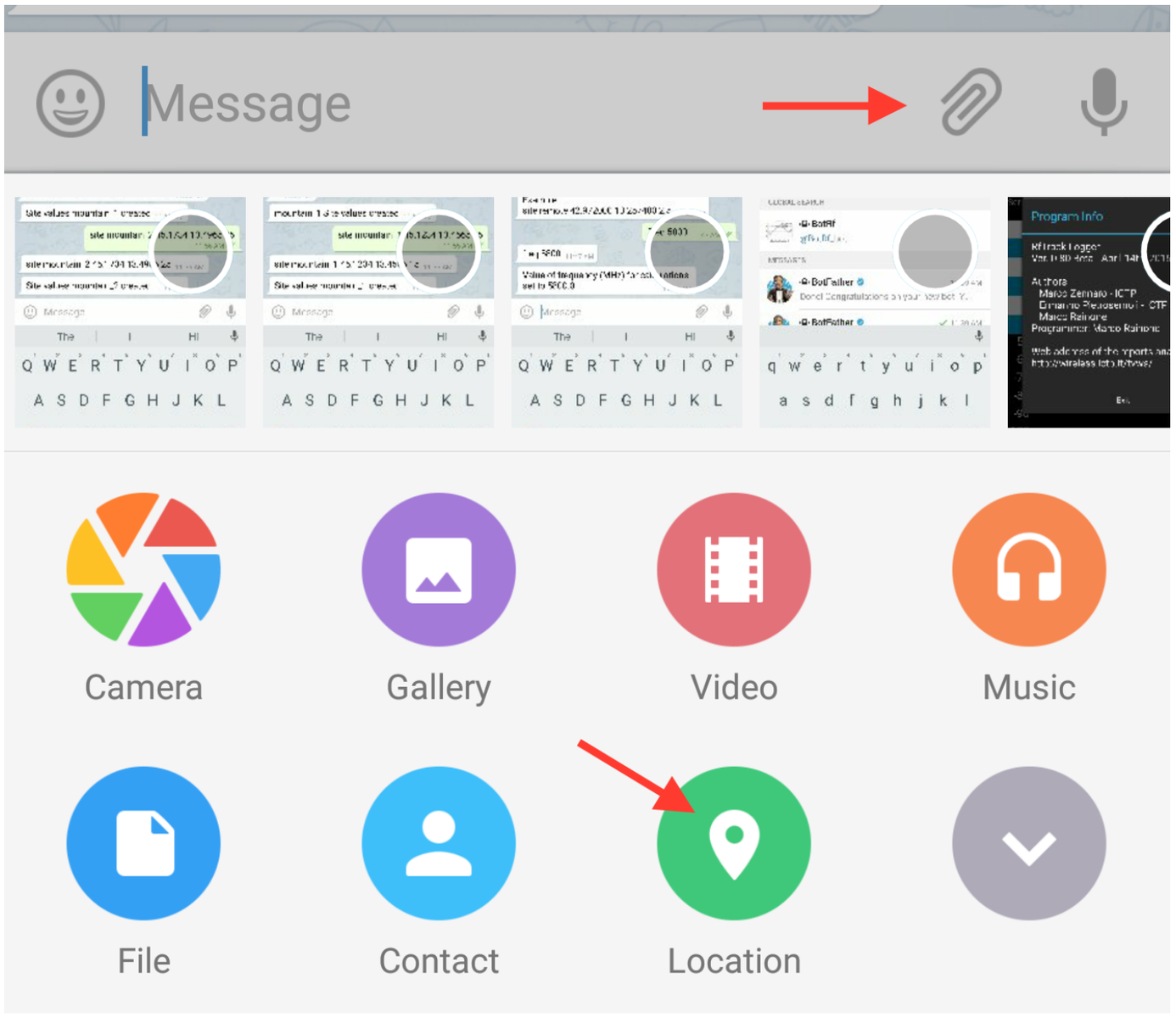
- You can find positions of sites using a GPS or by using this site:

- https://www.latlong.net

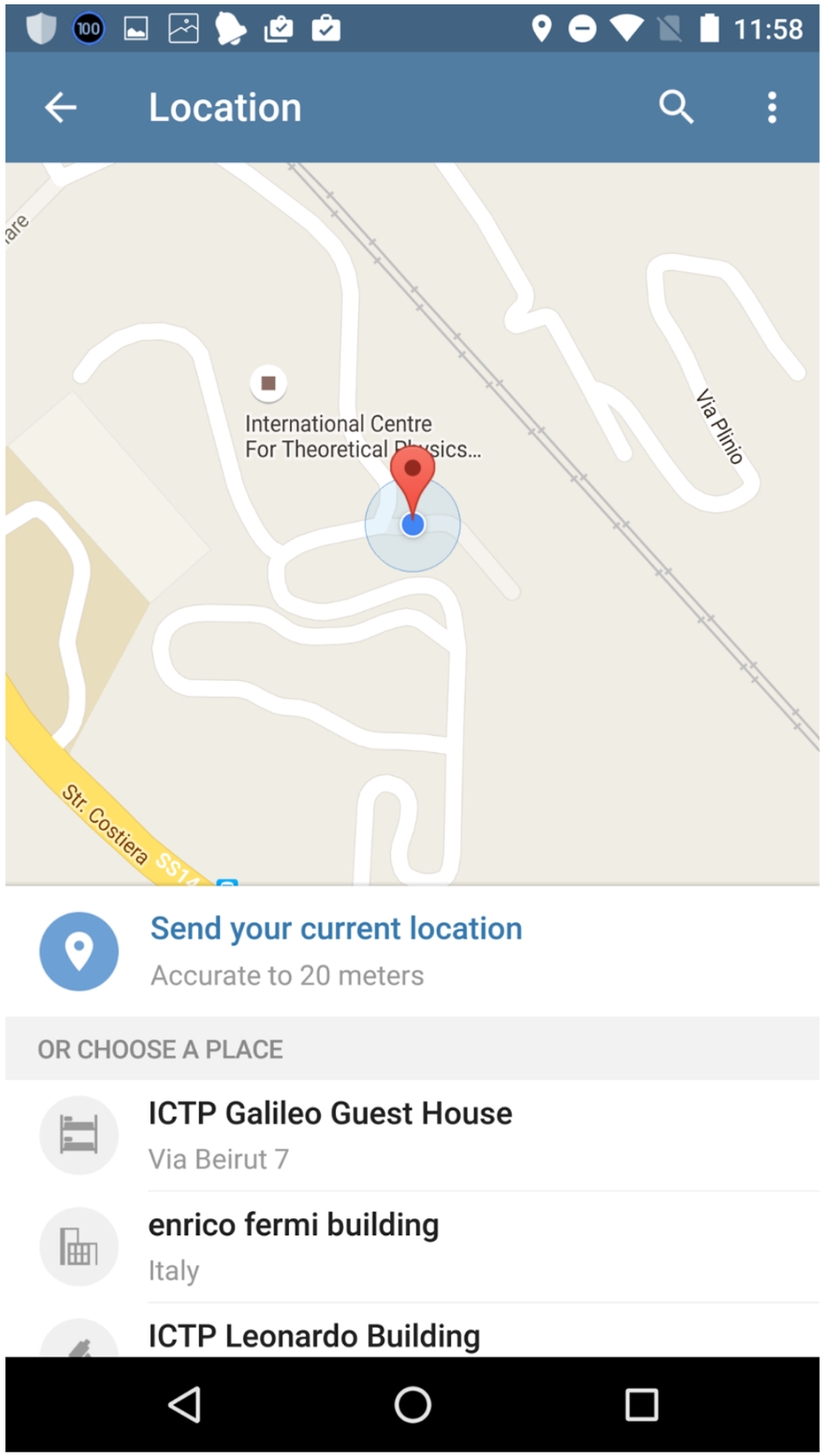


Telegram Bot: BotRf

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

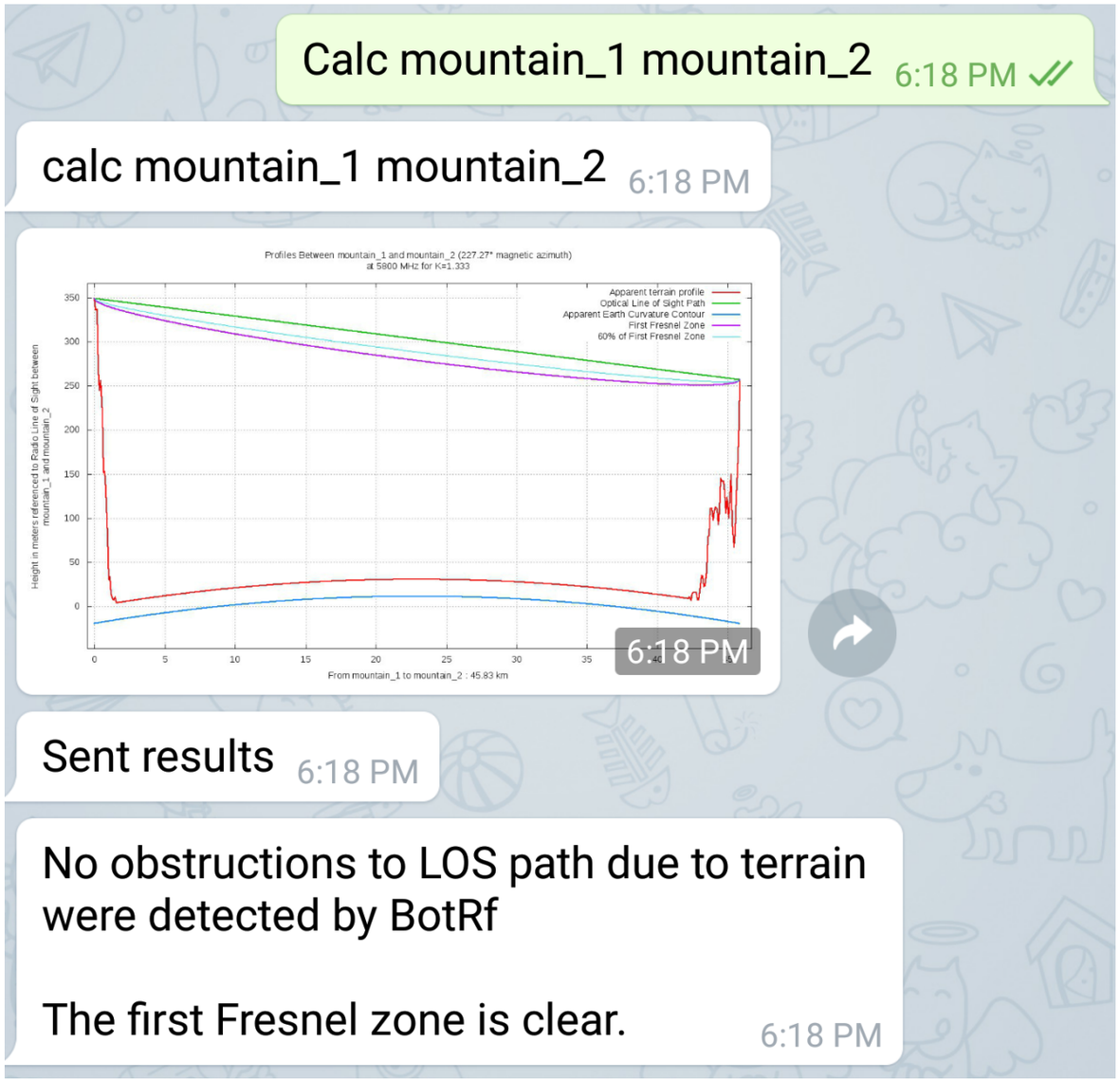


Telegram Bot: BotRf

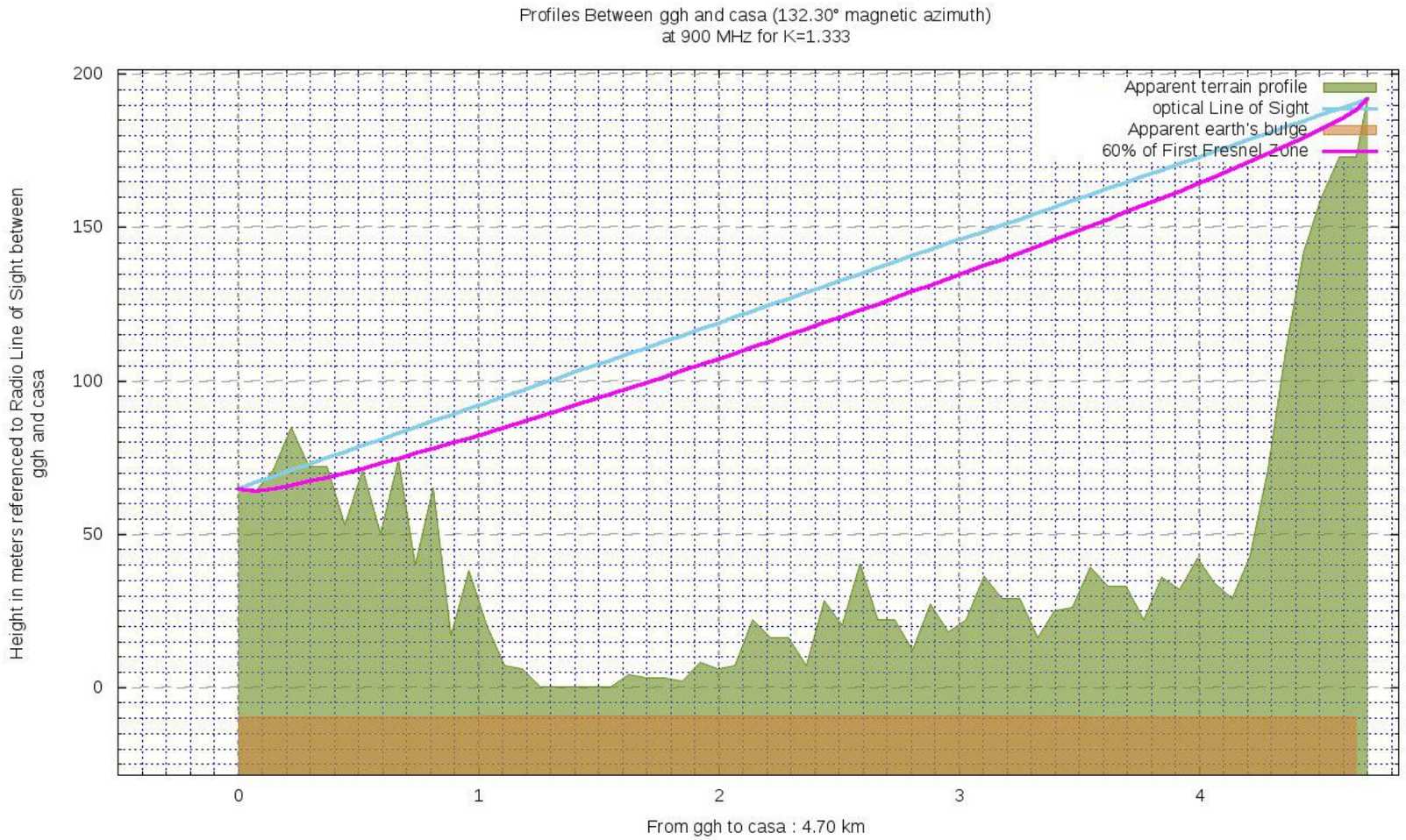


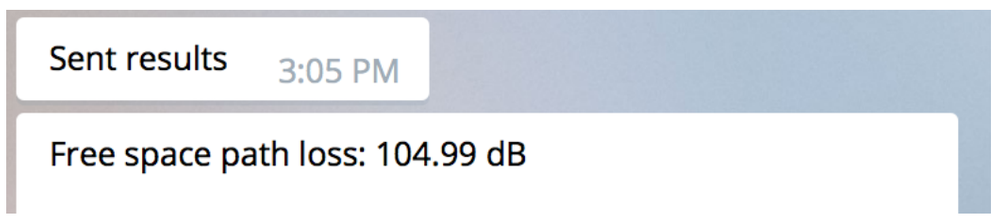
Telegram Bot: BotRf

- 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 IMSP to Cotonou at 868 MHz?
- How far are they?
- How high do you have to raise the antennas?
- Calculate the link budget using Pycom LoPy devices