Long Distance Links

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- What do we need for long distance links?
- Antenna Alignment
- Propagation times
- The 5 GHz band
- Conclusions

Introduction

WiFi Technology

Wireless Technology

Analog microwave links

1980 (low speeds)

1995 (11km)

2006 (279 km)

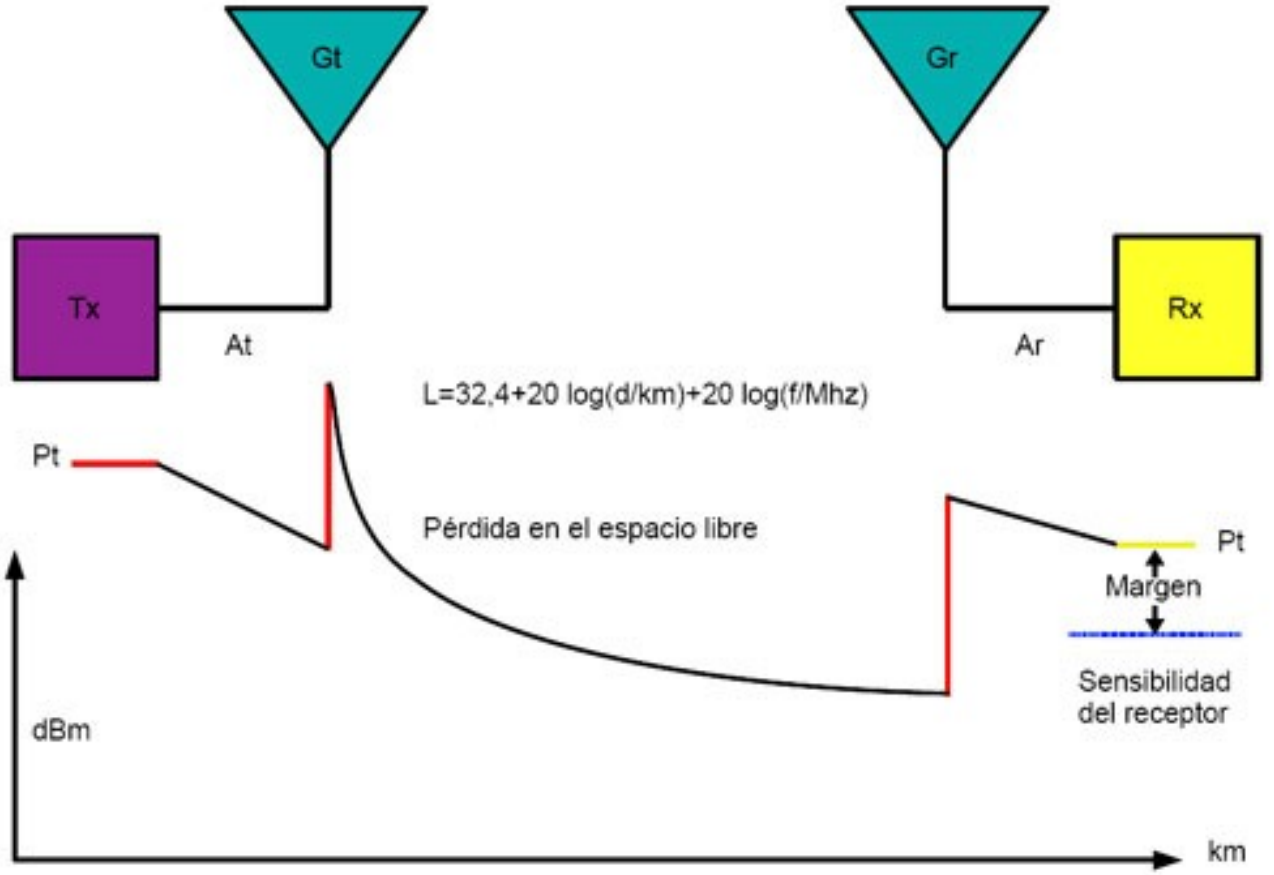
2007 (382 km)

What do we need for long distance links?

- Improve the power budget
- Modify parameters affecting propagation time
- Modify the media access method

How de we improve the power budget?

- Increase transmission power
- Increase antenna gain
- Decrease antenna cable losses
- Use a receiver with better sensitivity



How do we improve the power budget?

- We will assume that the other parameters have already been optimized and will focus on:

Increasing the antenna gain

This implies narrower radio beams and therefore careful consideration of the antenna alignment techniques

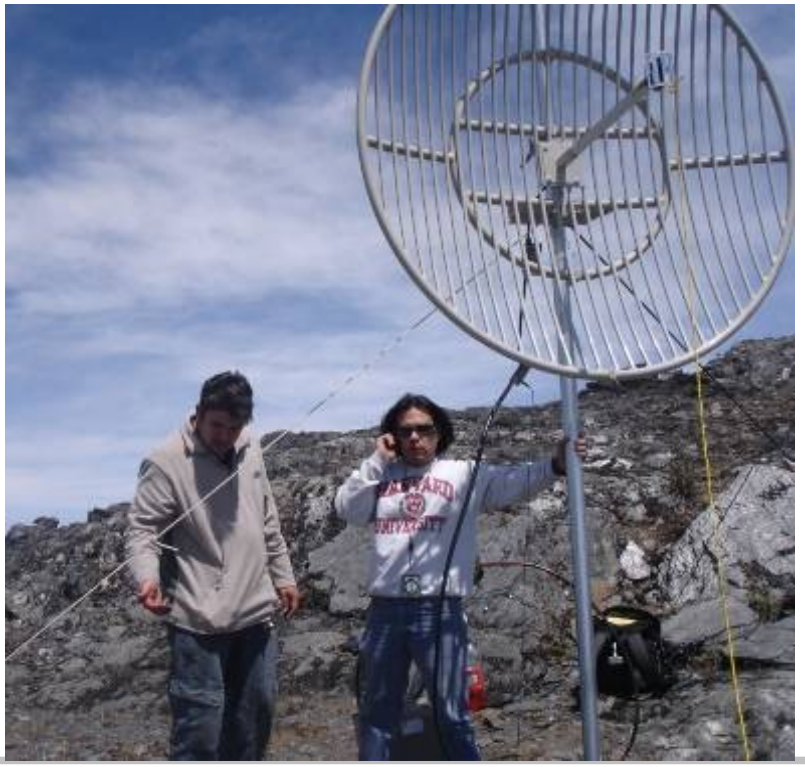
Antenna Alignment

Basic considerations:

- When the remote end is visible
- When the other end is NOT visible
- Low cost antenna alignment kit

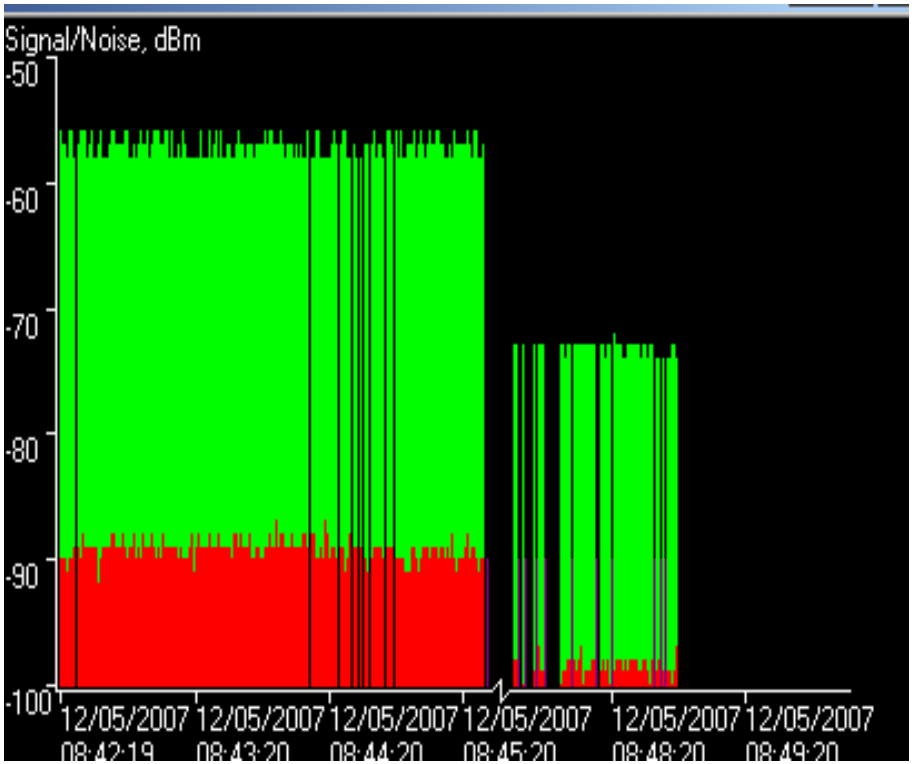
Antenna Alignment

Two teams are required for the antenna alignment job, one at each end of the link. They must have some means of real time communication like cell phones or two way radios.



Antenna Alignment Suggested tools:

- Cell phones or two way radios
- Laptop with software that allows RSSI (Received Signal Strength Indication) measurement
- WiFi Radios to be used on the link with proper pigtails and antennas
- Antenna supporting clamps and tightening tools



Network Stumbler is a very useful program for measuring both the received signal level and the noise

Antenna Alignment Suggested tools:

- Telescope or binoculars (can do without)

- Clinometer to measure inclination (can do without)
- If working at heights, climbing harness and sling for attachment to the tower or mast
- Safety hat, gloves and sunglasses

clinometer

Antenna Alignment Preparation:

Before going to the field it is necessary to test the two radios to be used at both ends of the link to make sure that their configuration is correct and that communication is possible. The most common configuration is one end as AP and the other as client, although both stations can also be configured in bridge mode. The software employed for measuring the received signal's intensity -netstumbler or the like- must be also tested.

Make sure you can establish the link and know how to measure the received signal strength

Antenna Alignment
Field Work:

- Install antennas in their supporting structures at each end
- Visually align both antennas and attach the radios by means of the pigtails
- Once the signal is received at the remote end, measure the received intensity using netstumbler or a similar program that indicates the signal level

Visual Alignment

Marco Zennaro and Tomas Krag

Antenna Alignment

The next step is to optimize the alignment working at one end at the time:

- Leaving the antenna in point A still, slowly rotate the antenna in point B, first in one direction, then in the other, observing the intensity of the received signal. Once it reaches the maximum, lock the horizontal position of antenna B.
- Repeat the procedure leaving antenna B fixed and rotating antenna A until a maximum is reached in the received signal. Now lock the horizontal clamp of antenna A.
- This procedure might have to be iterated

Antenna Alignment

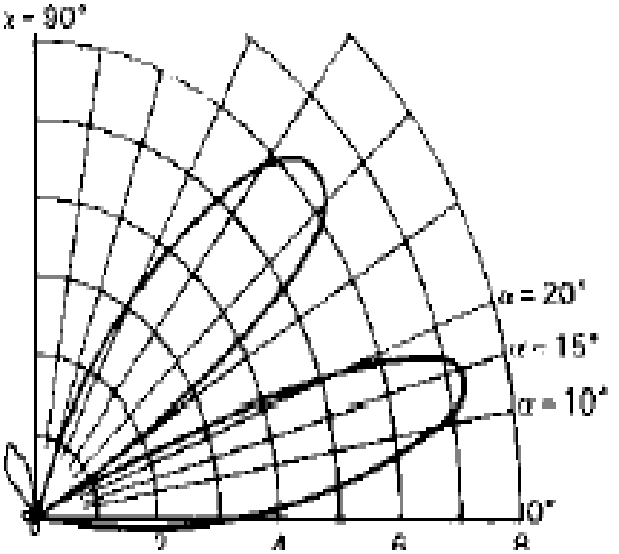
Repeat the procedure with the elevation angle if there is a big difference between the heights of the two end points.

- The elevation adjustement should be performed at both ends.
- The entire alignment procedure in both azimuth and elevation should be repeated if deemed necessary.

Visual alignment. Javier Triviño

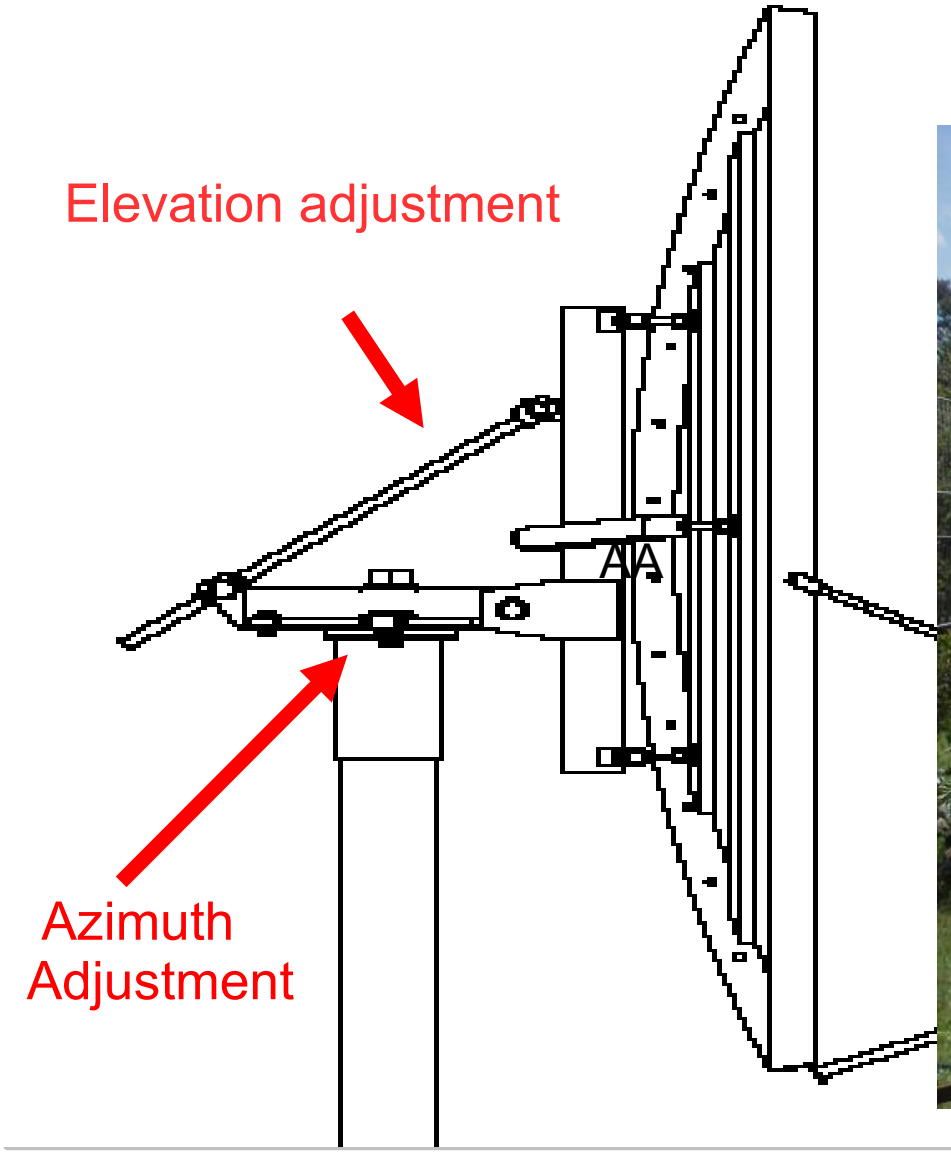
Antenna Alignment
False Maximum:

Keep in mind that most antenna patterns have side lobes, which sometimes result in the alignment being done in one of the sidelobes instead of the main lobe. To avoid this mistake, it is recommended to perform a wide horizontal sweep making sure that you are indeed working with the main lobe. It is also convenient to check the level of the received signal with the value previously calculated during the link planning.



Antenna radiation pattern

Vertical Antenna Alignment



Antenna Alignment

When the remote end is NOT visible:

We will also need:

Compass (the ones offering also reciprocal bearing are recommended): use the best quality you can, or a transit, as the ones used by land surveyors.

Antenna Alignment

- When the remote end is NOT visible:
  - GPS, highly reccommended and affordable nowadays
  - Radio Mobile or similar software for dealing with radio link planning

Magnetic and geographic bearing

Keep in mind that maps always refer to geographic or true north, while in the field you must rely on a compass that will indicate magnetic bearing for antenna alignment

Magnetic Declination

The magnetic pole does not coincide exactly with the geographic pole

- Declination changes in time and from place to place
- GPS normally will indicate both the magnetic and true bearing
- The declination of any place on earth can be found at:

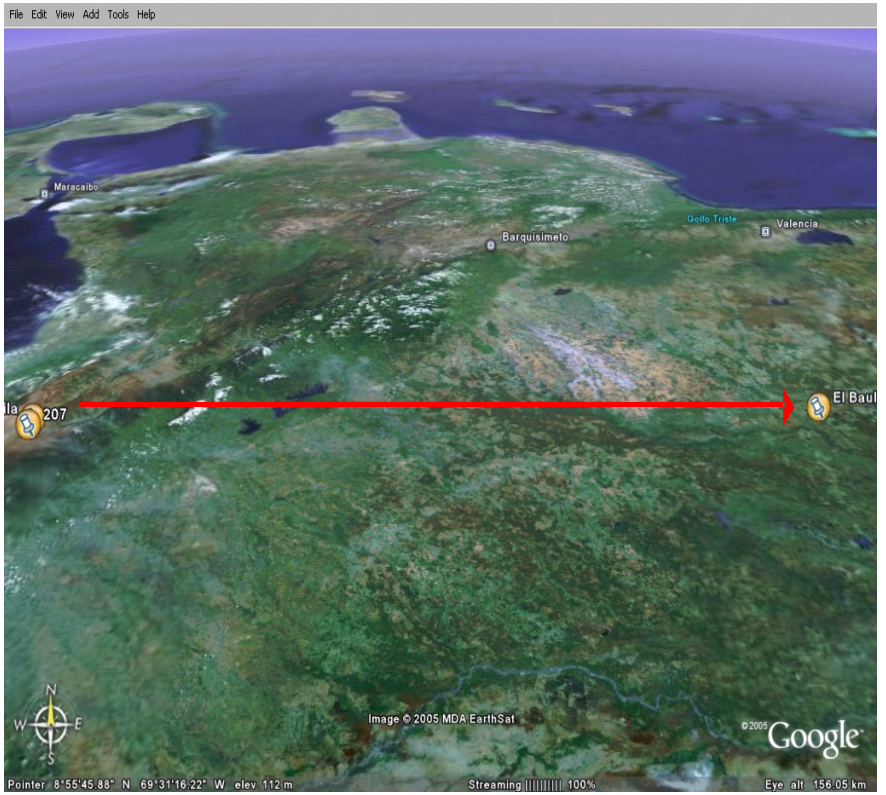
http://www.ngdc.noaa.gov/seg/geomag/jsp/Declination.jsp

Compass and geographic north landmark
El Baúl, Venezuela

Antenna Alignment

When the remote end is NOT visible

- The best maps we can get, preferably with contour lines or elevation data
- Google Earth computes distance and bearing between the ends of the link and allows the visualization of many topographic details



Google Earth map: www.google.com

Antenna Alignment

A string a few meters long can help estimating the direction at which the antenna is pointing.

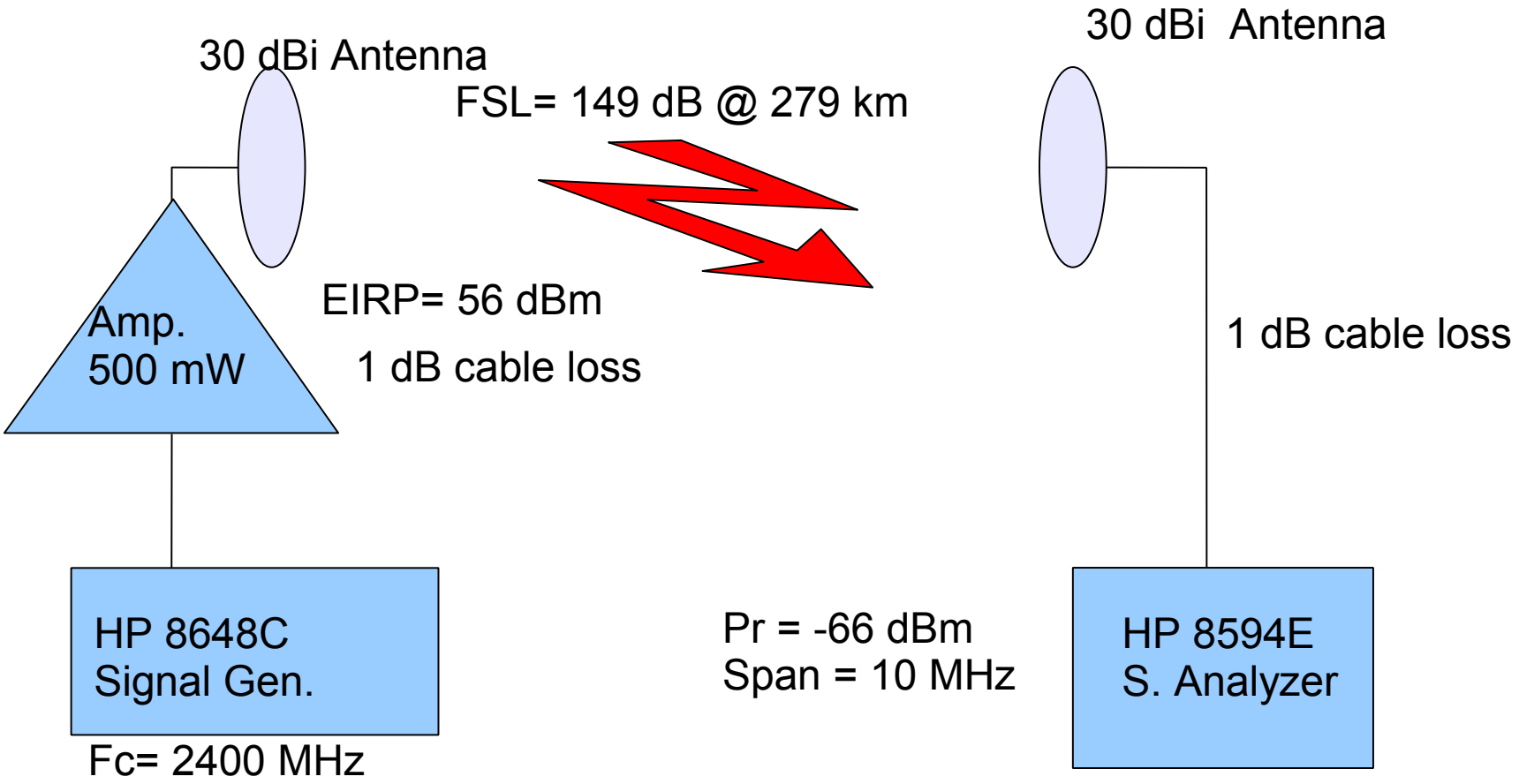
It also helps separating the compass from the influence of ferrous objects in the antenna mounting structure that might alter the compass reading

Antenna Alignment
When the remote end is NOT visible:

- Some parabolic antennas use a tube to support the feedhorn. Disassembling the support, the alignment task is facilitated by looking directly from behind the antenna towards the direction at which we are pointing.
- In many cases, it will be enough to repeat the alignment procedure described measuring the intensity of the received signal via software.
- However, for very long distances this method could fail, because the strength of the WiFi signal is not stable and spreads over 20 MHz. Moreover, the software can shows the intensity of the signal only after its decoding is completed and, in order to do so, the received signal must be strong. In other words, this methodology is not appropriate for very long distance links.

Antenna Alignment

When the remote end is NOT visible:



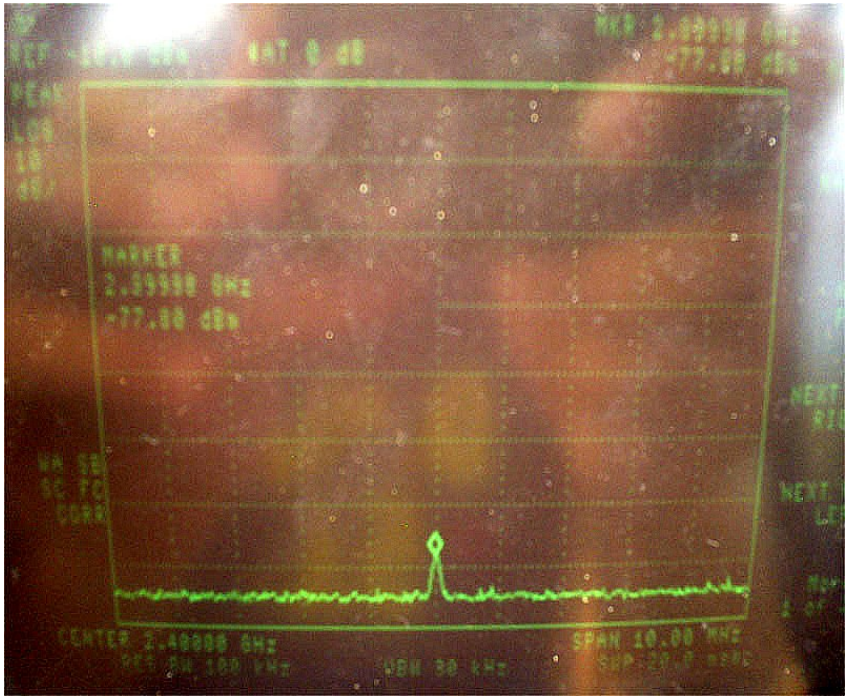
Antenna Alignment using instruments

Antenna Alignment

- When the remote end is NOT visible:

Using a signal generator in one end and a spectrum analyzer in the other end, the signal generator outputs a tone in the frequency of interest that will be detected by the Spectrum Analyzer at the other end.

Each antenna is rotated until the maximum signal is shown in the Spectrum Analyzer



Received tone at 382 km

Antenna Alignment: Low cost analyzer

WiSpy to the rescue

- Low cost USB device
- Carlo Fonda from ICTP soldered a pigtail which allows the connection of an external antenna thus emulating a Spectrum Analyzer.

Antenna Alignment

Google helps: Analog video transmitters in the 2,4 GHz band

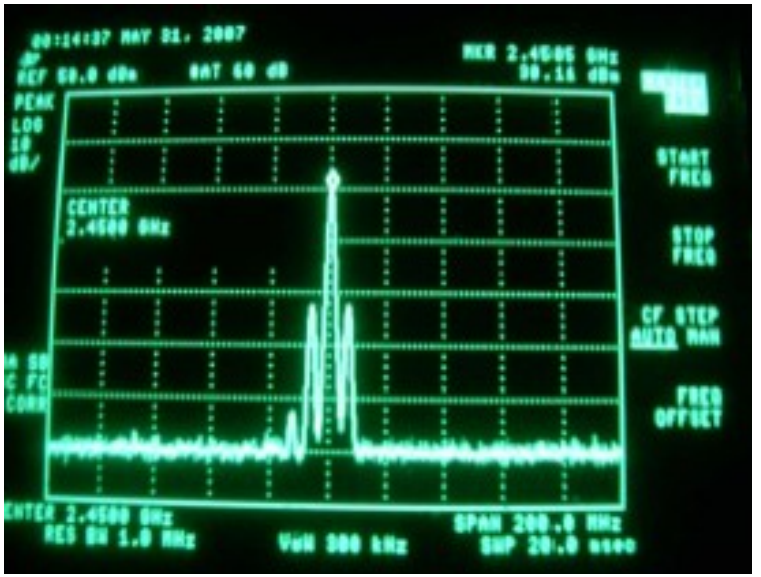
- Video sender:
  - Operates at 2,4 GHz
  - Allows the choice of 8 different tones spanning the 2,4 GHz band
  - 1 W output power

Video sender and signal generator

Antenna Alignment

Low cost signal generator

- Spectrum Analyzer display of the video sender output, 30,11 dBm at 2450 MHz.
- The two sidebands are 22 dB below the video carrier and therefore are not visible at the remote end, so they do not interfere in the alignment process



Analizador de espectros

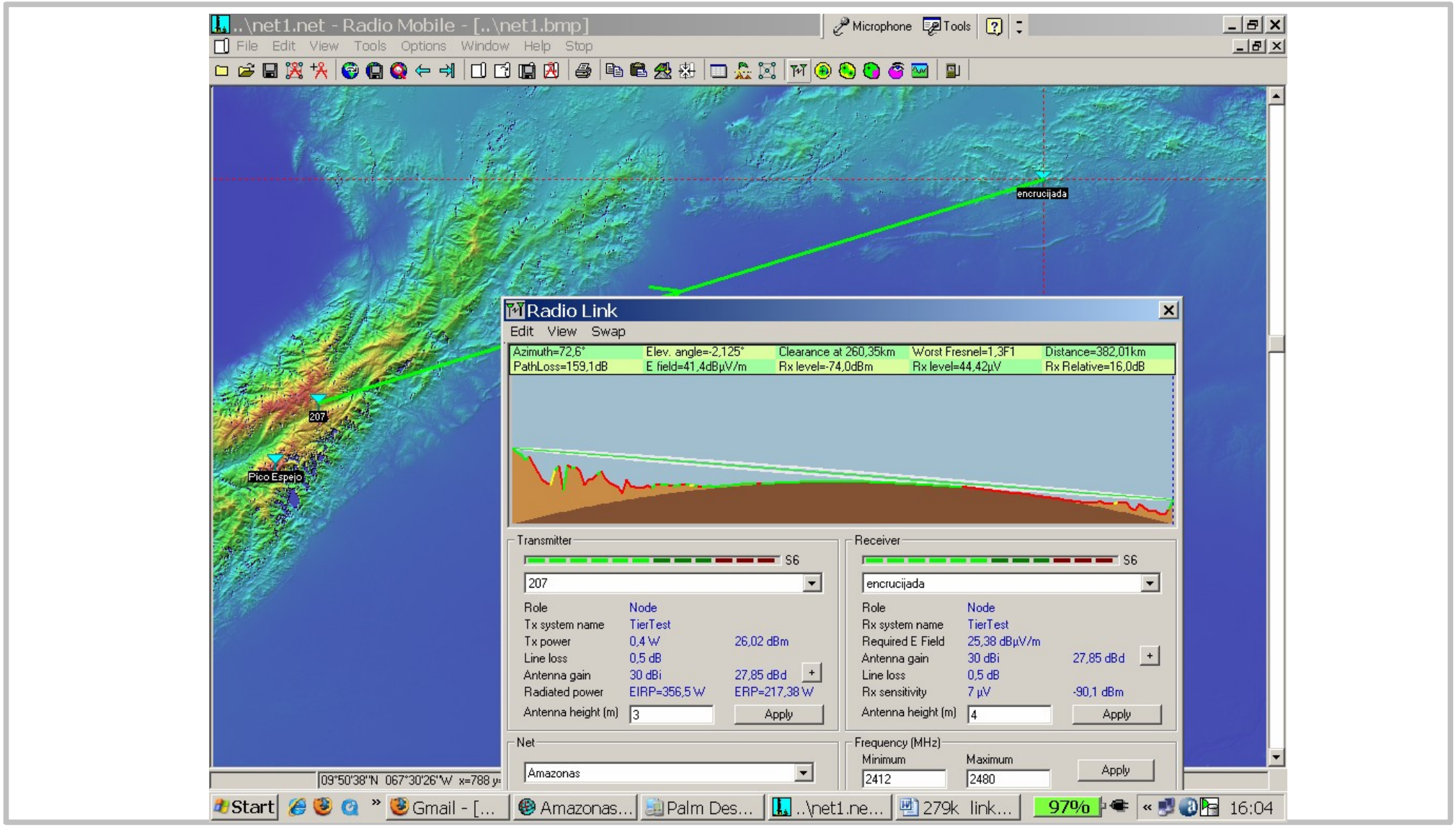
Media access techniques

Propagation times

- Use *ad hoc* mode, to avoid the ACK mechanism
- Increase the ACK waiting time
- Modify the medium acces technique instructing the transmitter to not expect an ACK.

Antenna Alignment

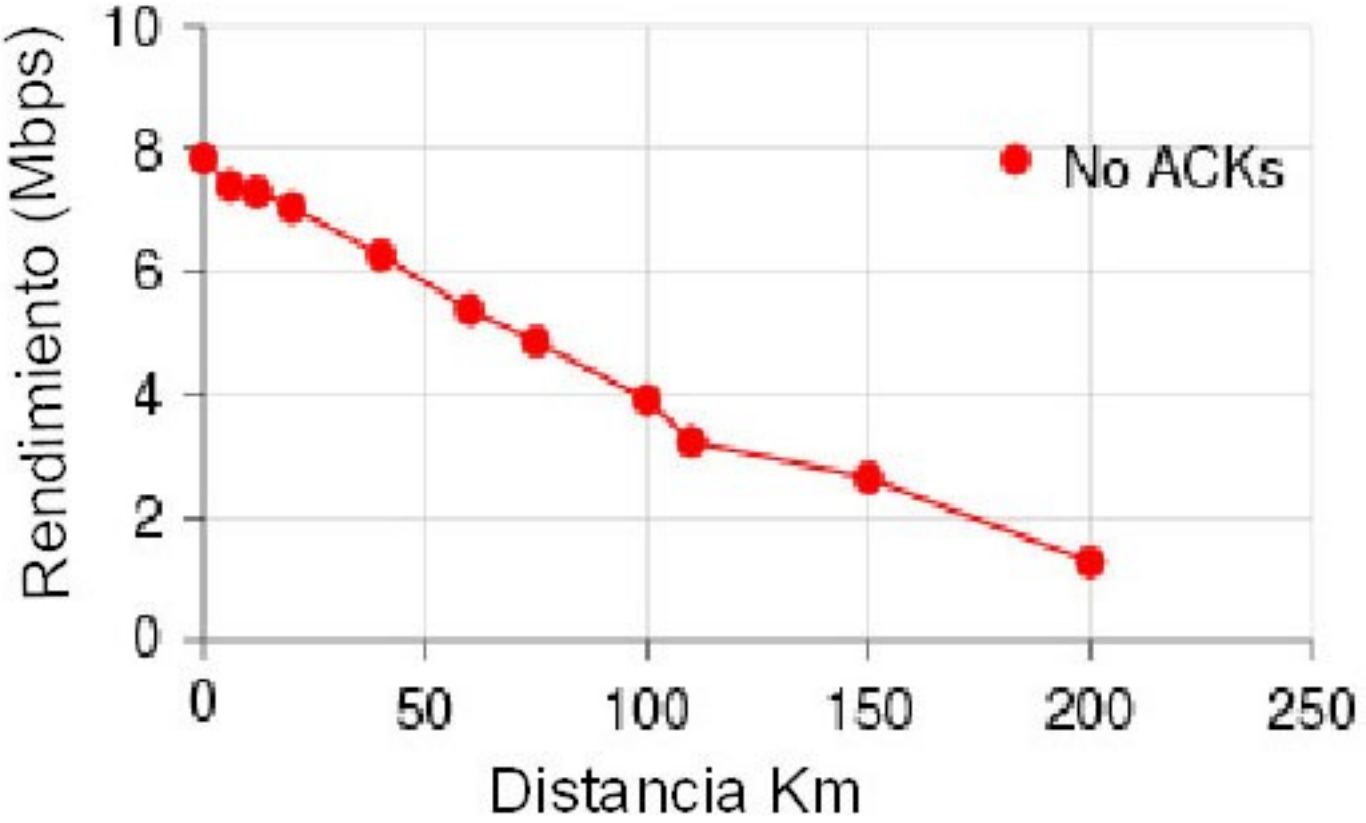
Software for antenna alignment



Medium Access Mechanism

Propagation time as measured by TIER

- Throughput reeduction with distance in WiF links

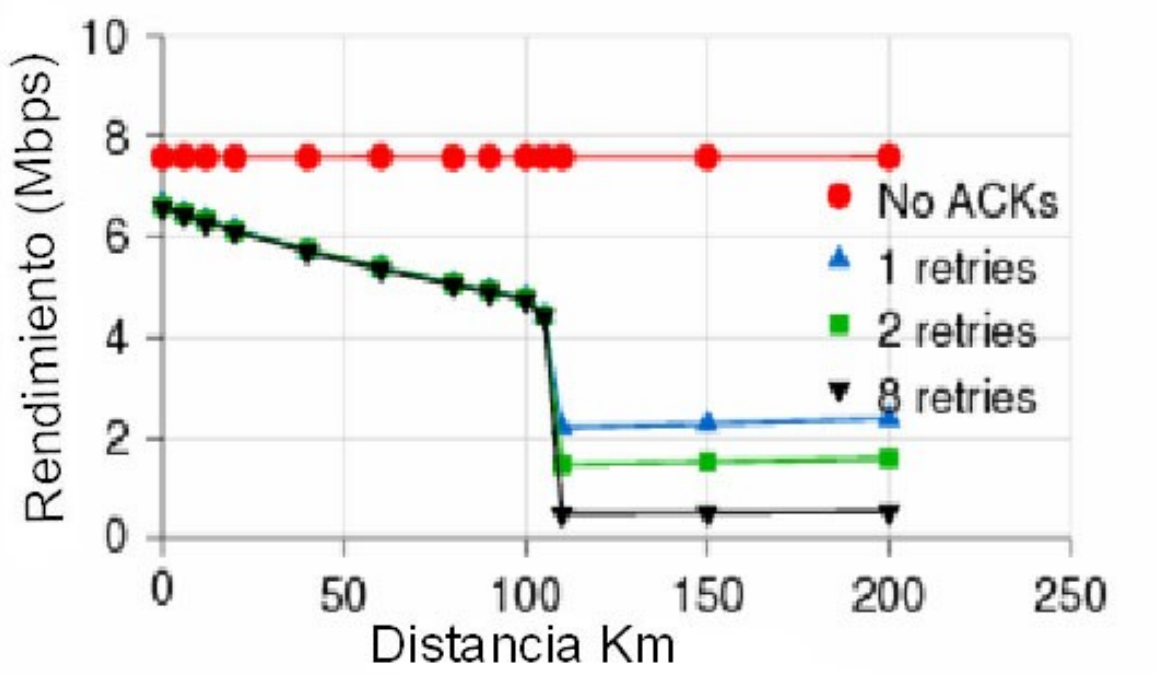


Fuente: WiLDNet: High performance WiFi-based Long Distance (WiLD) Networks, Sonesh SuranaTIER, UC Berkeley , 2007.Community Wireless Summit , May 18, 2007 , Loyola College, Columbia, MD

Mecanismo de Acceso al Medio

Tiempos de propagación

Througput Vs distance for a point to point WiFi link. Nota that eliminating the waiting for ACKs the throughput becomes independent of distance.



Medium acces mechanism

Changes proposed by the TIER group include:

- Modify the 'madwifi' driver for Atheros to inhibit the ACK and the carrier detect mechanism
- Implementation of of a new routing mechanism both at the kernel and user level to create virtual interfaces and capture packets

Medium acces mechanism

Changes proposed by the TIER group include:

- Use a 'sliding window' mechanism to acknowledge the reception of groups of packets
- Implementation of TDMA, thereby employing a new synchronization mechanism

Medium acces mechanism

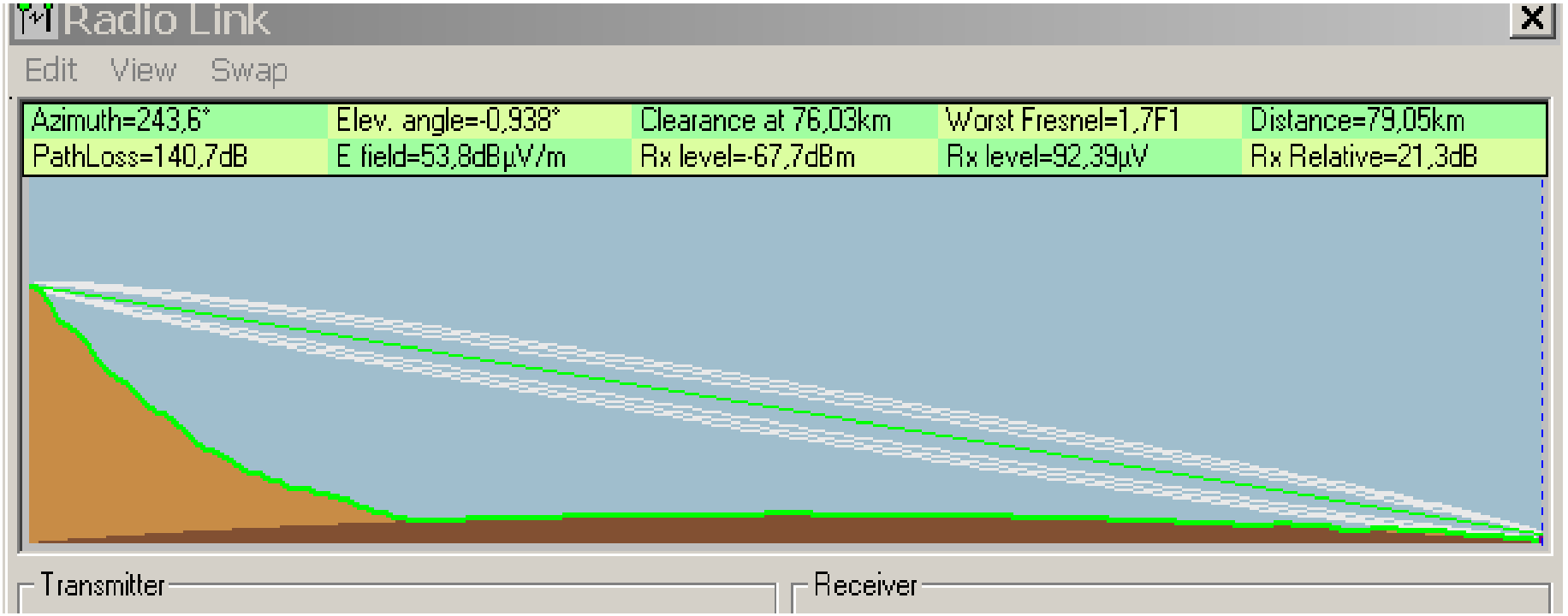
Changes proposed by the TIER group include:

- Use of FEC (Forward Error Correction) to minimise transmission errors.

We were able to corroborate the independence of throughput with distance with several field experiments performed at distances of 40, 79, 279 and 382 kilometers

79 km link

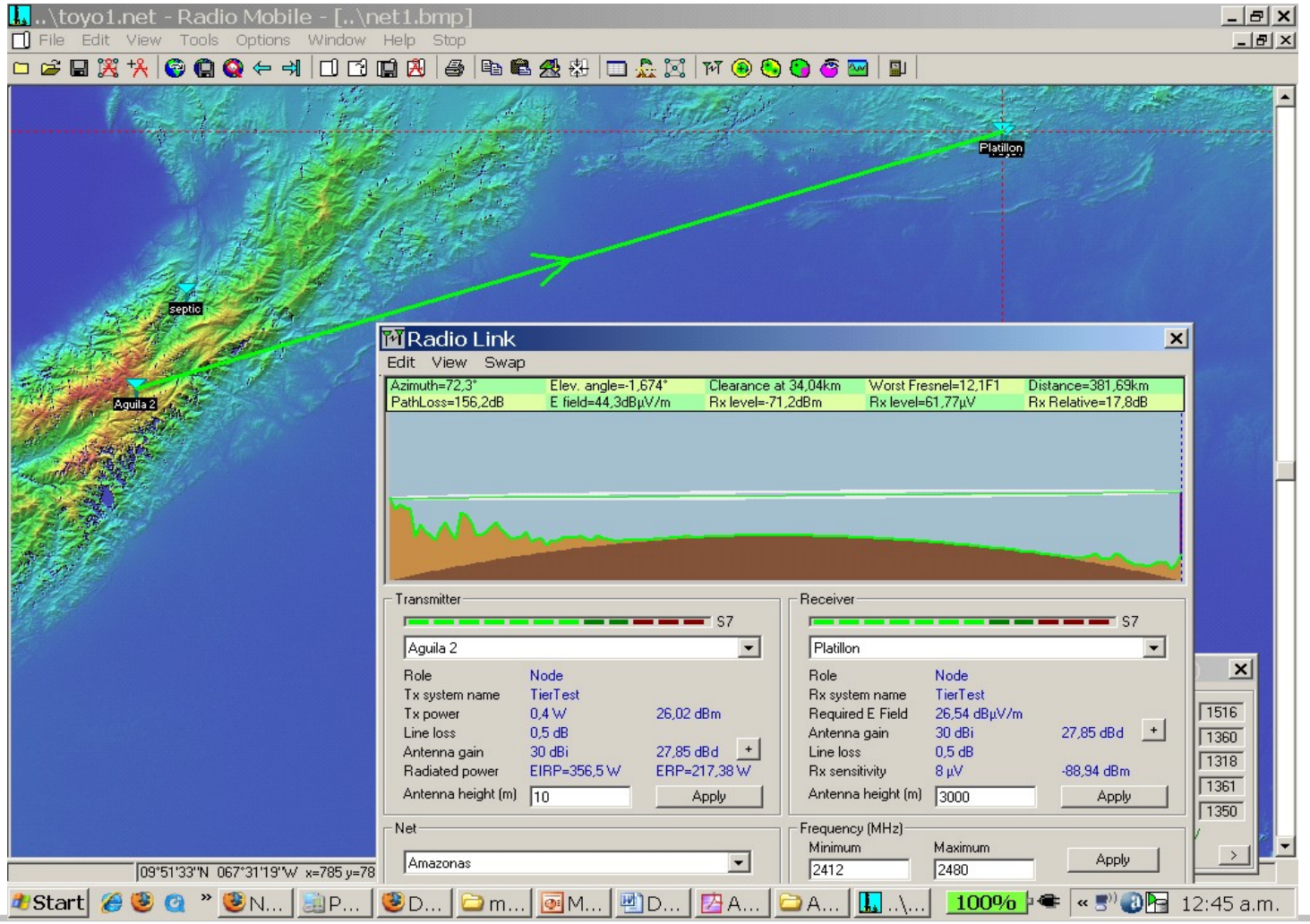
Profile of the 79 km link. The throughput with radios using the TIER modification was as predicted



280 km link

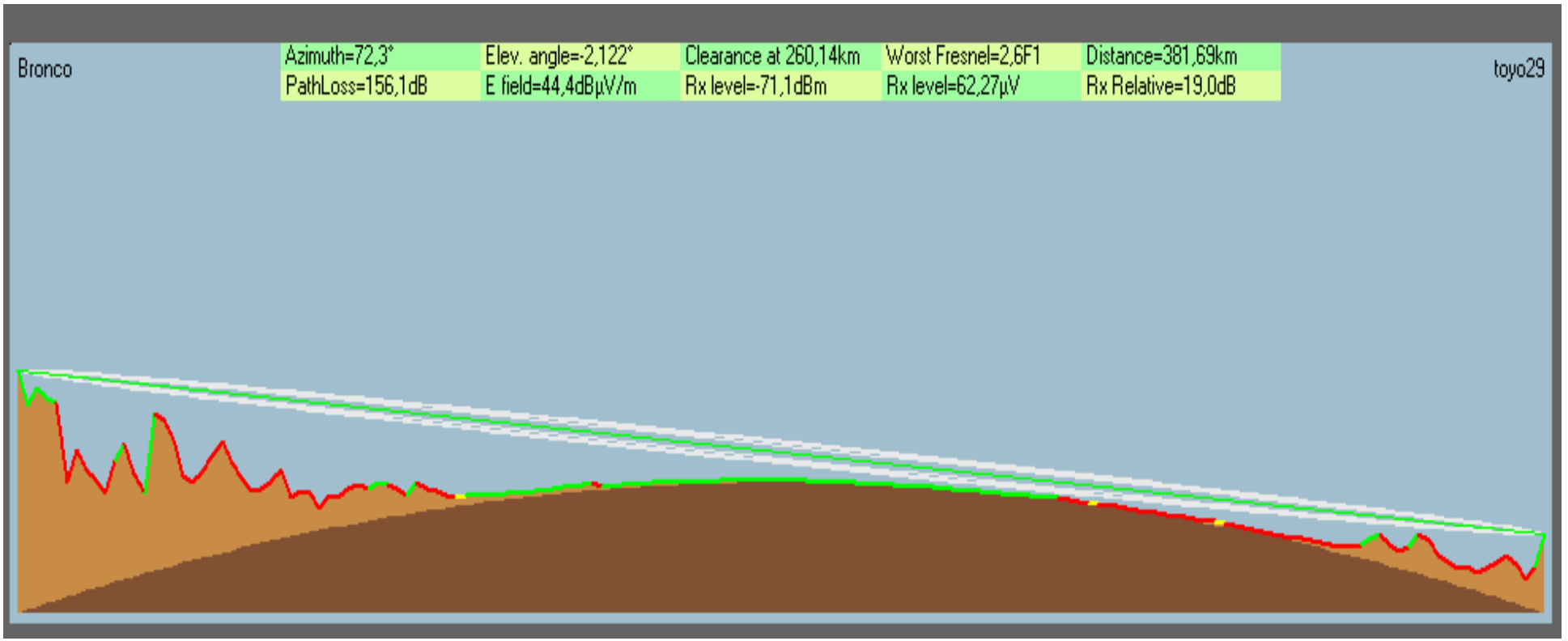
Propagation time

Profile for the 280 km. Propagation time is 2 ms.



382 km link

Path profile parameters



The 5 GHz band

- Run Radio Mobile simulations to compare the performance of both bands
- Factors to be considered are:
- Iit used to be difficult to find 802.11a devices with external antenna connectors. Nowadays they are available from several vendors

The 5 GHz band

Factors to consider:

- Free space losses are some 6 dB greater in the 5 GHz band as compared with the 2,4 GHz band. Nevertheless, a 5 GHz antenna will show a 6 dB improvement of gain as compared with a 2,4 GHz antenna of the same size. If antennas at both ends of the link are replaced, we would end up with a total improvement of 6 dB in the link power budget

The 5 Ghz band

Factors to consider:

- The size of the Fresnel zone is significantly smaller at 5 GHz, so shorter mast are required for the same trajectory
- Antenna cable losses are greater at 5 GHz. Keep them as short as possible
- Absortion by trees and due to rain is higher in this band

The 5 GHz band

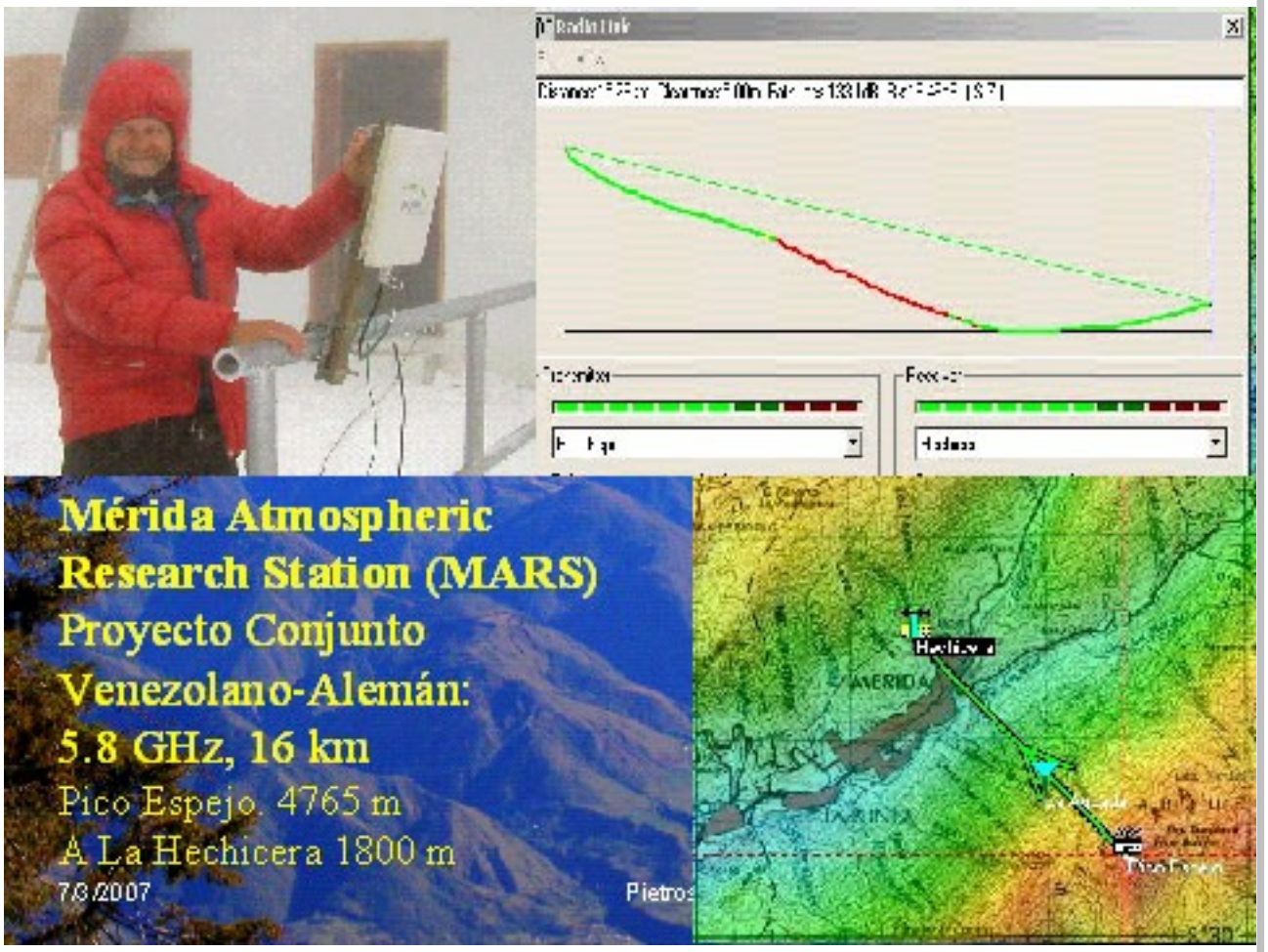
I do not know of any low cost device for antenna alignment in this frequency band

Please let me know if you find any suitable device

The 5 GHz band

5,8 GHz link. Although only 16 kilómeters long, one of the ends is at 4765 m altitude and transmits the output of a webcam pointed at Pico Bolívar, at 5000 m altitude.

Operational since 2002



http://www.eslared.org.ve

Conclusions

The five paramount aspects of this unit are:

- WiFi is an effective solution for long distance links provided that the interference is manageable
  - Line of sight and clearance of at least 60% of the first Fresnel zone is required to guarantee the link quality

- When the other of the link is not visible, instruments must be used for the antenna alignment. The most important are: Compass, Signal Generator and Spectrum Analyzer. Low cost solutions for these instruments are available.

Conclusions

The five paramount aspects of this unit are:

- For long distances it is necessary to modify the ACKs waiting or work in the *ad hoc mode*

- The modification proposed by the TIER group from Berkeley University allows for the througput to be maintaned even at very long distances