Long Reach WiFi Link: A joint EsLaRed-ICTP effort

ICTP-ITU School on
Wireless Networking for Scientific Applications
in Developing Countries
Abdus Salam ICTP, Triest, February 2007

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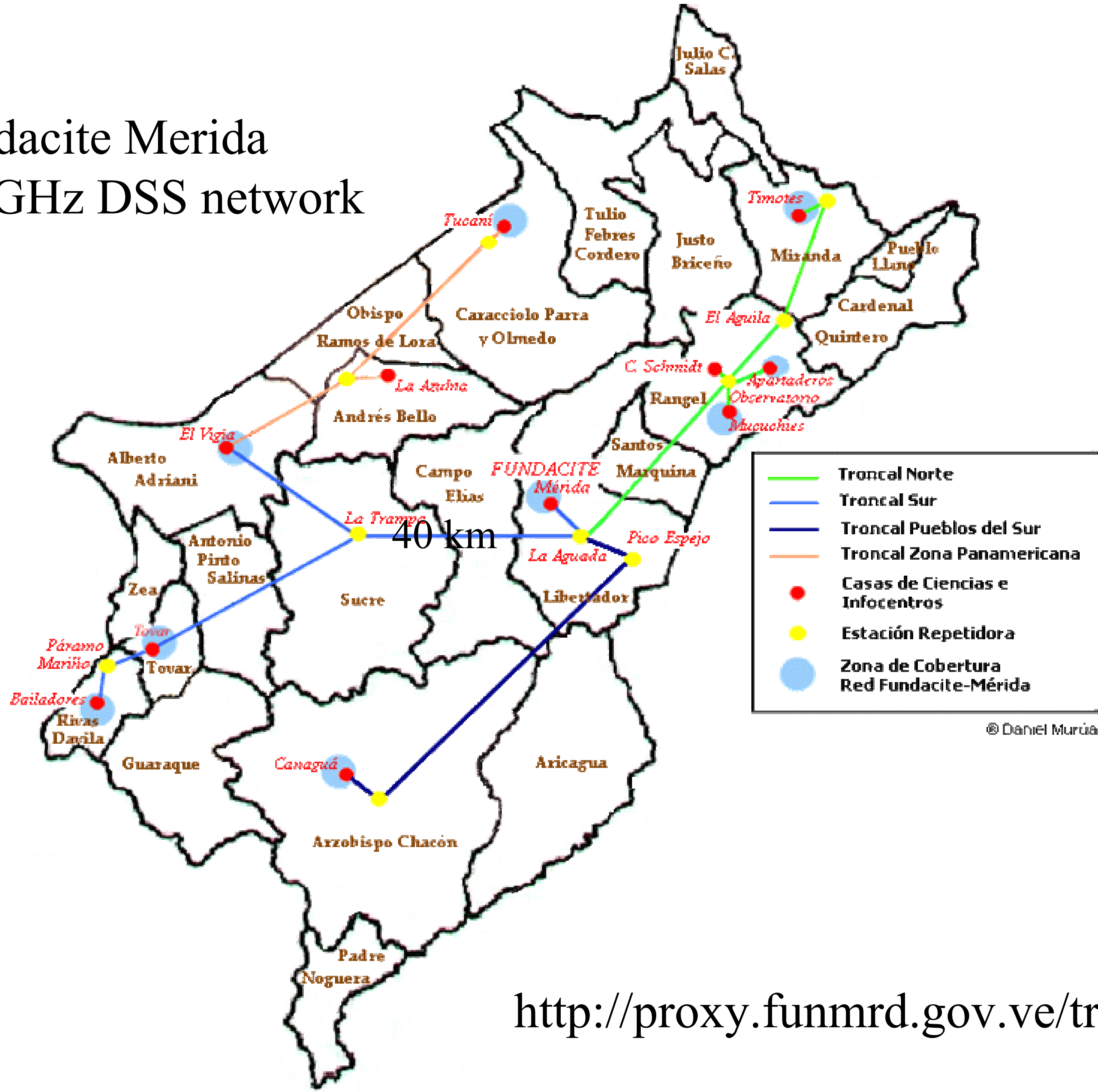
Motivation

- Wireless techniques are the most cost effective to provide communication service in rural areas
- Packet Radio cannot provide the access speed people demands nowadays
- Satellite is still too expensive and dependent on the offers of very large enterprises
- Data over cellular is expensive and current offers are limited in speed

Motivation

- Spread Spectrum technology based networks have been used for the last 15 years as a cost effective way to provide connectivity
- The estabishment of the IEEE 802.11 standard in 1999 spurred competition among manufacturers that allowed a substantial price decrease
- The limited telephony infrastructure of Venezuela in the eighties led us to use packet radio for data communications. In our LabCom at Universidad de los Andes we built antennas and used commercially available radios and modems to link several remote sites using Phil Karn's TCP/IP implementation

Fundacite Merida
2.4 GHz DSS network



http://proxy.funmrd.gov.ve/trafico

Why strive for long links?

- Every repeater site increase cost, logistics and frequentily significantly reduces throughput
- In rural areas, best repeaters sites often lack power amd may present security and accesibility problems

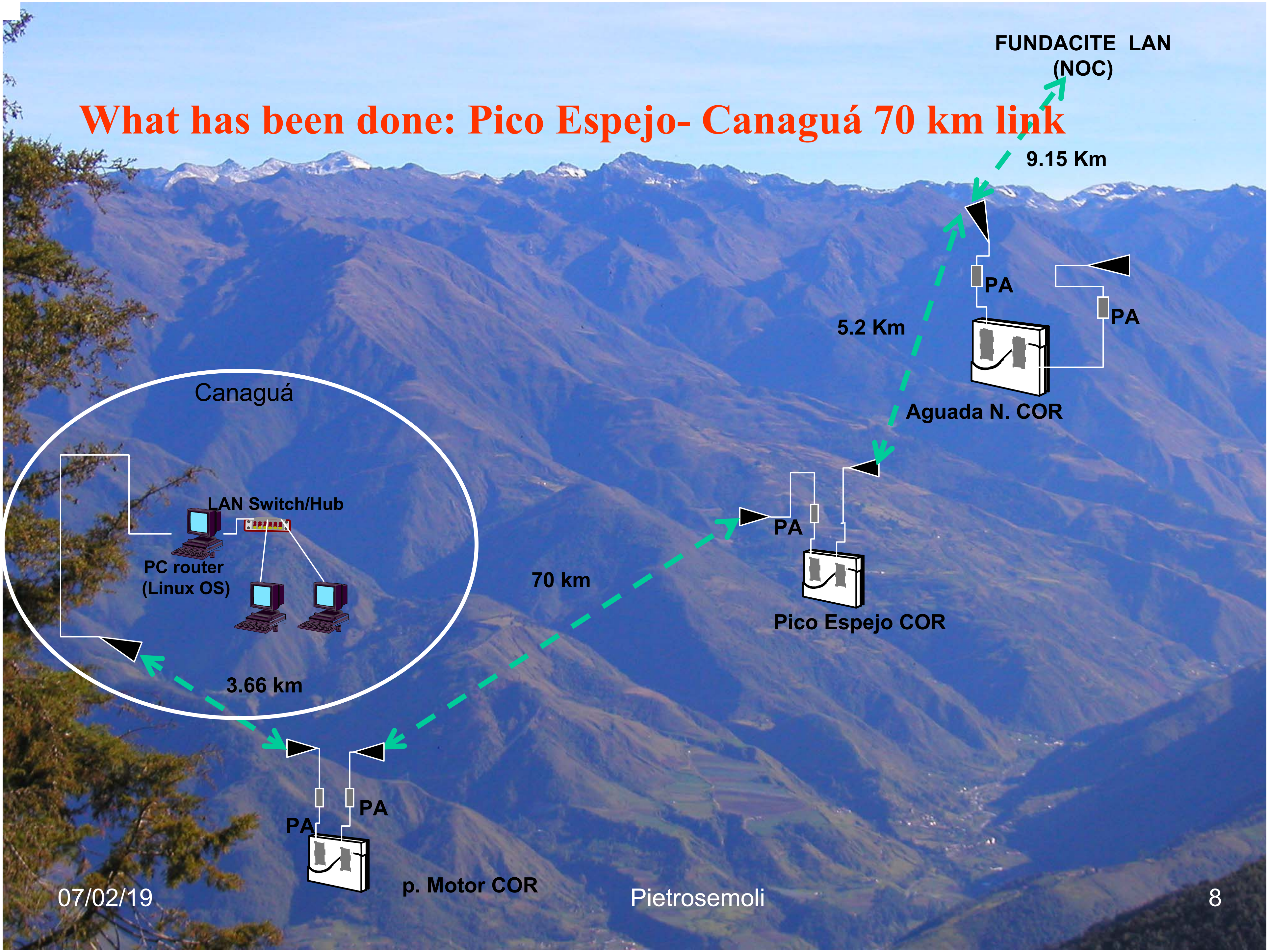
What factors limits the achievable span?

- Power budget
  - Legal regulations on maximum EIRP
  - Increased cost of high power devices
- Fresnel zone clearance
  - 60 % of first zone for a reliable link
- ACK timeout
  - IEEE 802.11 MAC requires that the sending station receives an ACK for evey frame sent. For WLANs the propagation time is negligible, but at 300 km it reaches 1 ms
- These factors are being addressed by WiMAX but at a consiederably higher cost for terminal equipment

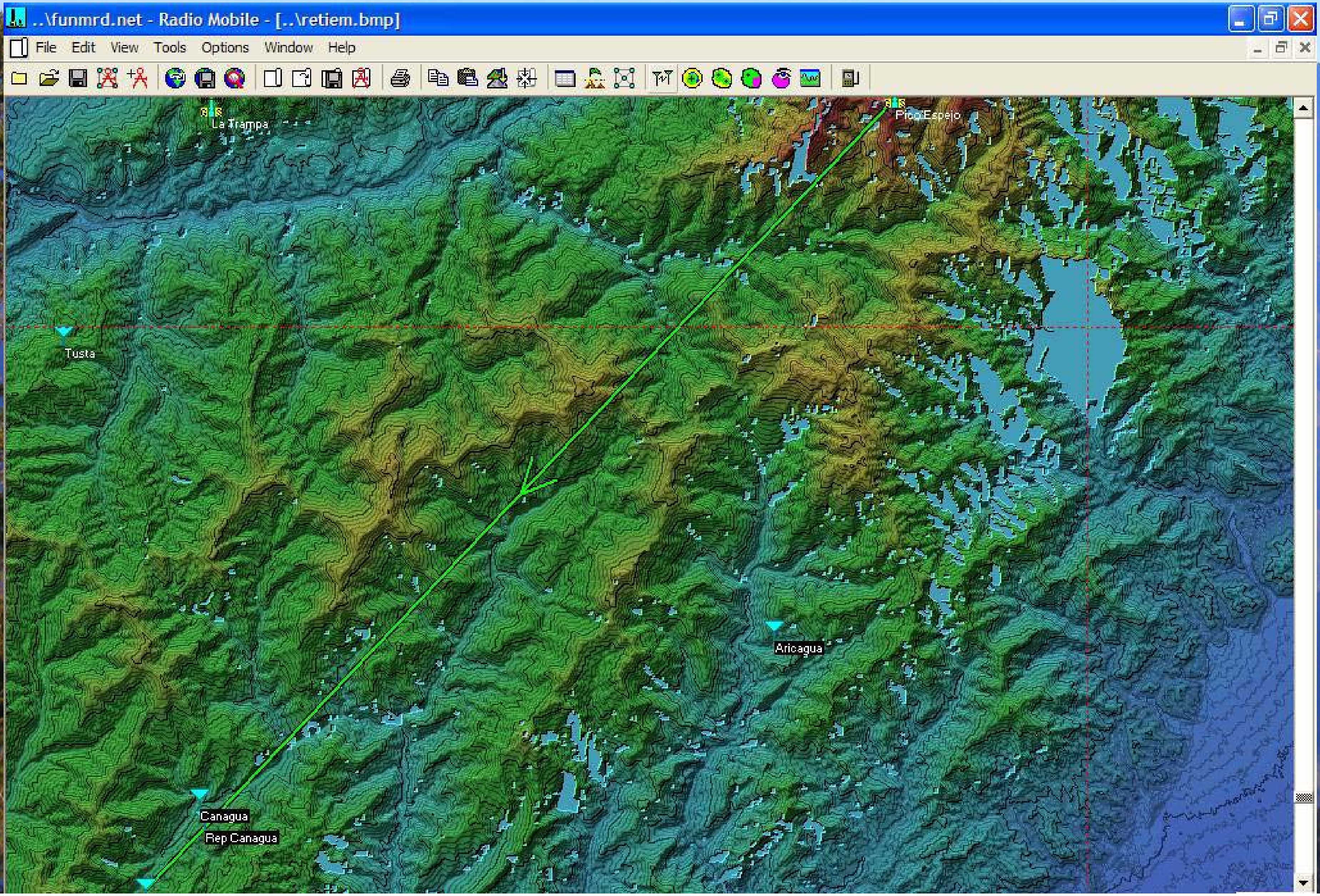
What can be done?

- Power budget
  - Use high gain antennas (cheaper if recycled)
  - Use more sensitive radios
  - Minimize RF cable lenght
- Fresnel zone clearance
  - Choose endpoints carefully using coverage prediction software like “radio mobile”
- ACK timeout
  - Third party firmware allows changing of this parameter
- MAC modifications to customize for longer distances

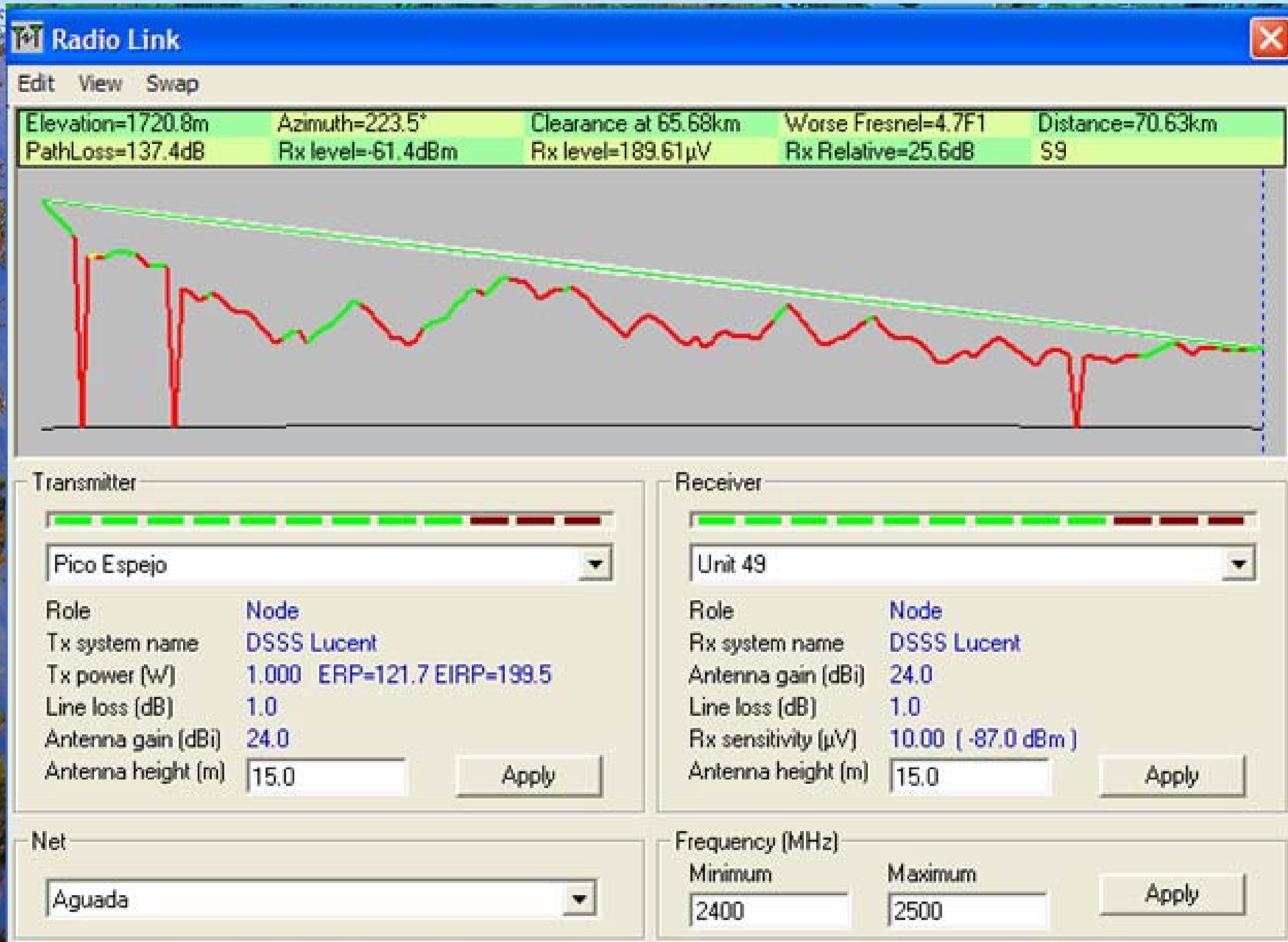
What has been done: Pico Espejo- Canaguá 70 km link



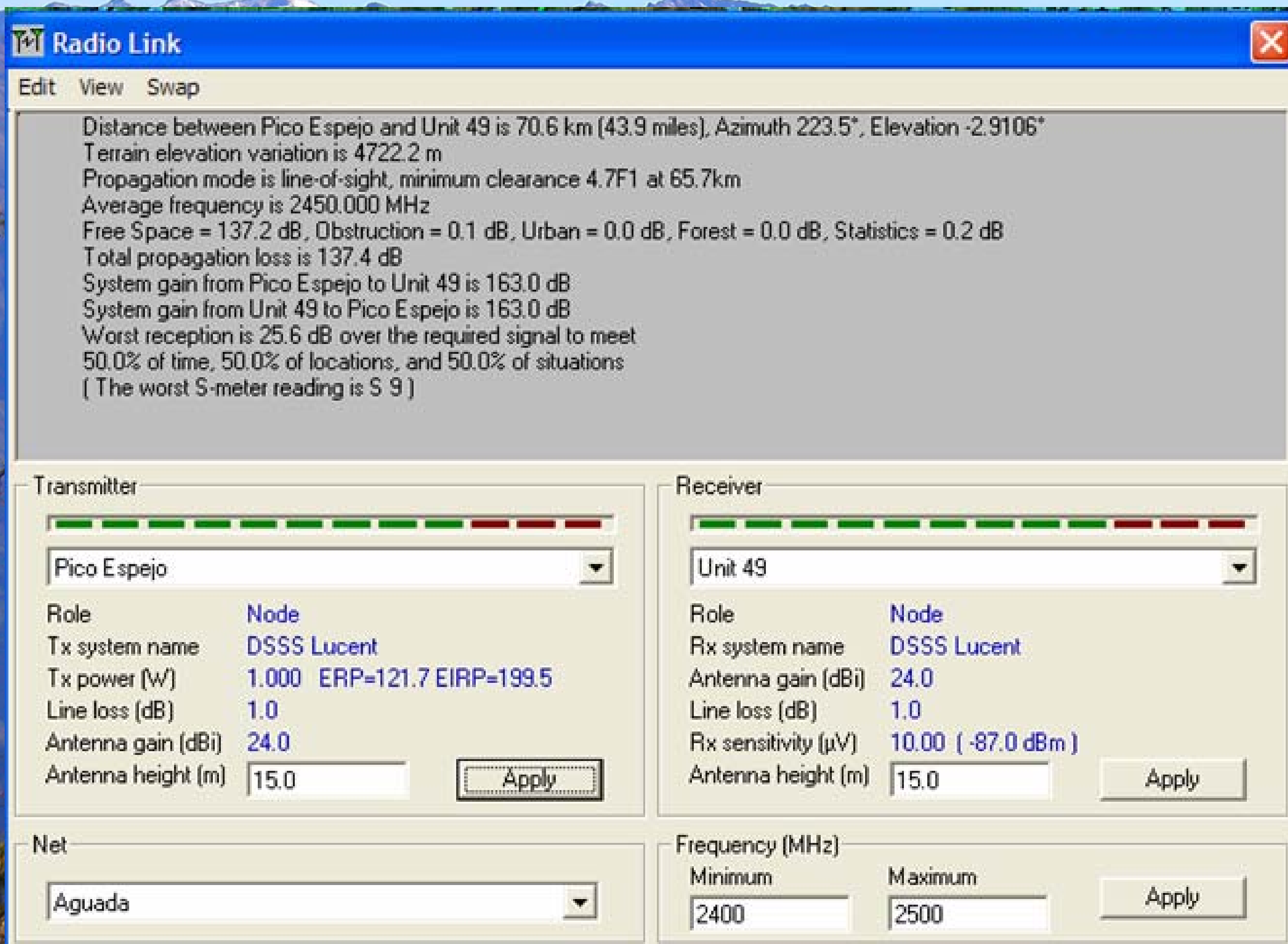
Pico Espejo- Canaguá 70 km link



Pico Espejo- Canaguá 70 km link



Pico Espejo- Canaguá 70 km link



What has been done:
Swedish Space Agency 310 km link

- **Guiness World Records Recognizes World's Longest Wi-Fi Connection**
-

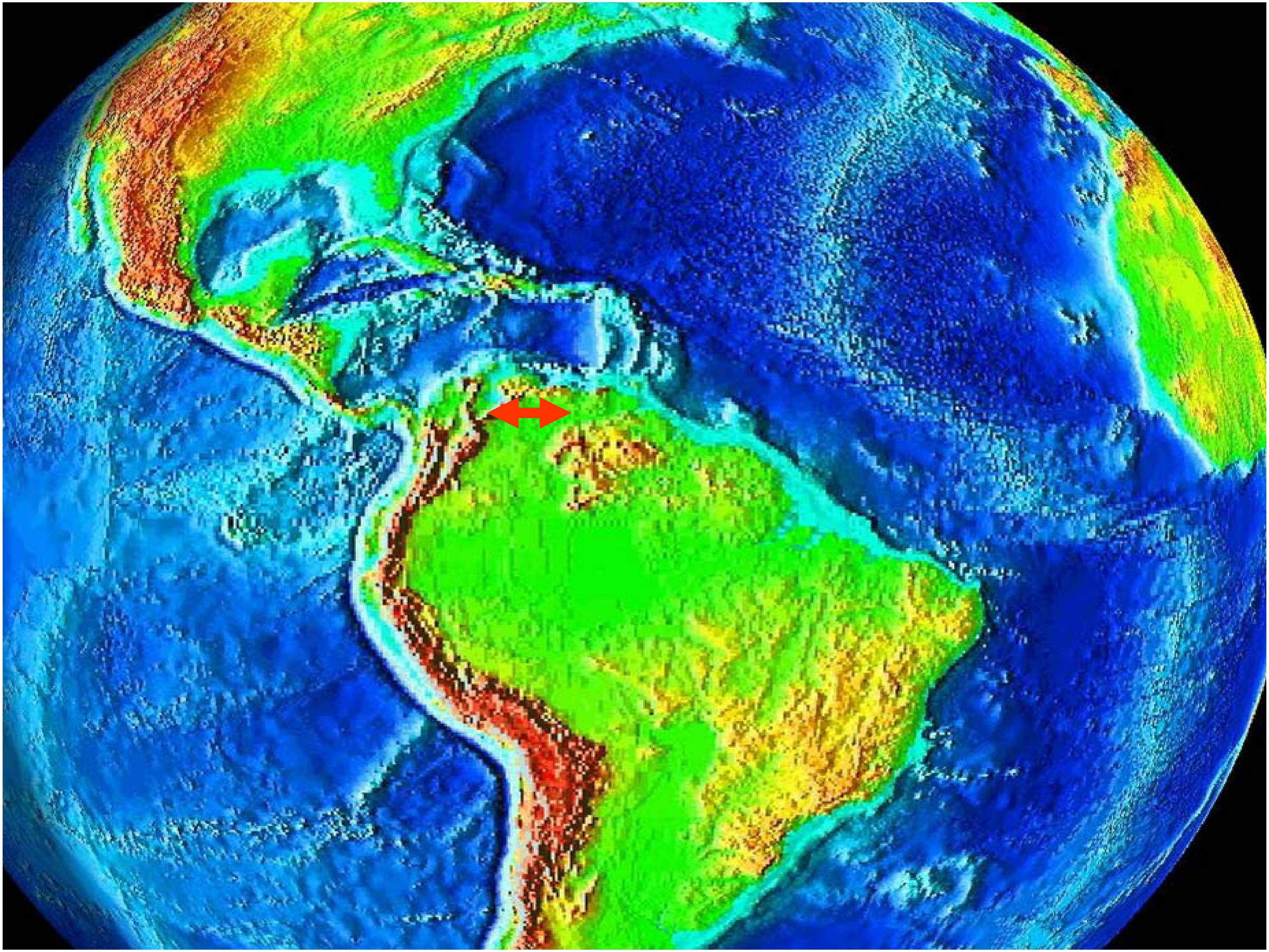
Alvarion and Swedish Space Corporation Achieve Wireless Broadband Connectivity Over 310km

The link was made in the end of 2002 between a stratospheric balloon that was launched from Esrange near the town of Kiruna in northern Sweden and a base station located near Esrange.

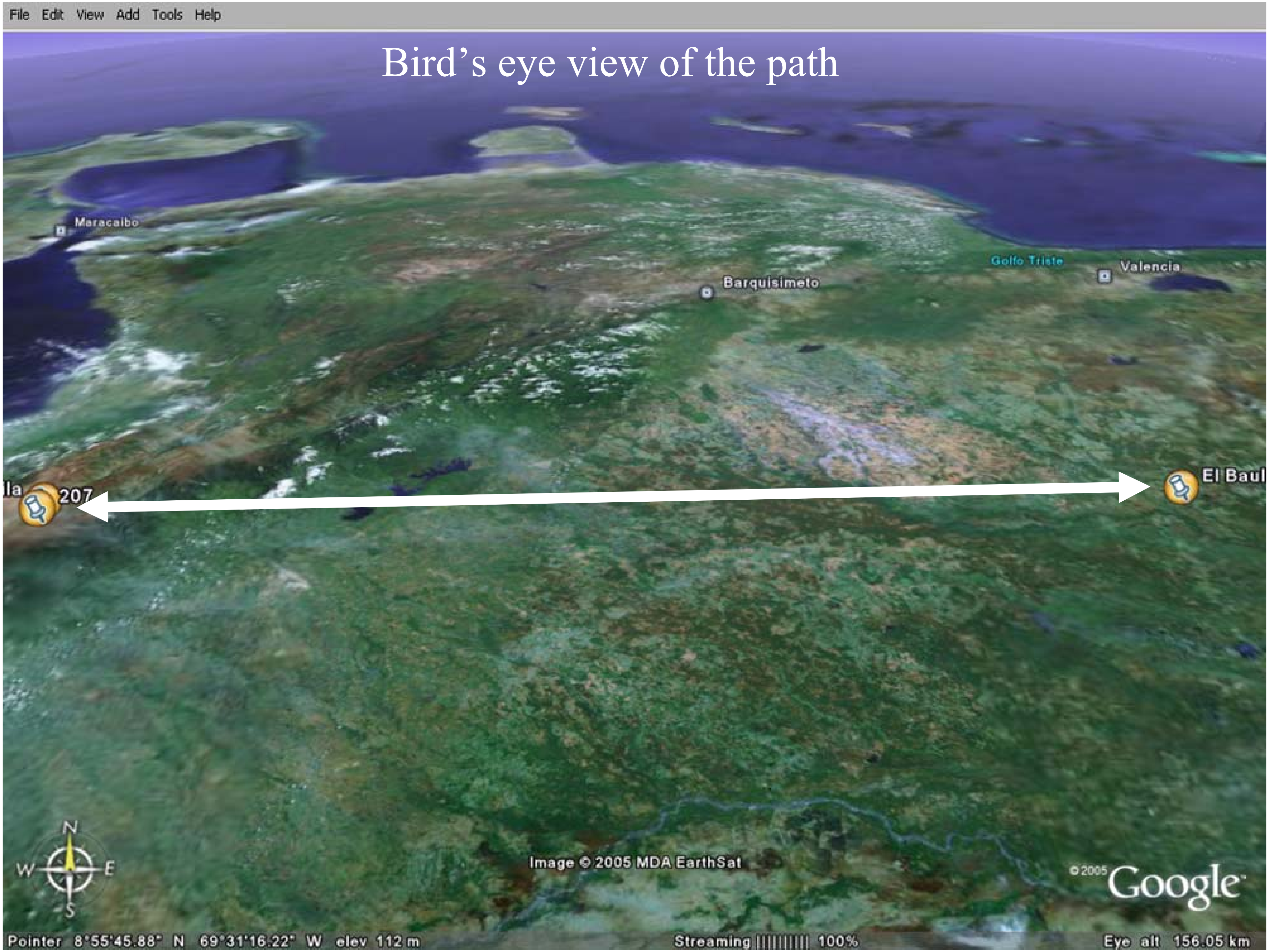
- http://www.alvarion.com/presscenter/pressreleases/3263/

What has been done: New world record for unamplified wireless networking!!

- **125 miles!** (201 km)
  http://www.wifi-shootout.com/

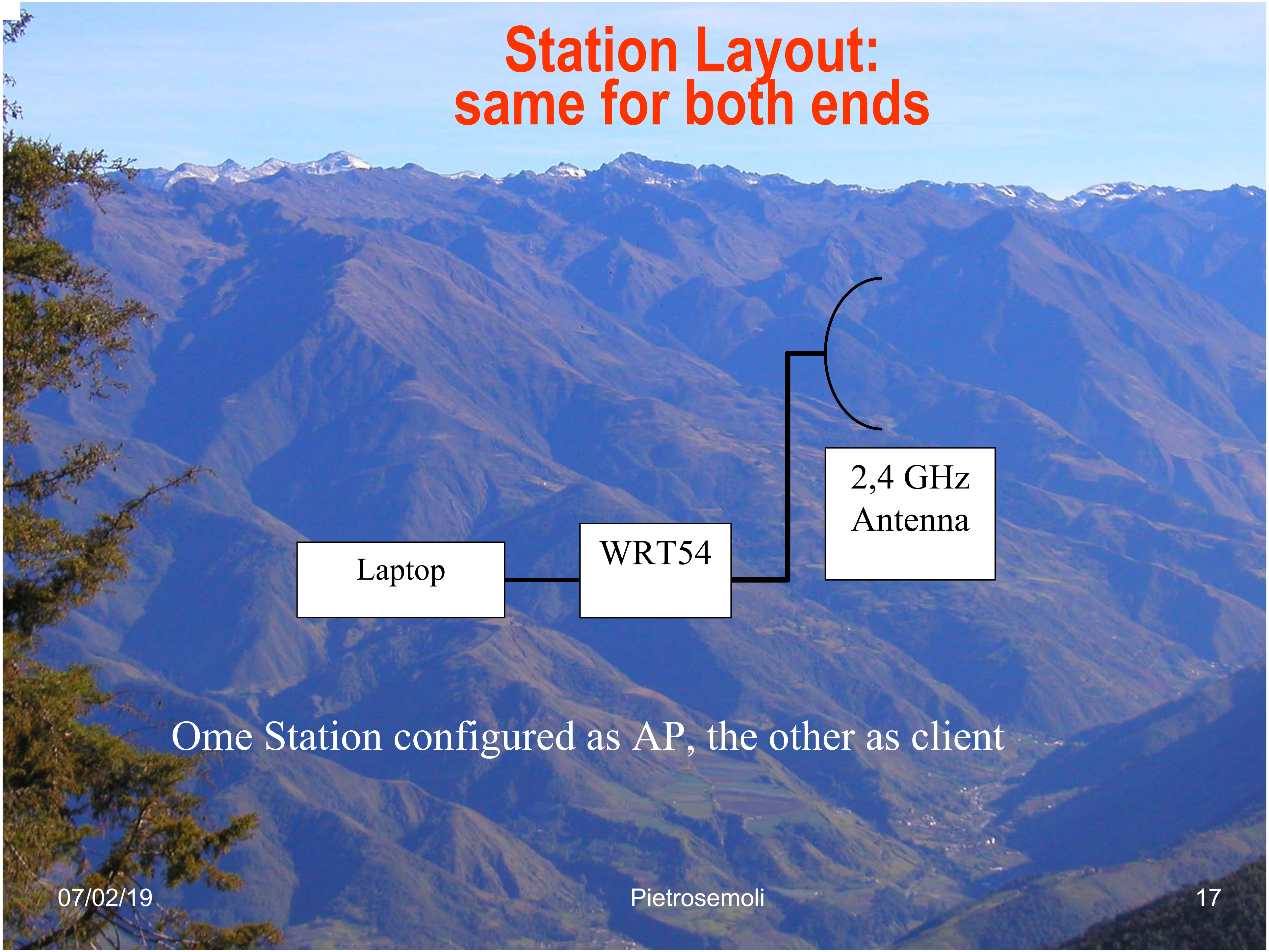


Bird's eye view of the path

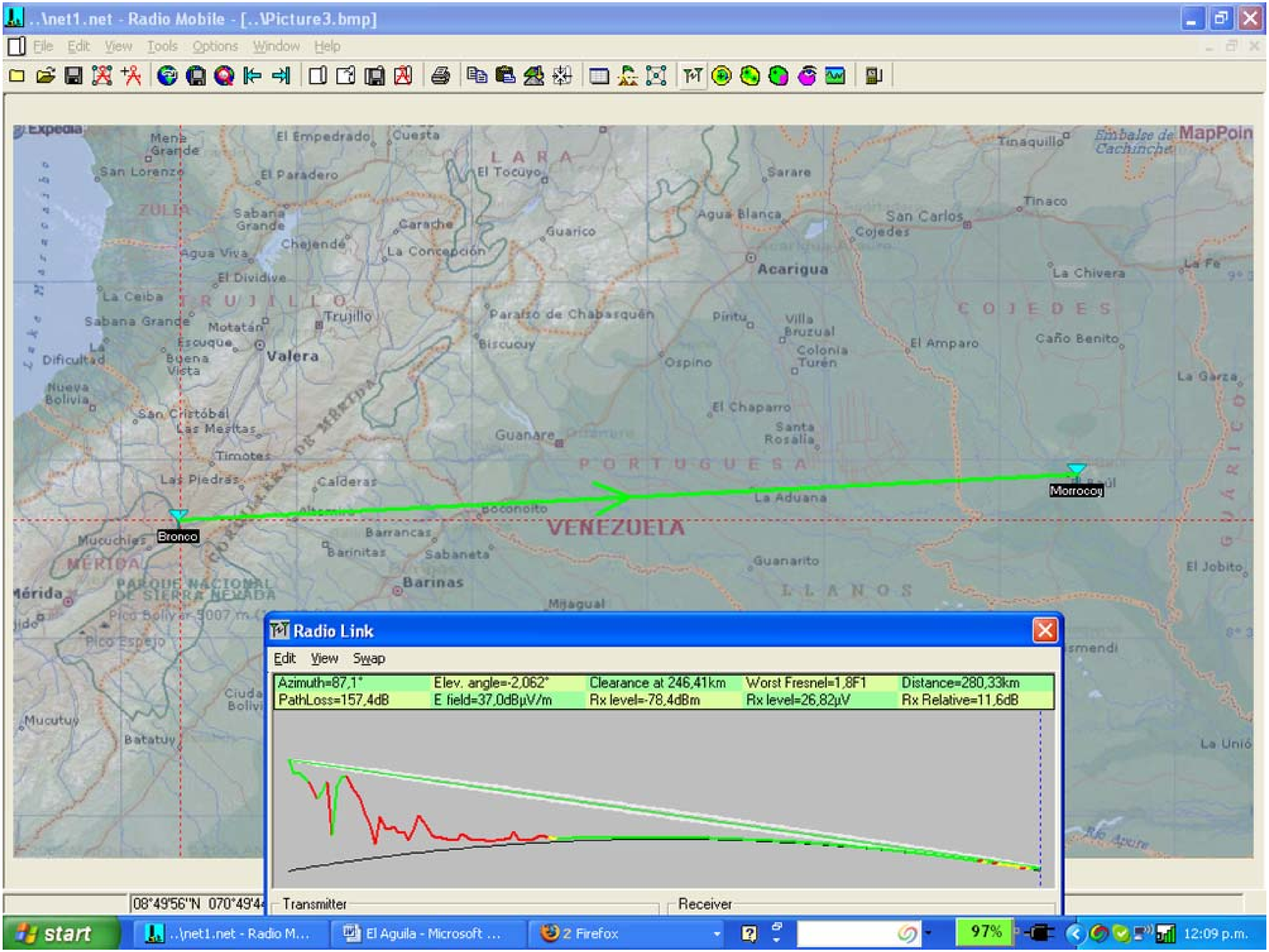


Aerial view of site 1
Pico del Aguila

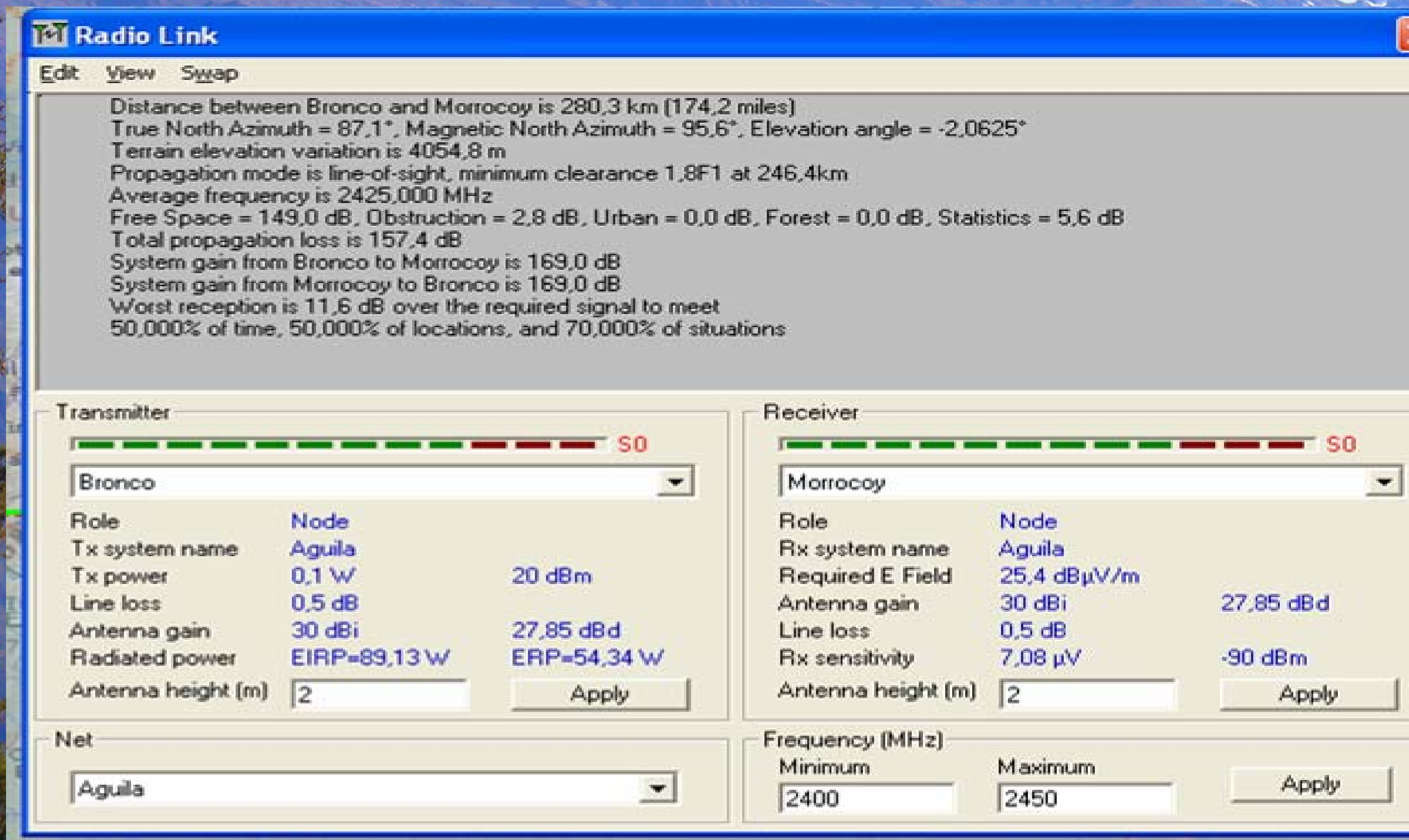
Station Layout: same for both ends



Ome Station configured as AP, the other as client


..\net1.net - Radio Mobile - [..\Picture3.bmp]
File Edit View Tools Options Window Help
Bronco
Morrocoy
VENEZUELA
LARA
TRUJILLO
PORTUGUESA
COJEDES
MERIDA
LLANOS
Valera
Trujillo
Acarigua
Guanare
Barinas
Mérida
El Tocuyo
San Carlos
Radio Link
Edit View Swap
Azimuth=87,1° Elev. angle=-2,062° Clearance at 246,41km Worst Fresnel=1,8F1 Distance=280,33km
PathLoss=157,4dB E field=37,0dBµV/m Rx level=-78,4dBm Rx level=26,82µV Rx Relative=11,6dB
Transmitter
Receiver
08°49'56"N 070°49'4
start
..\net1.net - Radio M...
El Aguila - Microsoft ...
2 Firefox
97%
12:09 p.m.

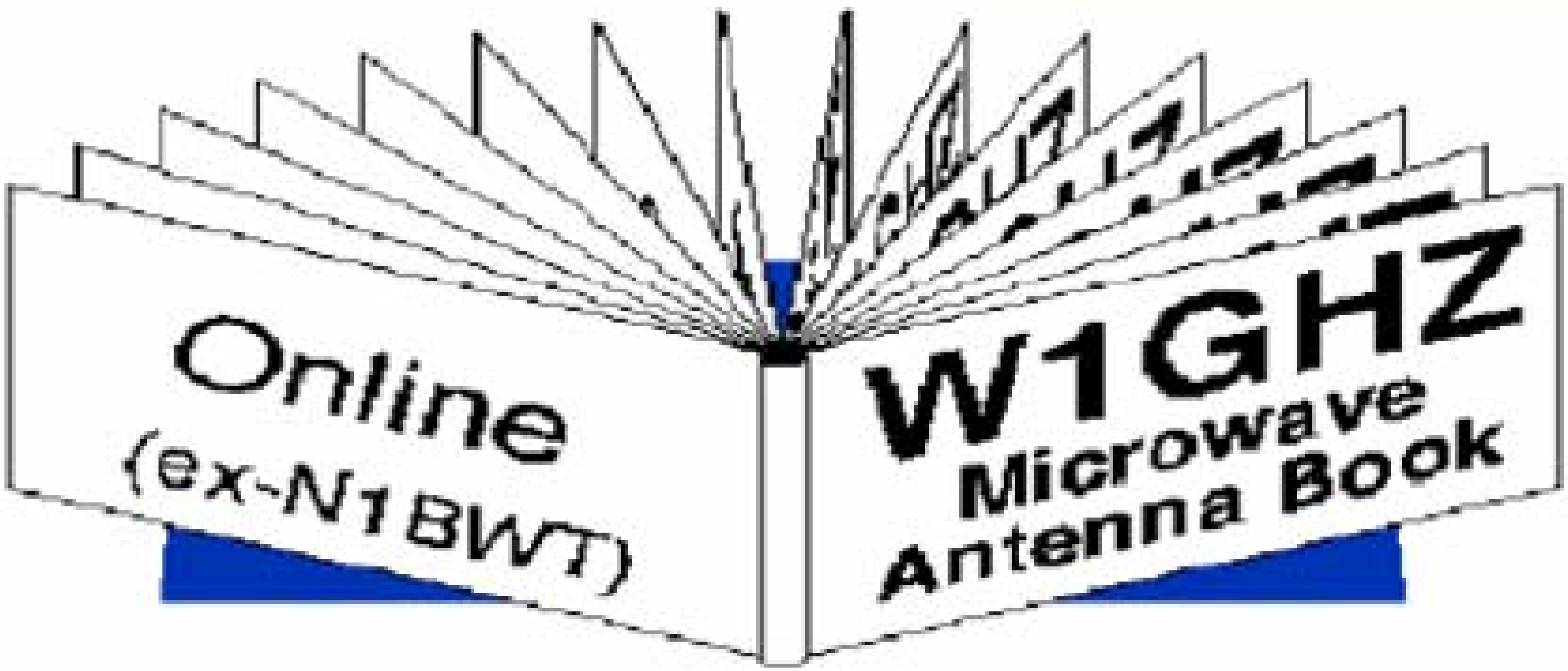
Links details



Higher gain antennas

- The parabolic antenna is by far the one that can provide the most gain in the WiFi band
- Plenty of reflector antennas have been built in many places of the world for satellite reception
- Often this antennas can be acquired at low cost

Very good source for antenna information: www.w1GHz.org



Chapter 5

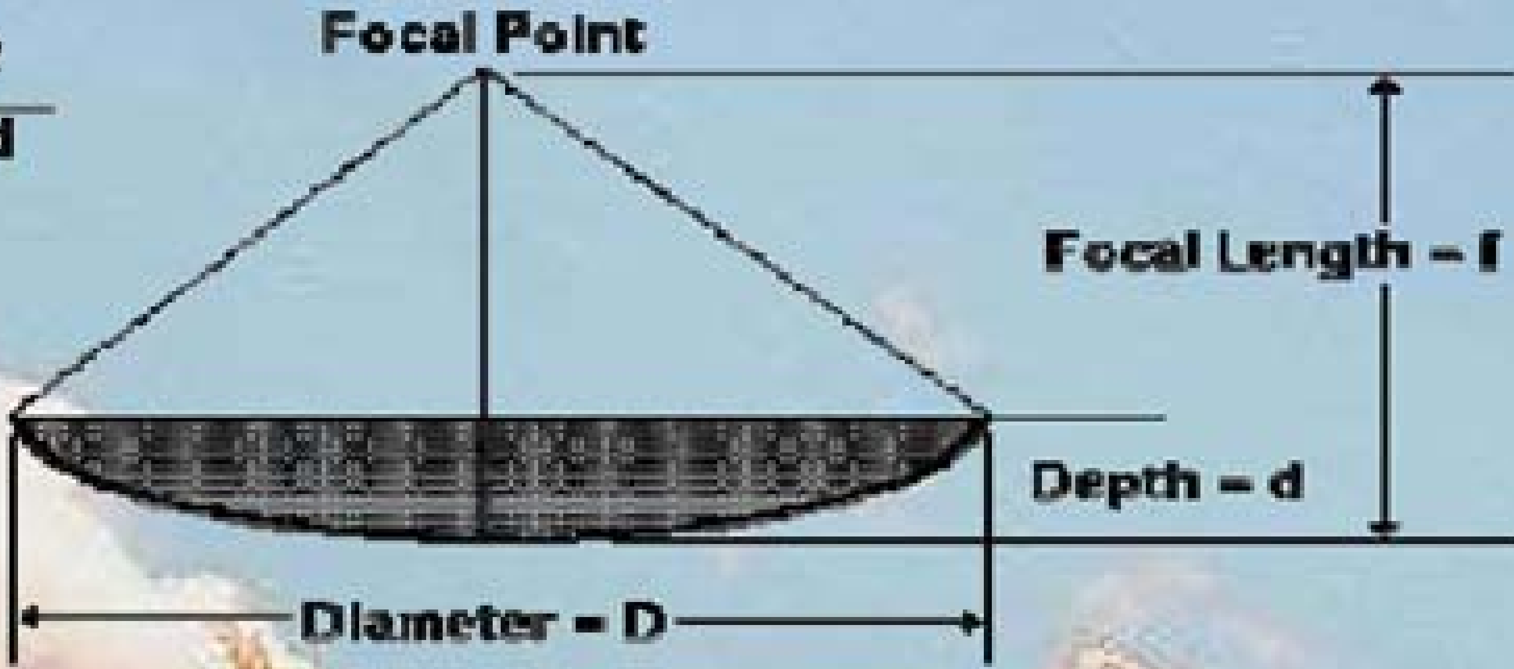
Offset-fed Parabolic Dishes

Paul Wade W1GHZ ©1998,1999

Geometry of parabolic reflectors

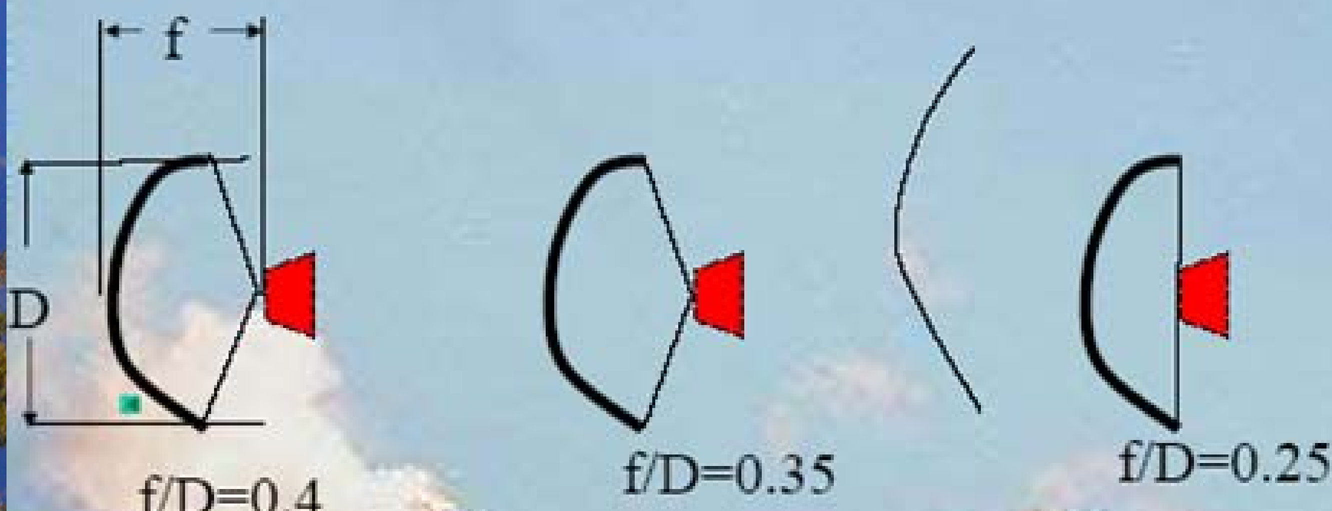
The basic property of a perfect parabolic reflector is that it converts a spherical wave irradiating from a point source placed at the focus into a plane wave. Conversely, all the energy received by the dish from a distant source is reflected to a single point at the focus of the dish. The position of the focus, or focal length, is given by:

$$f = \frac{D^2}{16d}$$



The ratio f/D (focal length/diameter of the dish) is the fundamental factor governing the design of the feed for a dish. The ratio is directly related to the beamwidth of the feed necessary to illuminate the dish effectively. Two dishes of the same diameter but different focal lengths require different design of feed if both are to be illuminated efficiently. The value of 0.25 corresponds to the common focal-plane dish in which the focus is in the same plane as the rim of the dish.

The lower the f/D ratio, the lower the sidelobes, because the feed is more protected from stray rays Sidelobes can also be reduced by means of additional Shielding on the rim of the parabolic reflector (skirt)



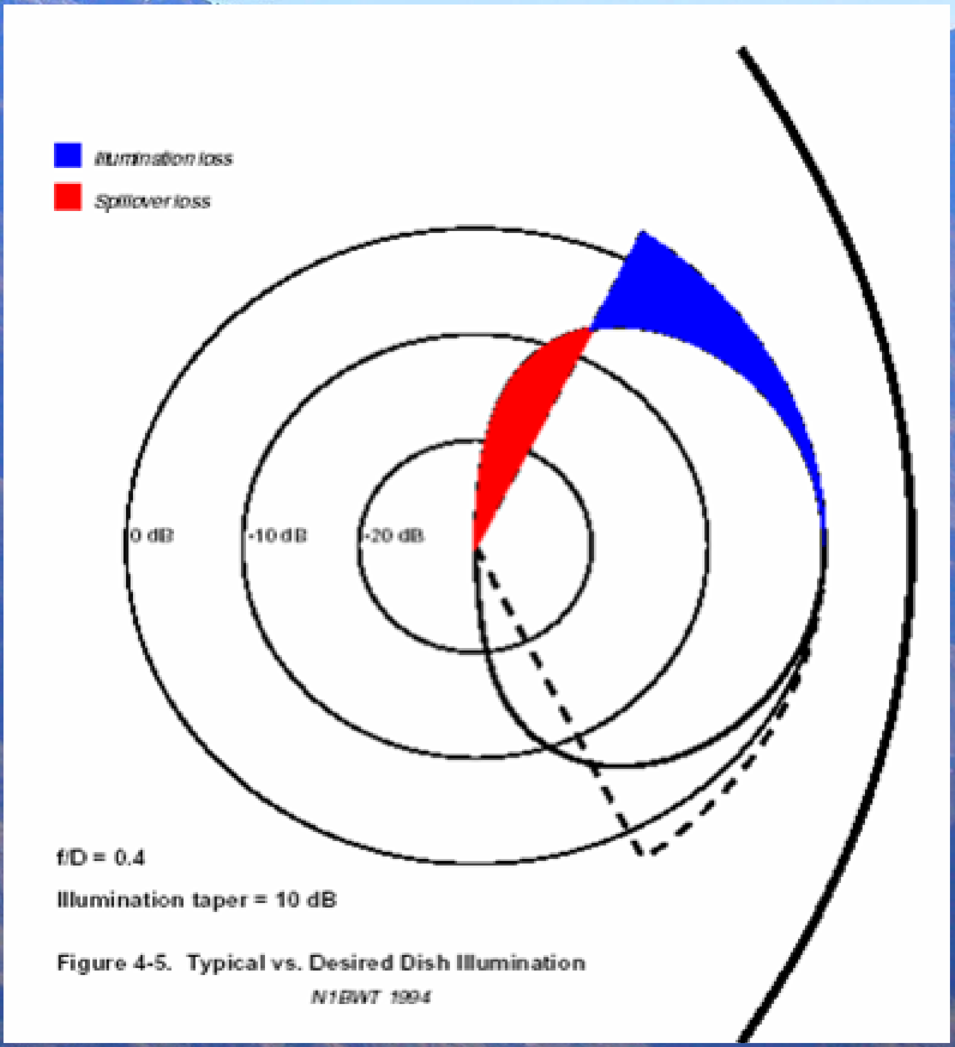
Dish Illumination

- The illumination of the dish
- is crucial to the performance
- We should illuminate as much
- as the reflecting surface as
- possible as well as avoiding spillover
- The best results are obtained with a tapered illuminator that will progressively diminish the illumination of the edges thus reducing sidelobes and spillover
- Another critical parameter is the position of the feed with respect to the reflector

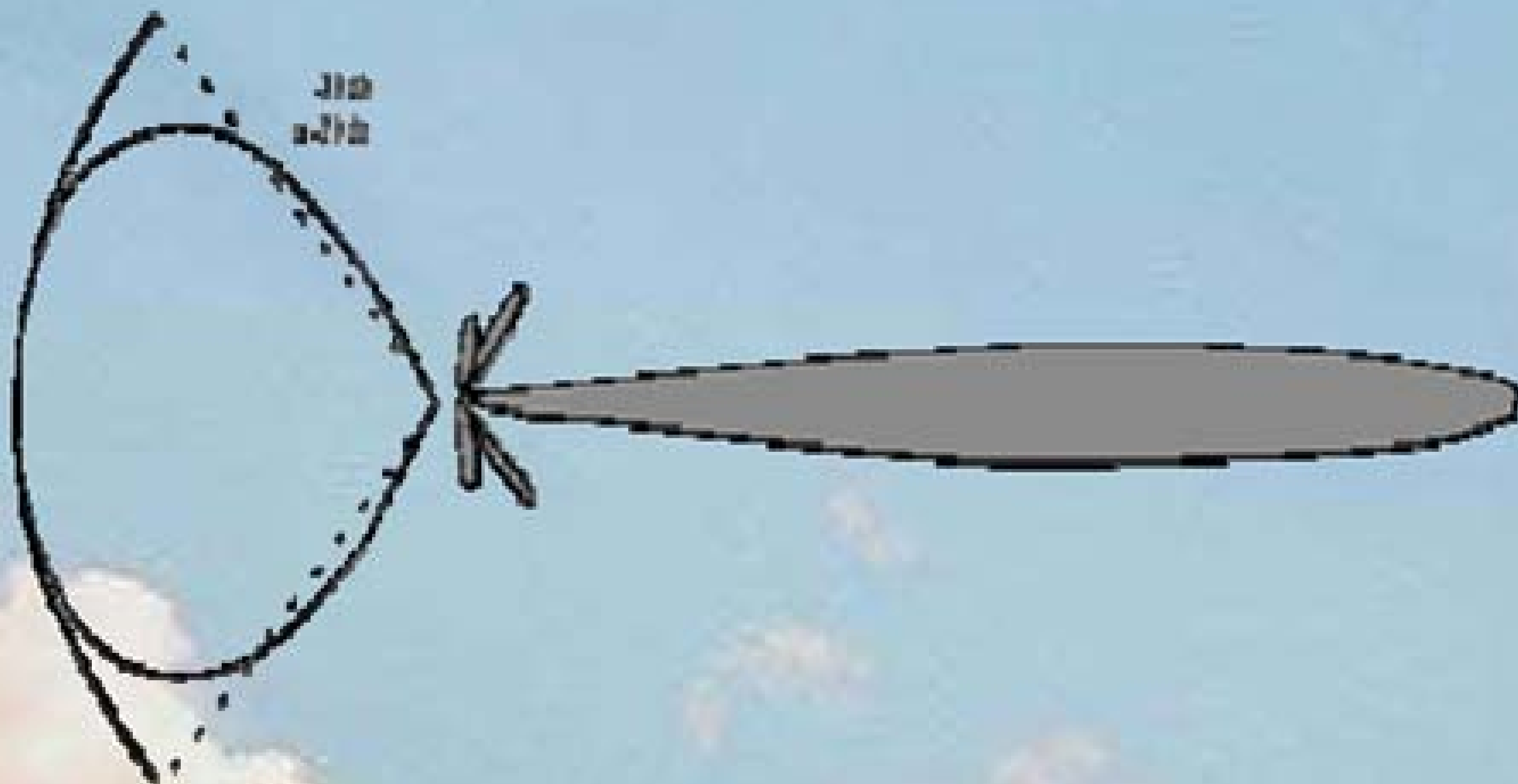
Feeding the parabolic Reflector

Illumination Efficiency:

Spillover loss
Sidelobes
Noise absorption



Radiation pattern with sidelobes



Feeding the parabolic Reflector: Some examples

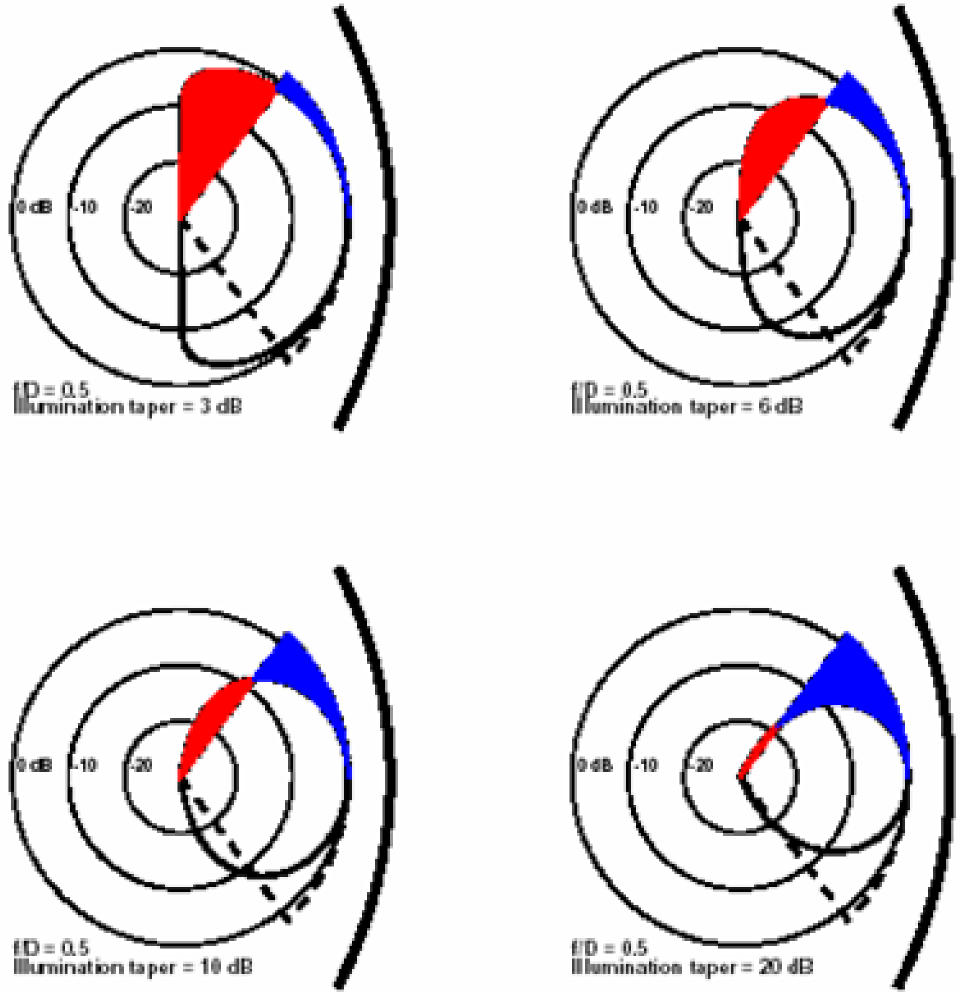


Figure 4-6. Dish Illumination with Various Illumination Tapers

N1BWT 1994

Feeding the parabolic Reflector

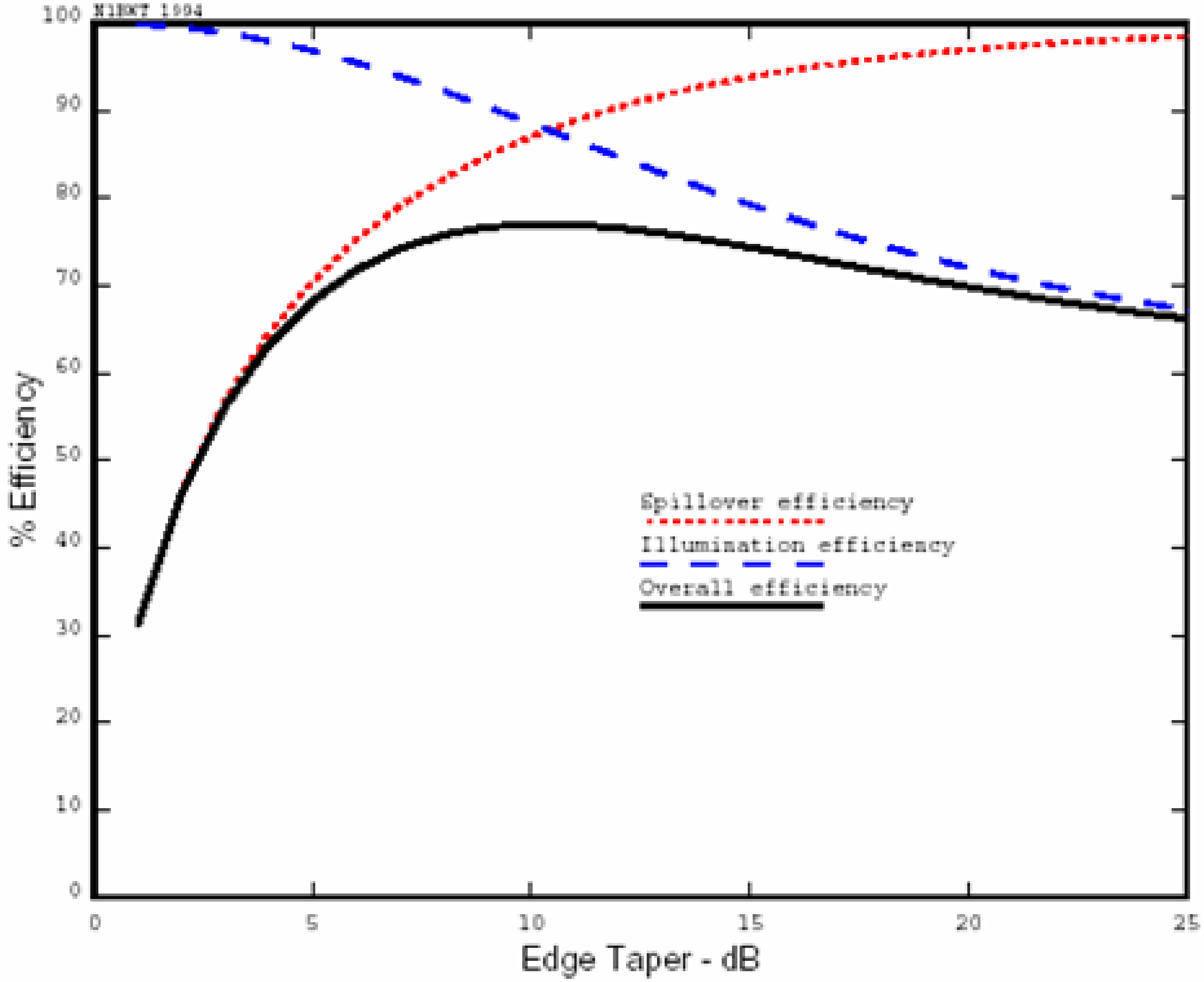


Figure 4-7. Efficiency vs. Edge Taper for a Dish

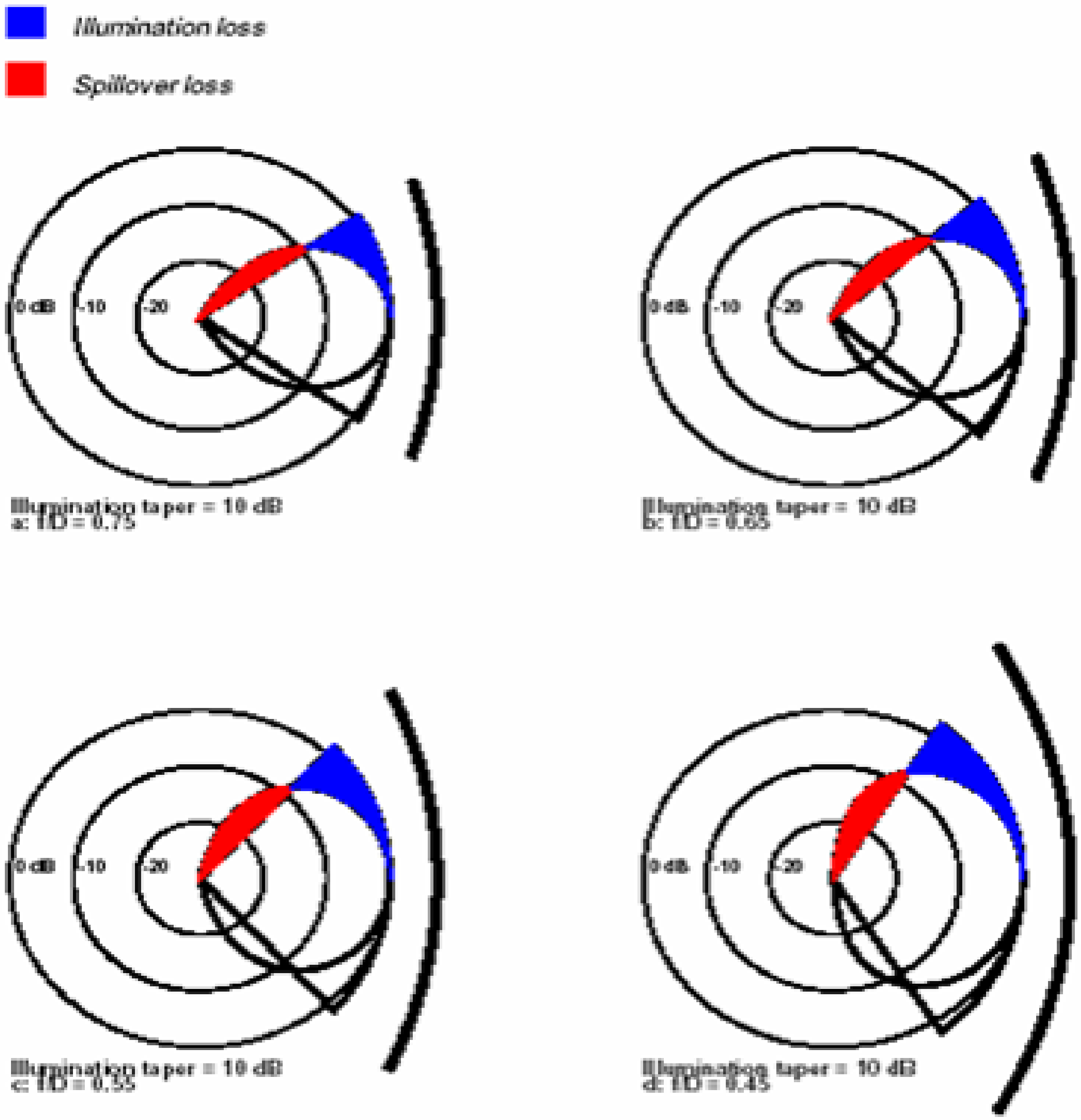
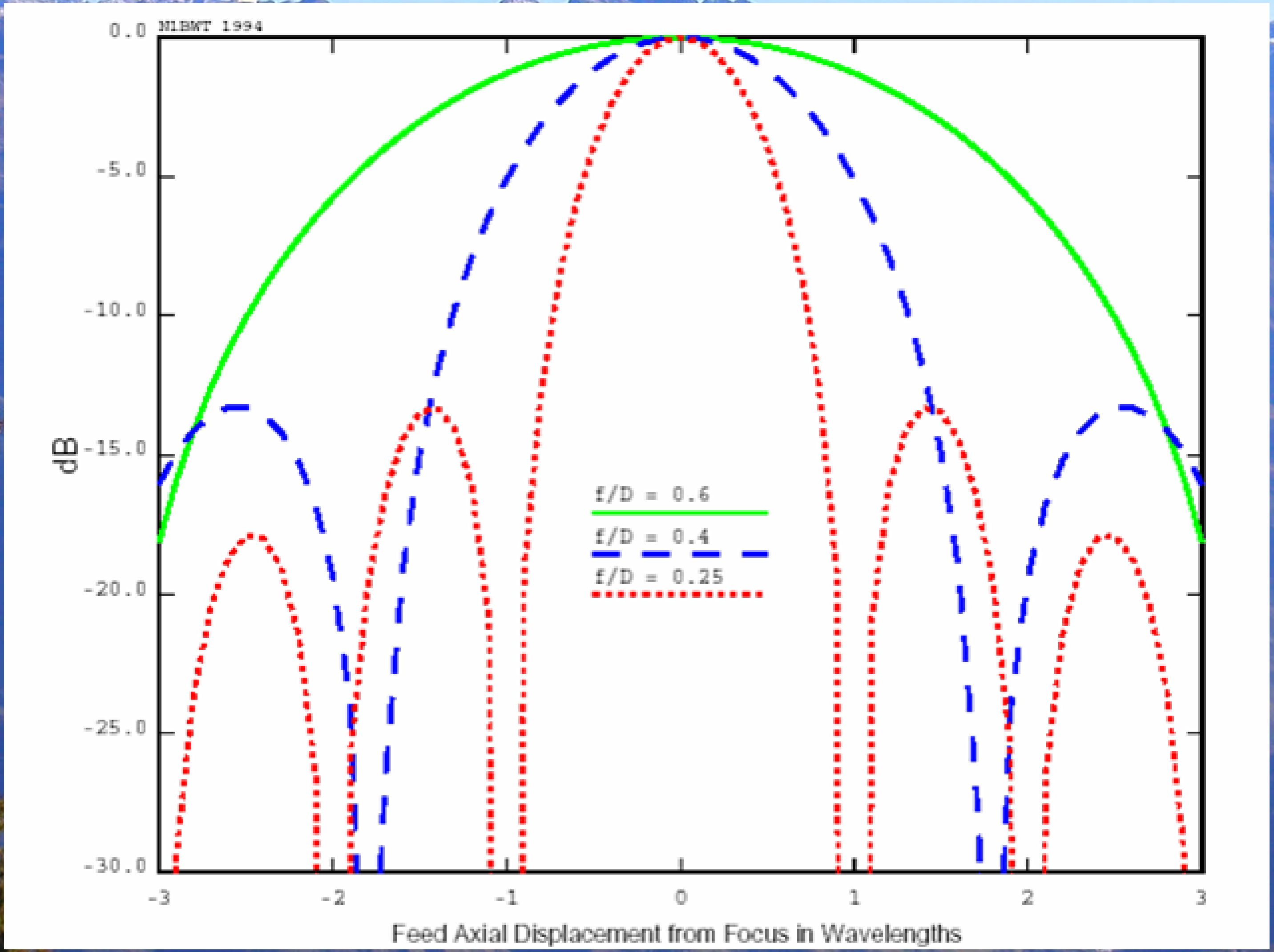


Figure 4-8. Dish Illumination for Various f/D Ratios

N1BWT 1994

Error in wavelength loss from focus displacement



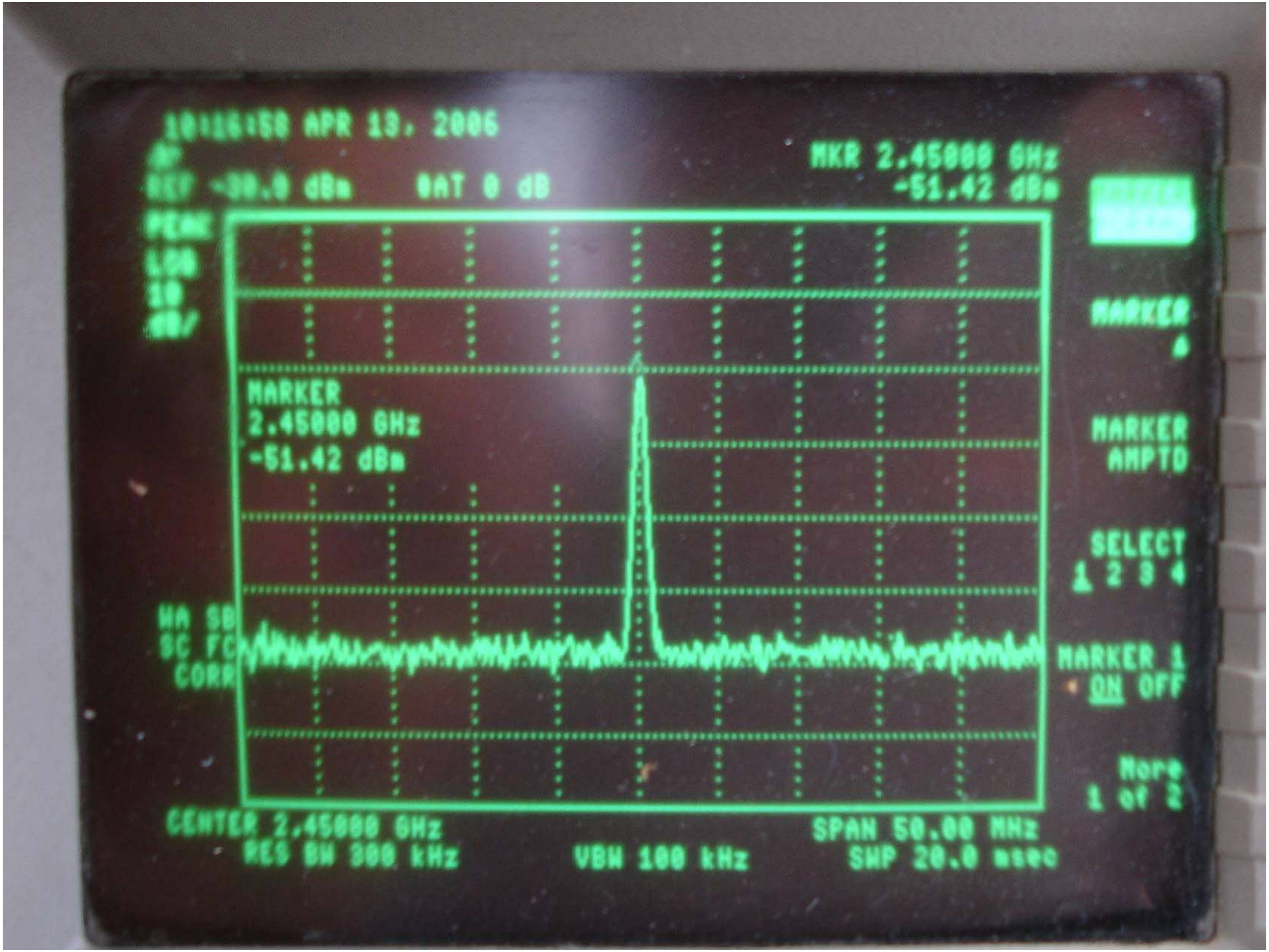
Disassembling one antenna

The two antennas

Elevation Angle

Antenna alignment

El Baúl site



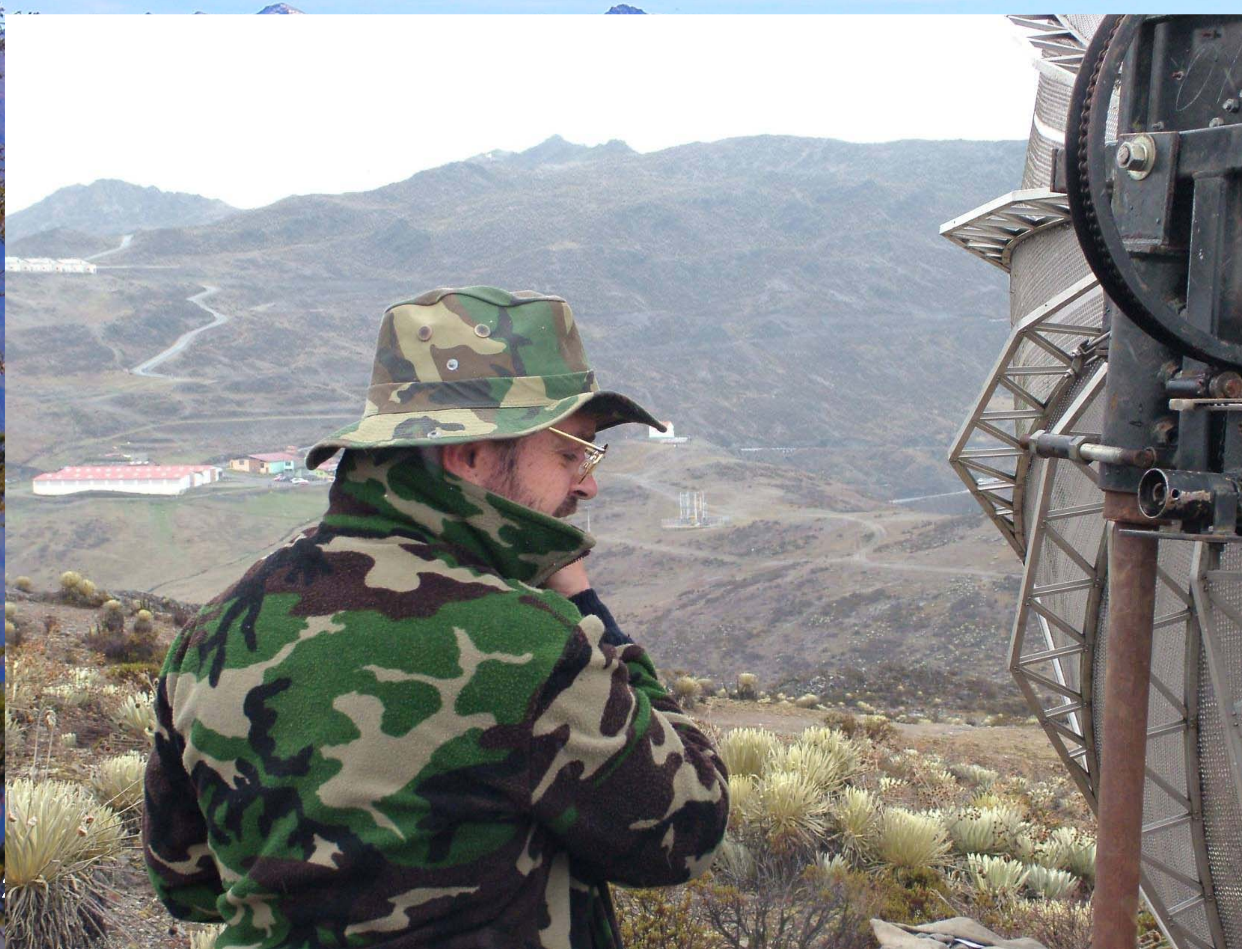
10:16:58 APR 13, 2006
MKR 2.45000 GHz
-51.42 dBm
MARKER
2.45000 GHz
-51.42 dBm
MARKER
AMPTD
SELECT
1 2 3 4
MARKER 1
ON OFF
More
1 of 2
CORR
CENTER 2.45000 GHz
RES BW 300 kHz
VBW 100 kHz
SPAN 50.00 MHz
SWP 20.0 msec

El Baúl site

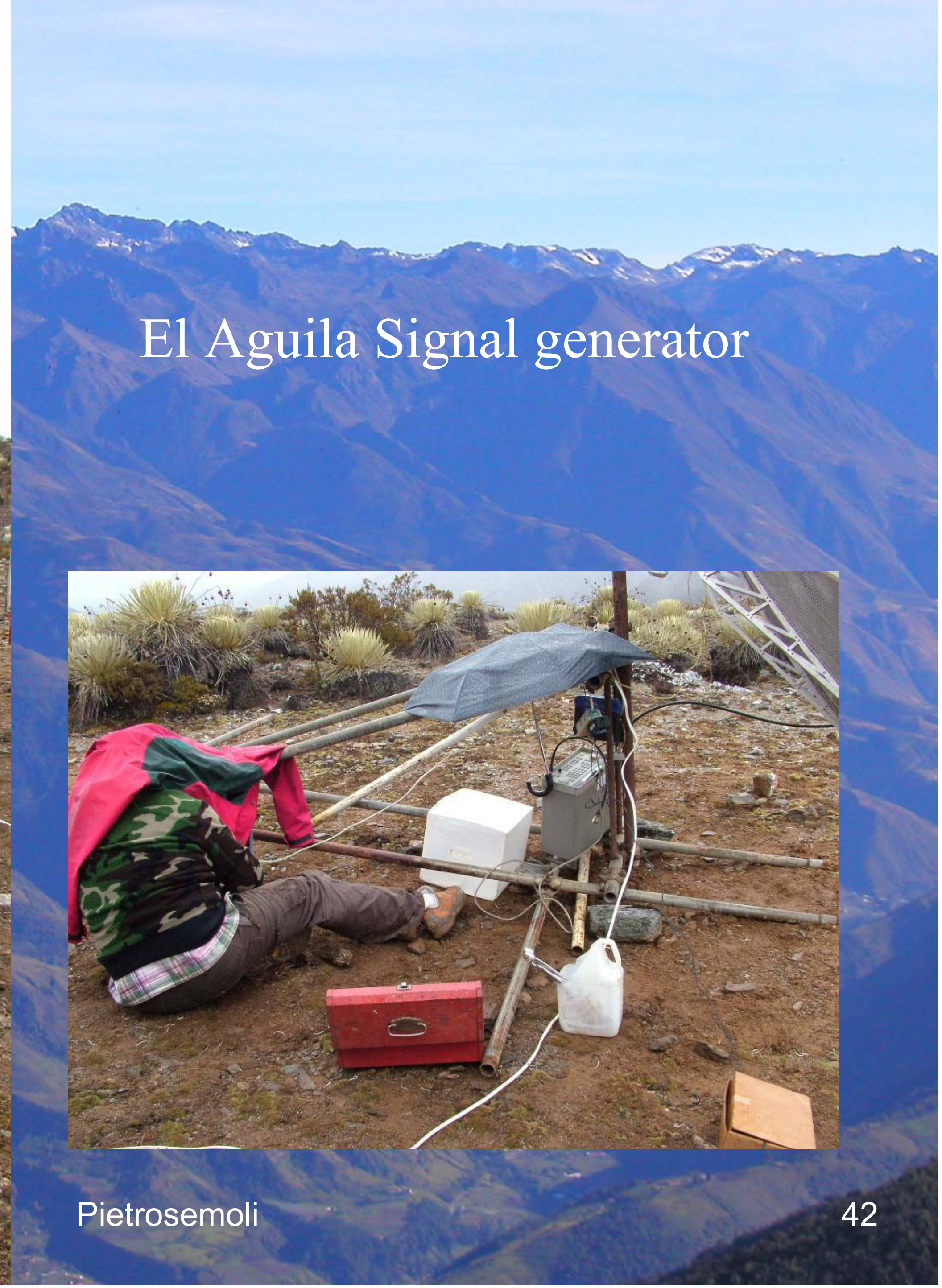
View from El Baúl towards El Águila

Javier Triviño and Ermanno Pietrosemoli in front of the 2,4 m dish

Carlo Fonda at El Aguila with the meshed dish



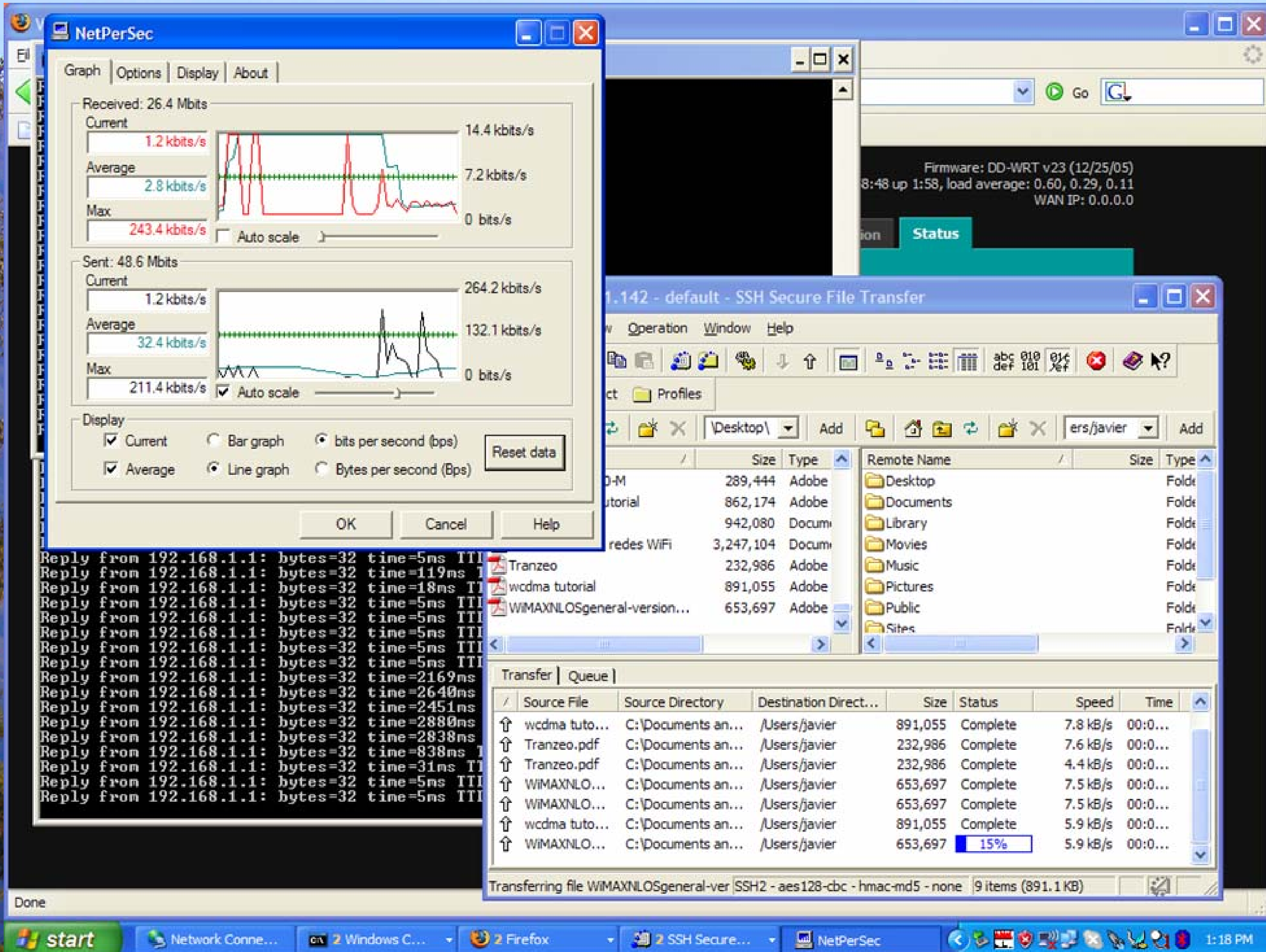
El Aguila Signal generator



Coordinates

- Site 1: 8° 49’ 57,0’ N, 70° 49’ 49,7” W, h=4090 m.
- Site 2: 8° 57’27,6 “ N, 68° 17”51,1” W,
- h= 125 m
- Distance : 279 km

Screenshots from April 13, 2006



Synopsis

Pico del Águila- El Baúl link

Frequency: 2412 MHz : channel 1

Terminal Equipment: Linksys WRT54G, flashed with Open WRT firmware

Length: 279 km

Parabolic antennas were used at both ends, recycled from satellite service: One meshed aluminum reflector central fed, 2,74 m diameter and a fiber glass offset fed reflector 2,4 x 2,74 m

Both reflectors were fed by 12 dBi Yagis.

Further work

- Repeat the experiment tweaking parameters to optimize throughput
- Use the 2P MAC to optimize throughput
- Repeat the experiment at 5,8 GHz
- Use another end point to increase the span