Long Distance Links

Training materials for wireless trainers

The Abdus Salam International Centre for Theoretical Physics

United Nations Educational, Scientific and Cultural Organization

Goals

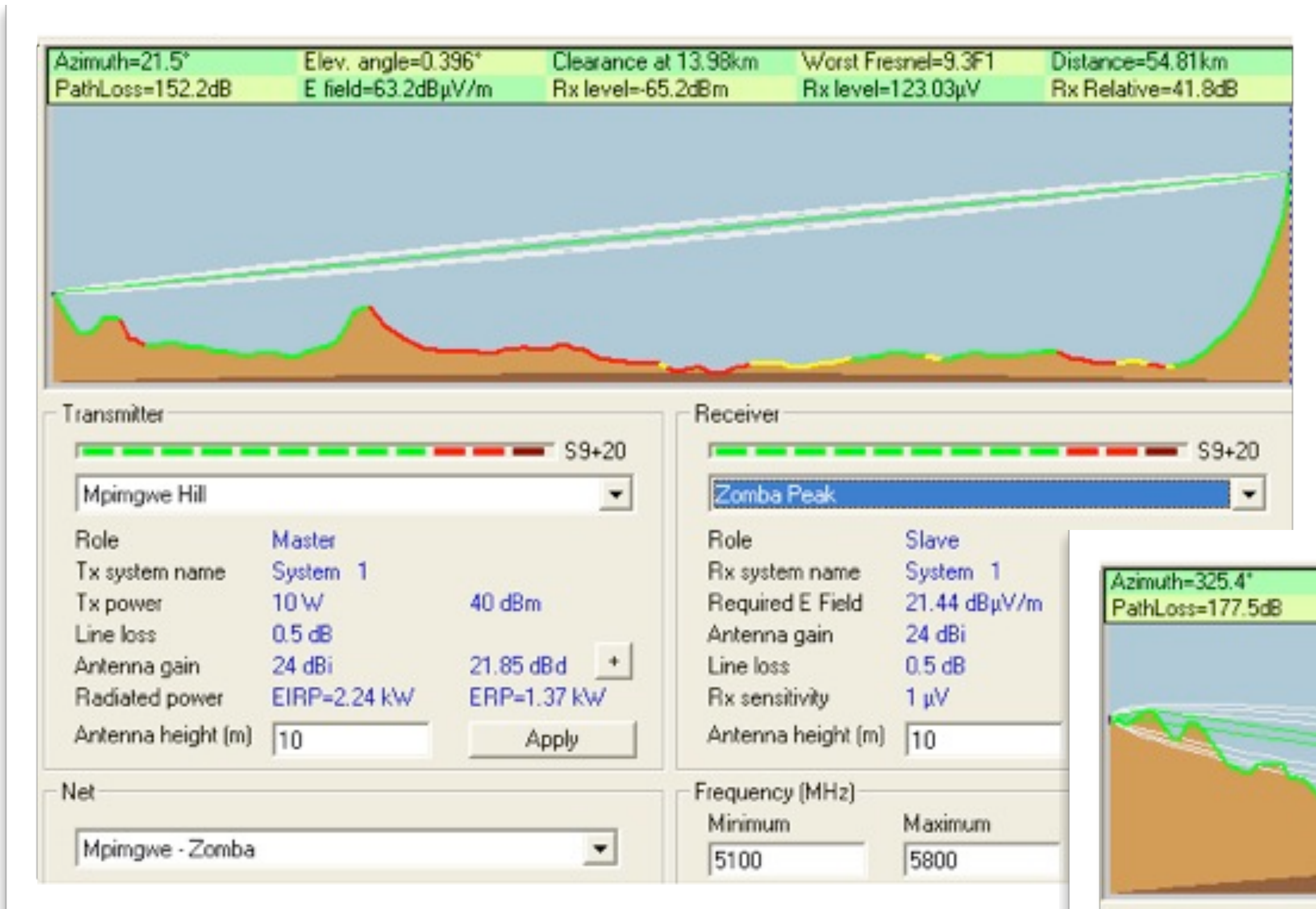
- To understand the engineering challenges of building long distance links
- To realize the limitations of long distance wireless
- To learn a methodology for aligning antennas at a distance
- To see some real world examples of extremely long distance wireless networks

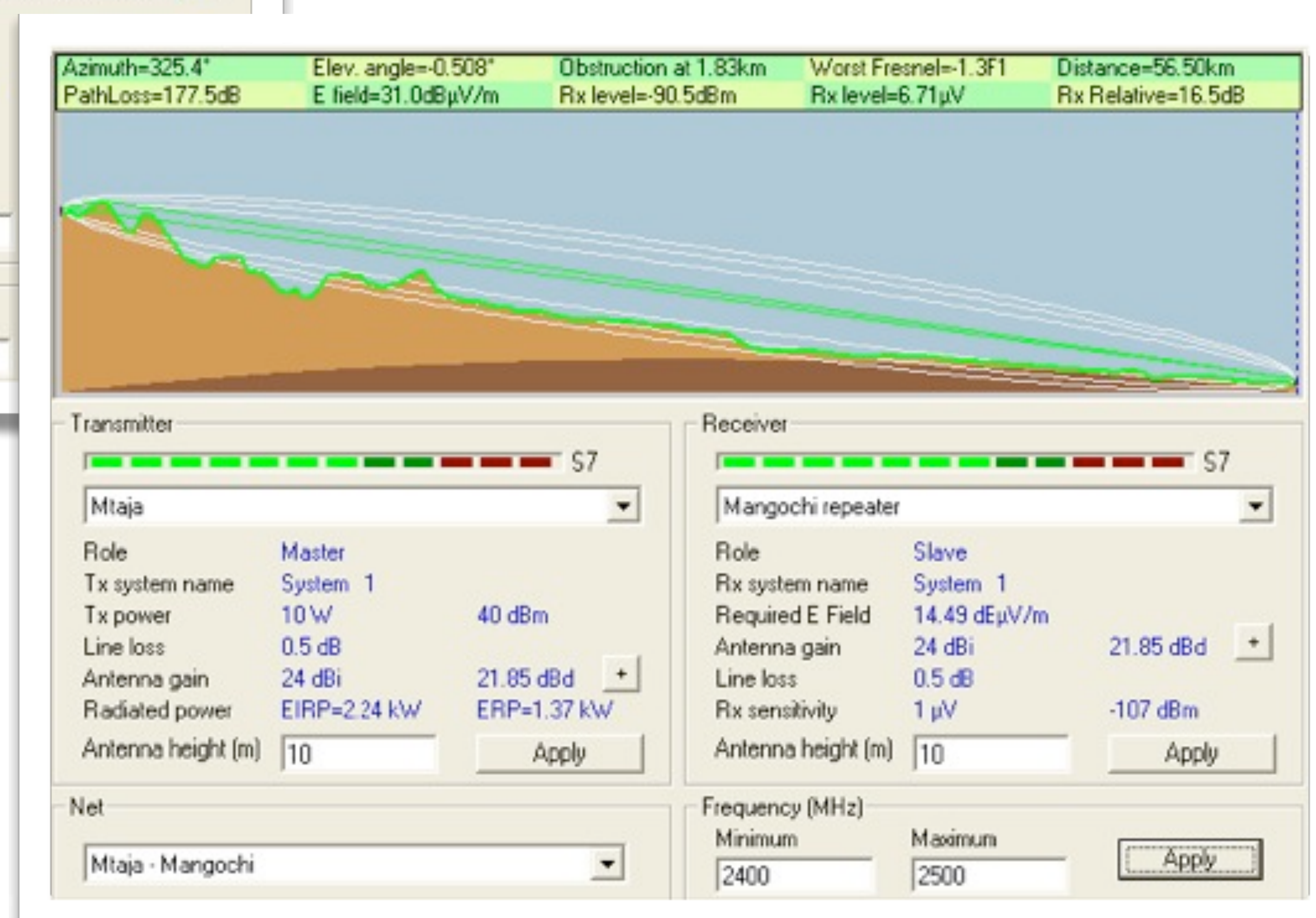
Long Distance Link Requirements

For a successful long distance link one must:

- Simulate the link and perform a site survey.
- Use suitable structures to hang antennas so that the Fresnel Zone and earth curvature can be cleared.
- Choose special purpose equipment, or modify short distance equipment, to allow for long distances.
- Use proper antenna alignment techniques.

Step 1: Simulate the link!





Step 2: Perform a site survey

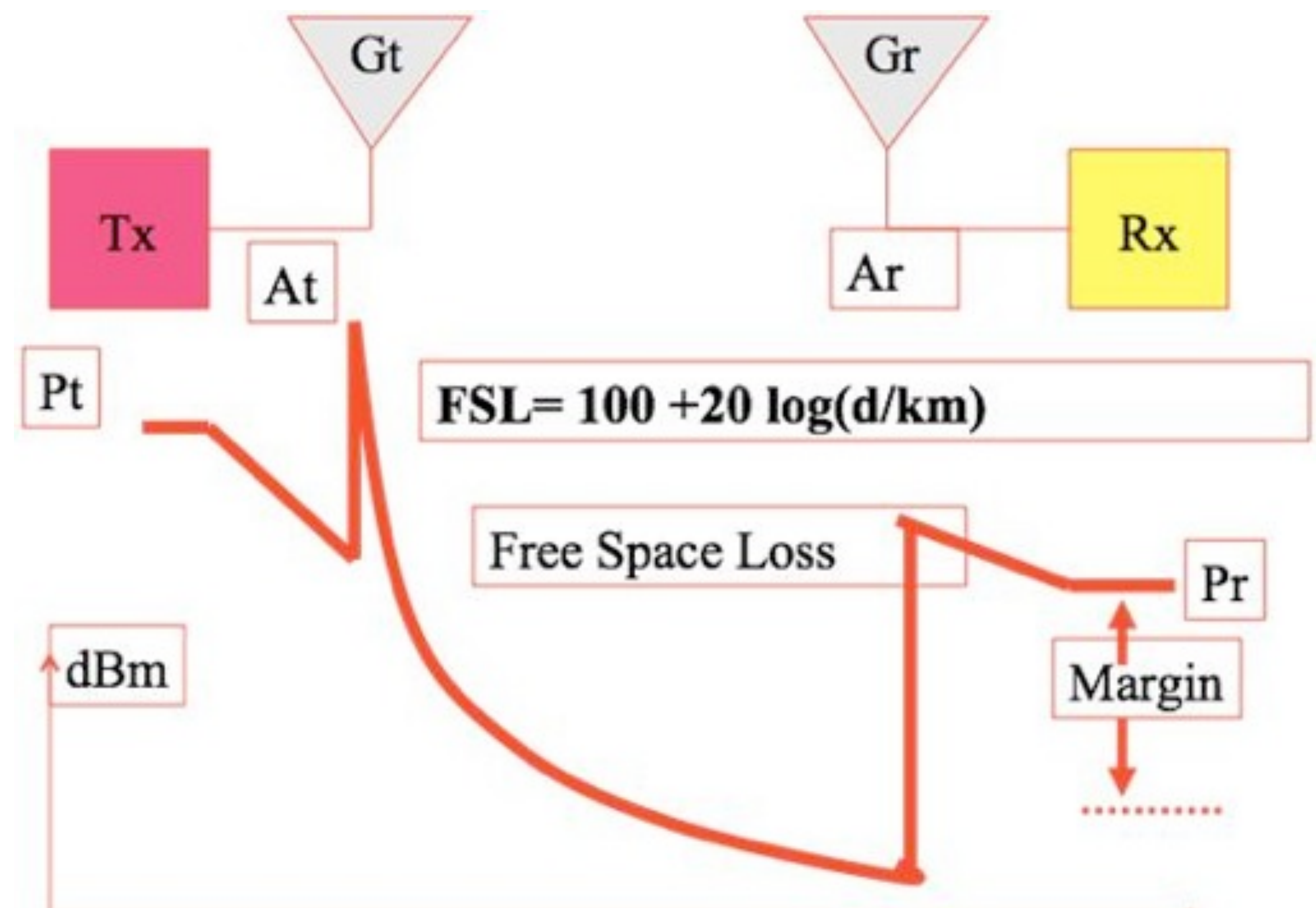
Step 3: Where to mount your gear?

Step 4: Selecting and preparing long-range equipment

- Equipment should be chosen that maximizes the available signal level at both ends of the link.
- External antennas are **required** for long links.
- In addition to link budget considerations, ***protocol issues*** (such as acknowledgment timing, hidden node, and other media access problems) become a factor.

Maximizing the power budget

- Increase the antenna gain on one or both ends of the link.
- Increase the transmitting power on **both** ends of the link.
- Use more sensitive radios (lower minimum received signal level) on both ends of the link.
- Reduce transmission line loss by using shorter or better quality radio cables, or eliminate them entirely.



Practical link budget considerations

- Legal regulations on maximum EIRP
- High power and very sensitive radios are often (but not always) more expensive.
- Amplifiers are very expensive and are almost never a good idea.
- High gain antennas (parabolic dishes) tend to be larger, more expensive, and difficult to transport.
- High gain antennas are difficult to align at long distance and have greater wind loads.

Timing issues

Due to the very fast timing of 802.11 frames, the speed of light becomes an issue at long distances. At approximately 15 km, standard timings are too short for ACKs to be received. It takes 1 ms for radio waves to travel 300 km!

Some cards and drivers (such as Atheros) allow timings to be adjusted, permitting very long distance communications.

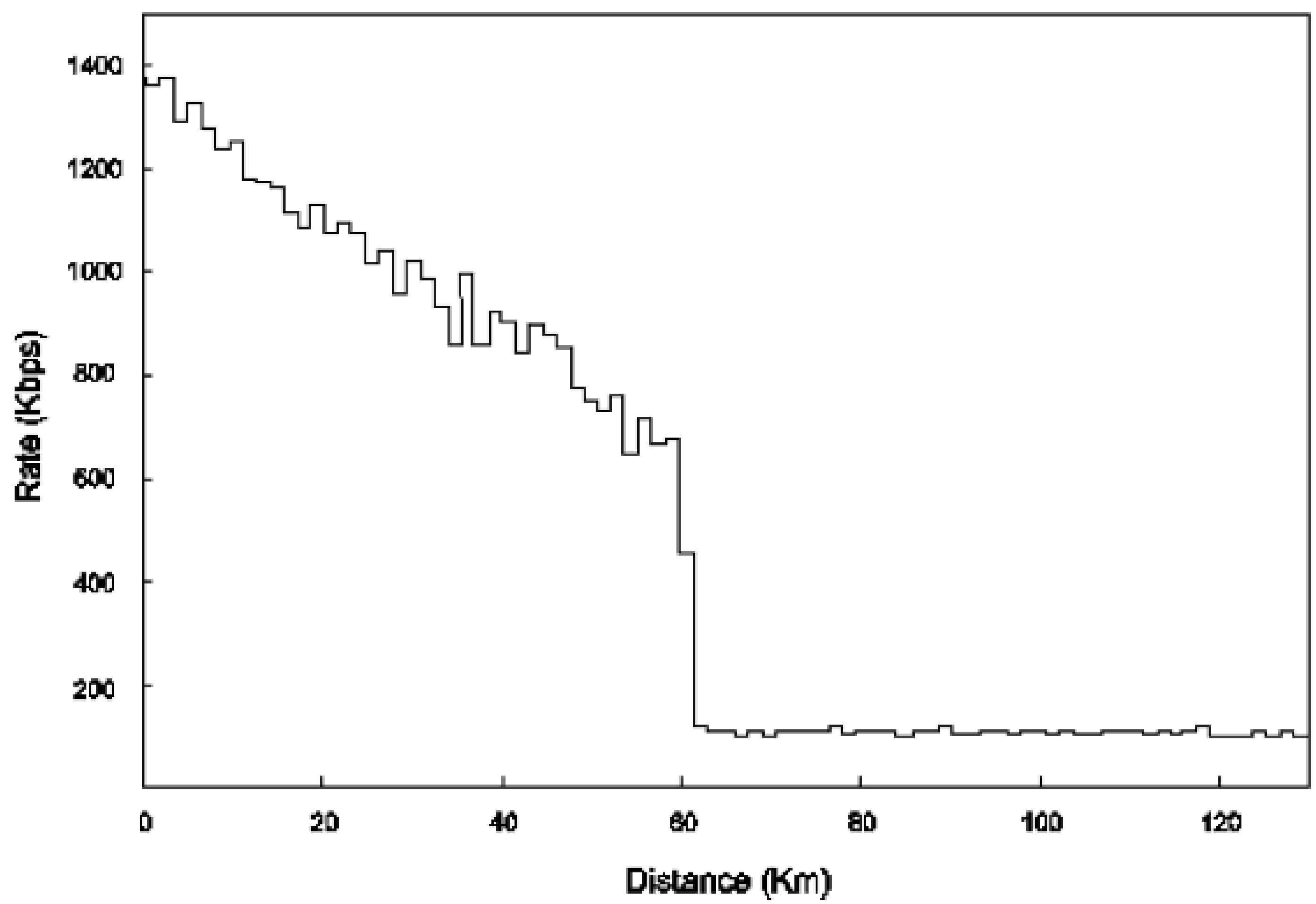
Proprietary protocols (such as WiMAX, Mikrotik Nstreme, or Ubiquiti AirMAX) use TDMA to avoid these ACK timing issues.

CSMA vs. TDMA

802.11 WiFi uses ***Carrier Sense Multiple Access*** (***CSMA***) to avoid transmission collisions. Before a node may transmit, it must first listen for transmissions from other radios. The node may only transmit when the channel becomes idle.

Other technologies (such as WiMAX, Nstreme, and AirMAX) use ***Time Division Multiple Access*** (***TDMA***) instead. TDMA divides access to a given channel into multiple time slots, and assigns these slots to each node on the network. Each node transmits only in its assigned slot, thereby avoiding collisions.

802.11 rate vs. distance behavior



Rate versus distance for an FTP file transfer, simulated with NS2

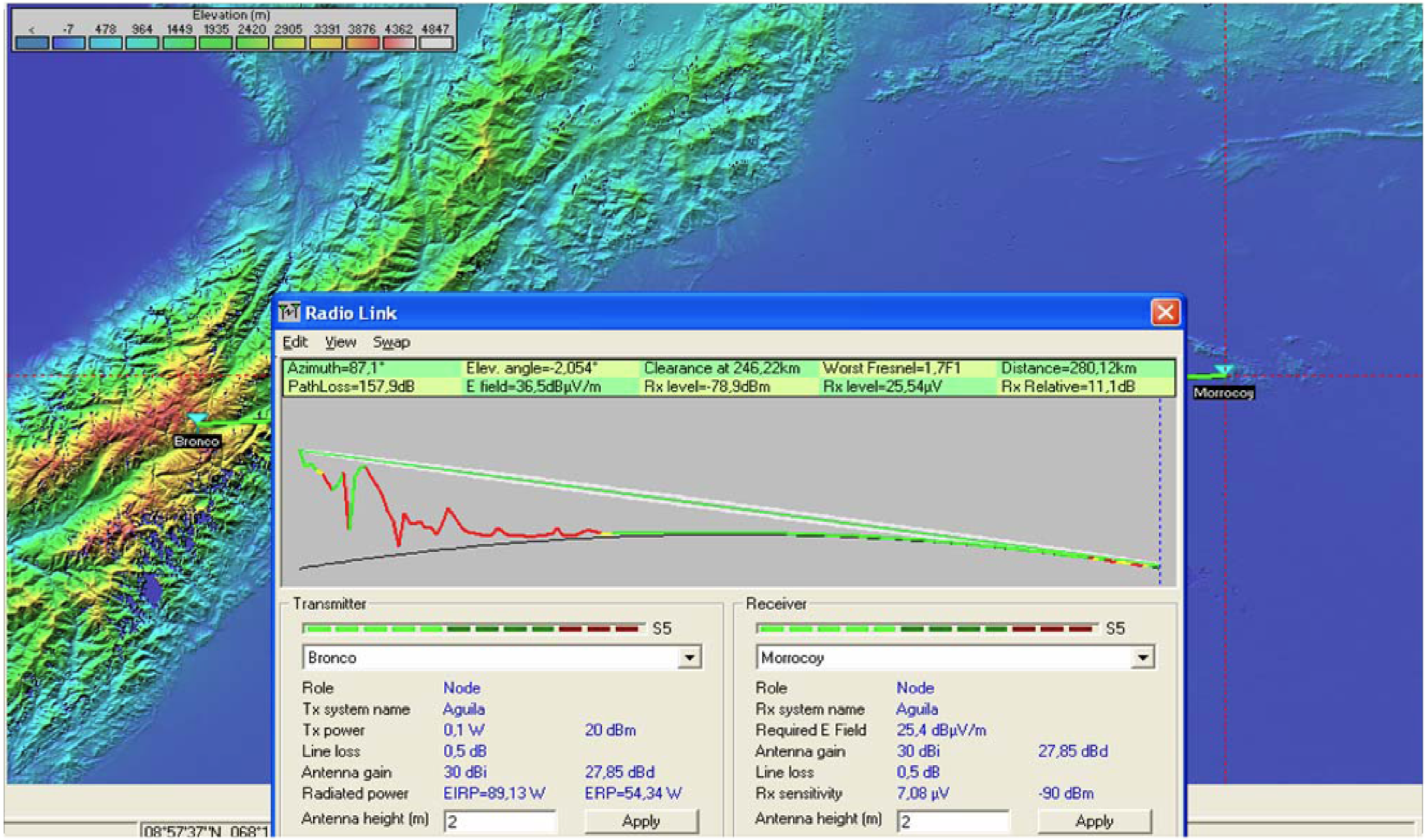
From *Distance Limits in IEEE 802.11 for Rural Networks in Developing Countries* by *Javier Simo, Andres Martinez, Carlos Figuera and Joaquin Seoane.*

The "Hidden Node"

When two clients are in range of the same access point but not each other, their transmissions can interfere with each other. This condition is called a ***hidden node*** problem.

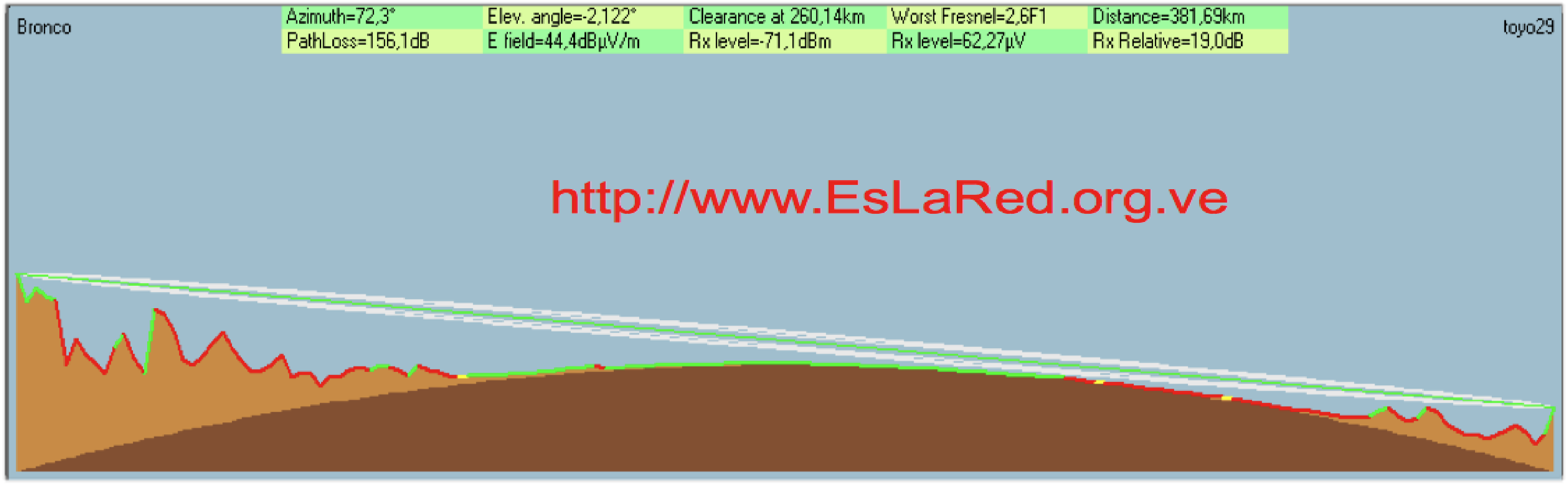
- Hidden node is alleviated somewhat by CTS/RTS (also known as channel reservation).
- CTS/RTS adds overhead, so you can specify a maximum packet size above which CTS/RTS is used.
- It is not perfect, but can help at a cost of maximum possible throughput. CTS/RTS should only be used with access points and clients, not ad-hoc networks.
- Only relevant on point-to-multipoint networks.

Real-world long distance links

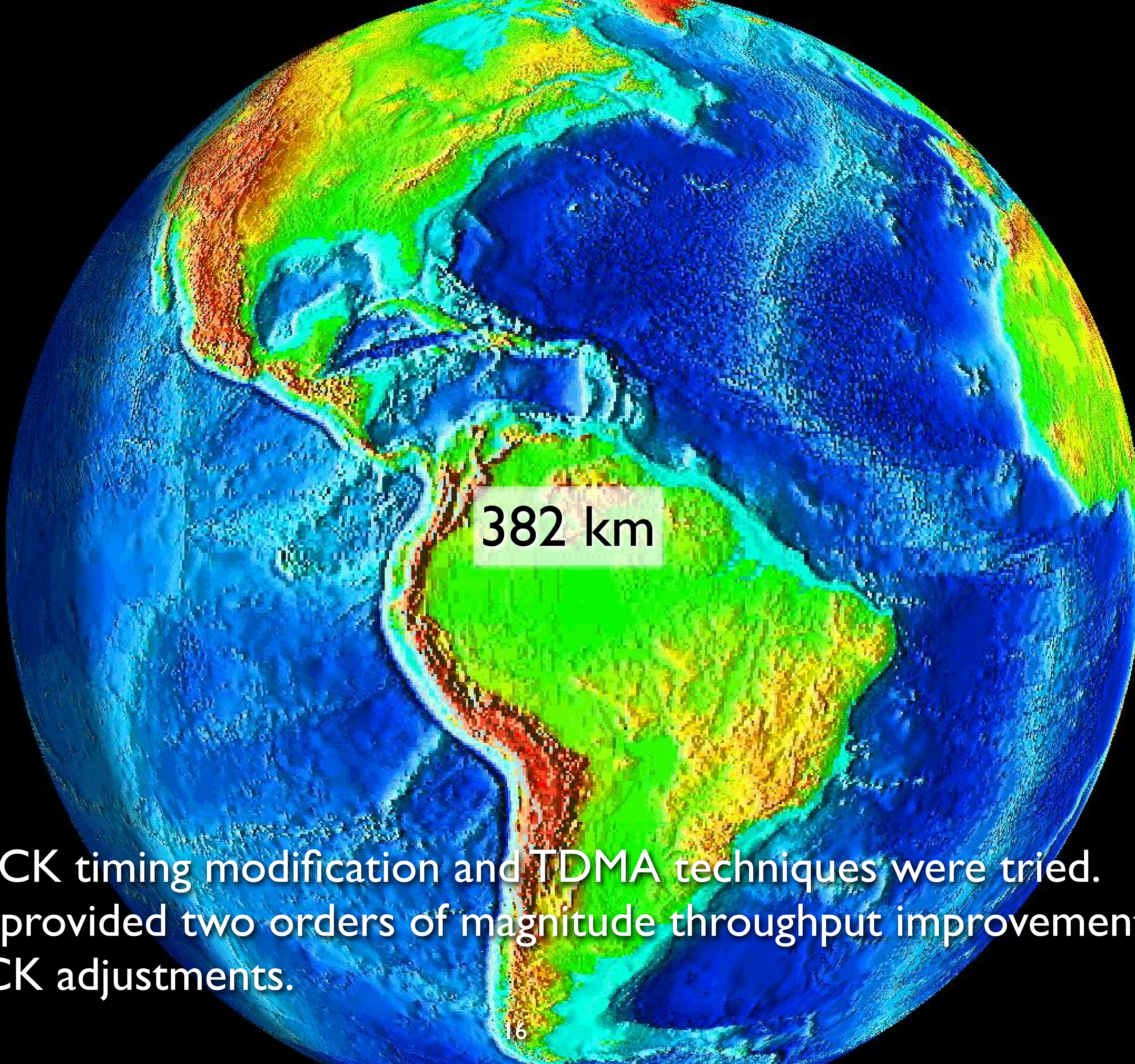


Profile of a 279 km test at 2.4 GHz performed in April 2006, Venezuela.

Real-world long distance links



Profile of a 382 km test at 2.4 GHz performed in April and August 2007, Venezuela.

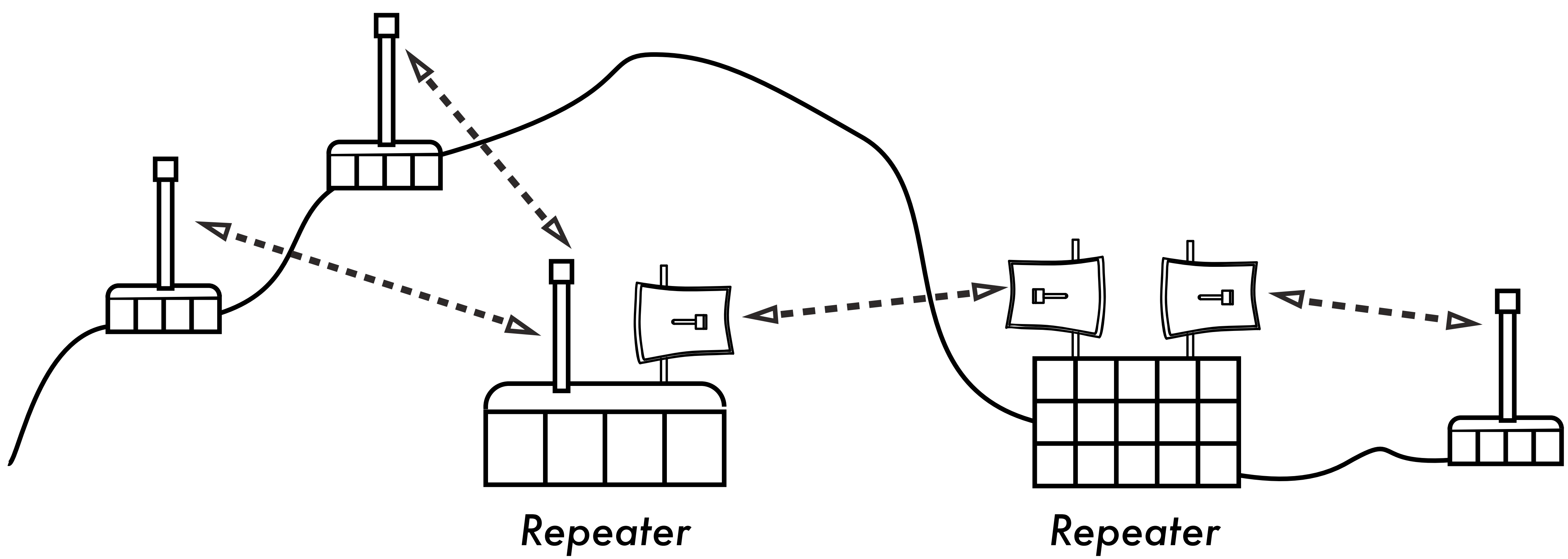


Both ACK timing modification and TDMA techniques were tried. TDMA provided two orders of magnitude throughput improvement over ACK adjustments.

Other long distance strategies: repeaters

Rather than attempt a single long-distance link, you can often make use of ***repeaters***. Repeaters are nodes that are configured to rebroadcast traffic that is not destined for the node itself.

Adding repeaters reduces the complexity of planning a single link, but adds additional hardware and maintenance overhead to the network.



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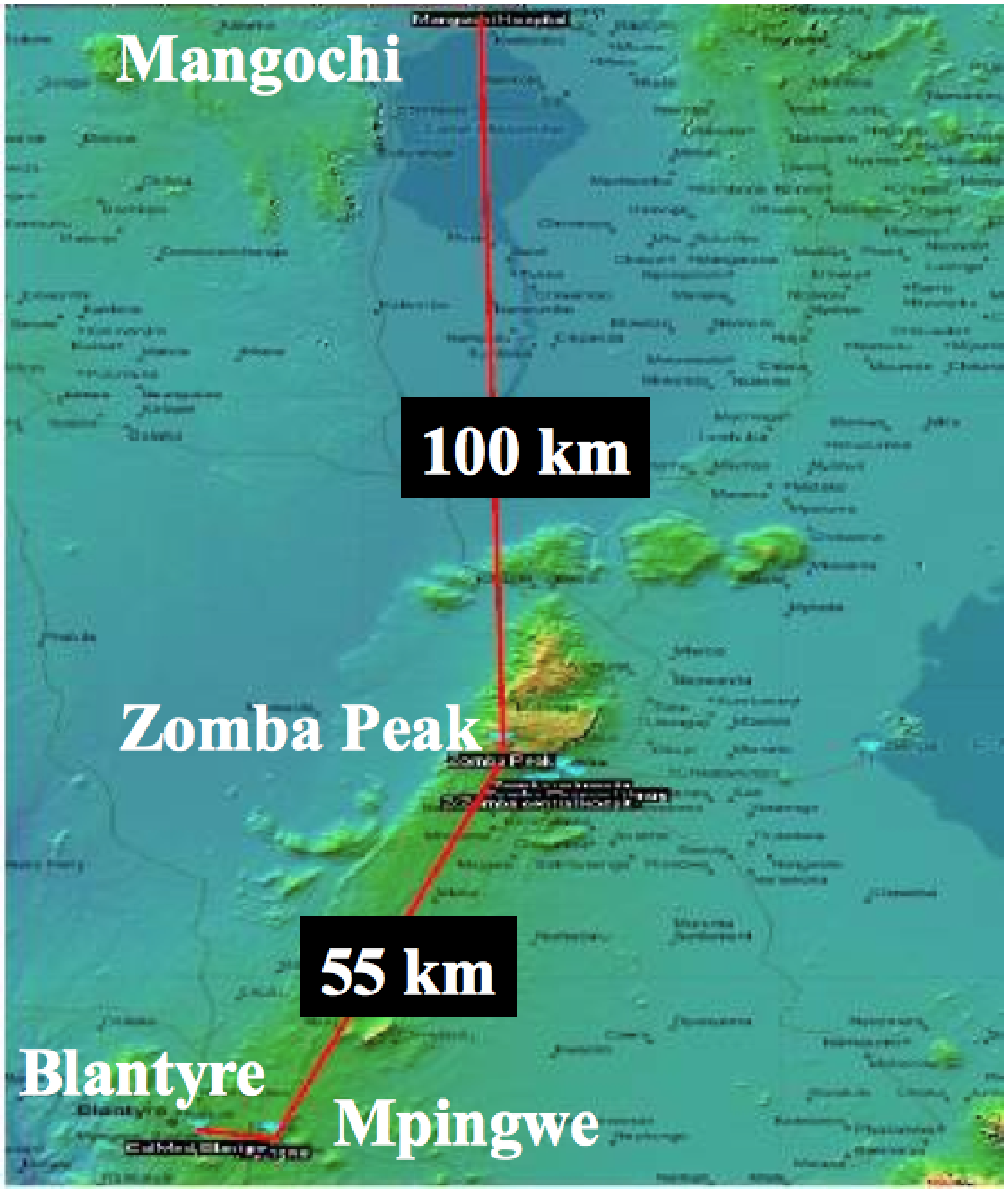

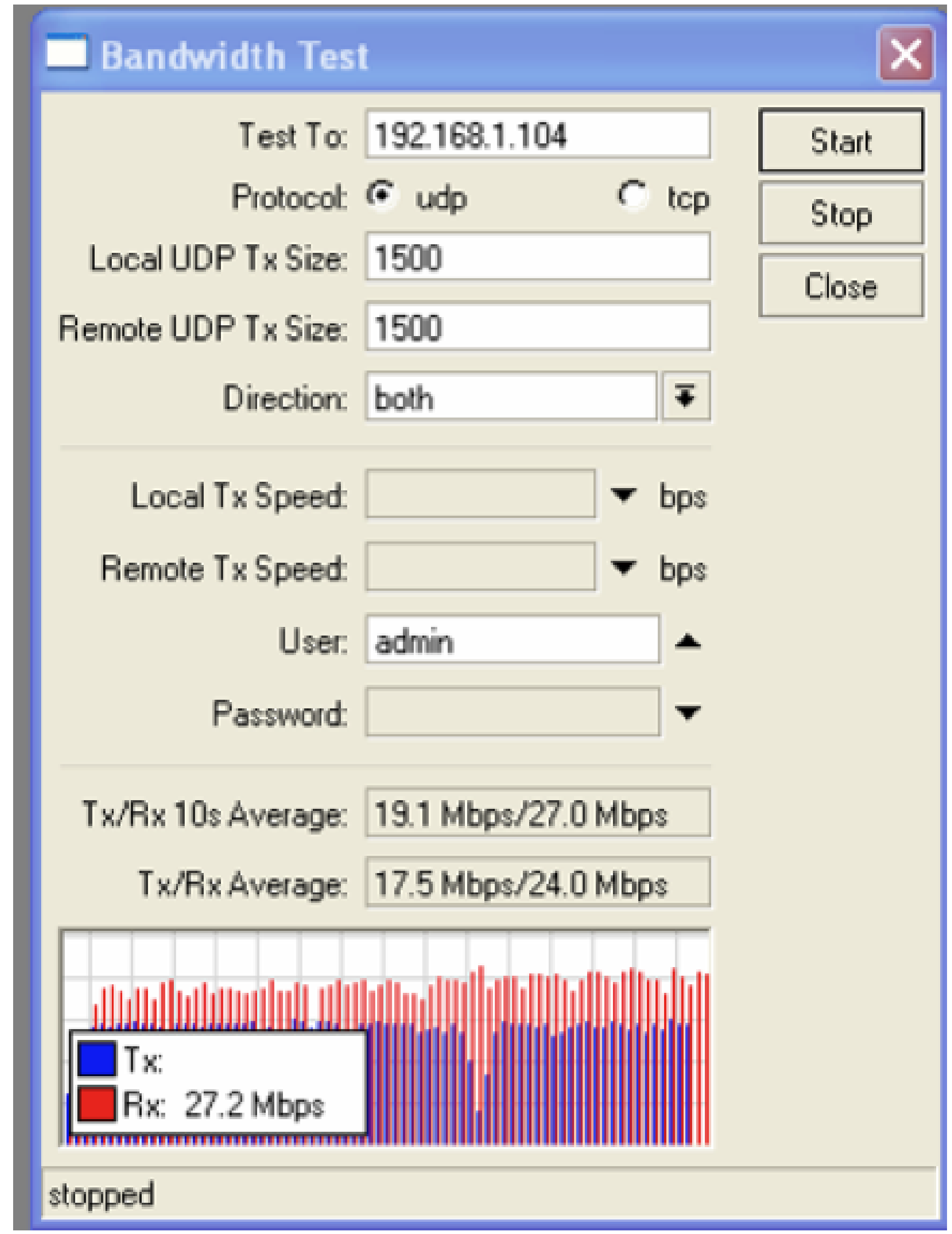

Step 5: Antenna alignment

To align dishes at a long distance, you must first start by aligning the antenna to the approximate bearing of the remote side.

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

It also helps to separate your compass from the influence of ferrous objects in the antenna mounting structure.

Once you have a rough idea of the bearing, other instruments are needed to properly align the antennas.

Aligning antennas

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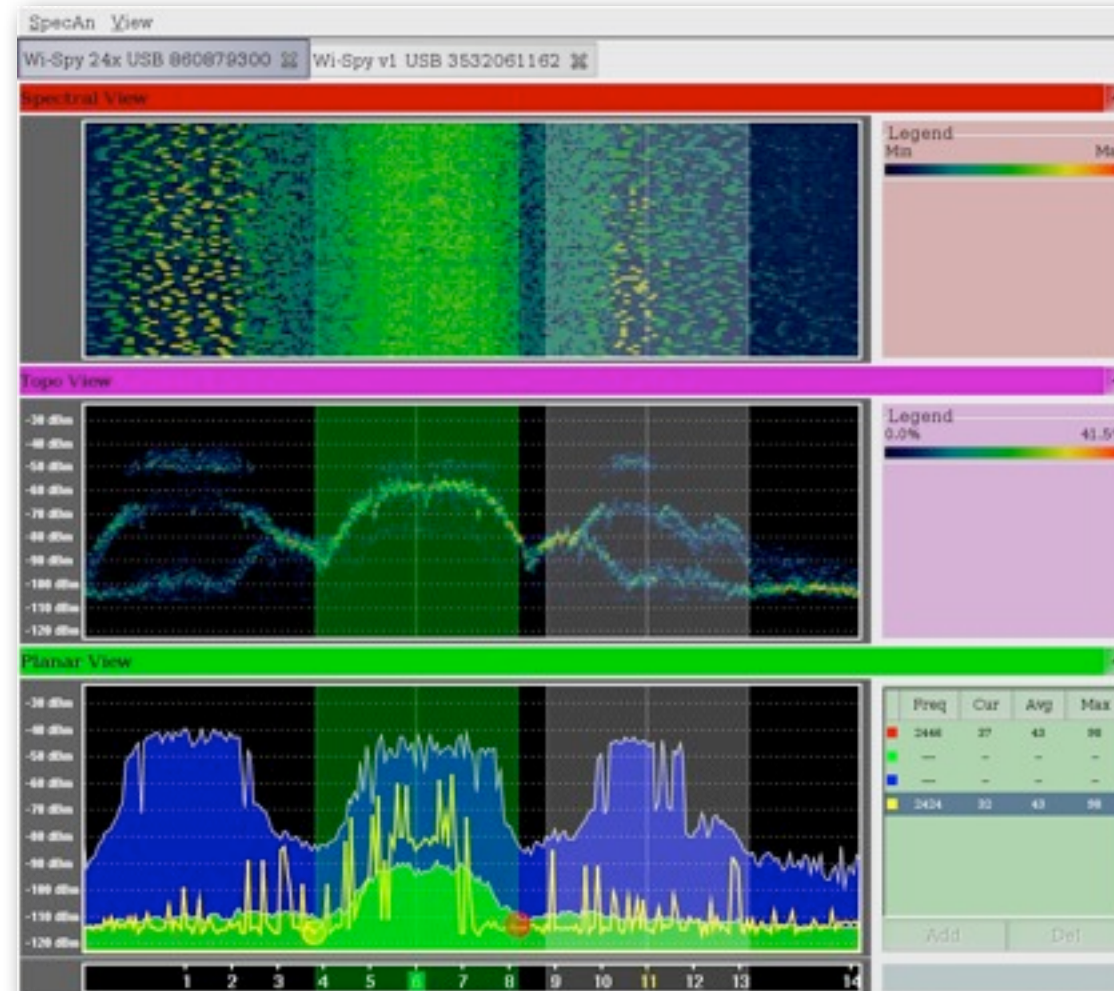

The ideal antenna alignment toolkit consists of a ***signal generator*** and a ***spectrum analyzer***, preferably one of each at both ends of the link.

By attaching a signal generator to one end of the link and a spectrum analyzer to the other, you can observe the received power and watch the effect of moving the antenna to various positions in real time.

Antenna alignment tips

Aligning antennas at very great distances is something of an art. These tips may help reduce the time you will spend getting your antenna alignment "just right".

- Test all equipment ahead of time
- Bring backup voice communications (FRS or ham radio in addition to mobile phones)
- Test the signal in both directions, but only one side at a time
- Don't touch the antenna when taking a reading
- Don't be afraid to push past the best received signal when adjusting the antenna
- The antenna angle may look completely wrong
- Double-check polarization on both ends

Conclusions

- By modifying consumer grade WiFi equipment and fitting it with external antennas, very cost effective long distance and high throughput links can be built in the non-licensed frequency bands.
- These techniques have been demonstrated in deployments in several countries.
- They are particularly useful in sparsely populated areas where interference from other users of the same spectrum is less likely.
    - Low cost commercial equipment that implements TDMA is available from Mikrotik and Ubiquiti.

Thank you for your attention

For more details about the topics presented in this lecture, please see the book ***Wireless Networking in the Developing World***, available as a free download in many languages:

http://wndw.net/