ITU-T Kaleidoscope 2009
Innovations for Digital Inclusion

Reliability and Scalability Analysis of Low Cost Long Distance IP-Based Wireless Networks

D. Trinchero, R. Stefanelli, A. Galardini
iXem Labs – Electronic Department
Politecnico di Torino
info@iXem.polito.it

iXem Labs

1859-2009 150 anni di Cultura Politecnica

POLITECNICO DI TORINO

POLITECNICO DI TORINO

LACE Laboratorio Antenne e Compatibilità Elettromagnetica

iXem Labs

iXem research activities

- wireless networks design and analysis
- wireless sensor networks design
- microwave sensors design
- electromagnetic propagation analysis
- antenna design
- microwave components design
- electromagnetic theory
- electromagnetic compatibility
- electromagnetic interference reduction
- **solutions for digital inclusion**

IEEE 802.11 long distance links

Long distance (low cost) wireless links => MKM

Some authors are presenting this technology
as an **affordable** and **practicable** solution
for the construction of telecommunication infrastructures
in remote and/or harsh locations

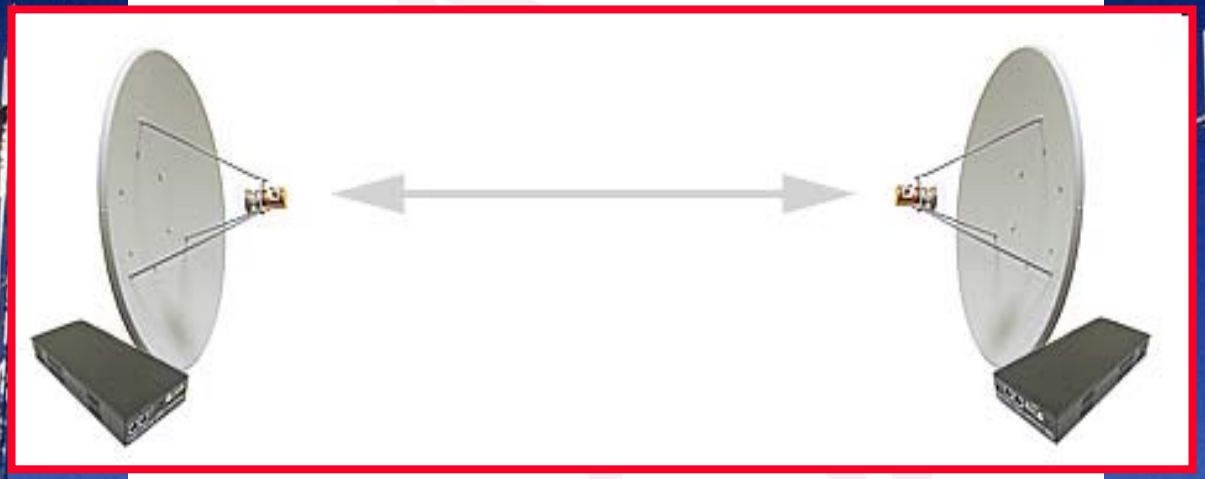
Some other authors are **strongly against** it

Are we allowed to think something in the middle?

Aim of the project

1. ASSEMBLE a real-case experiment
2. DEFINE guidelines and constrains for network design
3. IDENTIFY the most suitable (but also reaistic) hardware and system architecture
4. CONSTRUCT transmitters prototypes
5. TEST solutions to enhance transmission capabilities
6. STUDY physical and mac layer limits
7. EVALUATE long term hardware living capacity
8. TEST hardware strength after exposure to hard environmental and meteorological conditions

Our implementation

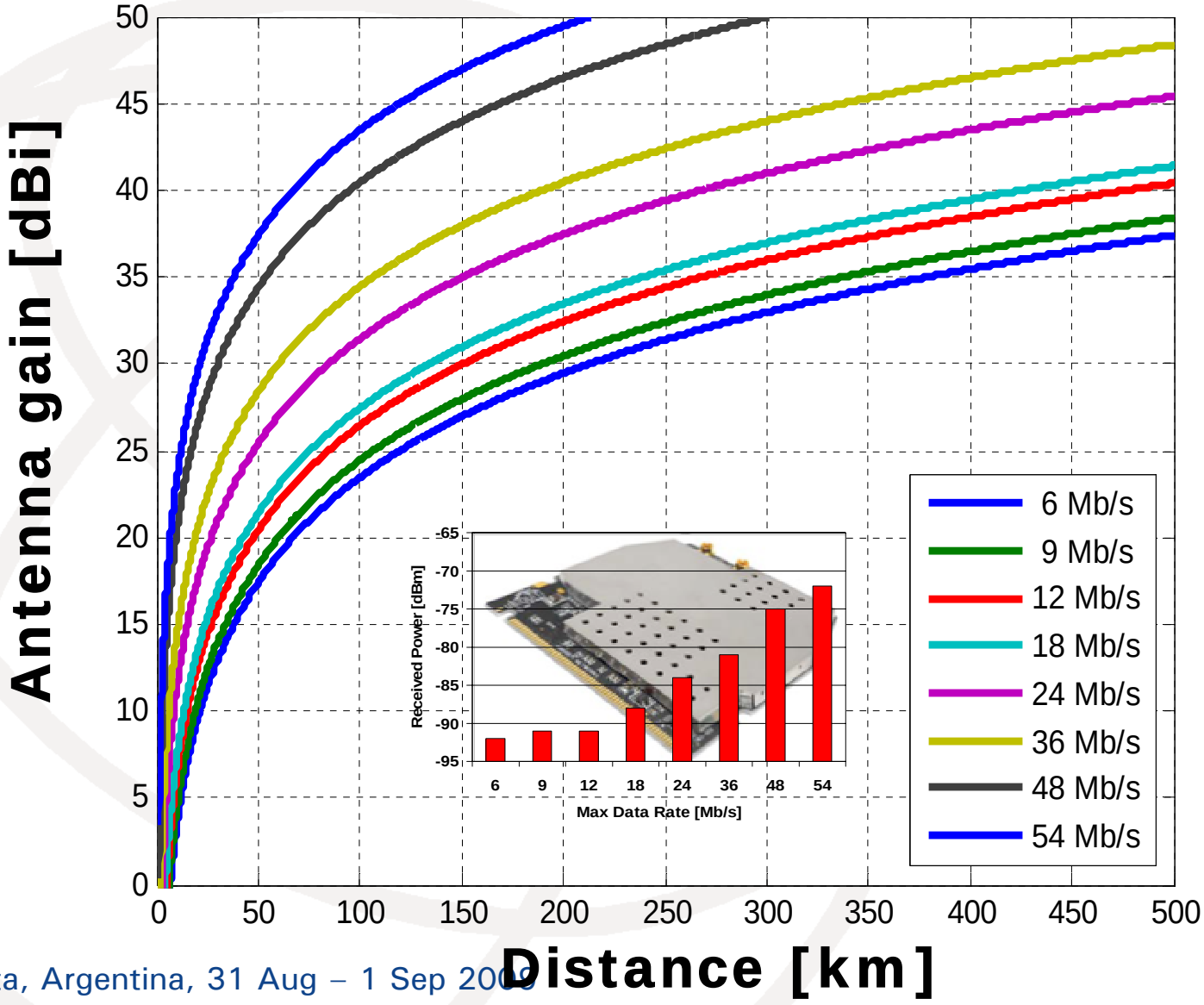


Ip 1: the link is bi-directional
Ip 2: the link makes use of unlicensed frequencies
Ip 3: regulatory EIRP limitation
Ip 4: hardware very cheap

Hardware architecture

1. Large bandwidth → use microwaves
2. EIRP limitation → choose radios with high sensitivity
3. Unlicensed freq → enhance antenna directivity
4. Bidirectional link → multiplex uplink and downlink on the same antenna
5. Bandwidth improvement → multiplex radios on the same antenna

30 dBm EIRP regulatory

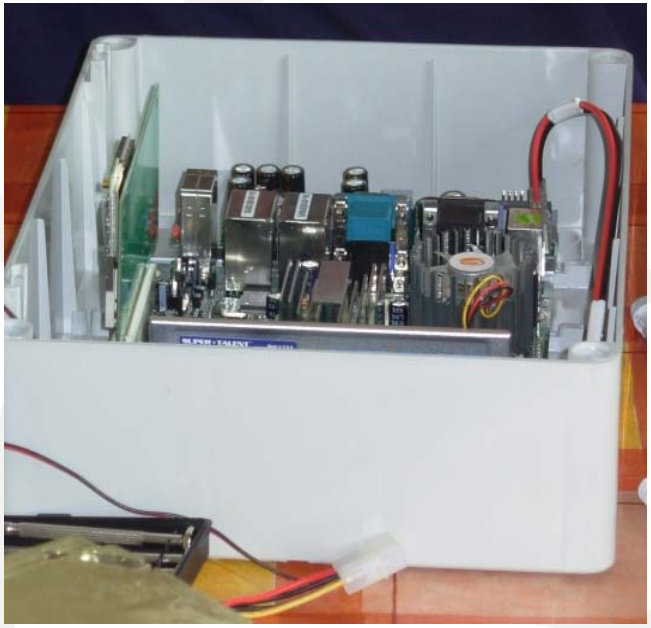


Transmitter prototypes

First objective: VERY LOW COST hardware

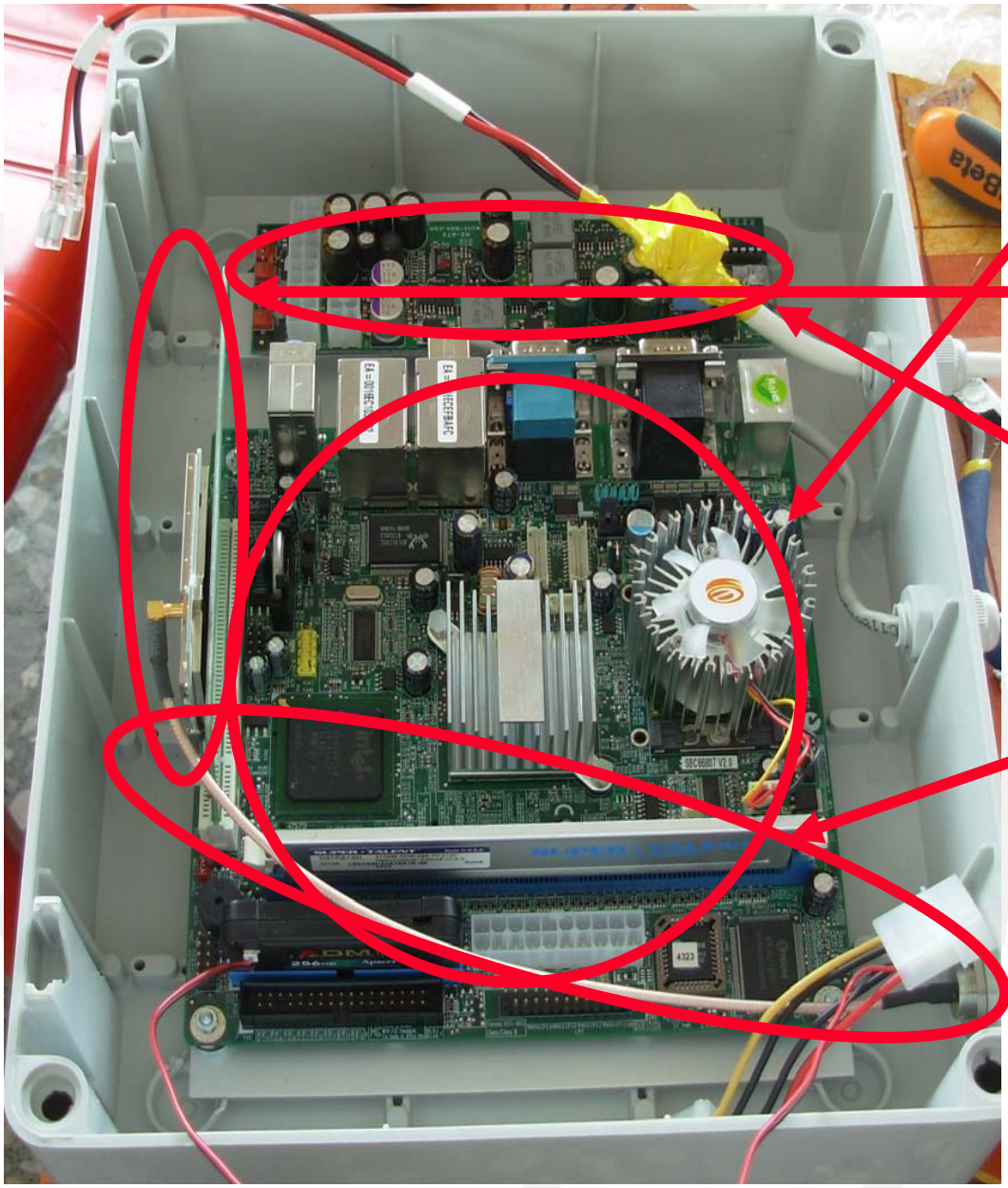
Solution: Use of commercial OFDM-based wireless chipsets combined with a robust MAC layer

How: using open source wireless physical drivers and low-cost PCs or SBCs to control the radio

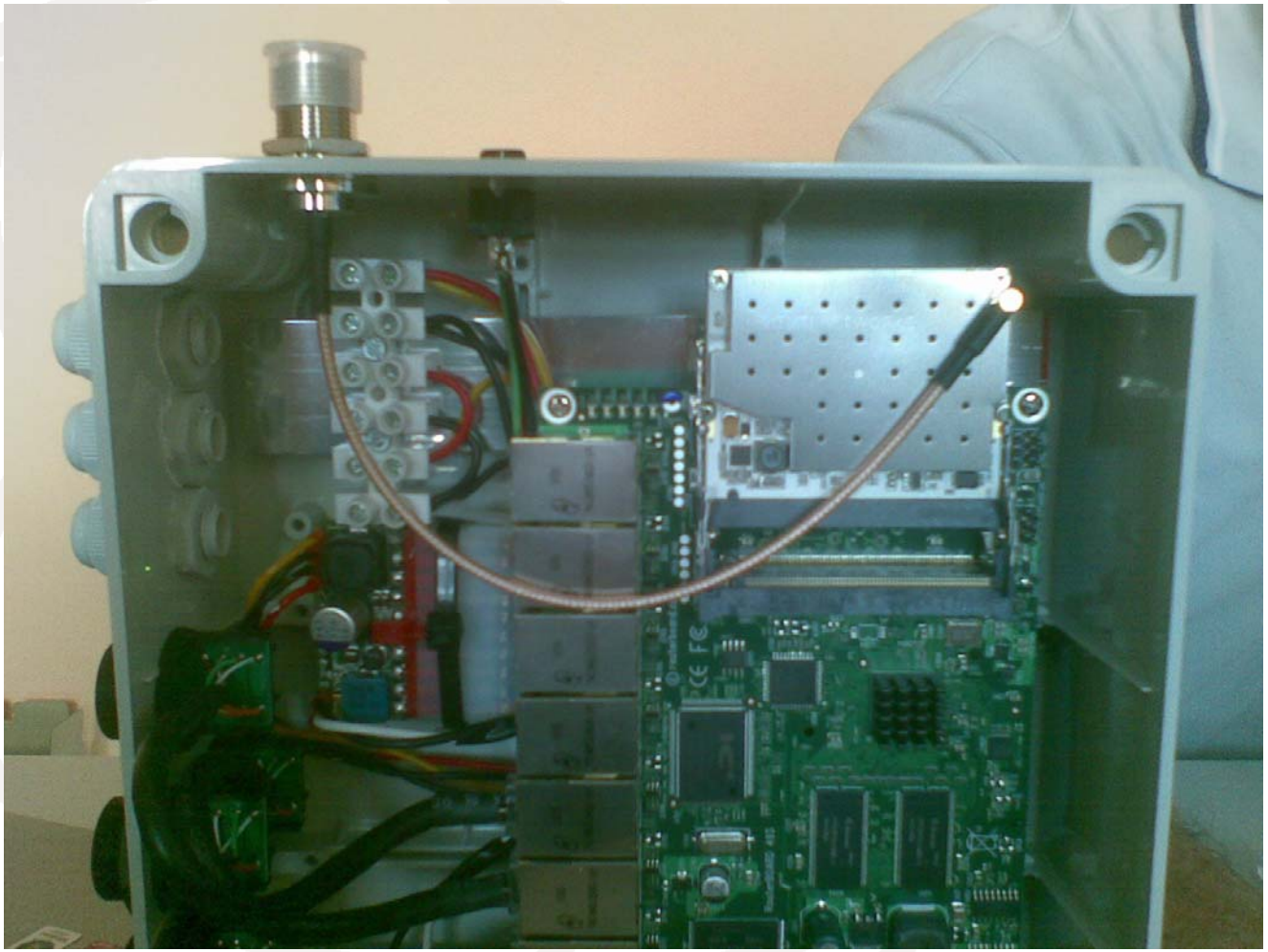


Our choice

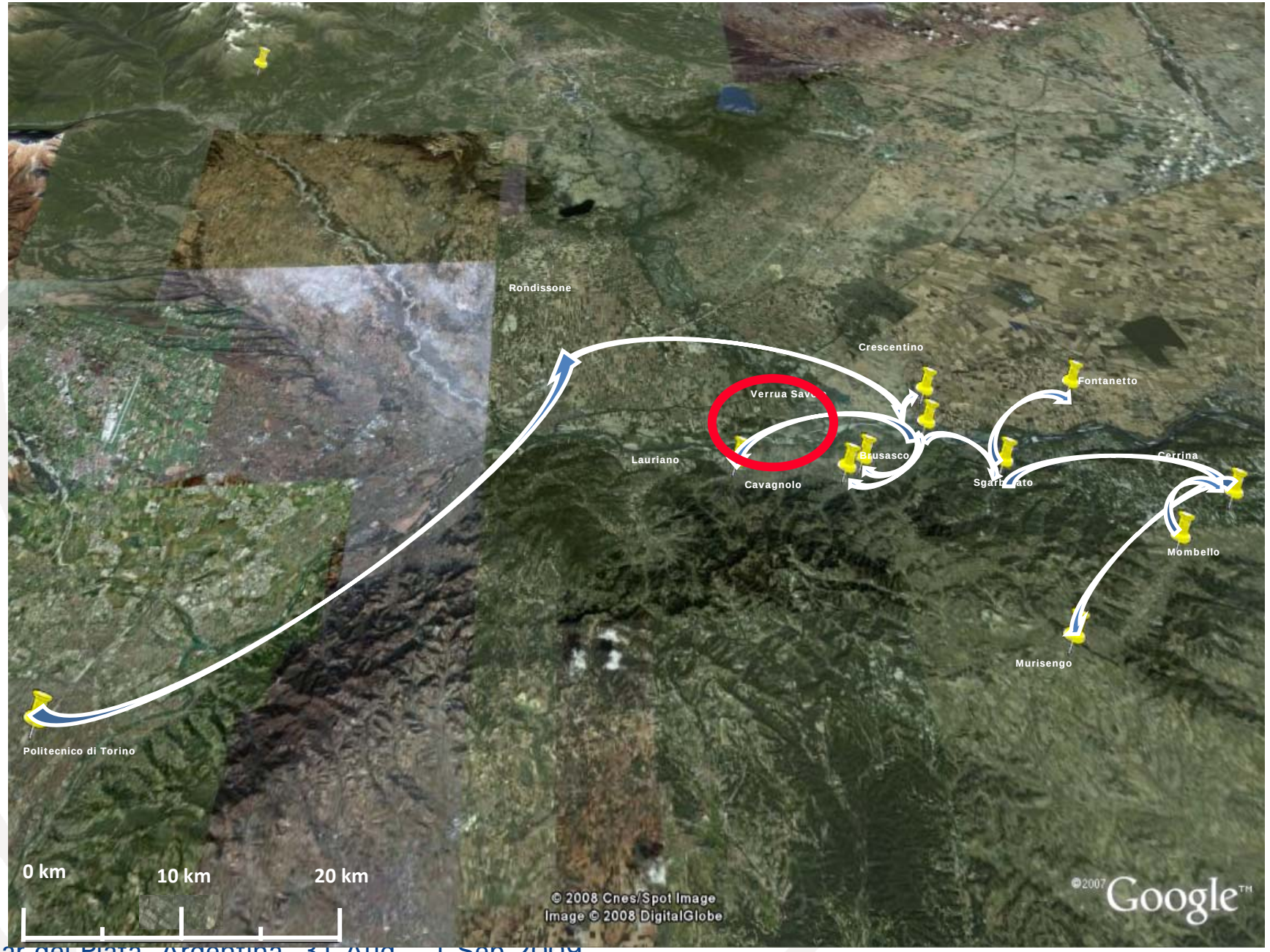
Platform: Commercial PCs LINUX based
Chipset: commercial Atheros chipsets originally born for 802.11x applications
Drivers: either commercial or taken from the open source MadWiFi projects
Frequency Band: Hiperlan (European 5 GHz unlicensed)
Antennas: standard high gain antennas (up to 35 dBi)
Communication protocol: either commercial or derived from 802.11 distributions, with some modifications to support p2p communications
Frequency use: hybrid TDD/FDD scheme
RF components: properly designed
Output: an experimental network to test the identified solution

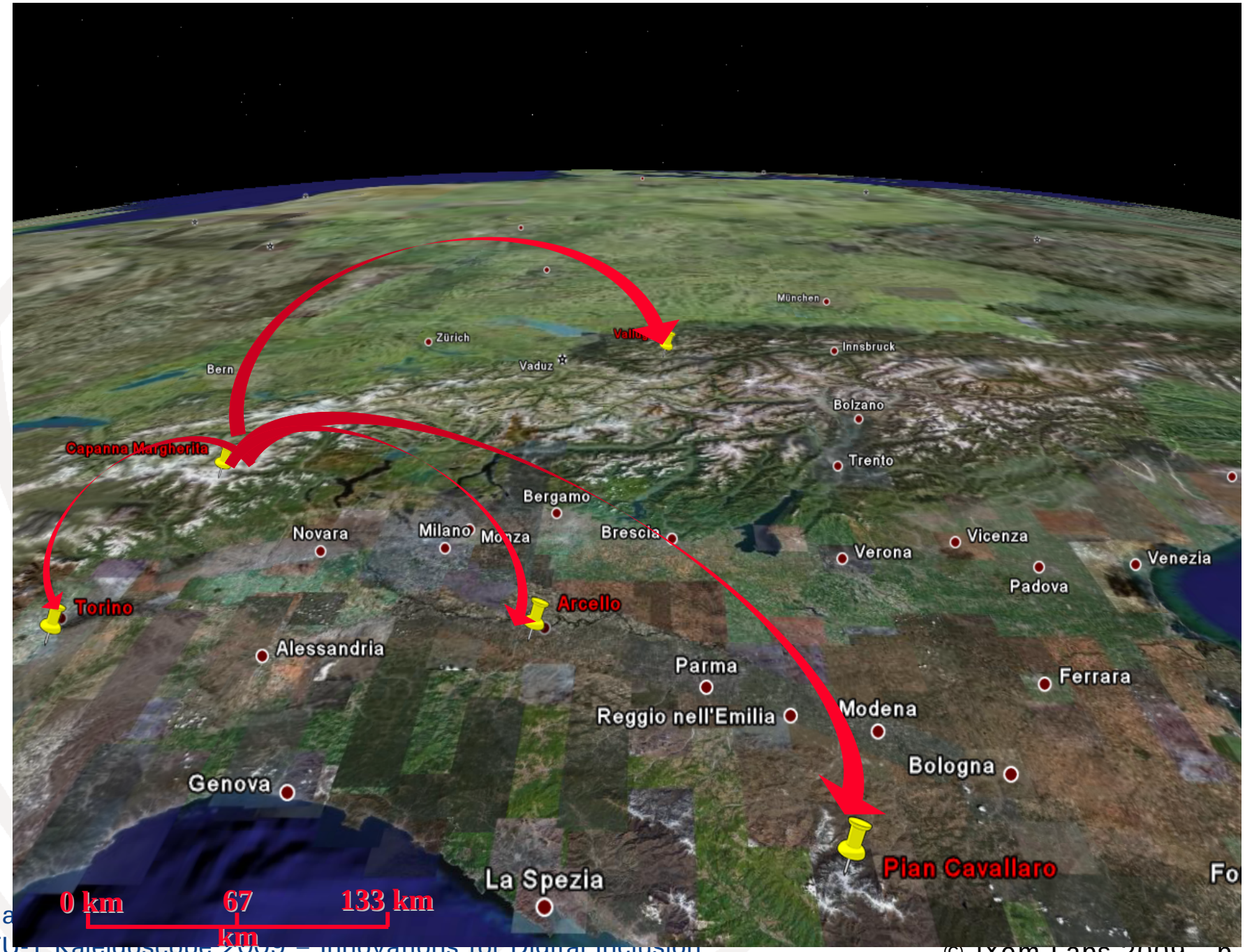


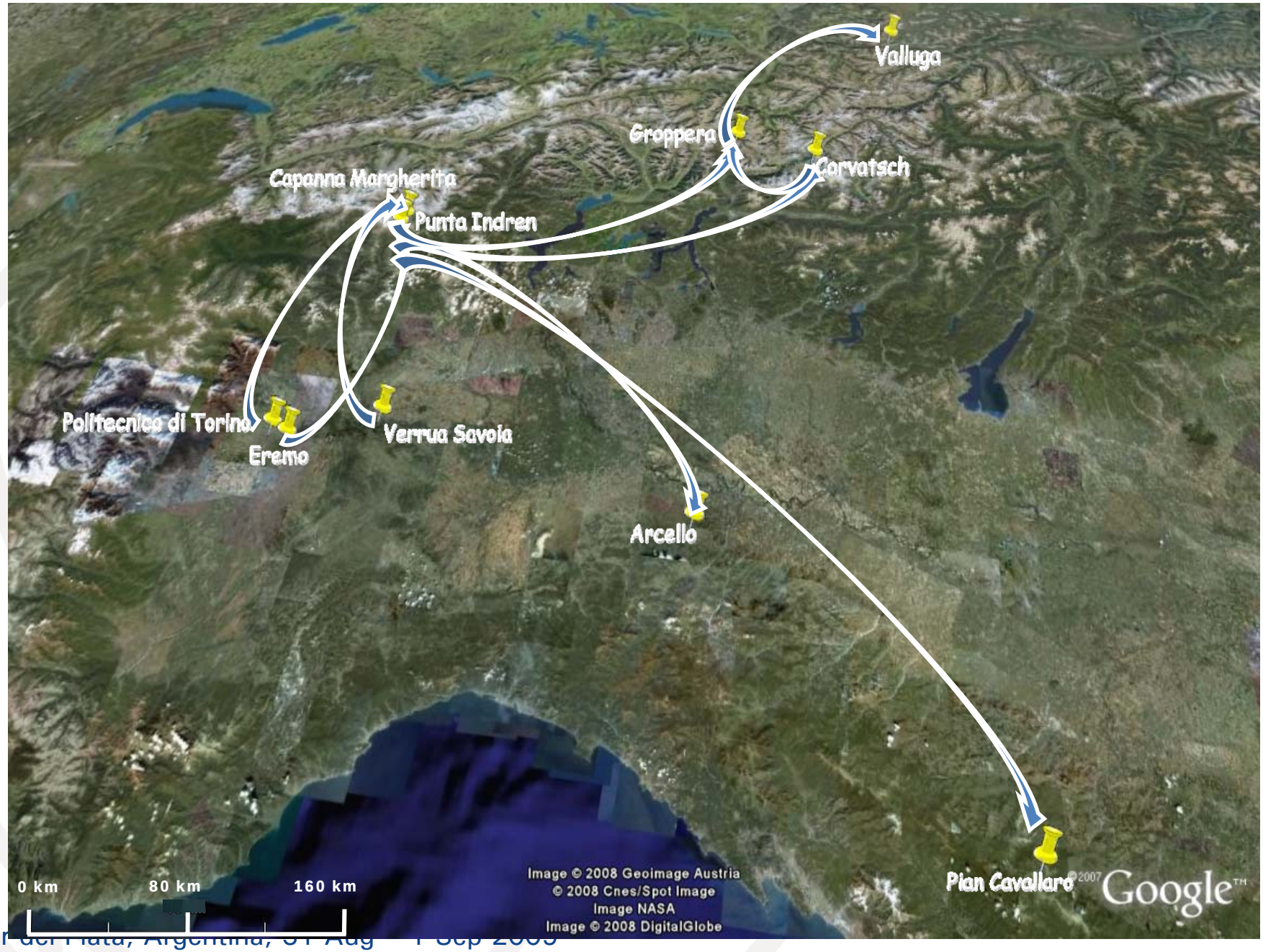
Transmitter prototypes



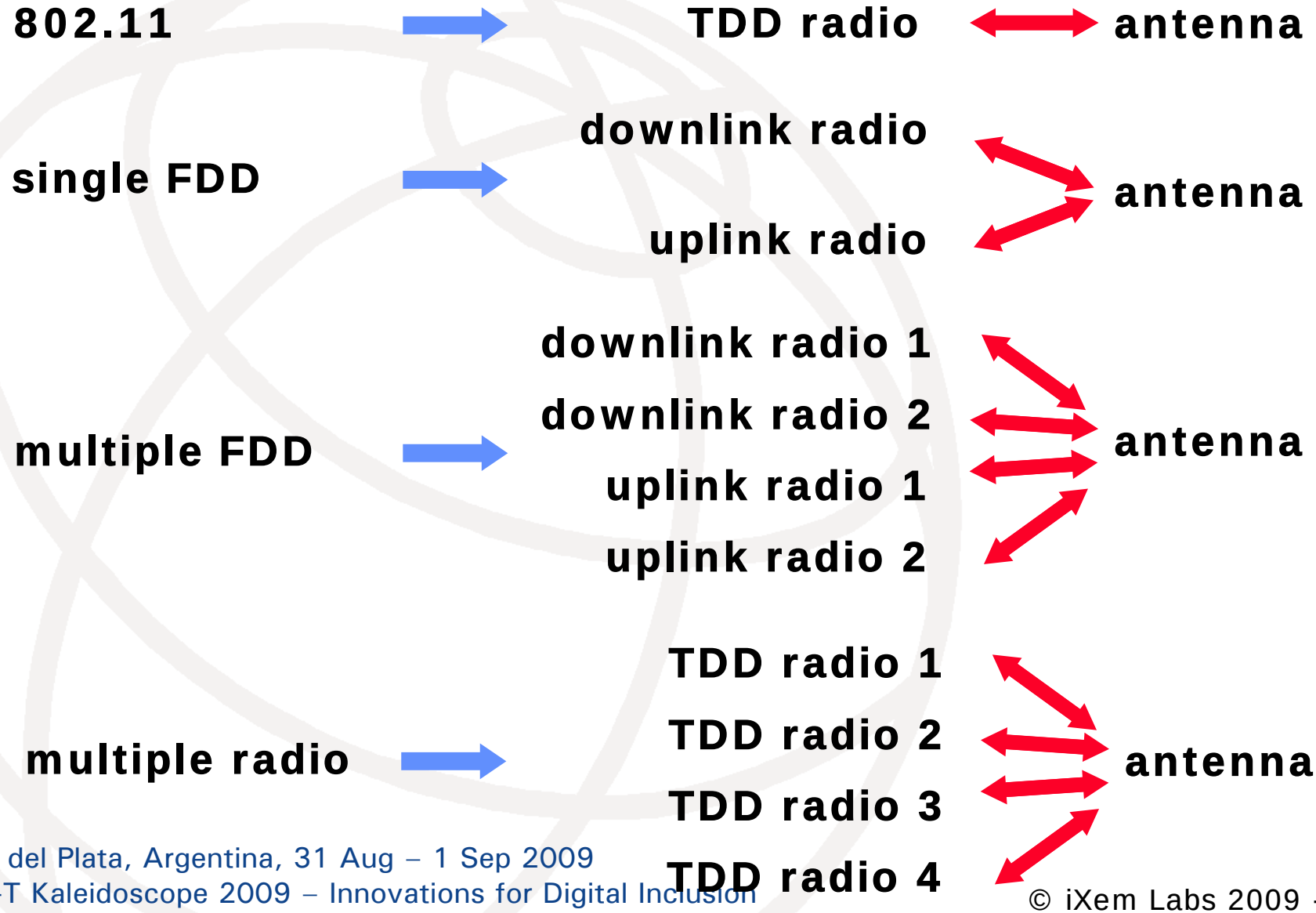
Power supply





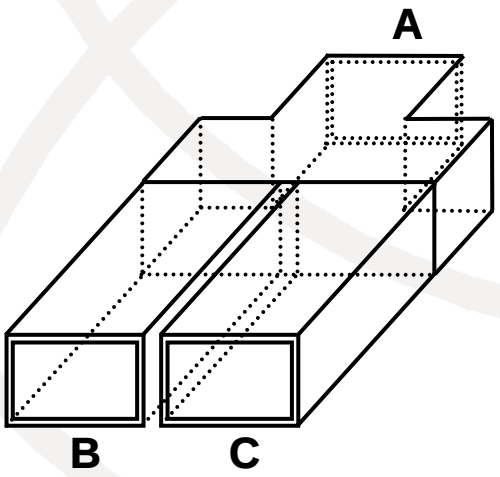


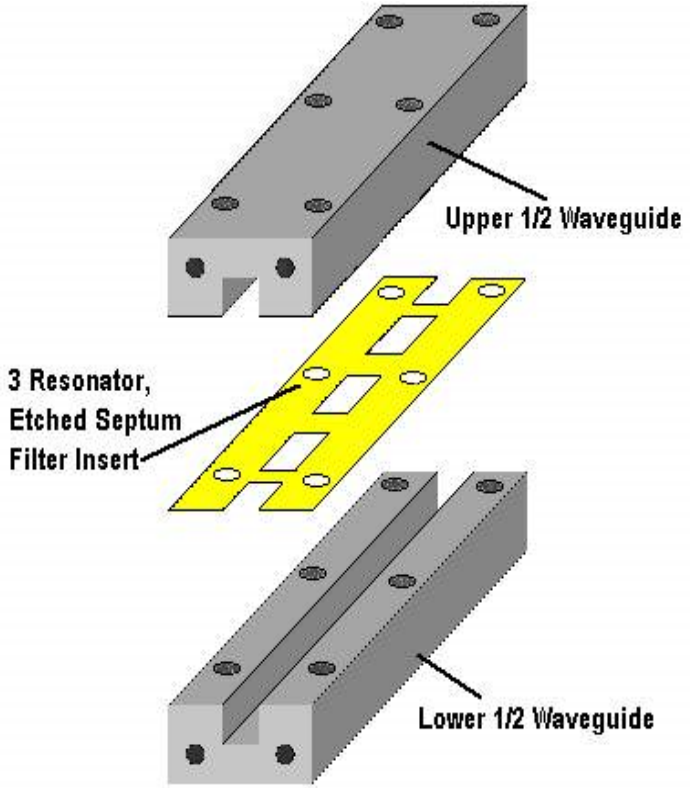
Channel enhancement



Multiplexer realisation

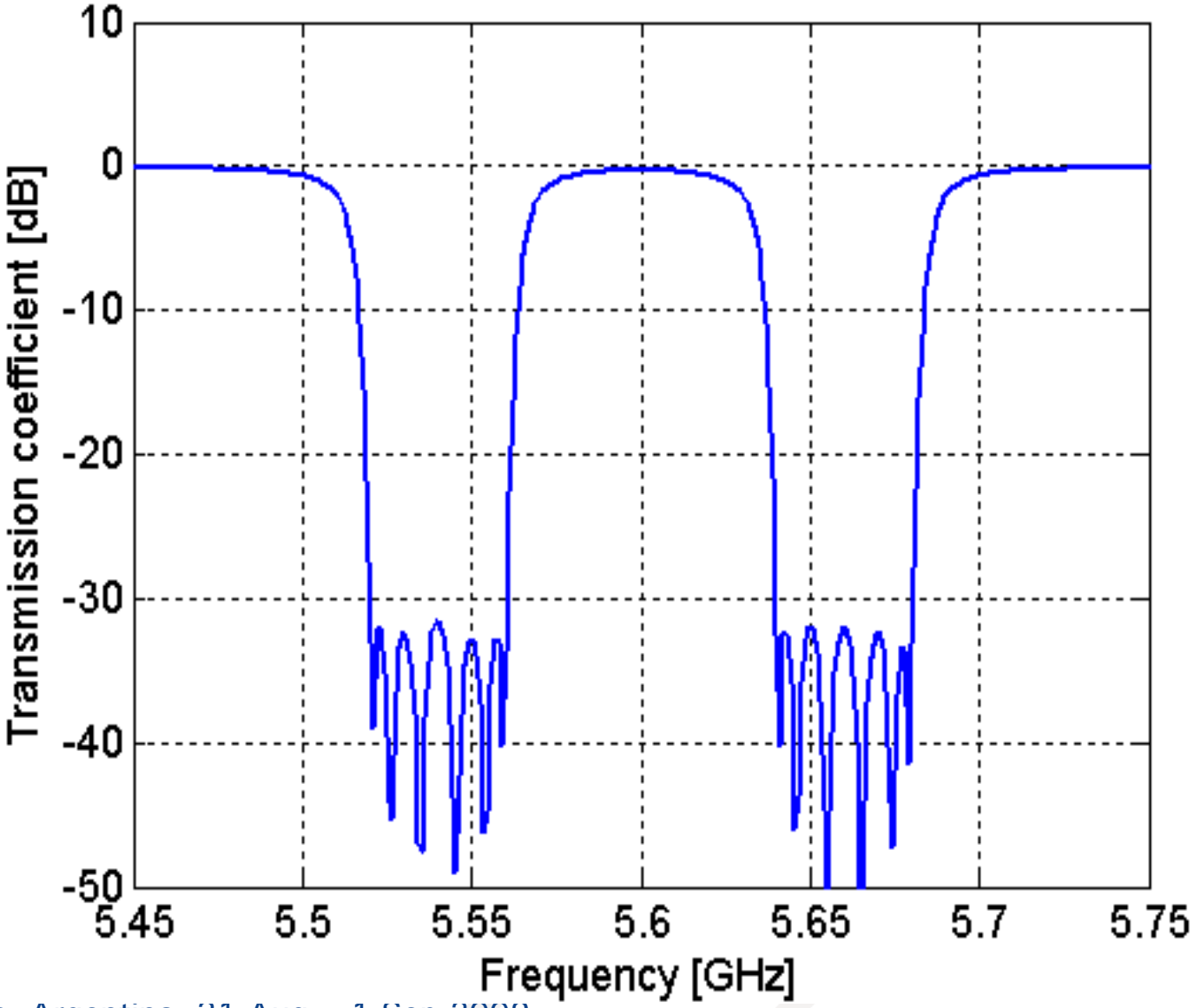
1. SCALABLE configuration
2. ADAPTIVE design (*)



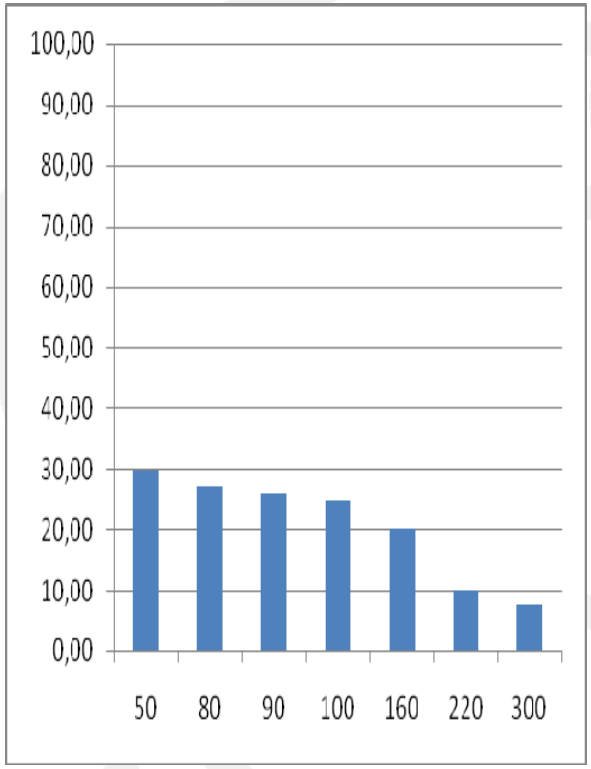


(*) TASCONE R; SAVI P; TRINCHERO D.; ORTA R, Scattering matrix approach for the design of microwave filters, IEEE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES, pp. 423-430, 2000, Vol. 48, ISSN: 0018-9480

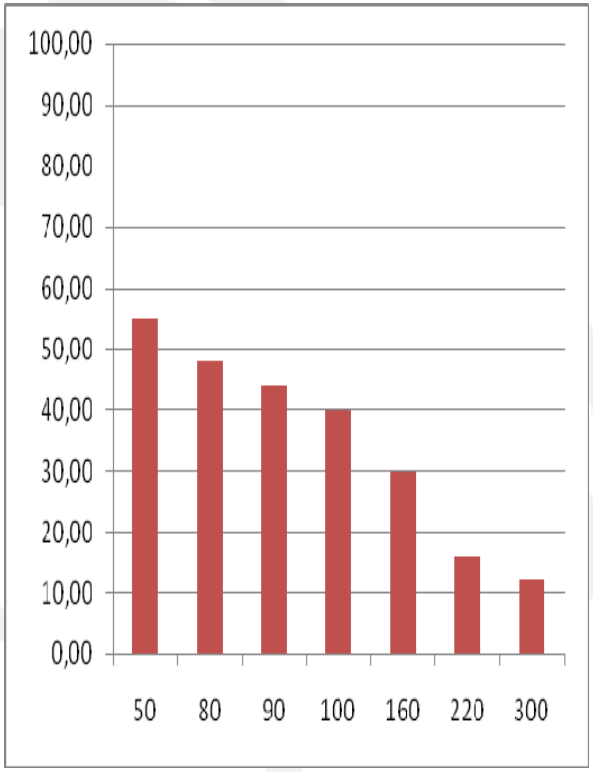
Duplexer in the Hiperlan band



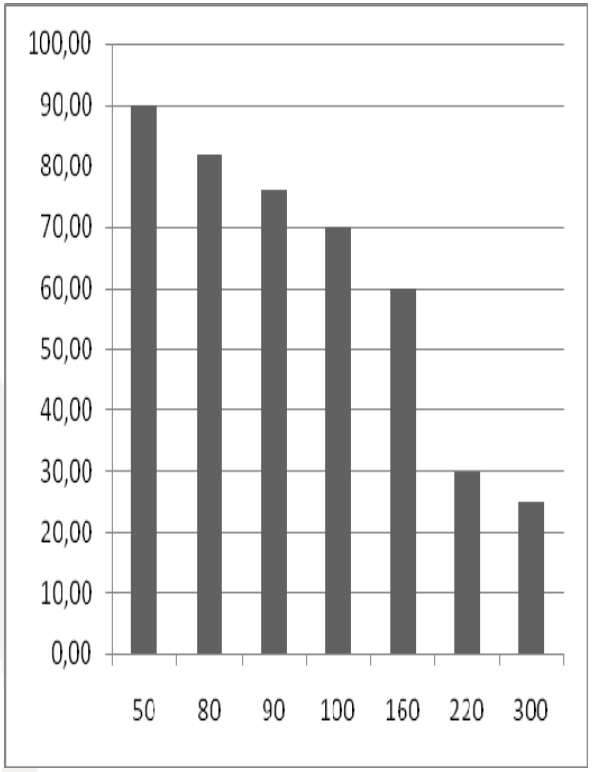
Measured Throughput



Single radio



Two radios



Four radios

Operating problems

1. **lightning**: one transmitter destruction at Capanna Margherita (in the same occasion also the satellite connection was affected in the same way);
2. **ice falls**: solar panels damaged at Capanna Margherita (in the same occasion also the satellite power supply was affected in the same way);
3. **overvoltage damages**: two times (MB and ATX power supply wrecked, no problems for radios), due to failures of the solar panels regulator;
4. **link down-time**: around 0% for links under 100 km, up to 4% increasing the distance to 300 km; the link towards Capanna Margherita, in presence of strong snowstorms, was experimenting extraordinary attenuation;

Operating problems

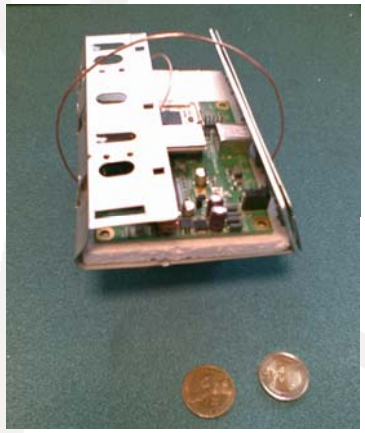
5. **hardware wear**: no appreciable problems for radio cards, new ATX motherboards, automotive ATX power supply; only one SBC failure over twenty boards, after 9 months of usage; one failure over ten recycled motherboards, after 6 months of usage; two failures over ten recycled standard ATX power supply;
6. **strong winds**: no problems, even if some hops (Capanna Margherita) were exposed to winds up to 200 km/h;
7. **extreme temperatures**: destruction of two batteries below -30° Celsius (after we started isolating them)

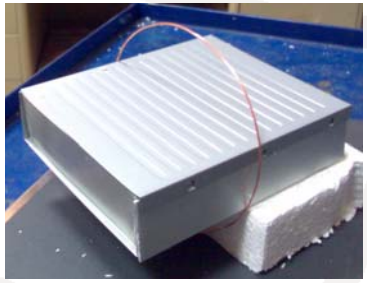
Conclusions

1. MKM networks **can be reliable** as a **first step** in the implementation of communication infrastructures in developing regions.
2. MKM networks can be **easily installed**, they do **not need high expertise**, can be efficient for **basic service provisioning**, they can be **simply scaled up**.
3. We must **keep in mind** that transmission capacity and long term duration are **not comparable** with more developed, transmission systems.
4. Thanks to their low costs, MKM networks can be implemented for the construction of simple backhaul networks, for essential services like telemedicine and distance learning applications, or to start the digital inclusion process.

The Amazonian Region of Puero Francisco de Orellana

Wireless (Sensor) Networks



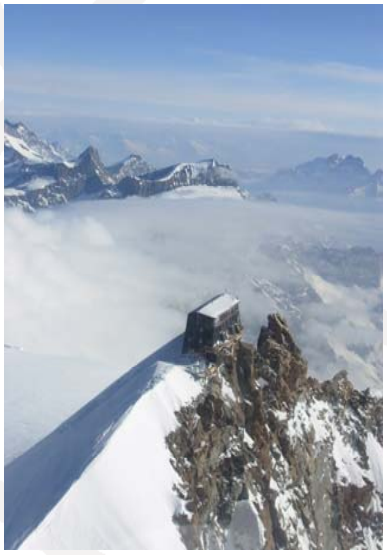


iXem Labs

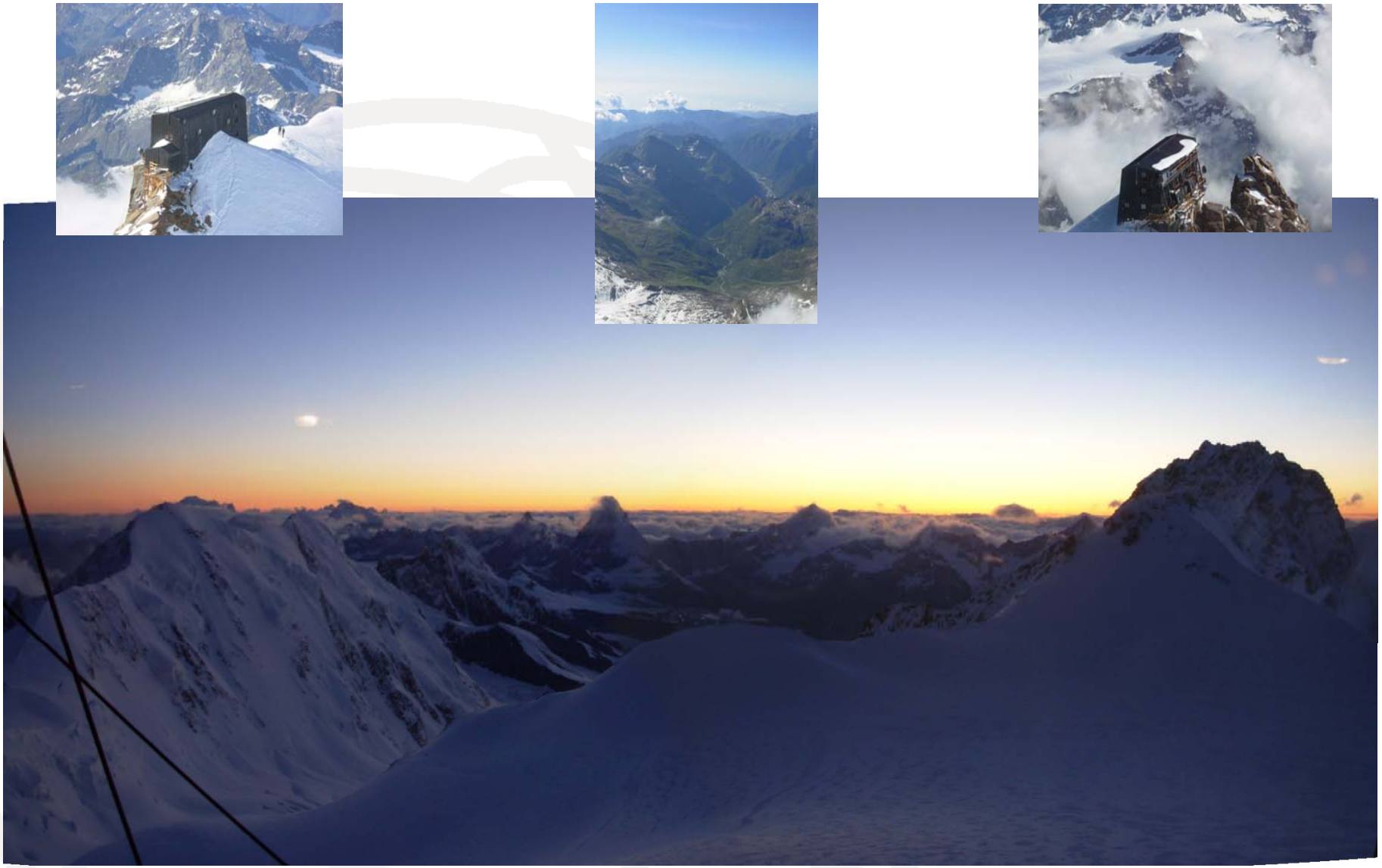
LACE
Laboratorio Antenne e Compatibilità Elettromagnetica

iXem Mission

Where you can't imagine to place an antenna, we (try to) DO



http://www.iXem.polito.it/



MultiKiloMetric Wireless Links

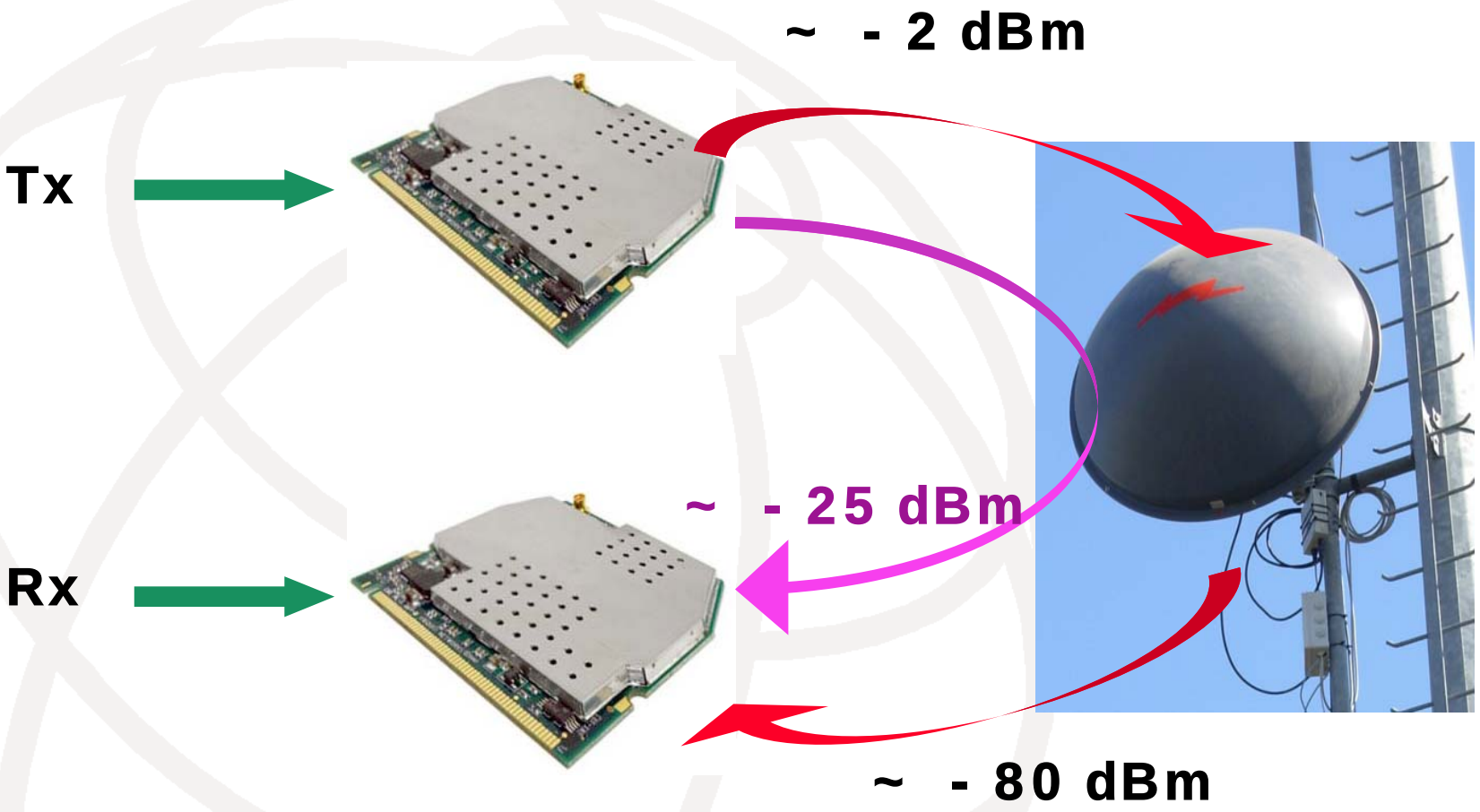
Long distance (low cost) wireless links

Some authors are presenting this technology as an affordable and practicable solution for the construction of telecommunication infrastructures in remote and/or harsh locations

MKM link: a point to point bidirectional radio connection ranging from 50 km to 300 km, normally working on unlicensed frequency bands

MKM network: a wireless network based on a whole of master stations interconnected by means of MKM links

Channel enhancement: multiplexing



Duplexer in the Hiperlan band