IOT APPLICATIONS FOR DEVELOPMENT

Daniele Trinchero

POLITECNICO DI TORINO 1859 1906

iXem Labs foundation

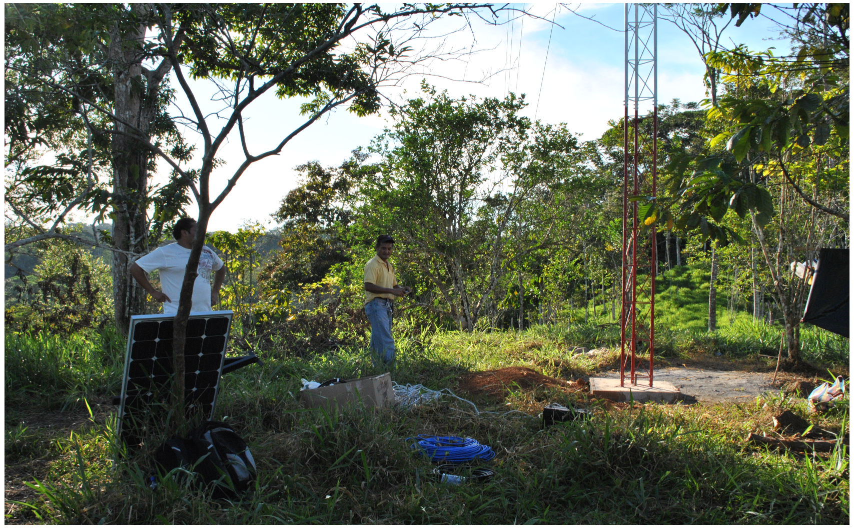
IoT and Agriculture

2007

Long-haul Wireless

2008

Puerto Francisco de Orellana



2012

Comoros Islands

2014


Home
Associazione
Network
Social
Contatti
SENZA FILI SENZA CONFINI
Liberi • di • Comunicare
You Tube
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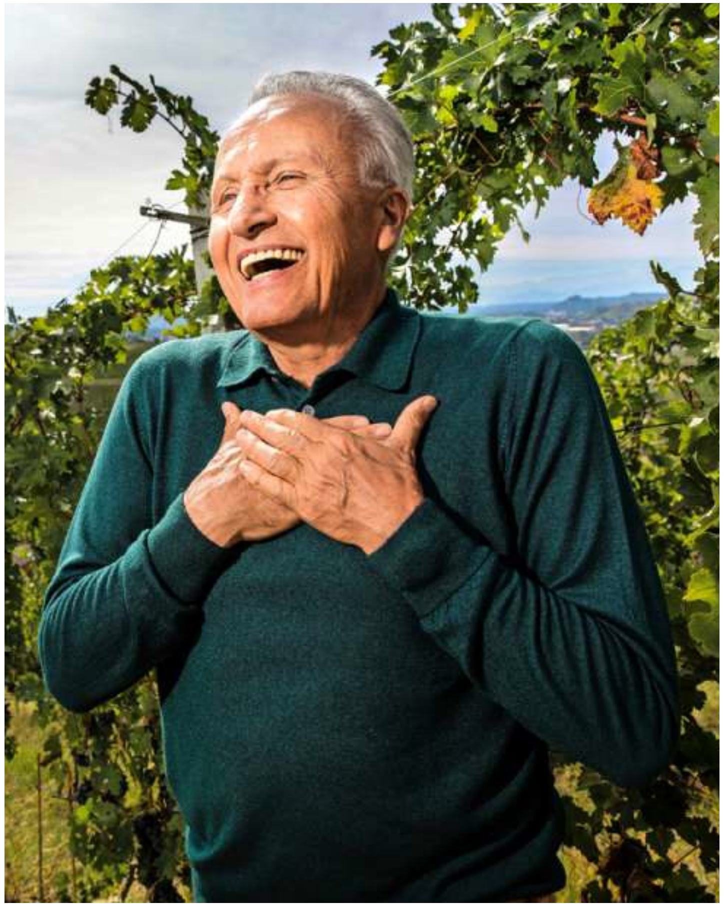
iXem Labs



iXem Labs

Intelligent agriculture

- E-agriculture → Electronic
- I-agriculture → Intelligent
- P-agriculture → Precision
- E-agriculture → Enhanced

Everything means IoT

Instrumented

Interconnected

Intelligent

Smart traffic systems
Intelligent oil fields
Smart food systems
Smart healthcare
Smart energy grids
Smart retail

Smart water management
Smart supply chains
Smart countries
Smart weather
Smart regions
Smart cities

What is E-agriculture?

- technical hardware and technological tools

1/2

- information dissemination, access and exchange, communication and participation processes improvements around rural development

1/2

Developed vs Developing

- Information is Remote Monitoring, Permanent Control, Extended Security

- Information is Access to Knowledge, Emancipation, Vicinity to Markets, Improved Competitiveness

Tools are different?

- Scopes might be COMPLEMENTARY

- Overall scope is COMMON:
  - extend competitiveness
  - improve quality
  - enhance (at least, maintain) sustainability
  - avoid emigration

Data collection + monitoring and evaluation (M&E)

Factors

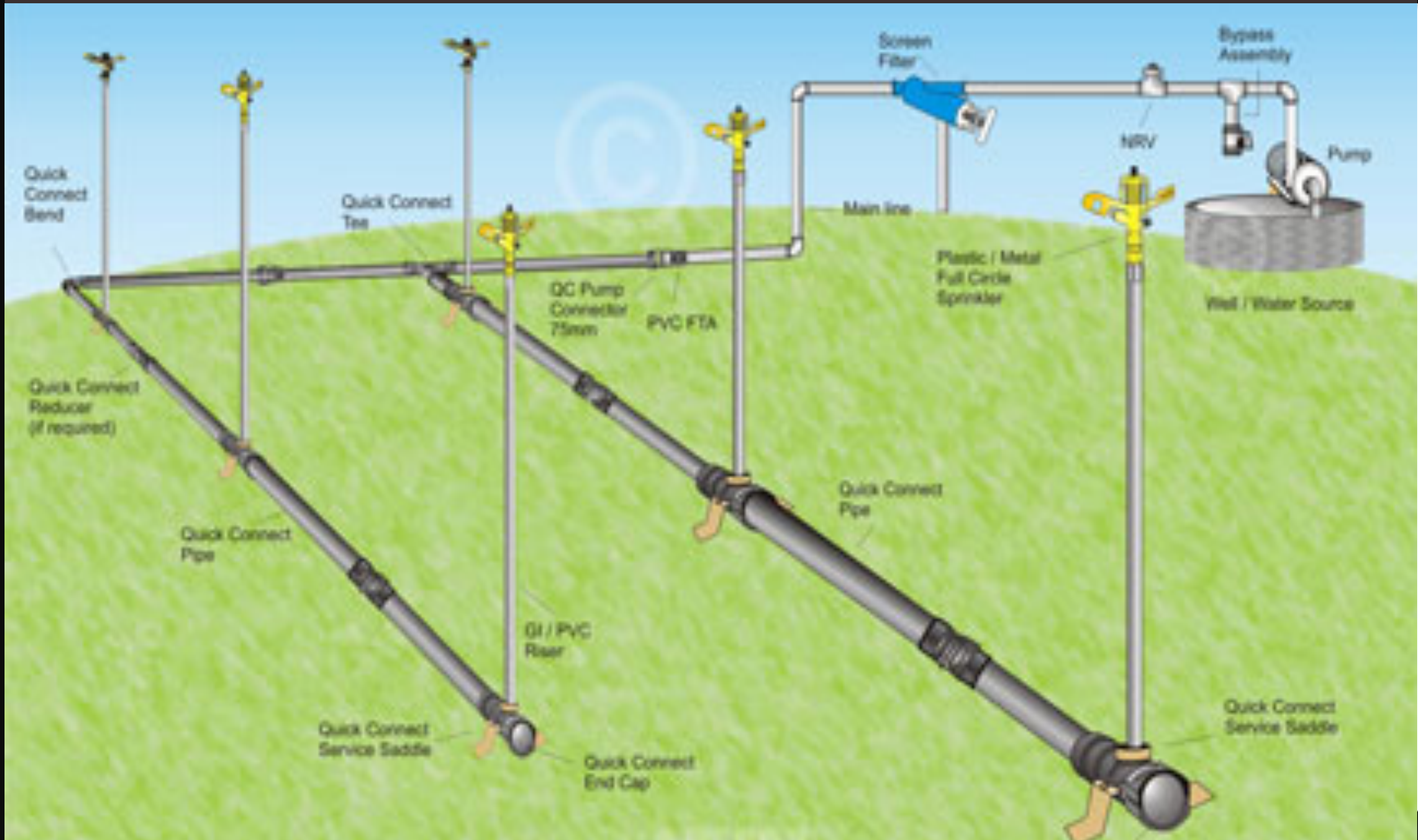
- Technology itself is not sufficient, a well trained team is also required
- Complex ICT or complex platforms are not necessarily essential
- Contextual factors
- Data integrity and security

Tech-transfer

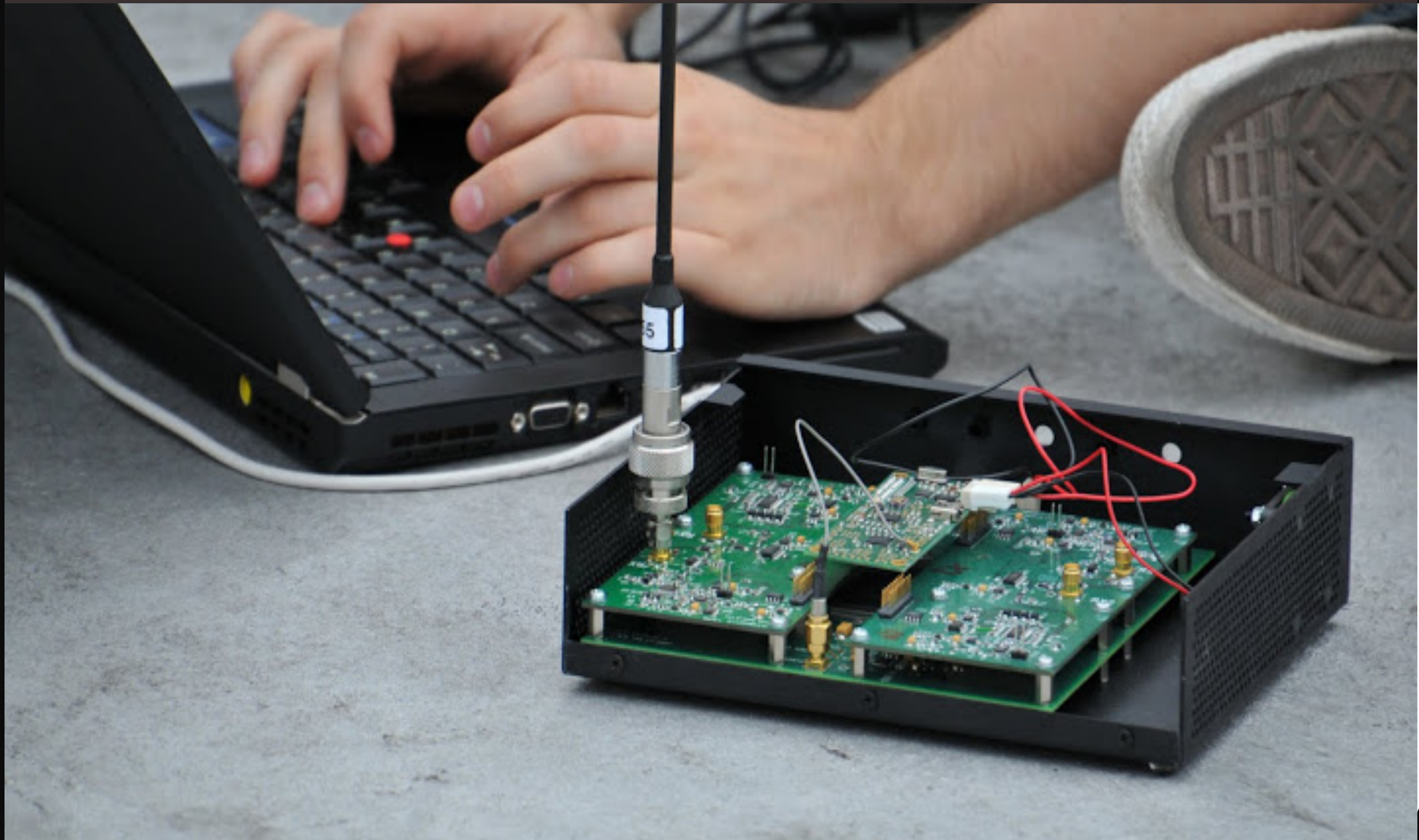
High speed Internet

- More opportunities
- Minimization of distance
- Easy farming
- Better marketing
- Frequent Weather Forecast updates
- State of the art knowledge
- Technical consultancy

Sprinkler Systems



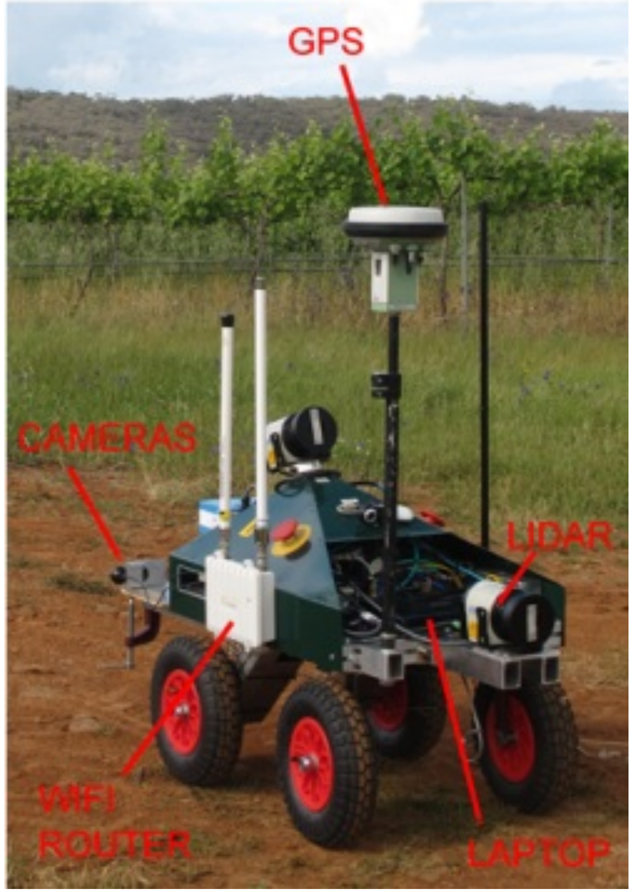
ICTs and small farmers

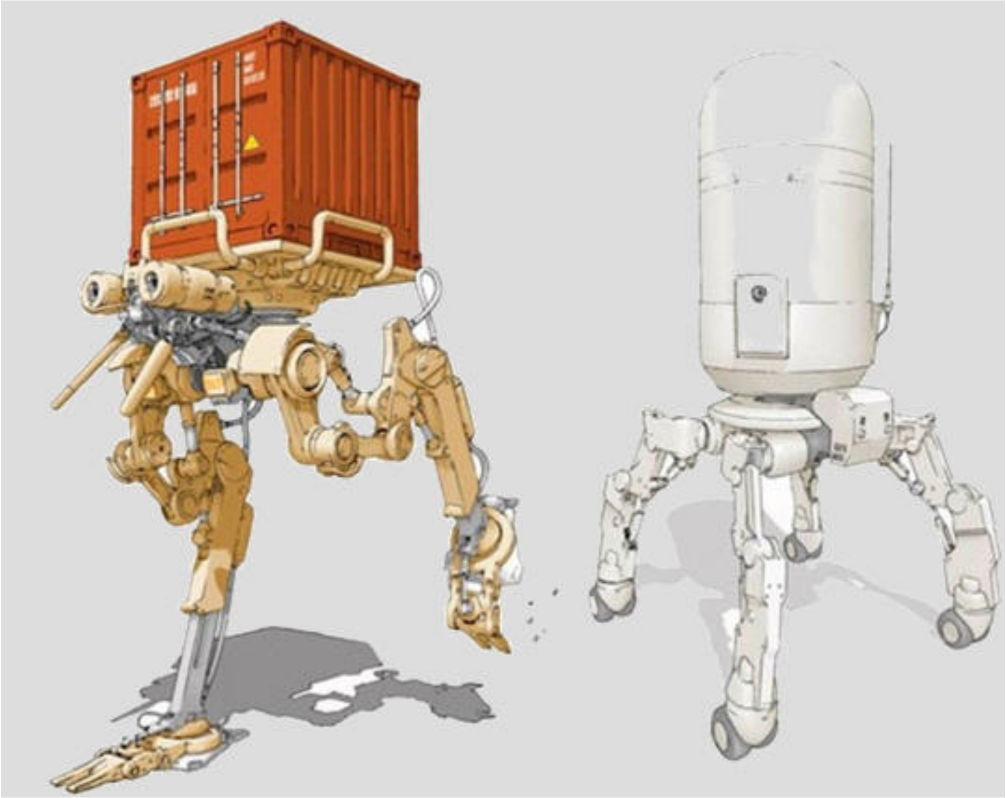


Do it Yourself?

- *Ex: Heimerl and Brewer*
- *Essentially an outdoor PC with a software-defined radio that implements a low-power low-capacity GSM base station.*
- *Long-distance WiFi provides 'backhaul' into the carrier*

Vehicle automation





Vehicle automation

- Security
- Safety
- Quantity
- Efficiency
- Punctuality
- Quality

Vehicle automation

Monitoring → Sensing

- Quality
- Consultancy
- Efficiency
- Tech-Transfer
- Networking
- Visibility

Assisted Agriculture

- Maintaining historical traditions against the global climate change
- Using mainly autochthone plants
- Improving efficiency
- Extending security
- Optmizing costs
- Fighting new diseases
- Reducing chemicals (pesticides, fertilizers)

IMPROVING SUSTANINABILITY

Agronomical techniques

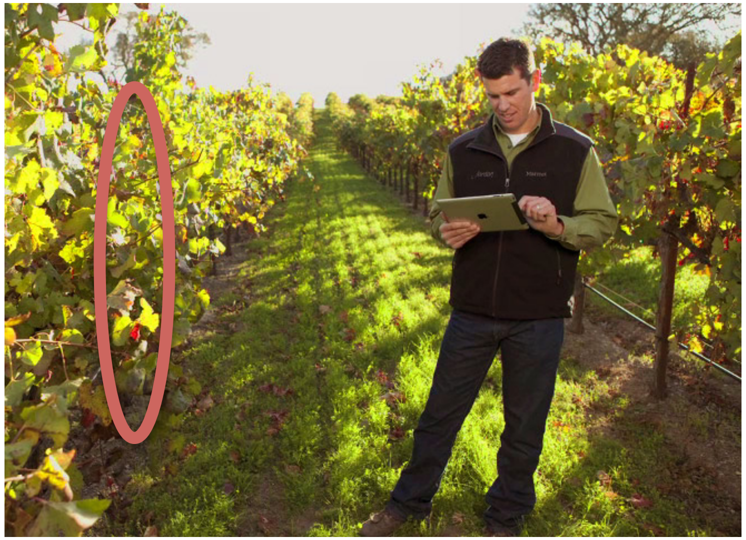
- Systemic Treatment
  - periodic undifferentiated attack

Agronomical techniques

- Natural Agriculture

Agronomical techniques

- Monitoring, observation



untreated testimonials

Treatments reduction

- Observation → measurable
- Capillary observation → significant

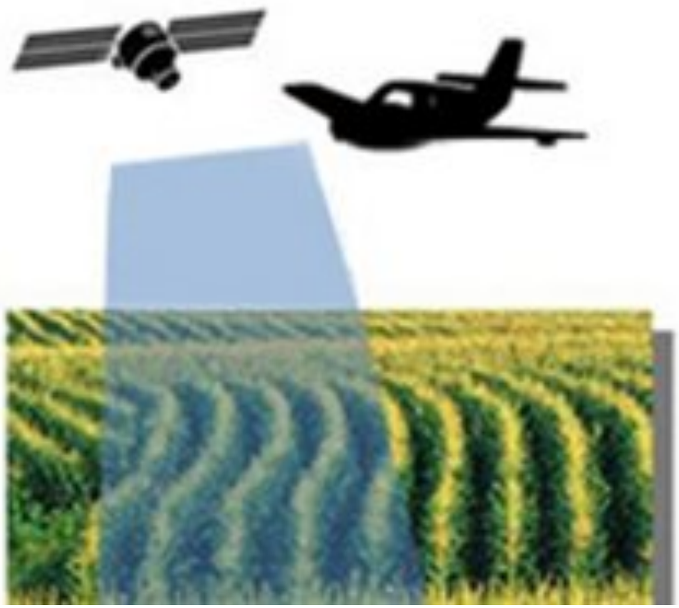
↓

- Exponential growth of costs

↓

- Assisted remote monitoring

Internet assisted Agriculture



Counter

- Infrastructural limits
  - Broadband availability in the countryside
  - Broadband availability among the crops
- Budget limits
  - Farmers capability to afford investments
  - Dense/uniform applicability
- Cultural limits
  - Farmers interest in technology
  - Farmers trusting of technology

Before …

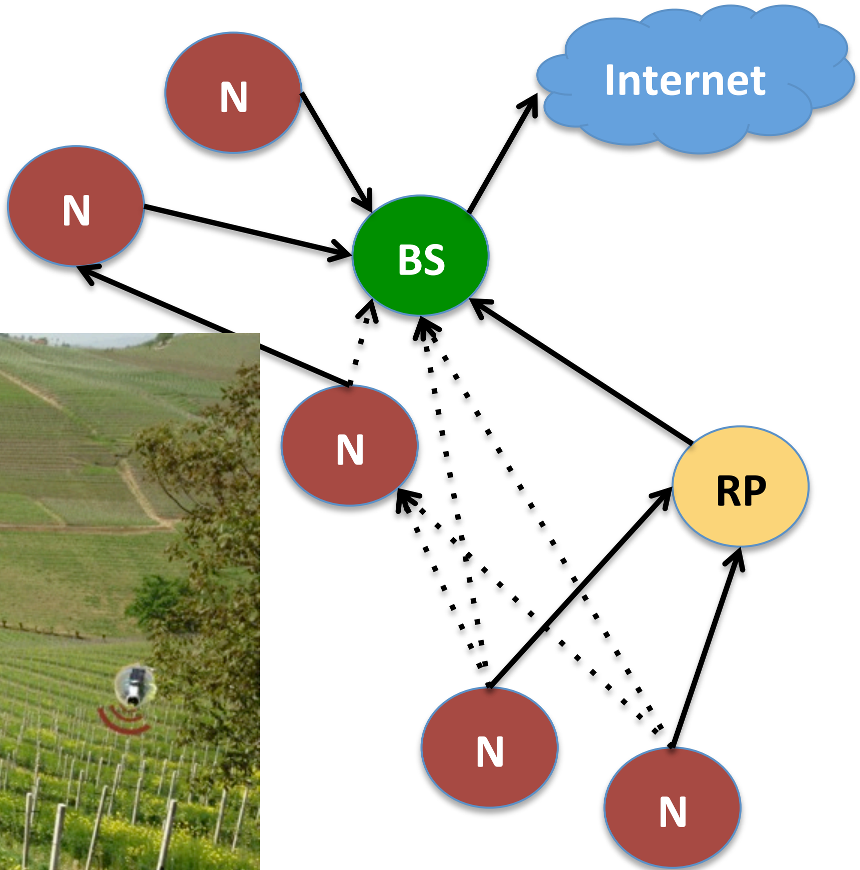
then ... iXemCam

Application Field

Field of application

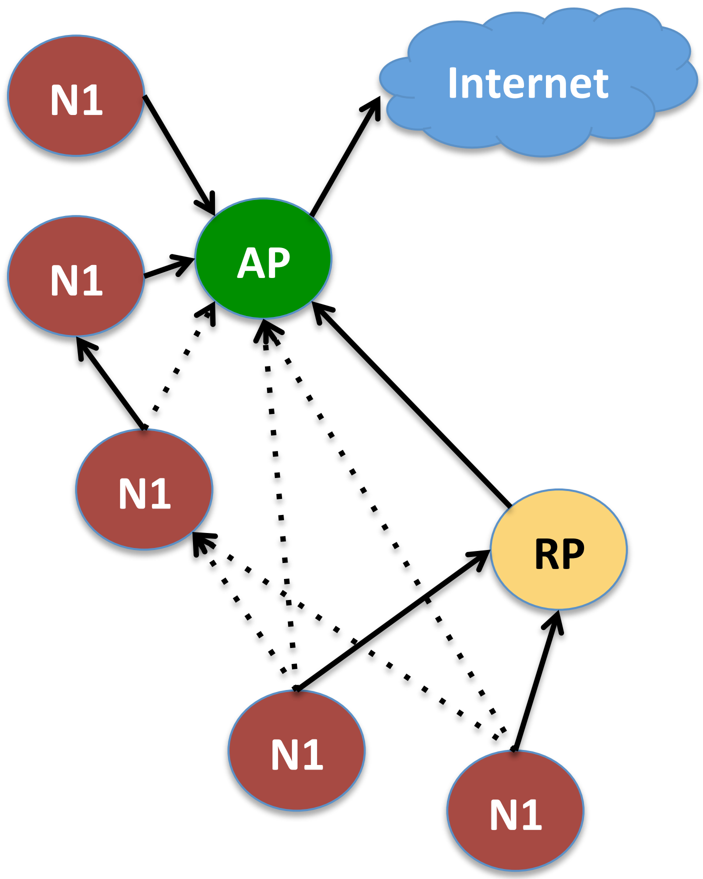
Application Field

iXemCam: level 1

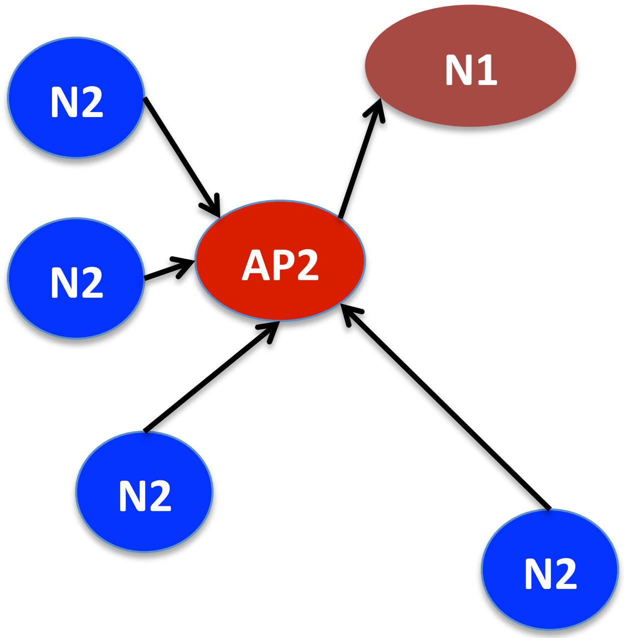


Network level 1: multi-hop

- Access Points
  - Gateway
  - always on (solar powered)
  - 3G or LAN interface (solar powered)
  - Omni (or sector)
- Nodes
  - almost LOS
  - almost always on (solar powered)
  - Yagi or Omni
  - can act as forwarders
  - **images**
- Repeaters (when and if needed)
  - LOS
  - always on (solar powered)
  - improved data rate
  - 1 Yagi+1 omni

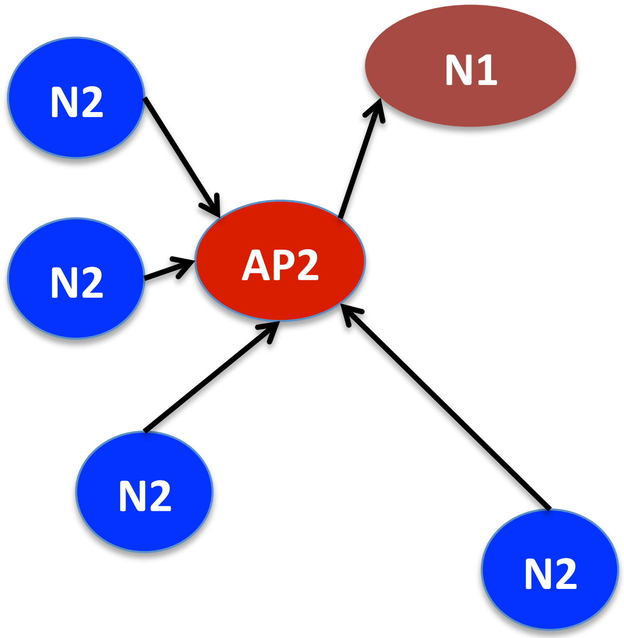


iXemCam: level 2



Network level 2: single-hop

- Access Point
  - Gateway to Node N1
  - Takes power from N1
  - Omni
- Nodes
  - NLOS
  - battery powered
  - Omni
  - no forwarding functions
  - **any physical parameter**



Towards distributed sensors

UV radiation

visible radiation

plant humidity

leaves wetness

ground humidity

temperature

iXemCam

- Physical parameters: up to 16
  - temperature
  - Humidity
  - leaves wetness
  - radiation
  - terrain humidity
  - …
  - **high definition images**

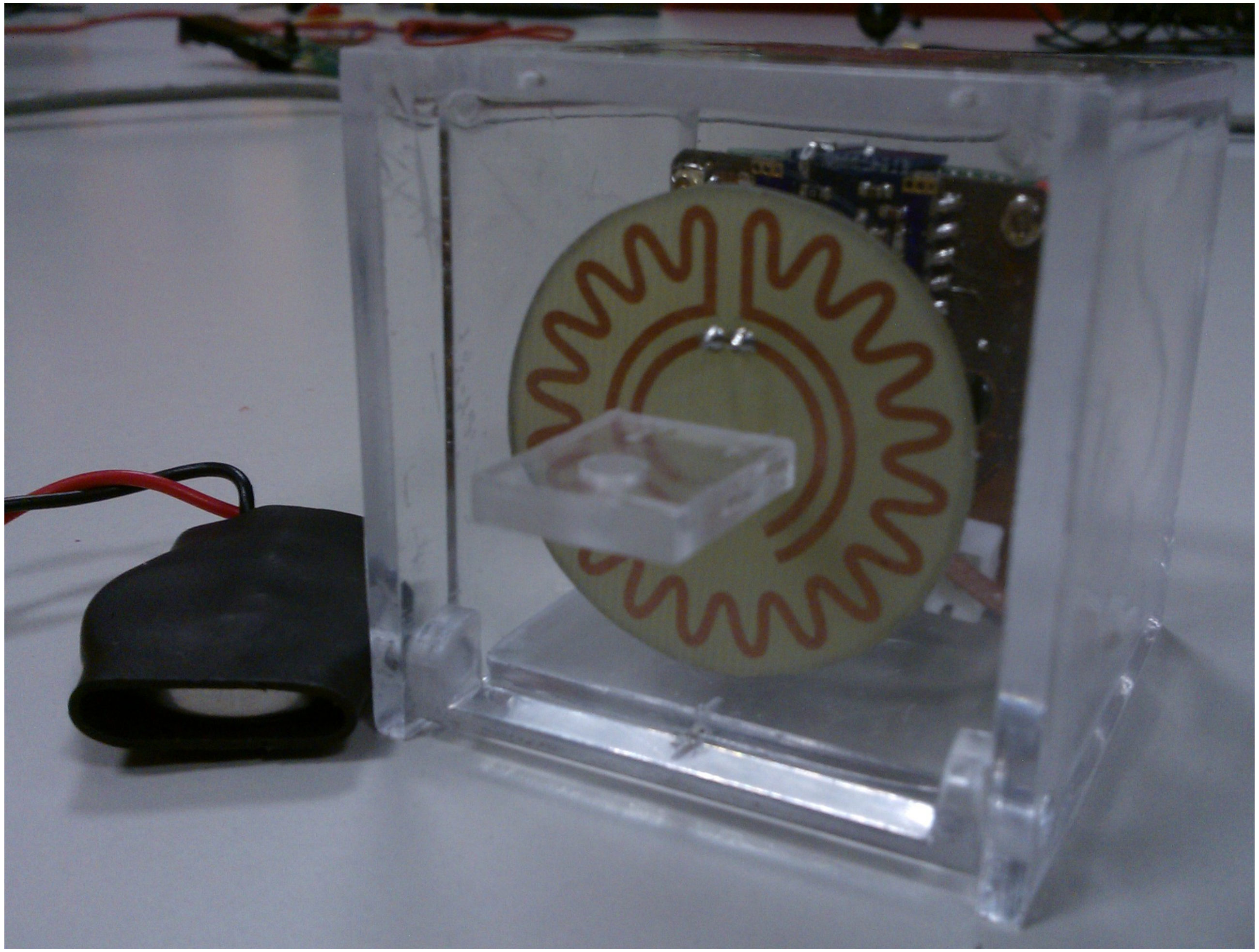
iXemCam

- acquire High Definition images by radio devices

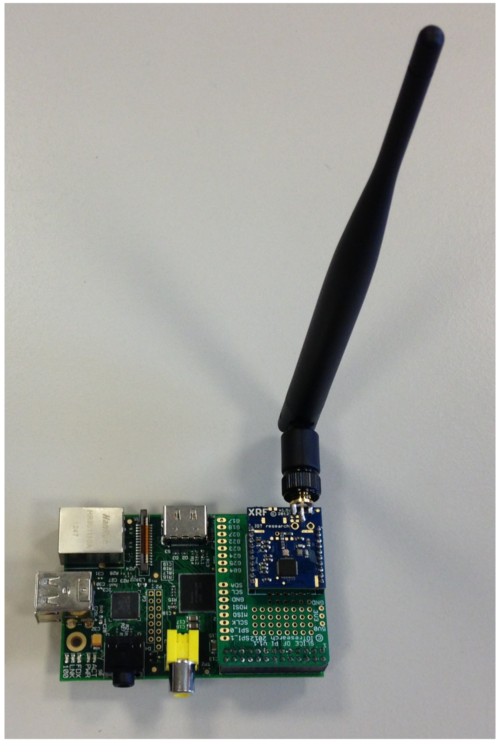
- riduced power
- minimal dimensions
- robust devices
- easy to use, install, maintain
- communication above obstacles (hills, vegetation, humidity)

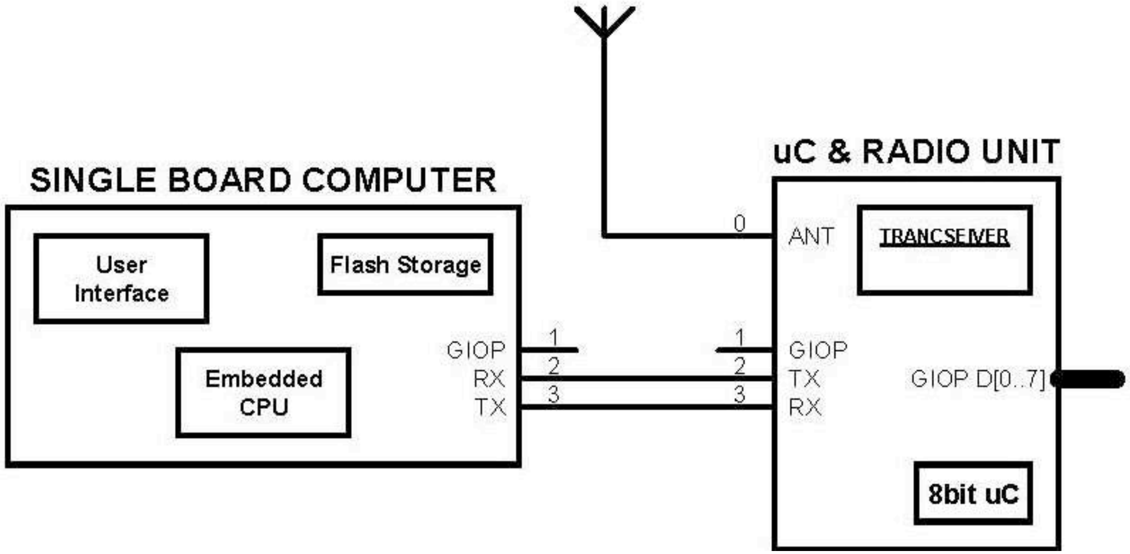
then … iXemCam

iXemCam

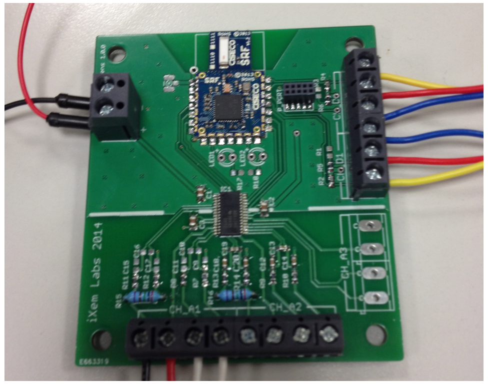


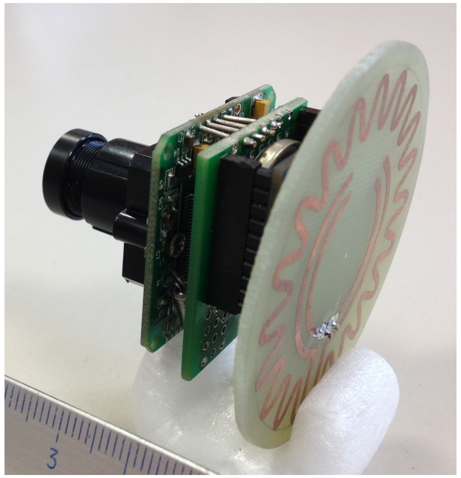
Access Point 1

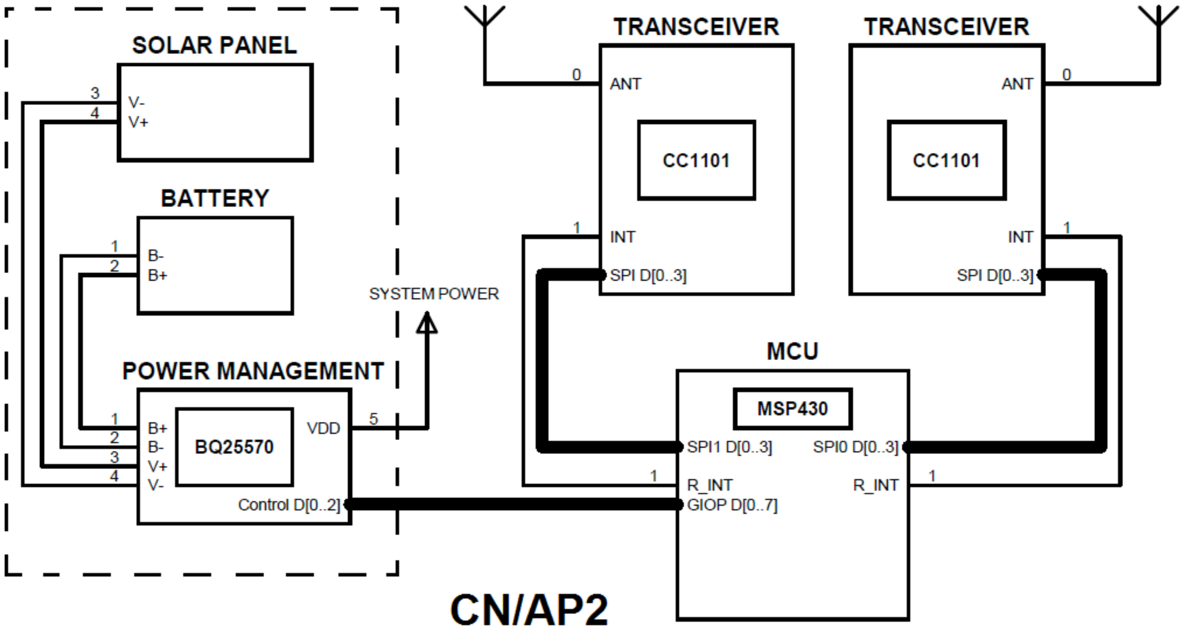




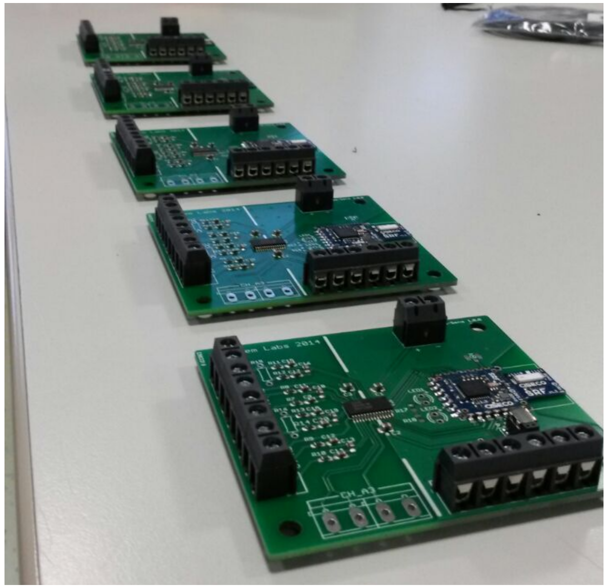
Node 1 + Access Point 2

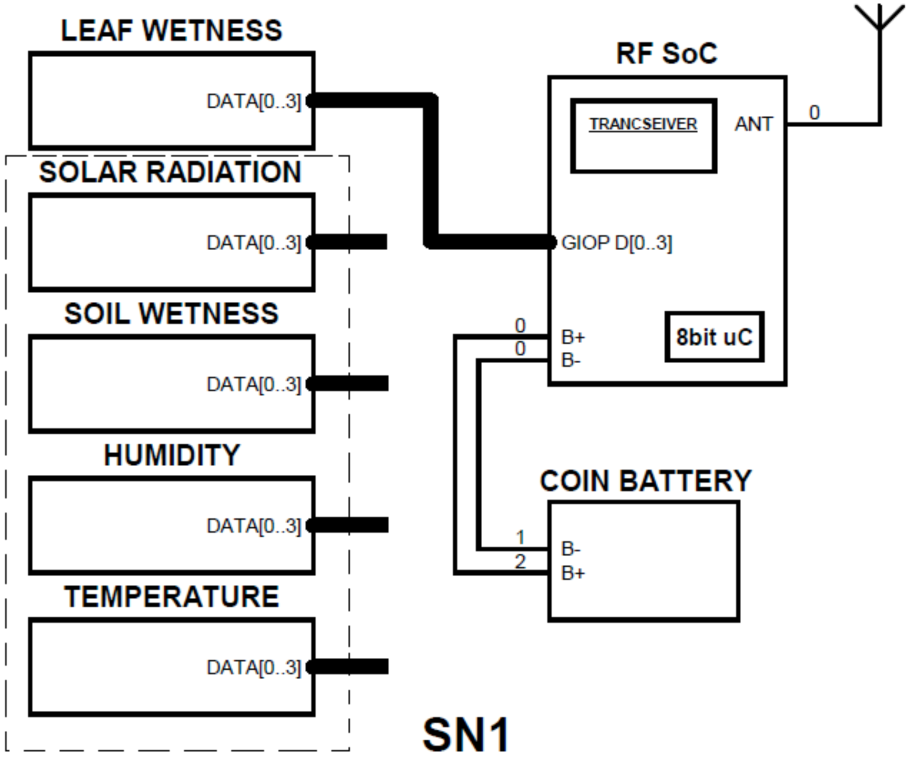






Node Layer 2




LEAF WETNESS
DATA[0..3]
SOLAR RADIATION
DATA[0..3]
SOIL WETNESS
DATA[0..3]
HUMIDITY
DATA[0..3]
TEMPERATURE
DATA[0..3]
RF SoC
TRANCSEIVER
ANT
0
GIOP D[0..3]
0
0
B+
B-
8bit uC
COIN BATTERY
1
2
B-
B+
SN1

The components

- Transceiver

Texas Instruments CC1110

PARAMETER	VALUE
Frequency bands [MHz]	315/433/868/915
TX Current consumption [mA]	31
RX Current consumption [mA]	22
Sleep power consumption [uA]	0.6
Data rate [kbps]	1.2 - 250
Sensitivity [dBm]	-110 (@ 2.5 Kbps)
Output power [dBm]	up to 10
Frequency modulation	2-FSK/GFSK
Amplitude modulation	OOK/ASK

The components

- Transceiver

Texas Instruments CC1110

FREQ [MHz]	MOD	BAND [kHz]	SENSITIVITY [dBm]
315	GSK	58	-107
	GSK	100	-99
	GSK	540	-94
433	GSK	58	-107
	GSK	100	-98
	GSK	540	-93
865	GSK	58	-107
	GSK	100	-100
	GSK	540	-91

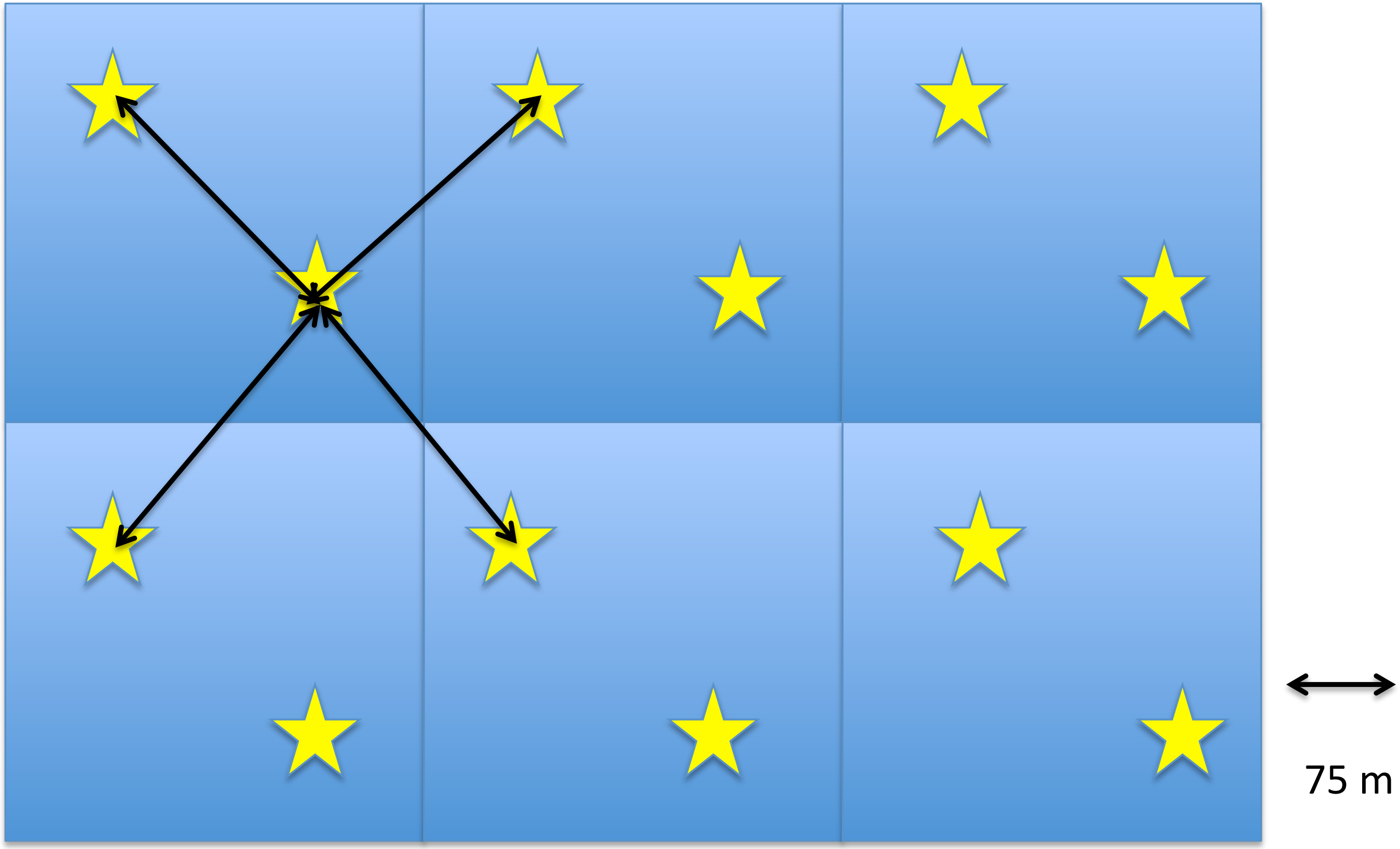
Layer 1 Specifications

- distance among nodes: 750 meters
- EIRP < 5 dBm

- @ 433 MHz PRx = -75 dBm
- @ 865 MHz PRx = -81 dBm
- real throughput between nodes: 30 kb/s

  (S/N ~ 20/18 dB)

Specifications



Layer 1 Specifications

- distance among nodes: 750 meters
- real throughput between nodes: 30 kb/s
- frame transmission time: 90 s

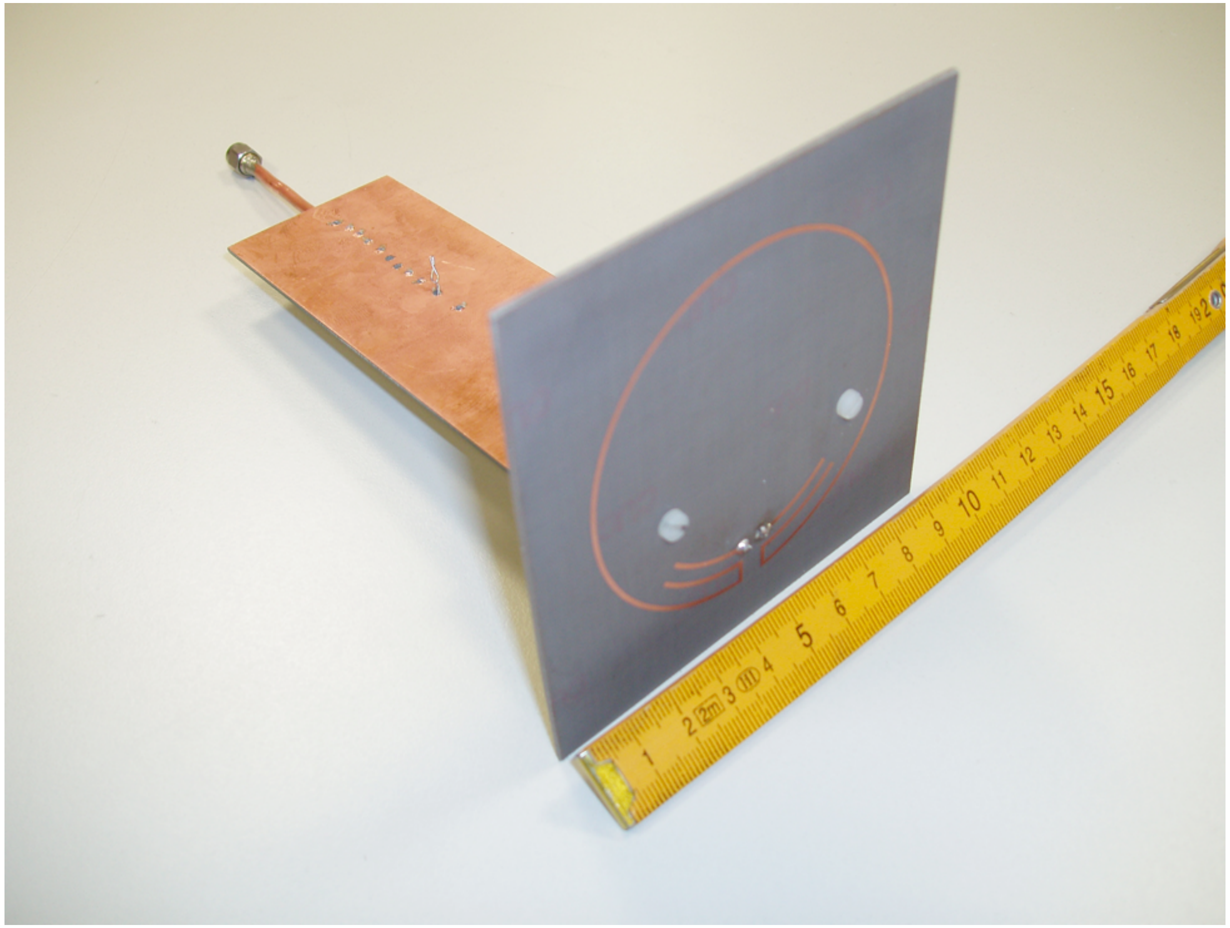
- each area can handle at least 30 nodes
- 1 repeater every 3000 hectares

Specifications

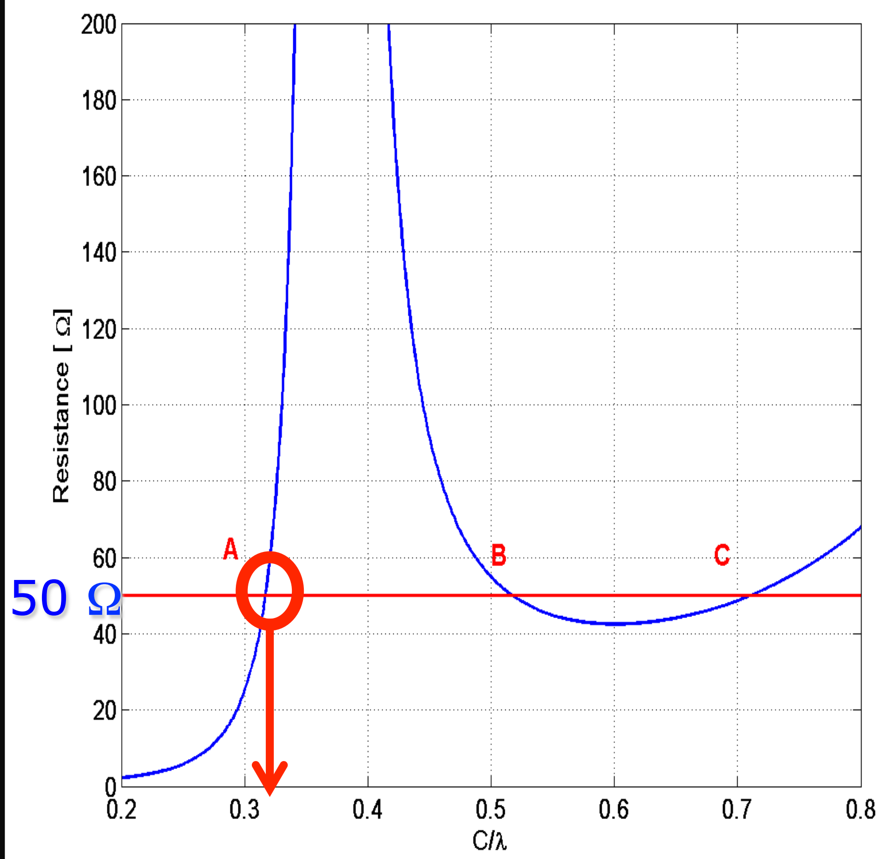
- Max distance among ndes: 750 meters
- 4 nodes in direct communication
- 1 picture per hour per node
- 16 physical parameters every 5 minutes
- Communication speed among nodes: 30 kb/s
- Frame transmission time: 90 s

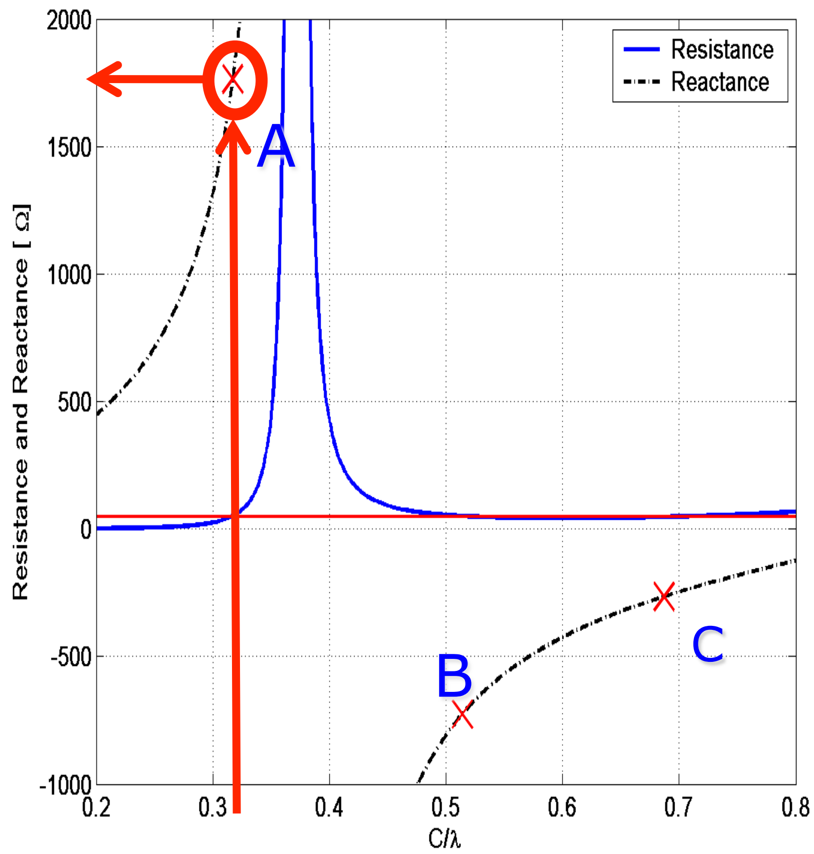
- 30 nodes per area
- 1 repeater every 735 ectars
- 1 AA battery is enough for one month

Micro magnetic radiator

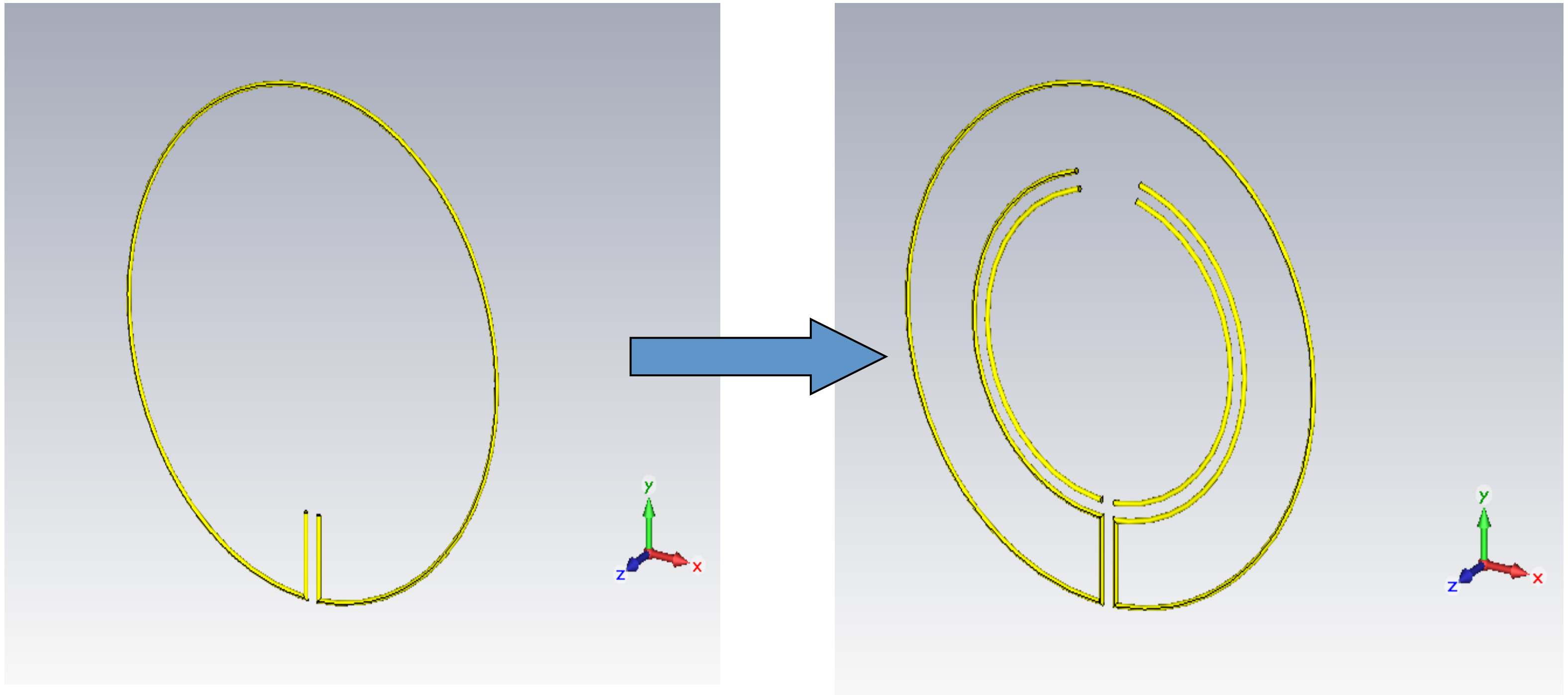


Antenna principle

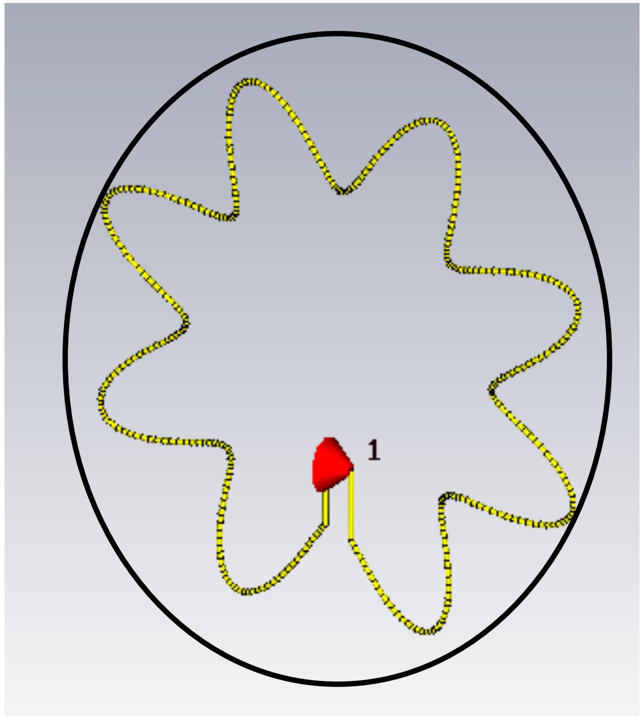


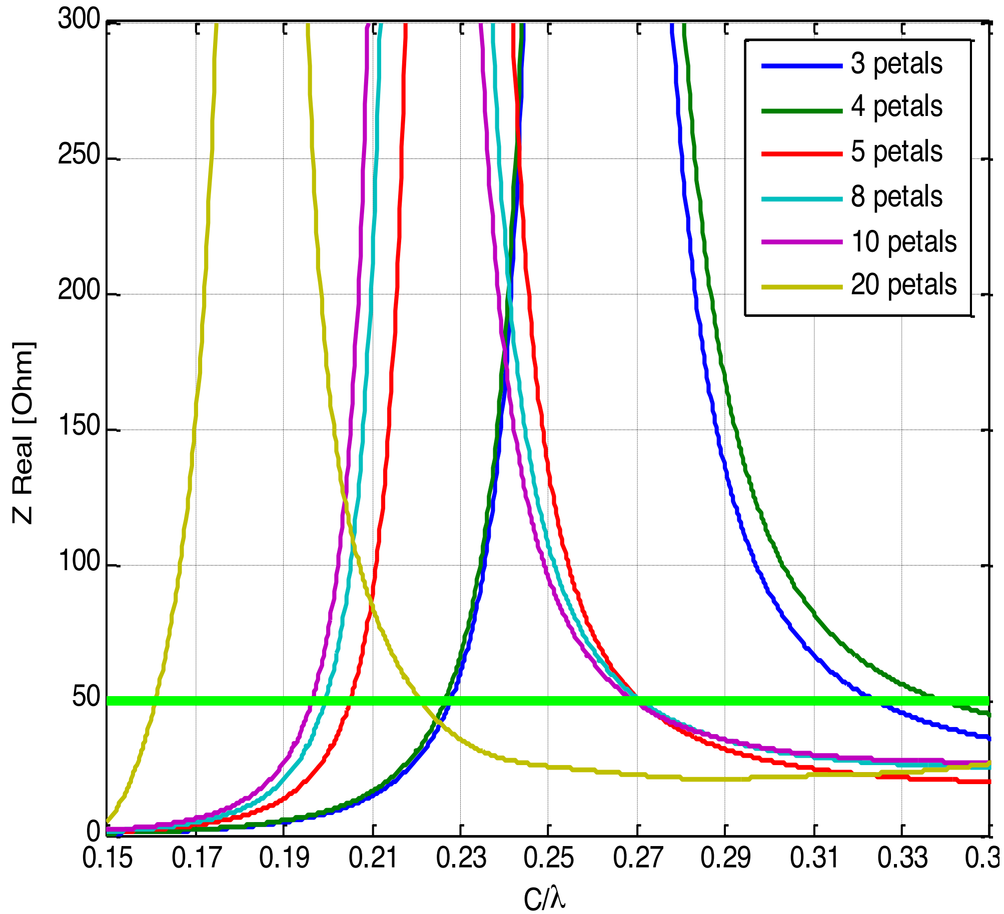


Antenna matching

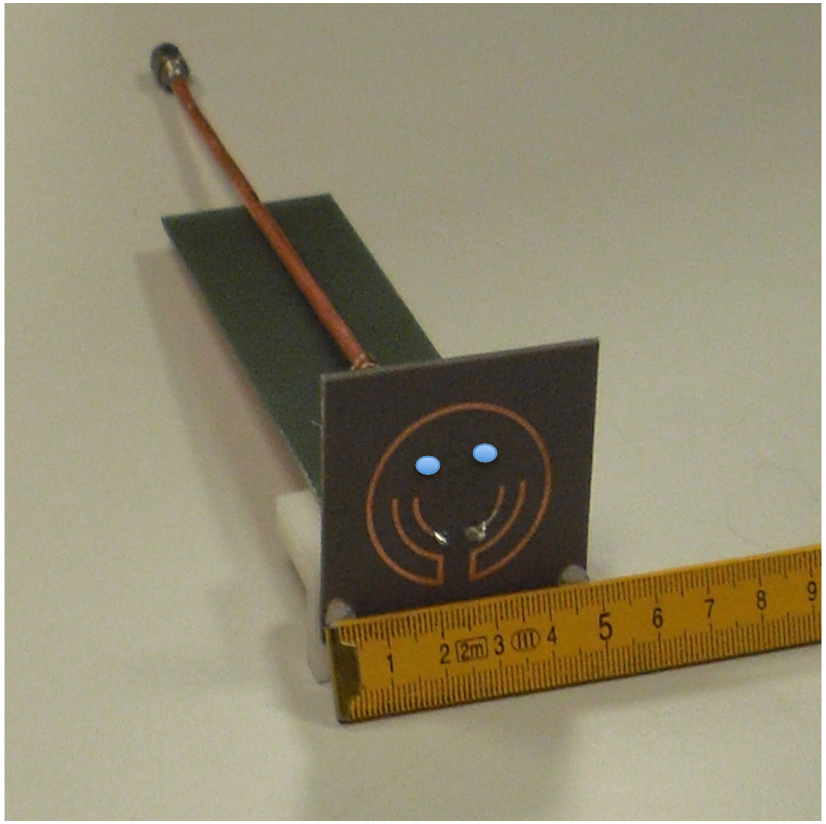
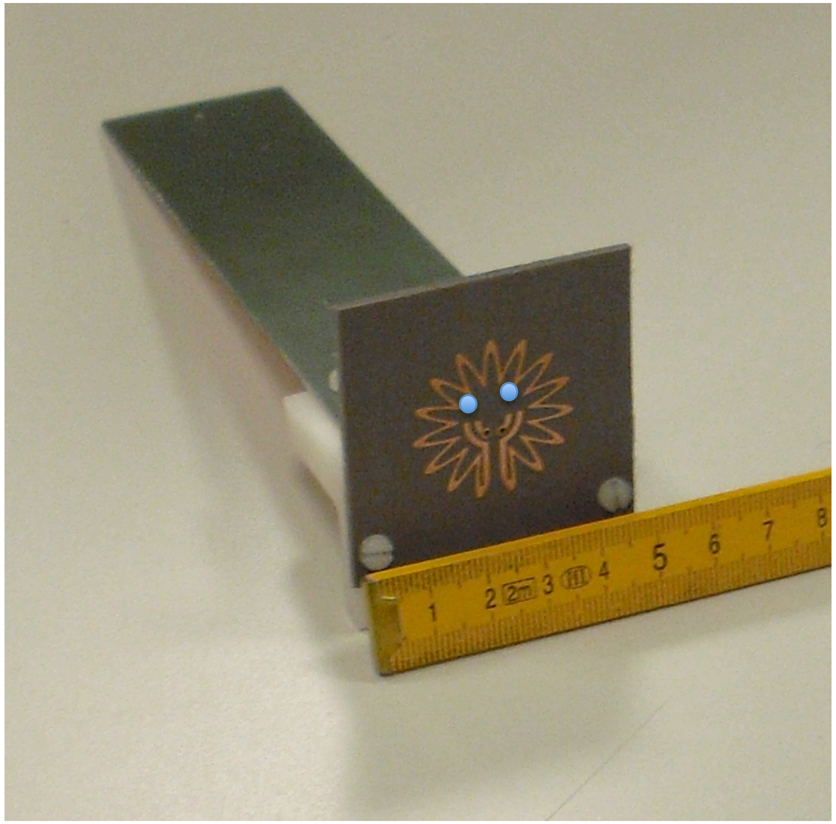


Size reduction





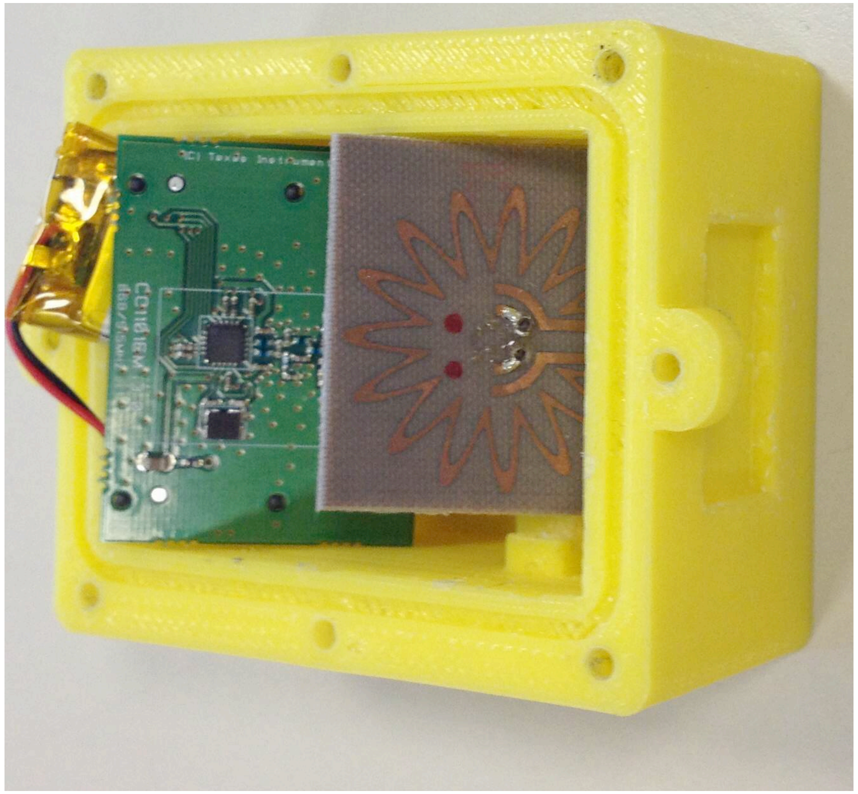
Smiley & Hear

Bandwidth exchange

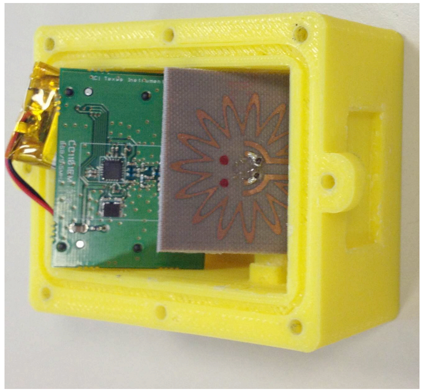
- Purpose:
  - make us of the double-band properties of the transceiver
  - use the most convenient band depending on scenario
- How:
  - synthesize a **double-band magnetic radiator**
- Why magnetic?
  - because magnetic radiators have shown better performance and stability when inserted among leaves

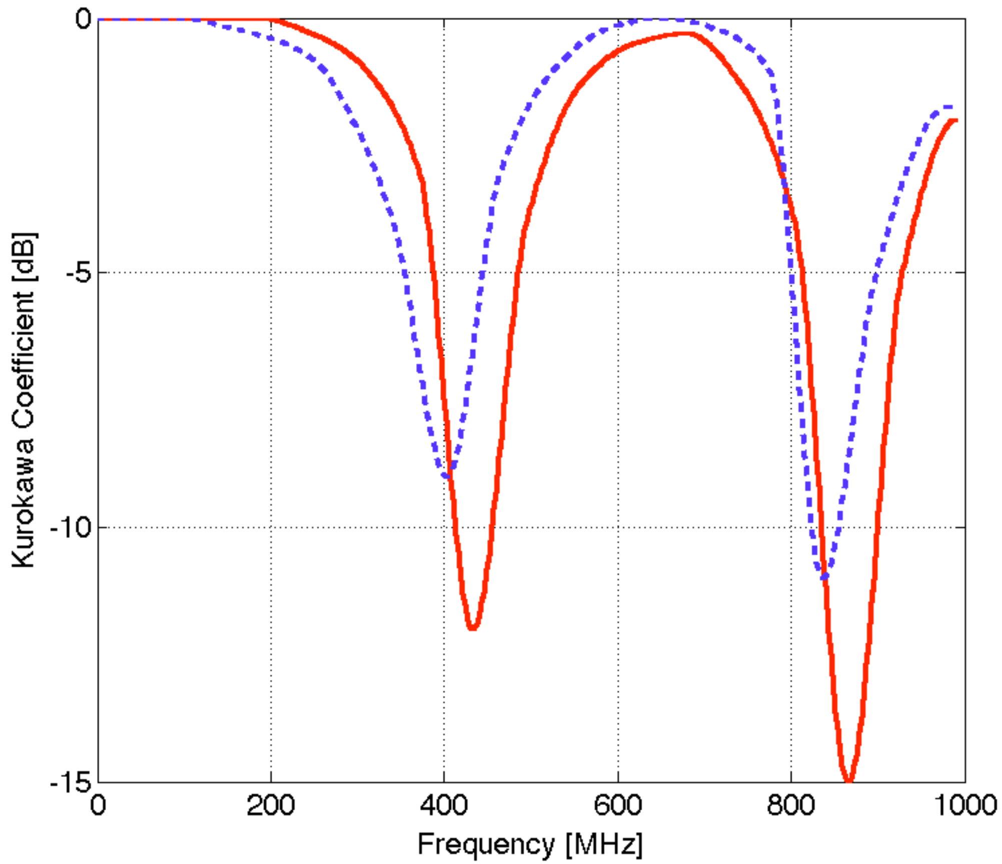
Antenna Example



13 petals
petal penetration: 39%
external circumference: 9.8 cm
matching lines: 1.3 cm each
lines separation: 0.65 cm

Results





Kurokawa Coefficient [dB]
0
-5
-10
-15
0
200
400
600
800
1000
Frequency [MHz]

Layer 1 Power Consumption

- Terminal Node
  - 1 frame per hour, 12 frames per day
  - average current absorption 0.9 mA per hour
  - a 870 mA battery lasts for 78 days (939 frames)
- Intermediate Node
  - 12 hours per day working
  - average current absorption 60 mA per hour
  - a 4400 mAh battery lasts for 5 days

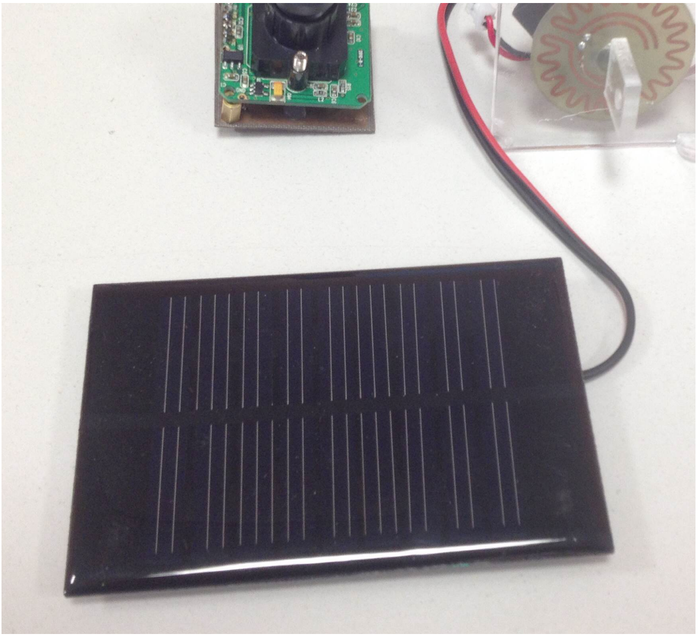
Energy consumption

- Gateway towards Internet
  - It works 12 hours a day
  - Average current absorption 60 mA per hour
  - one 4400 mAh battery battery dura 5 giorni

Layer 1 Specifications

Solar Harvesting

- Intermediate Node
  - 8x18 cm solar panel
  - 200 mA output current (underestimate)
  - 5 hours daylight per day
  - 3.7 Wh per day against 2.60 Wh needed



iXemCam

Real implementation

Economical analysis

- Systemic Treatments
  - Cost: 90 Euro per hectare per treatment
  - Average number of treatments: 10 (2013), 15(2014)
  - Total: 900 Euro per hectare
- Contact Treatments
  - Cost: 30 Euro per hectare per treatment
  - Average number of treatments: 15 (2013), 22 (2014)
  - Total: 450 Euro per hectare
  - Observation: 550 Euro per hectare

Economical perspective

- Contact treatments 2012 (no WSN) 12
- Contact treatments 2013 (WSN) 6
- Contact treatments 2014 (WSN) 10
- Money saving (average): 225-300 Euro
- Money saving (observation): 400 Euro
- Total (average season): 600-900 Euro per hectare
- Cost of one node (layer1+full layer2): 100 Euro


Barbaresco - Sorii San Lorenzo - 18 Maggio 2013 10:00
iXem Labs

iXemCam

Water/Fertilizer Use Reduction

iXemWine

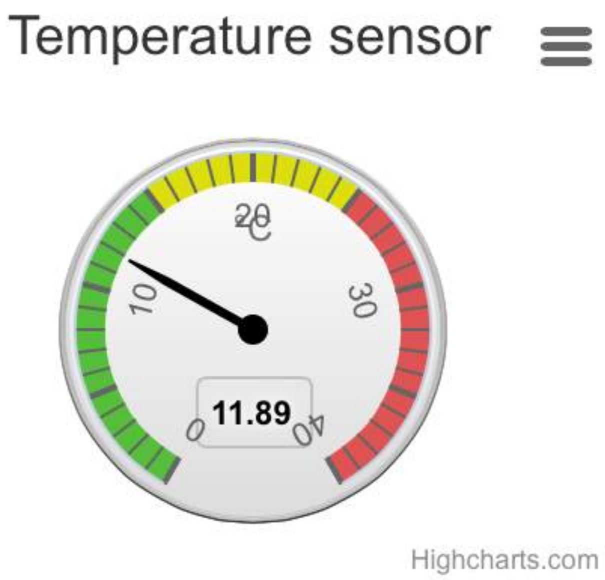
iXemWine

iXemWine

iXemWine

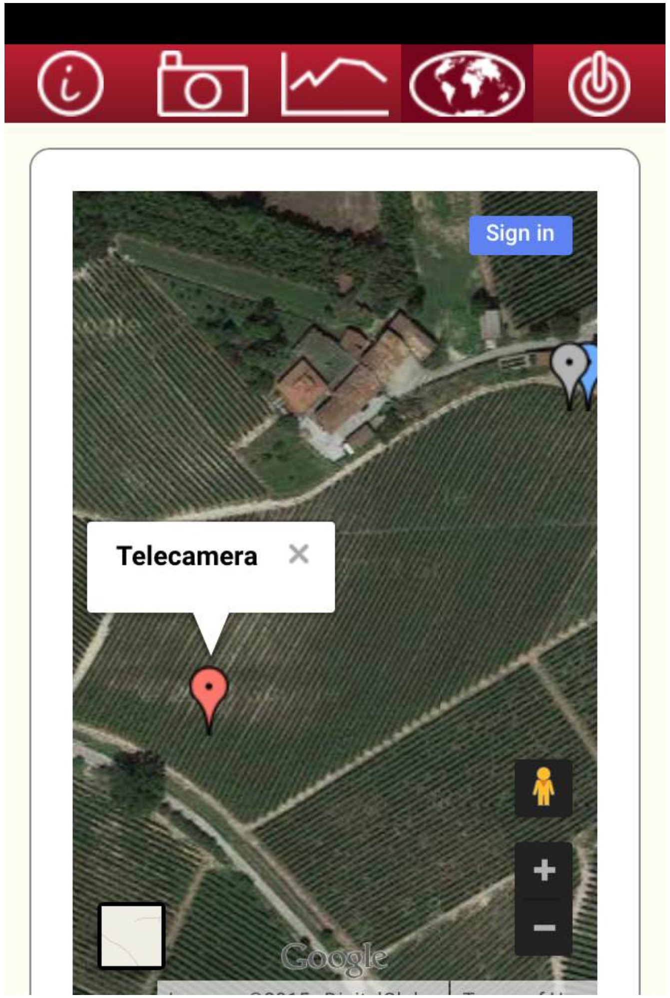

FOTO
Storico delle fotografie:
2015-03-20 11:46:22
Temperature sensor

iXemWine

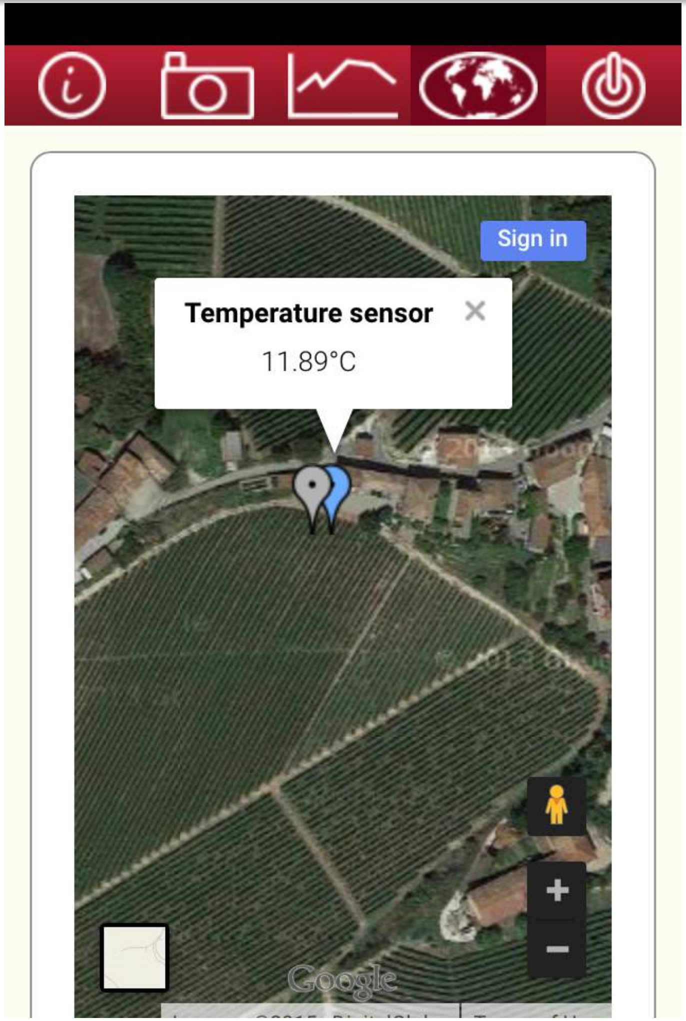

Temperature sensor
0
10
20
30
40
°C
11.89
Highcharts.com


Humidity Sensor
0
20
40
60
80
100
%
57.48
Highcharts.com

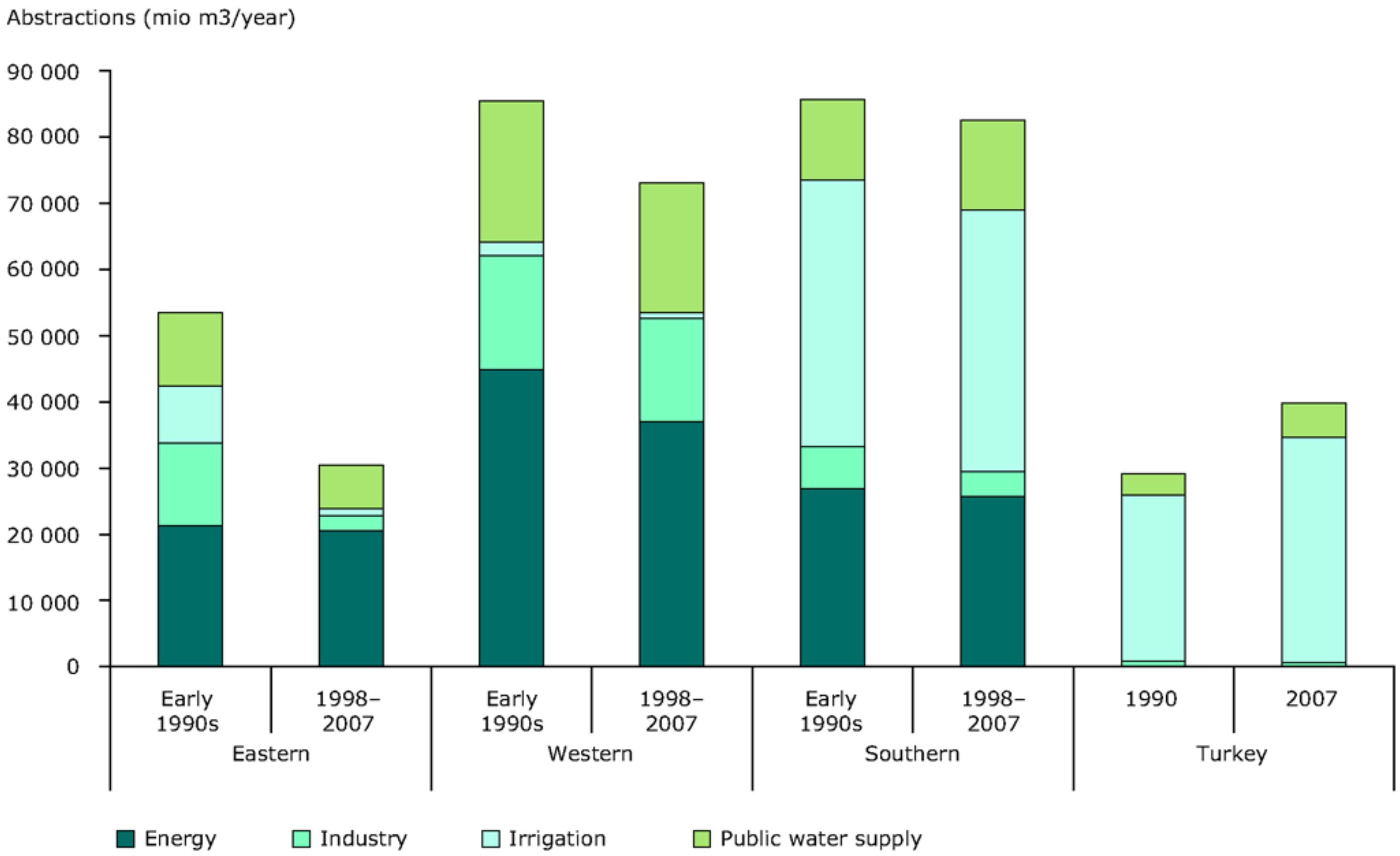
iXemWine



iXemWine

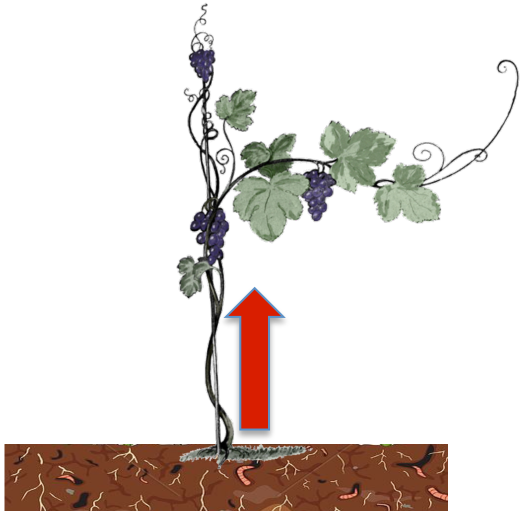


Towards efficient use of water resources in Europe

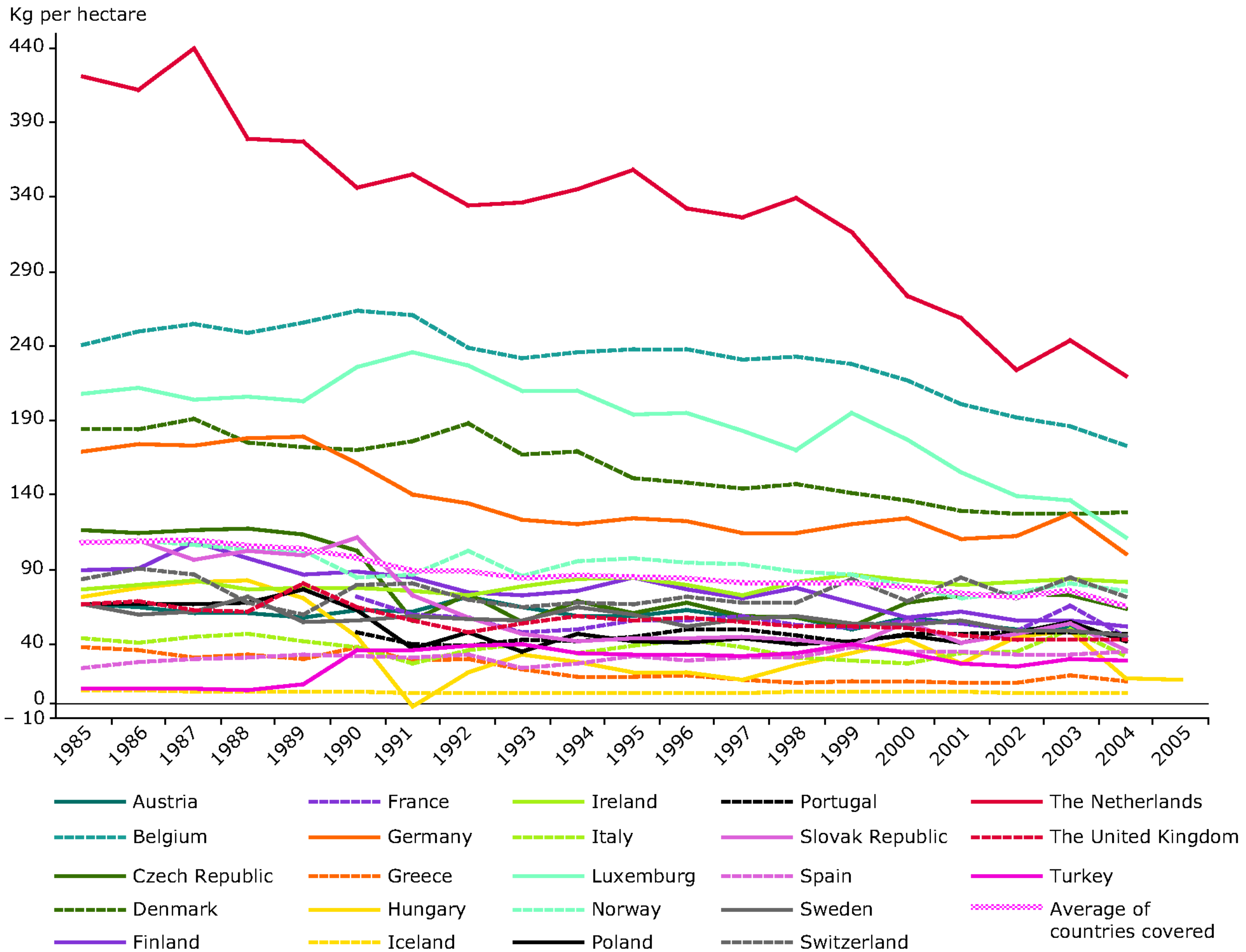


Nitrogen Surplus

- Towards efficient use of water resources in Europe
  - "The nitrogen surplus is currently the best indication of agricultural pressures on water environment, taking into account problems of eutrophication and high nitrate concentration in ground water."



Nitrogen Surplus

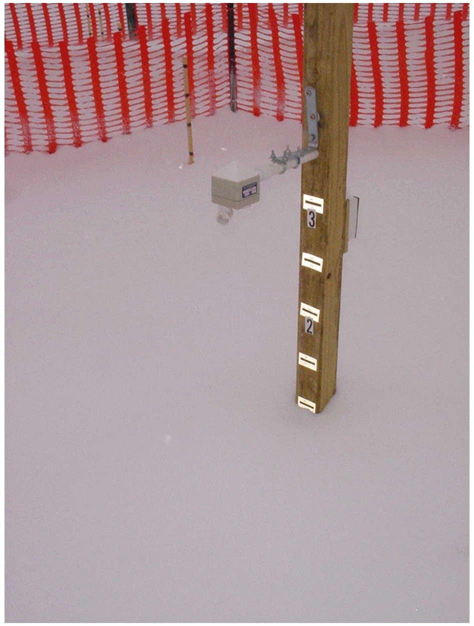


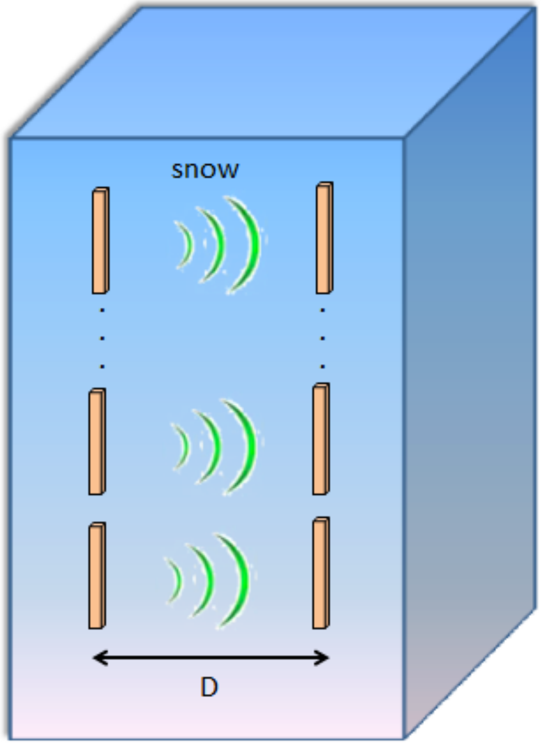
SoilWorm

SoilWorm

SnowHound

SnowHound



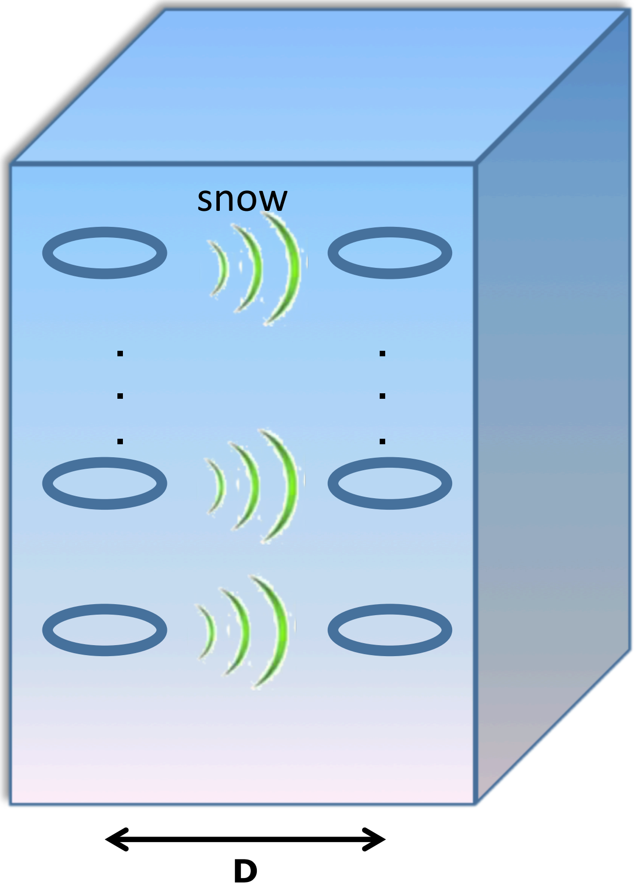


SnowHound

- **Dry Snow**
  - heterogeneous medium composed of air and ice
- **Wet Snow**
  - dielectric mixture of liquid water, air and ice
- **Dielectric Parameters**
  - Air: constant
  - Ice: almost constant
  - Water: almost constant

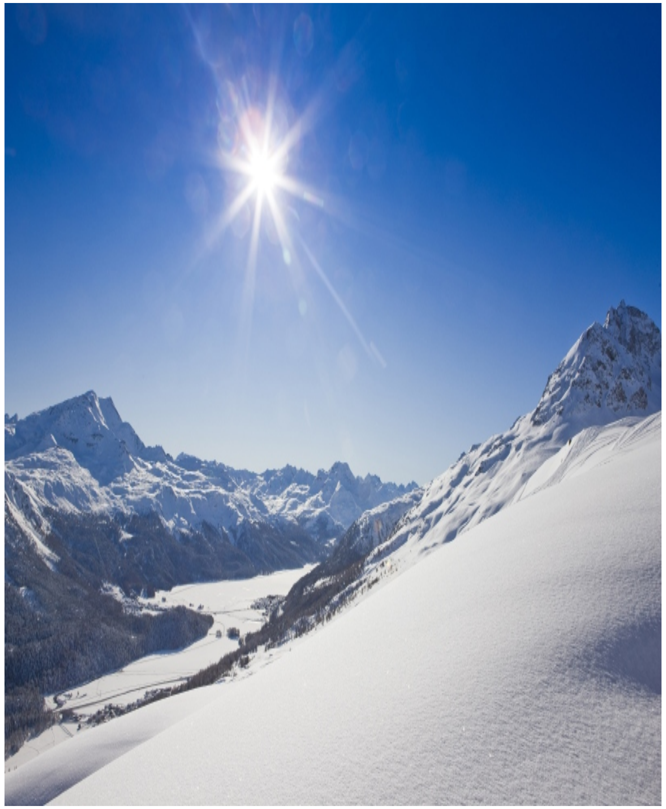
- Complex Dielectric Constant of Snow depends ONLY on water percentage

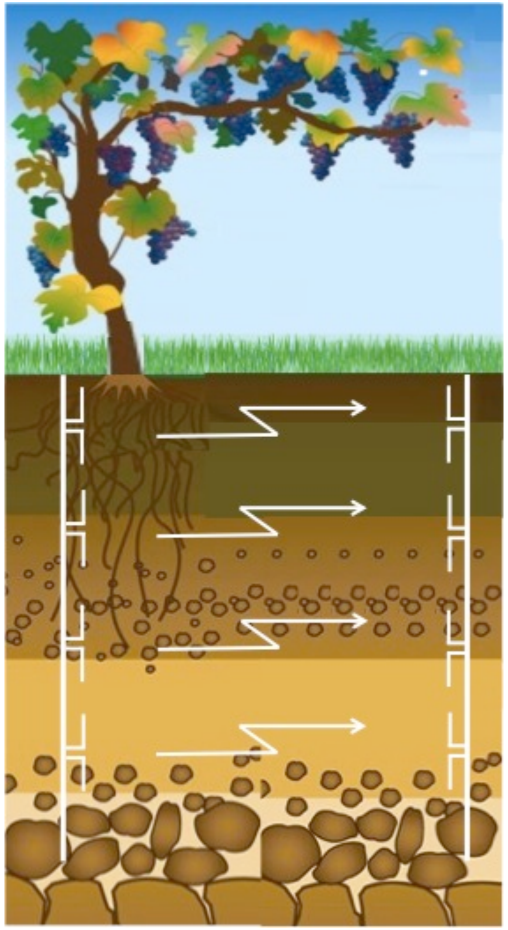
SnowHound



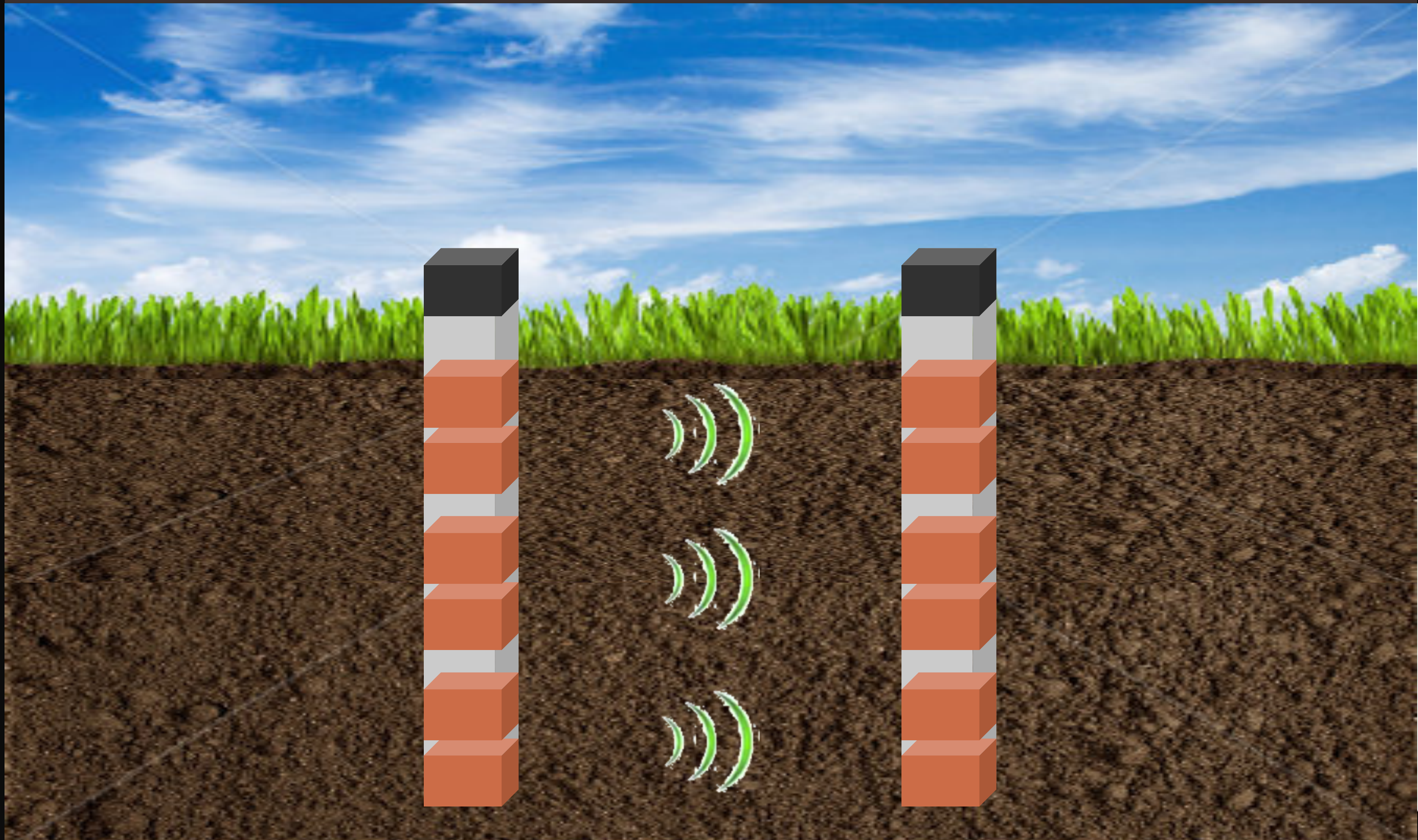
- two alignments of parallel radiators
- one radiator fed per time
- power budget depends on complex dielectric permittivity of the snow
- use of low power transmitters
- use of photovoltaic harvesters

SoilWorm



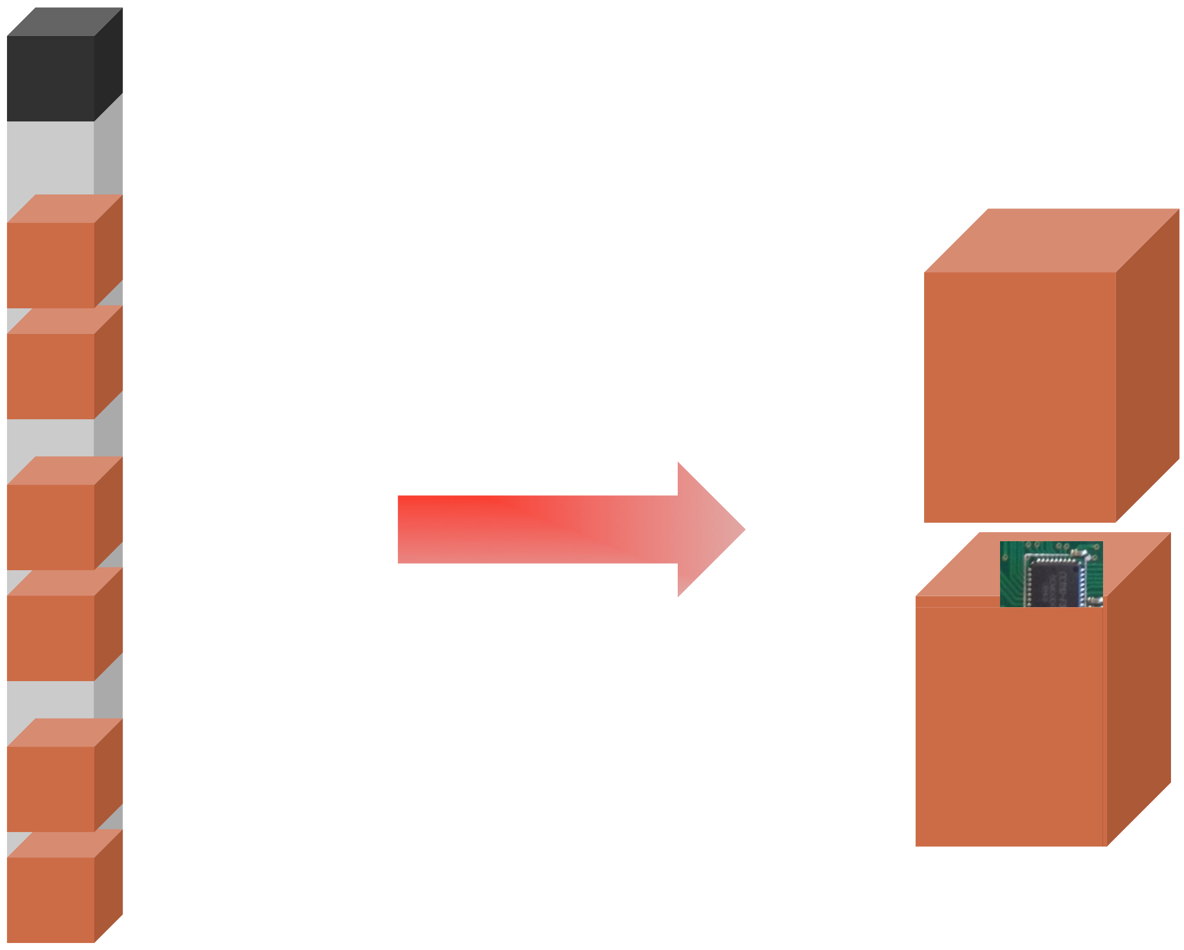


SoilWorm

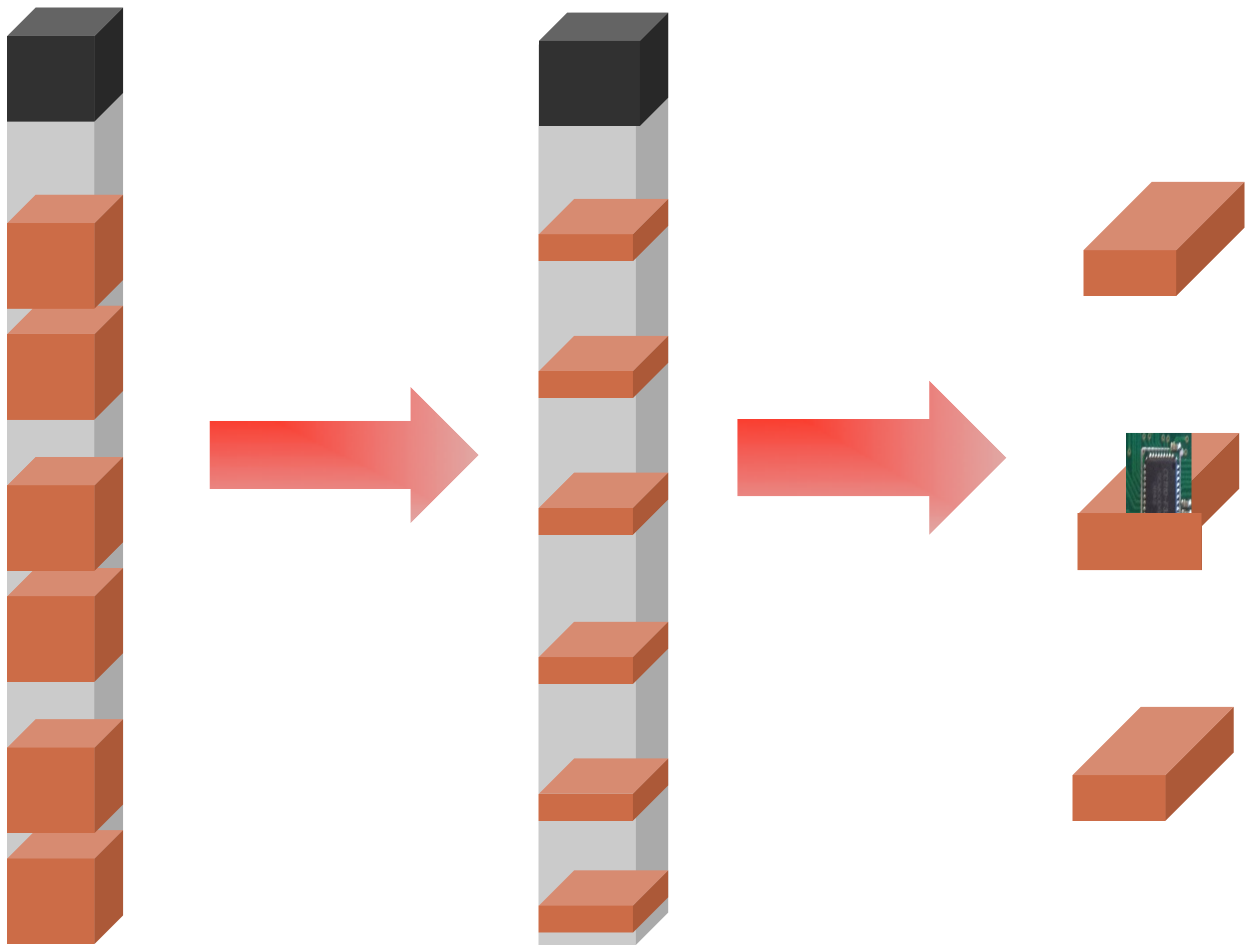


iXem Labs foundation

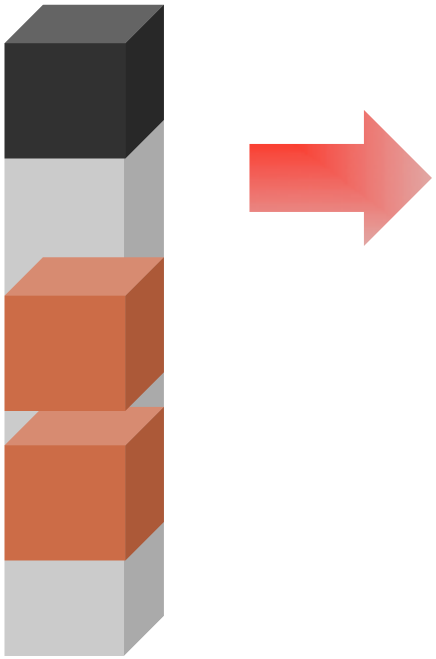
SoilWorm Node

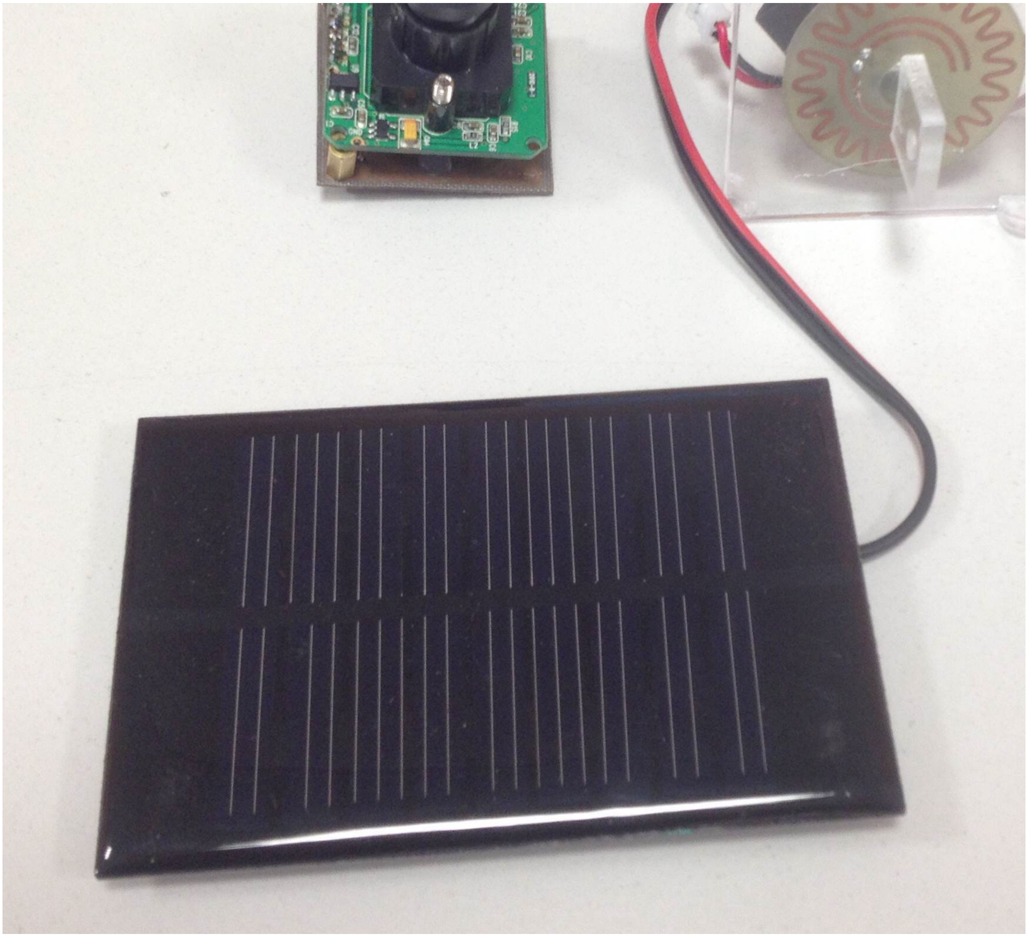


SoilWorm Node



SoilWorm





SoilWorm

Increase of humidity

↓

Increase of
electrical permittivity
conductivity

Impedance
grows

Wavelenght
decreases

Current
in antenna is
more localized

Soil Losses
increase

Design Parameters

- Water (humidity) content
- **Soil Texture**

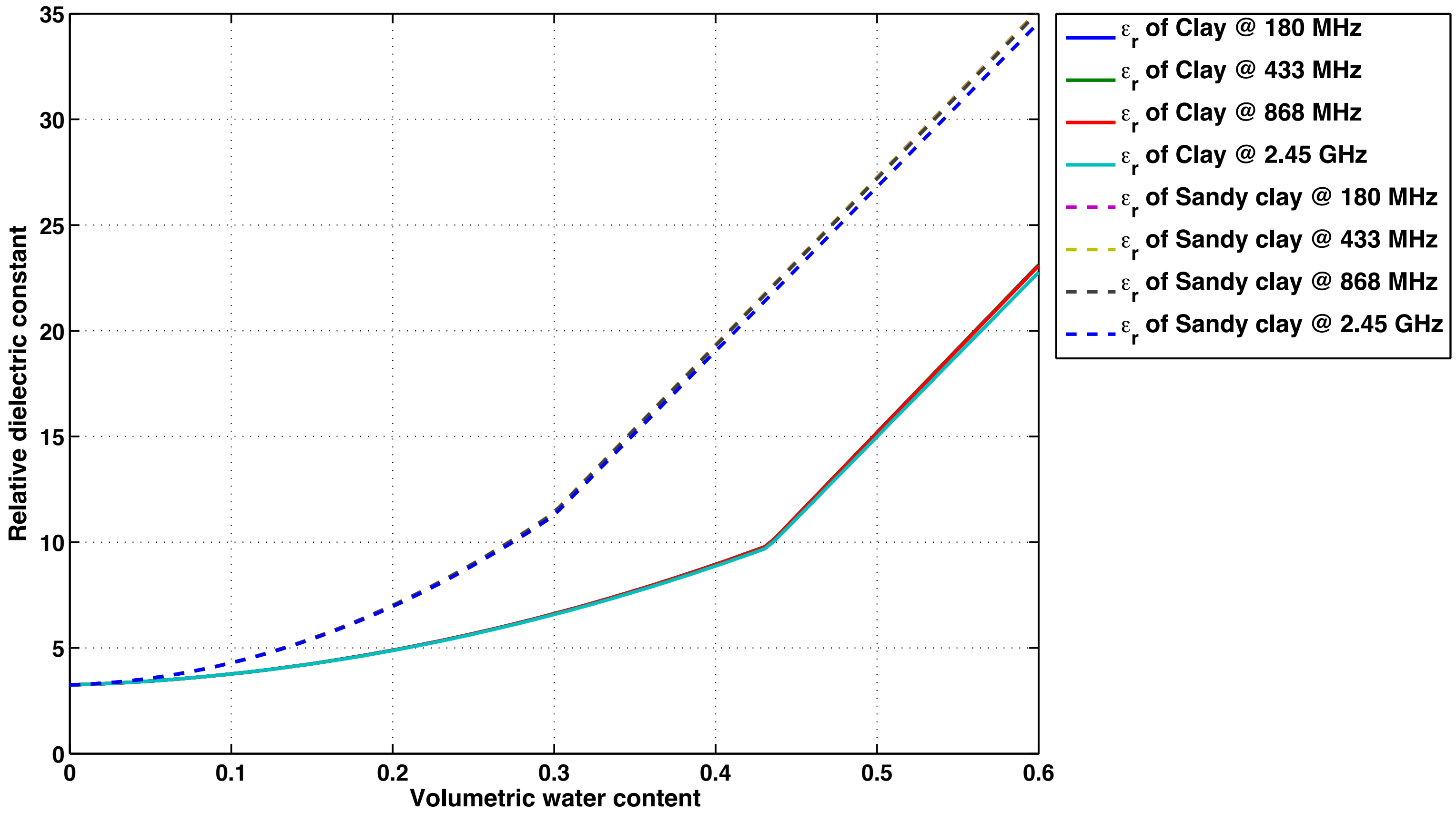
↓

- Electromagnetic Parameters

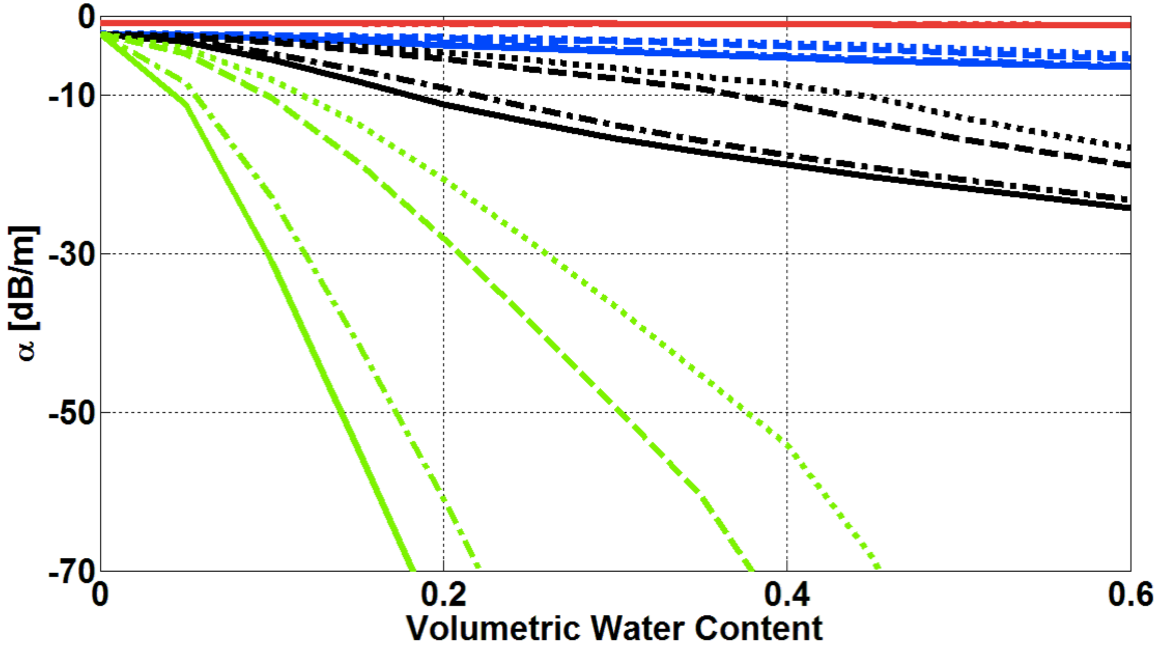
↓

- Antenna matching (L/λ)
- Power lost in medium (α)

Water Effect



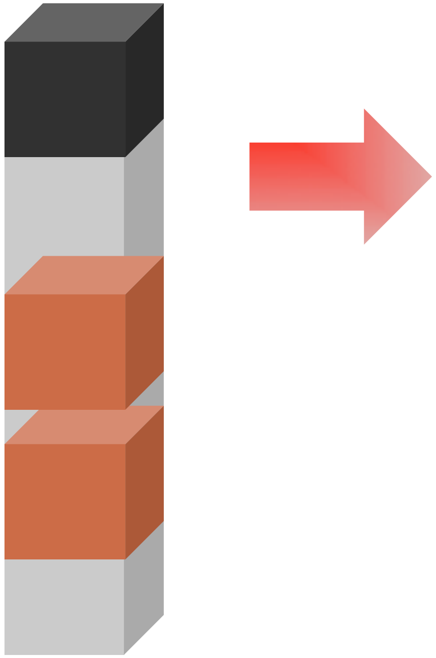
Water Effect

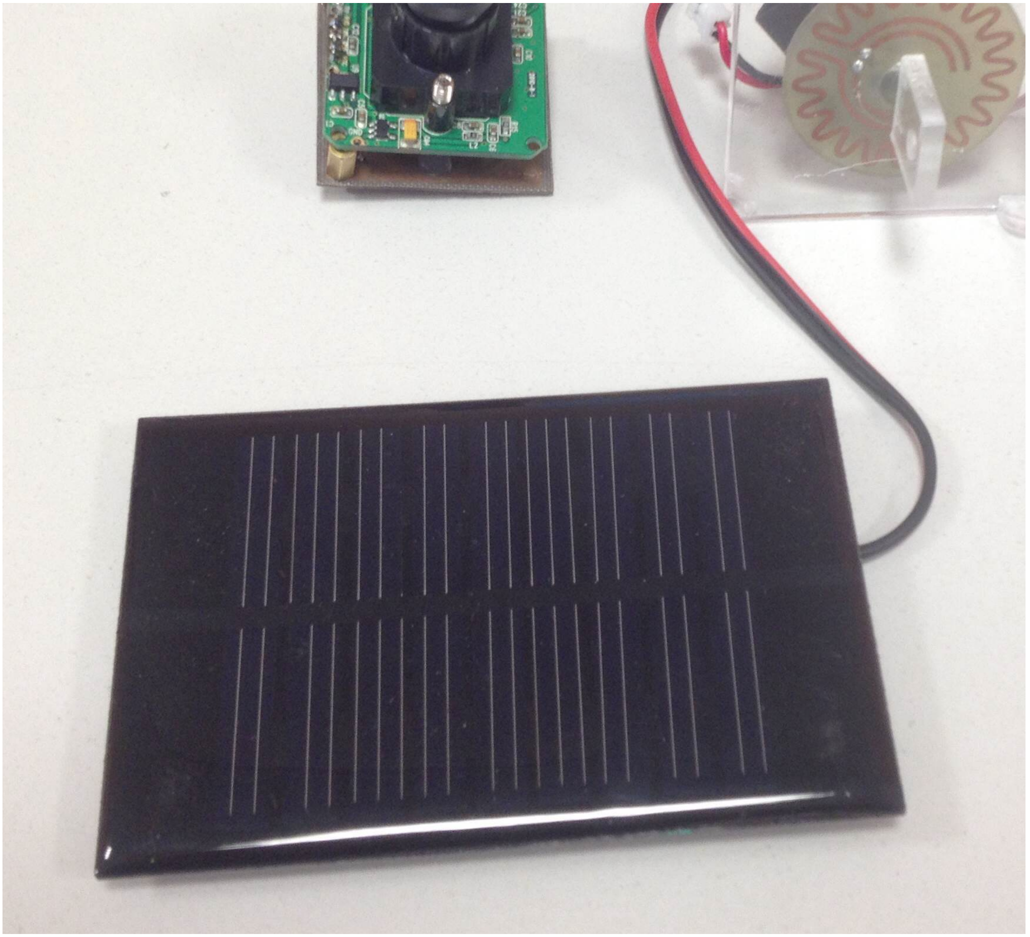


168 MHz
433 MHz
868 MHz,
2450 MHz

------- 100% sand
–•–•–• 80% sand and 20% clay
– – – – – 20% sand and 80 % clay
••••••• 100% clay

SoilWorm





The experiment at Case Basse

Electromagnetic Characterization of Soil

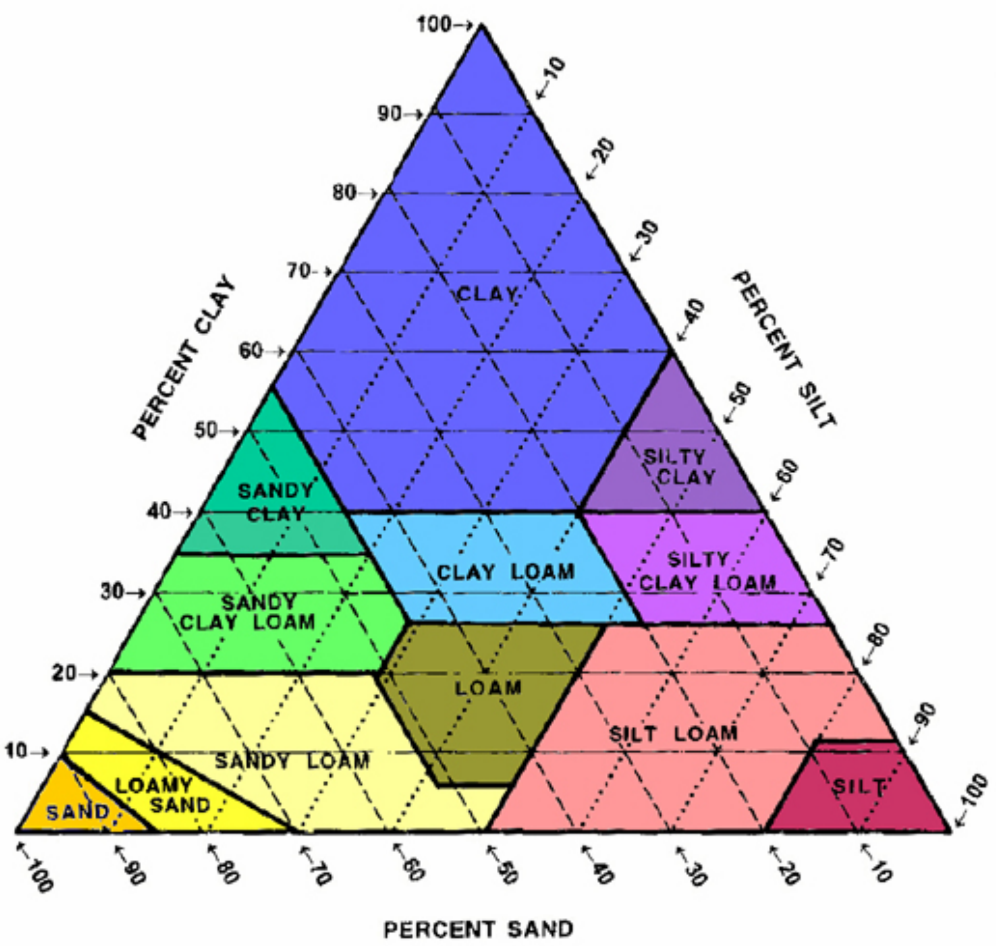
Wang and Schmugge [1980]:

The complex dielectric constant is a function of:

- Sand and clay percentage
- Air, Ice, Water, Stone dielectric constants

Soil		180 MHz		433 MHz		868 MHz		2.45 GHz	
Name	Soil composition	ε_r	σ [S/m]	ε_r	σ [S/m]	ε_r	σ [S/m]	ε_r	σ [S/m]
Sandy Clay	Sand: 50% Clay: 50%	11.4141	0.0020	11.4102	0.0074	11.3955	0.0239	11.2730	0.1581
Clay	Sand: 0% Clay: 100%	6.6205	0.0015	6.6190	0.0047	6.6137	0.0127	6.5789	0.0686

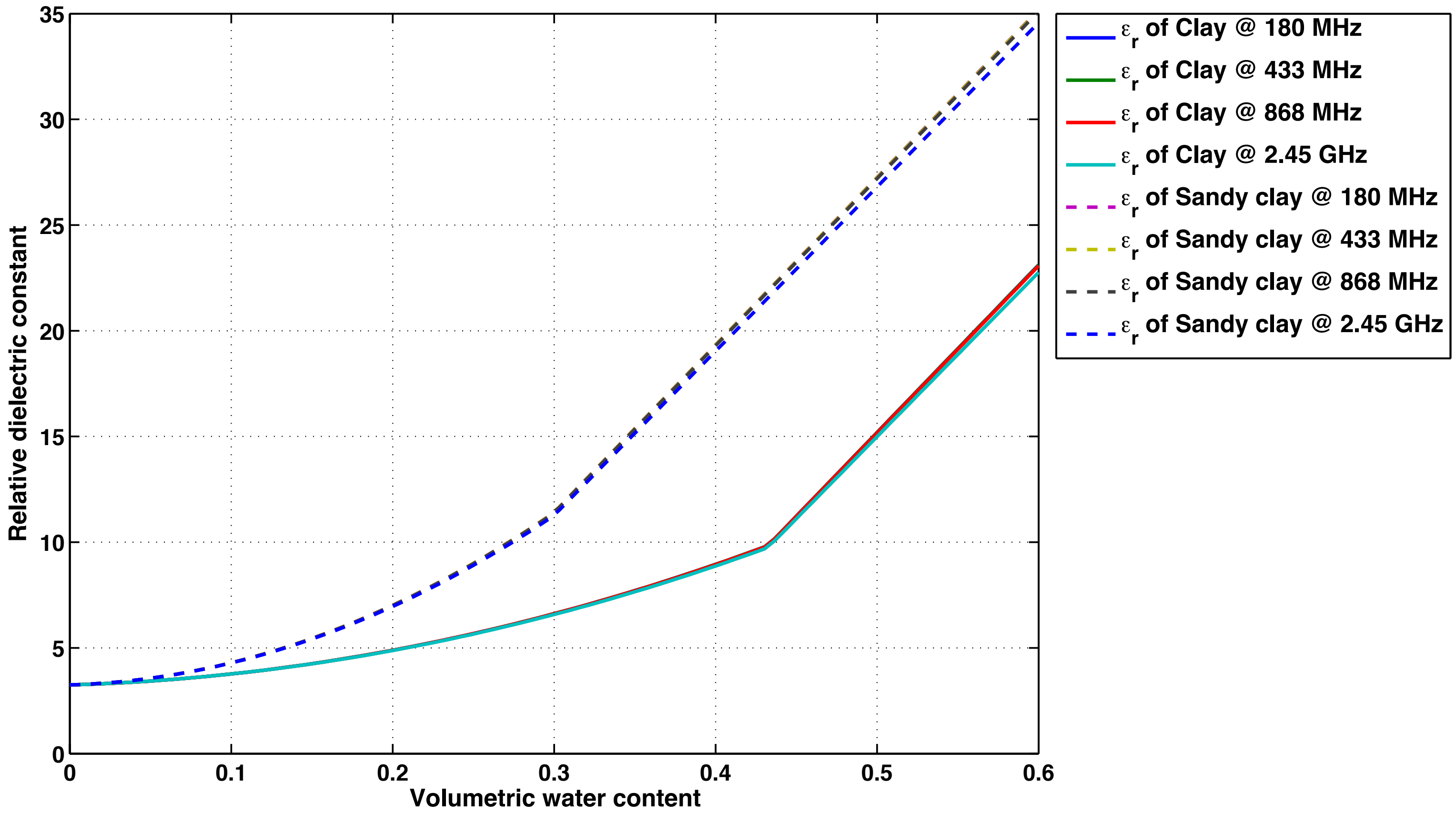
Soil Texture Triangle



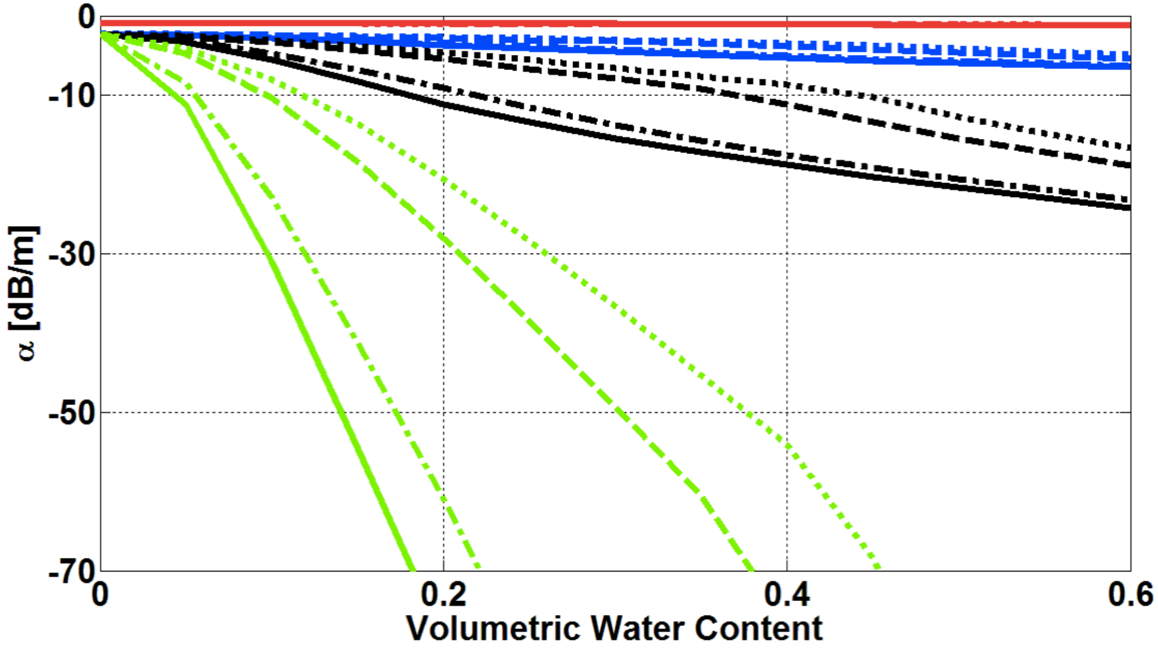
Electromagnetic Characterization of Soil

		168 MHz	433 MHz	868 MHz	2450 MHz
Air	**ε'**	1	1	1	1
	ε''	0	0	0	0
Ice	**ε'**	3.15	3.15	3.15	3.15
	ε''	0.16	0.1	0.1	0.1
Rock	**ε'**	5.5	5.5	5.5	5.5
	ε''	0.2	0.2	0.1	0.03
Water	**ε'**	80.2	80.1	80	78.6
	ε''	0.8	1.92	3.84	10.6

Water Effect



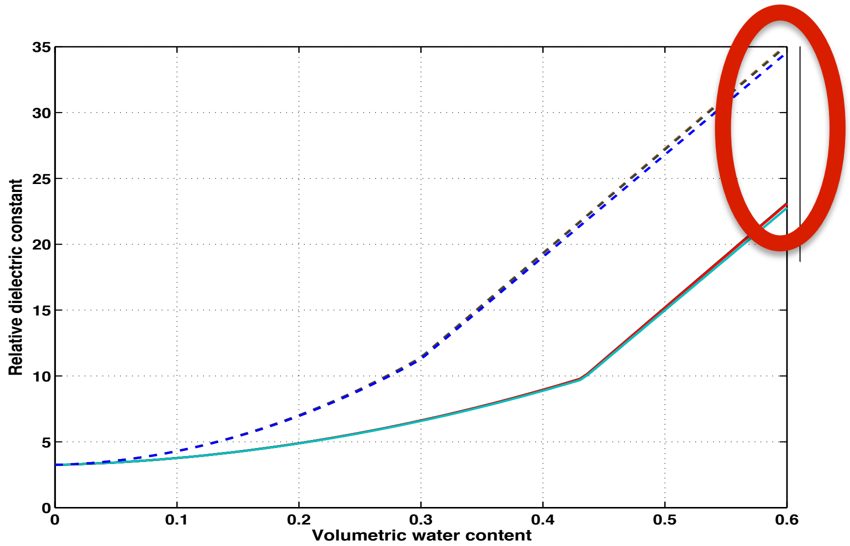
Water Effect



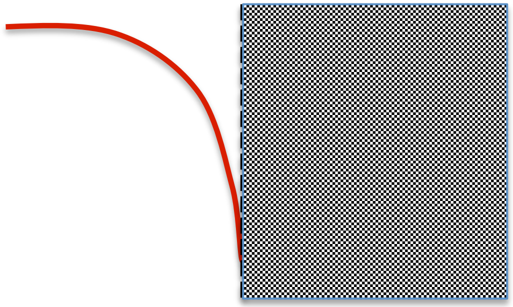
168 MHz
433 MHz
868 MHz,
2450 MHz

------- 100% sand
-•-•-• 80% sand and 20% clay
- - - - - 20% sand and 80 % clay
••••••• 100% clay

Which radiator length?



λ/2 is the maximum accepted length to avoid ambiguity

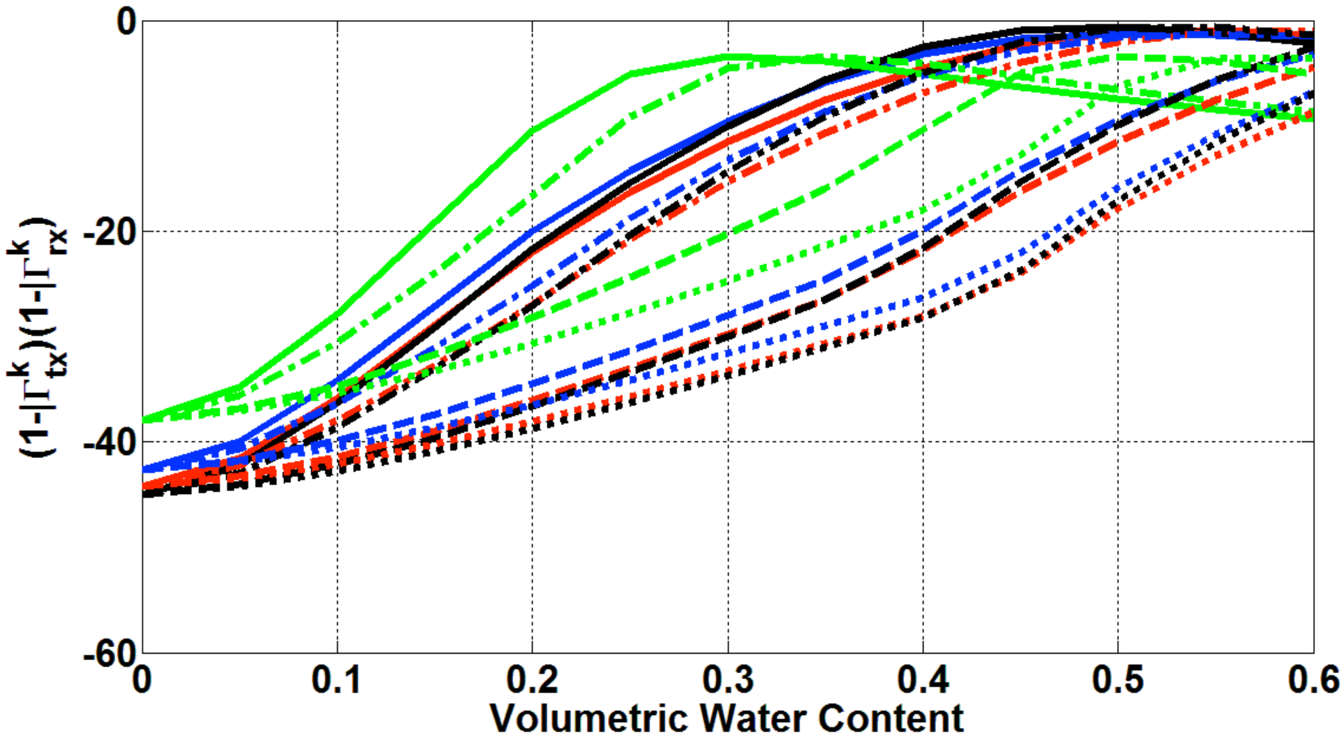


Dipole design

Soil	λ/2 180 MHz [cm]	λ/2 433 MHz [cm]	λ/2 868 MHz [cm]	λ/2 2.45 GHz [cm]
100% Sand	12.55	5.22	2.60	0.93
80% Sand 20% Clay	13.03	5.42	2.70	0.96
20% Sand 80% Clay	15.66	6.51	3.25	1.16
100% Clay	17.33	7.20	3.60	1.28

	168 MHz	433 MHz	868 MHz	2450 MHz
Length [cm]	12.55	5.22	2.6	1.5

Matching



168 MHz
433 MHz
868 MHz,
2450 MHz

——— 100% sand
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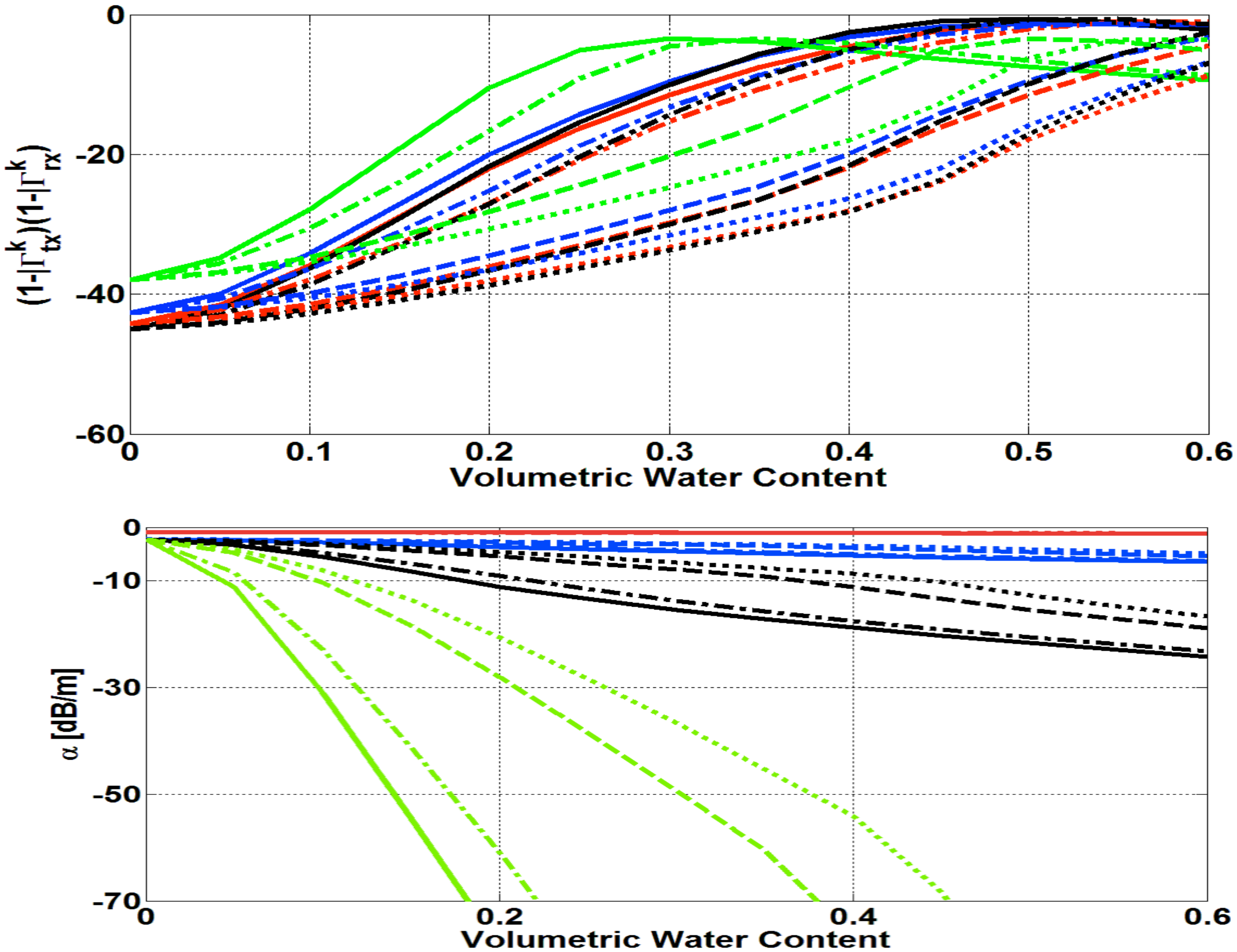
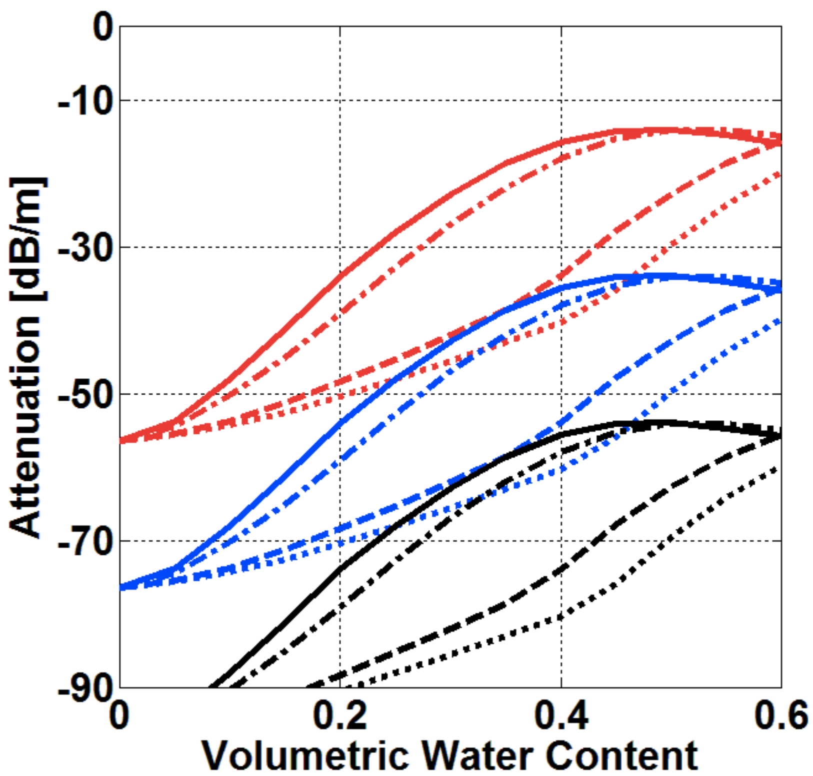
Choice of the frequency



The choice: 868 MHz

- - - - - - - 100% sand
-•-•-• 80% sand and 20% clay
- - - - - 20% sand and 80 % clay
••••••• 100% clay

10 cm
30 cm
60 cm



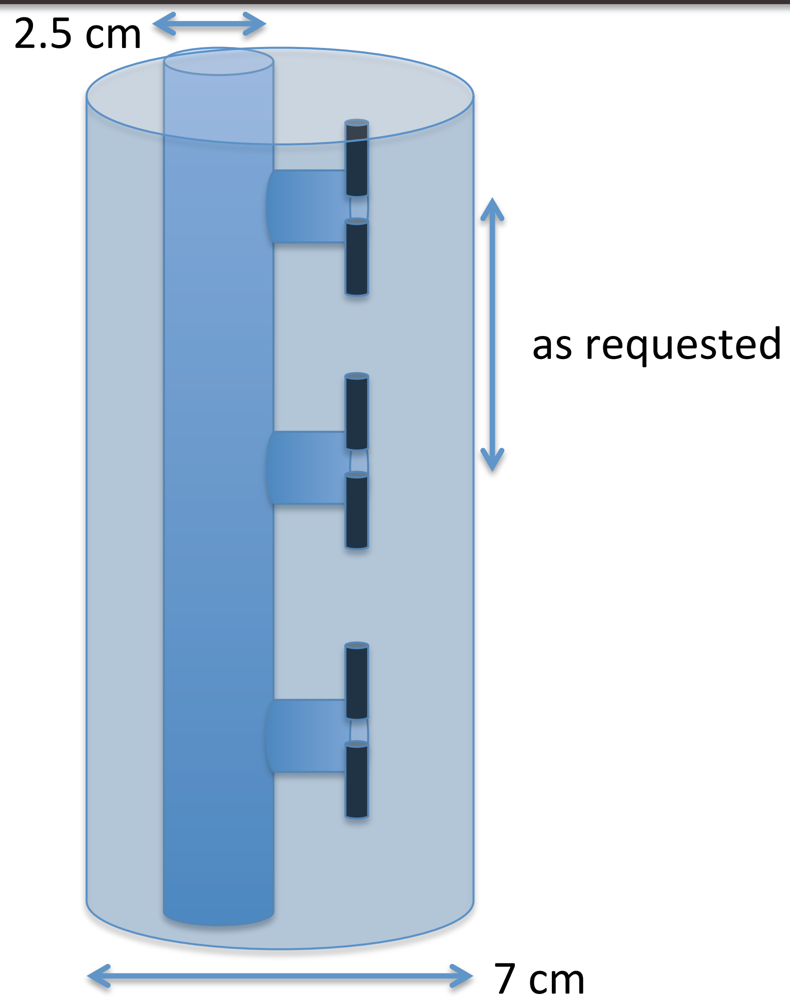
iXem Labs foundation

The experiment at Case Basse

Layer	Composition	Start	End	Thick [m]	ε_r	σ
1	Topsoil	0	-1	1	3-5	0.001-1
2	Stones + Sand + Silt + some Clay	-1	-4.7	3.7	7.8	0.005-0.1
3	Clay	-4.7	-8.5	3.8	2.6	0.001-0.1

SoilWorm

SoilWorm



SoilWorm

SoilWorm

Risoluzione di lettura della percentuale di umidità	**0.2 %**
Campionamento spaziale	**30 cm (E ant)** **10 cm (H ant)**
Campionamento temporale	**10 secondi (EH)**
Vita media	**5 anni**

SoilWorm

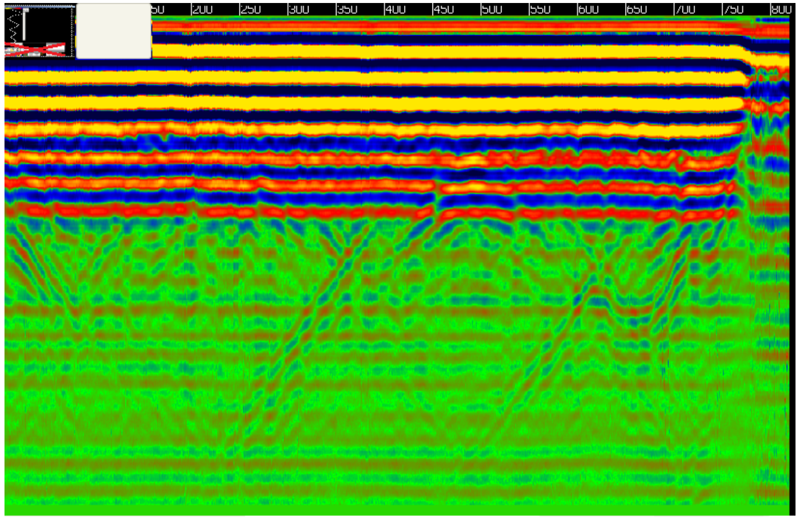
PARAMETER	VALUE
Frequency bands [MHz]	315/433/868/915
TX Current consumption [mA]	31
RX Current consumption [mA]	22
Sleep power consumption [uA]	0.6
Data rate [kbps]	1.2 - 250
Sensitivity [dBm]	-110 (@ 2.5 Kbps)
Output power [dBm]	up to 10
Frequency modulation	2-FSK/GFSK
Amplitude modulation	OOK/ASK

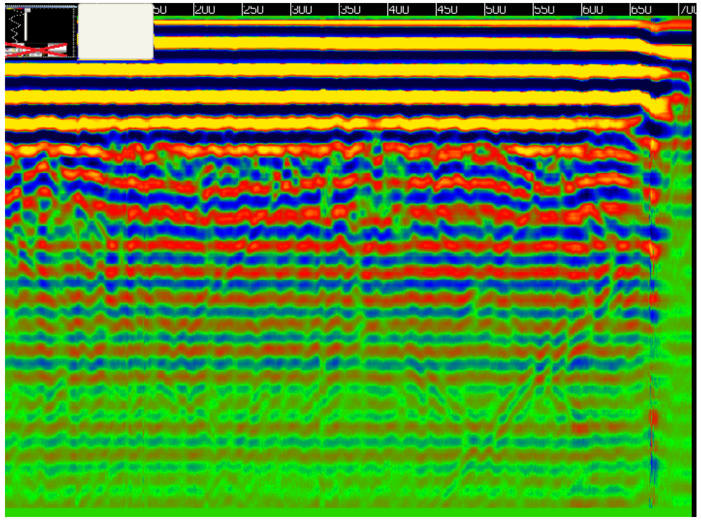
SoilWorm

SoilWorm

SoilWorm

SoilWorm





asciutto **umido**

See you …

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- @iXemOrg
- @iXemLabs
- @Ludwig_dG

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