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Modeling of Through-The-Snow electric field propagation for rescue systems

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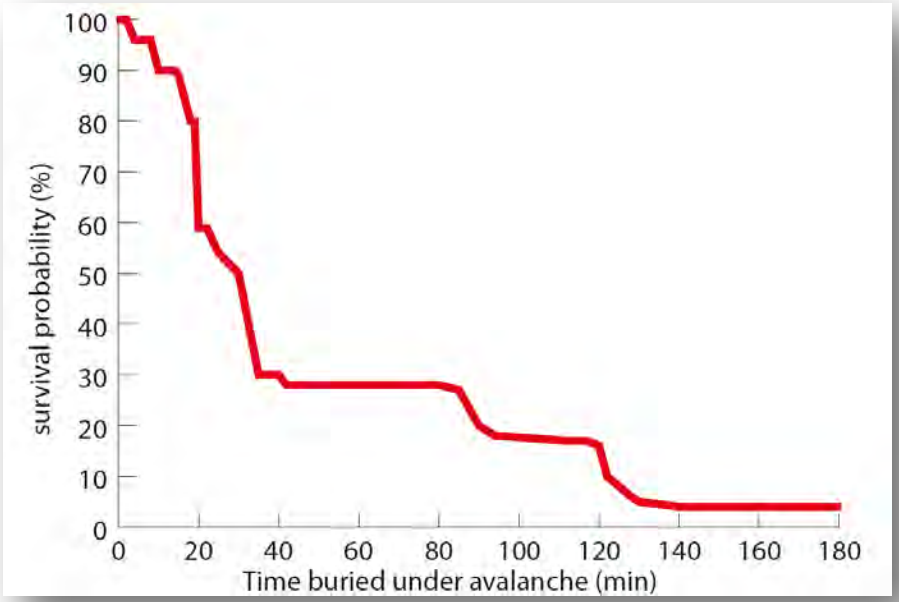
GTE U.Z.

Outline

- Introduction
- Problem description
- Snow cover signal propagation model
- Field tests
- Experimental results
- Conclusions and future work

Motivation

- More than 150 lives worldwide every year by snow avalanches
- Burial time is crucial



M. Falk, M. Brugger, and L. Adler-Kastner, Avalanche survival chances, Nature, 368 (1), 21, 1994

Avalanche rescue systems

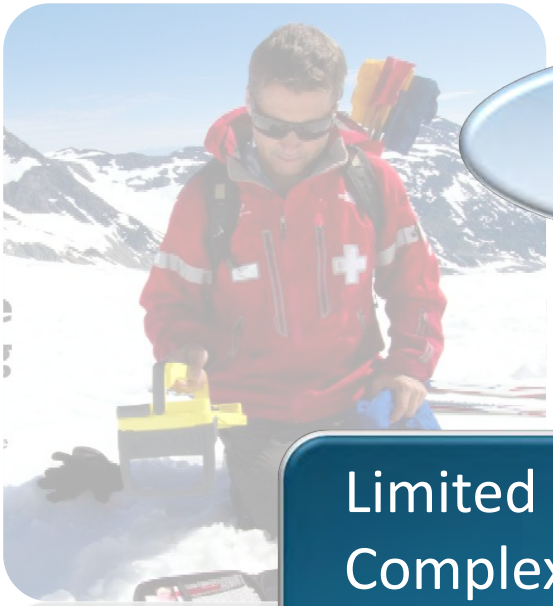
RECCO®

Avalanche beacons

Avalanche rescue systems

RECCO®

Avalanche beacons



Problems

Limited in range an accuracy
Complex usage
Training required

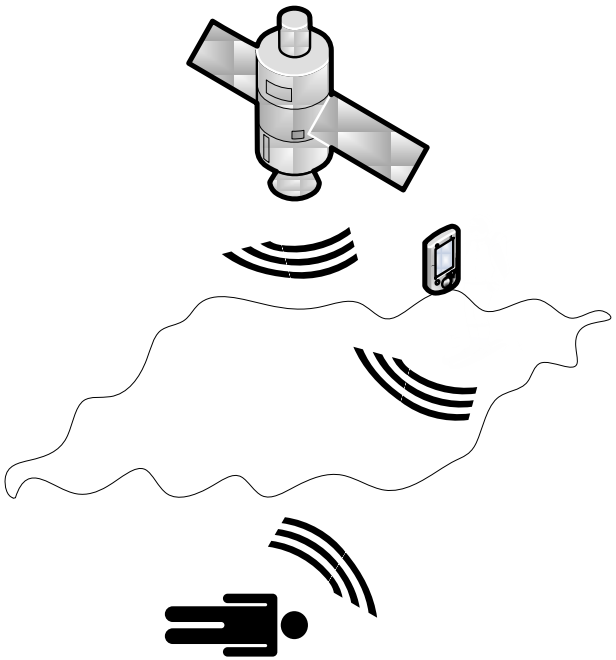
GPS and communications in rescue systems

GPS

- Transmission of victim location
- Commercial system (PIEPS Vector)

Data communications

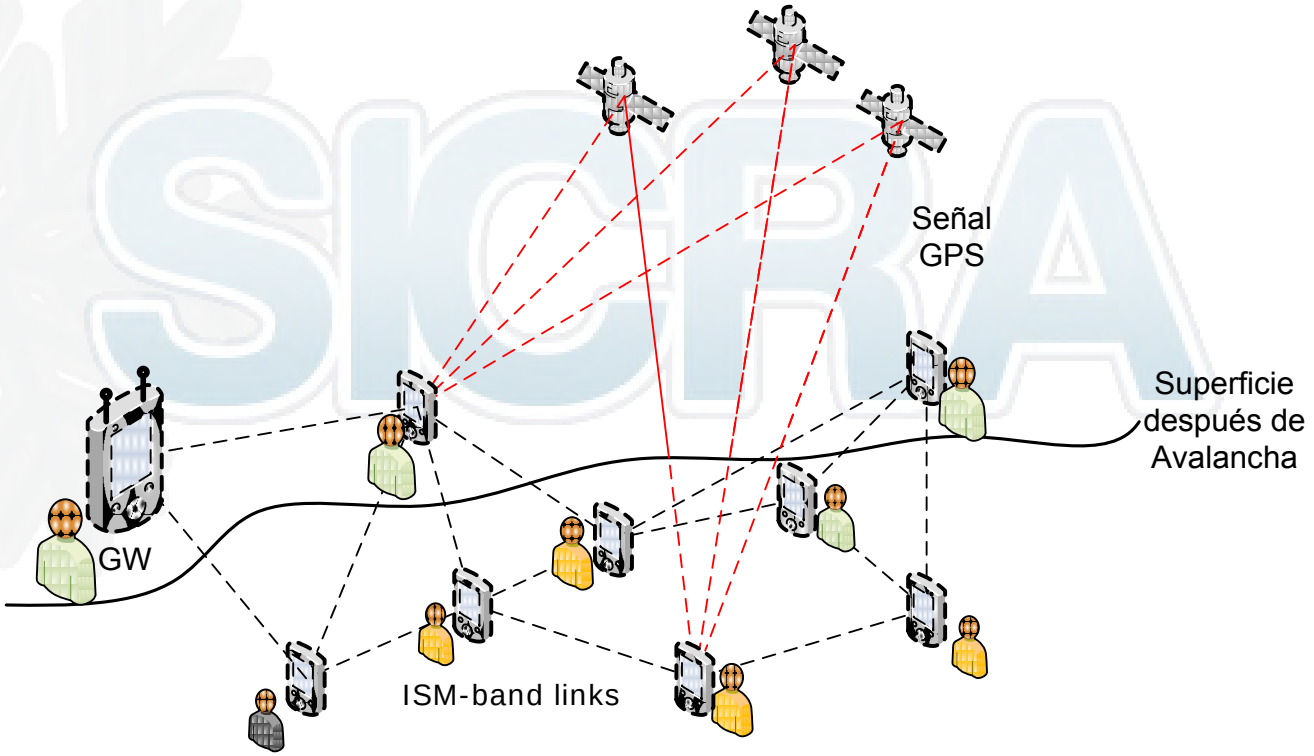
- Location, orientation or vital signs
- Commercial systems (PULSE, ARVA-LINK)



Zona de la avalancha – Asistencia de GNSS para la detección e identificación de accidentados

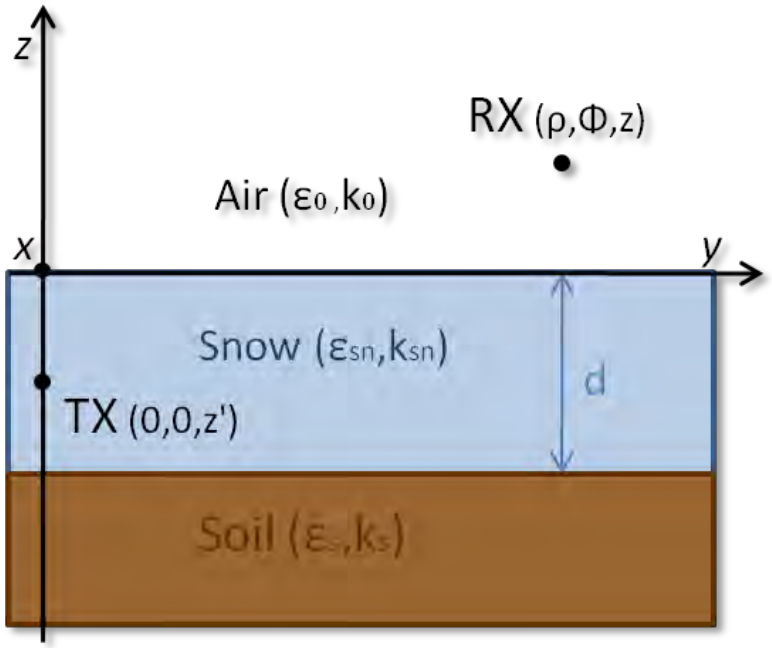
SICRA project

Cooperative System for Rescue in Avalanches



Problem description

Vertical electric dipoles TX and RX



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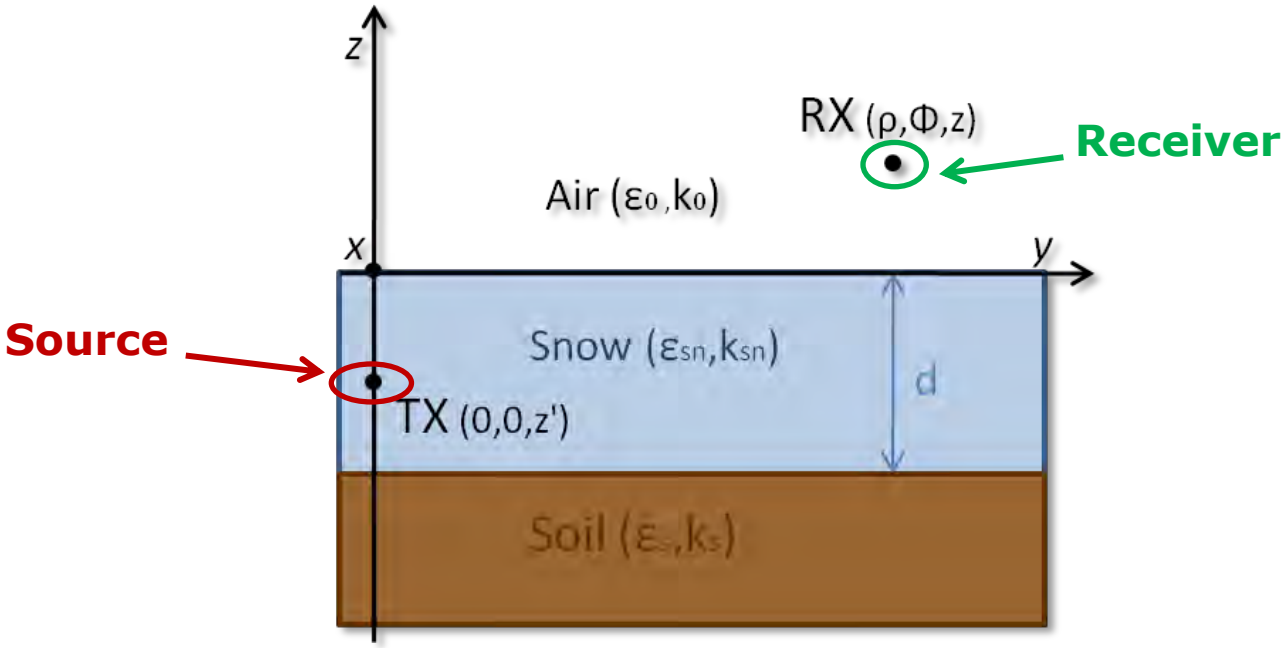
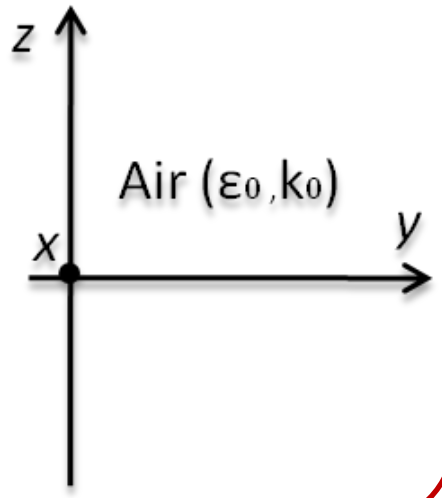


Propagation models

Air model

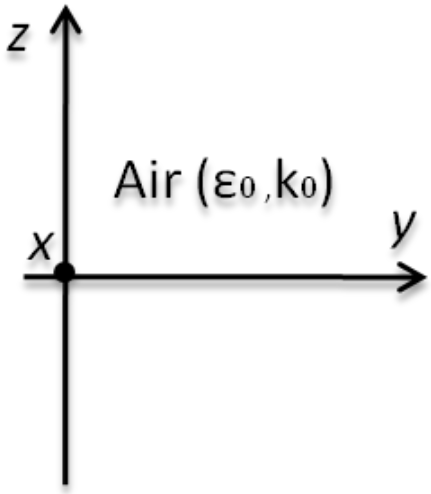


Snow model

Three layered model

Propagation models

Air model



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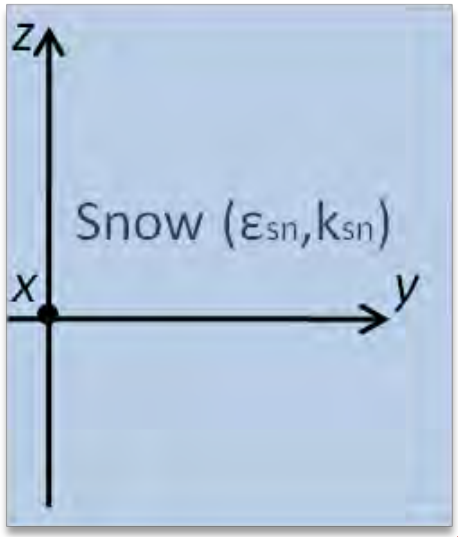

Three layered model

Propagation models

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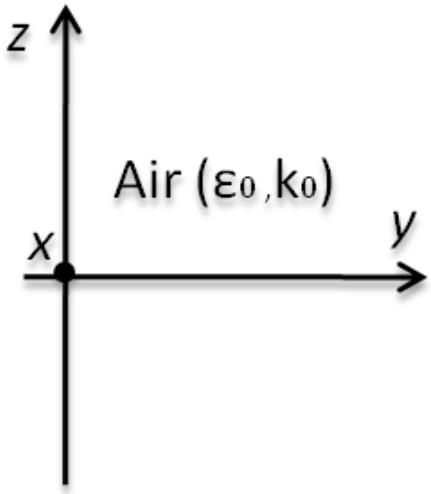

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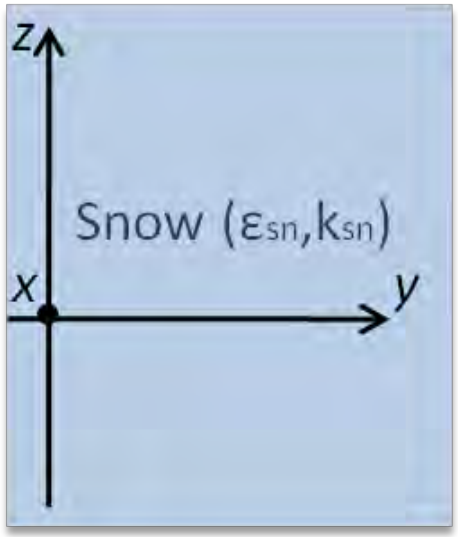
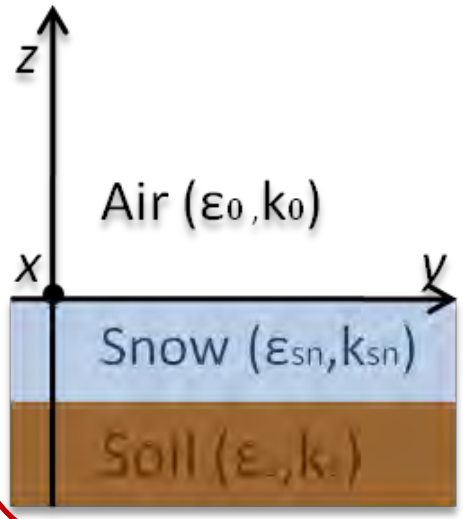


Three layered model



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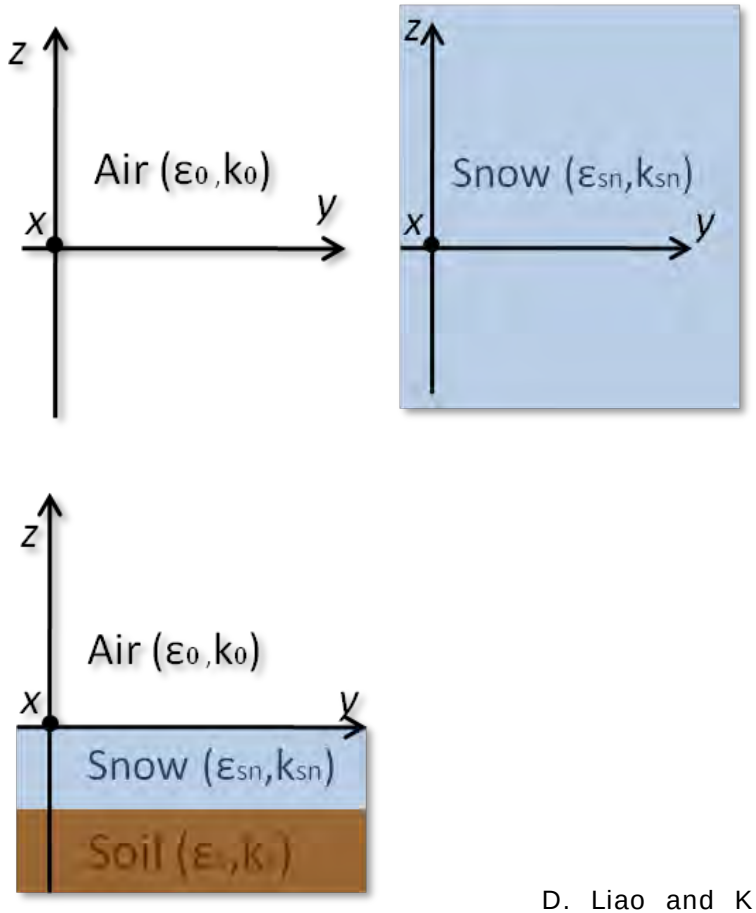
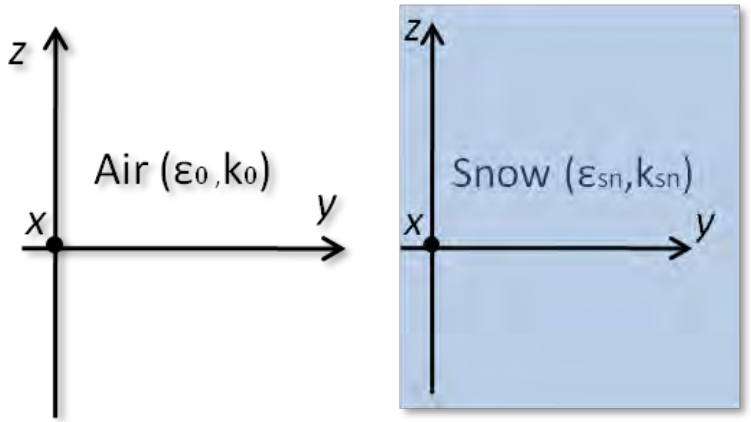
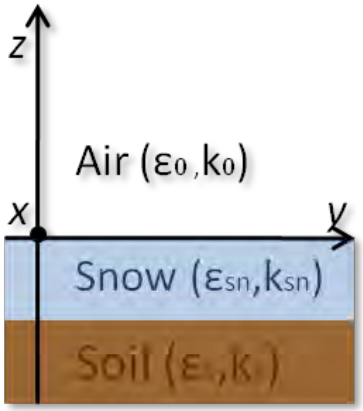


D. Liao and K. Sarabandi, Near-Earth Wave Propagation Characteristics of Electric Dipole in Presence of Vegetation or Snow Layer, *IEEE Transactions on Antennas and Propagation*, 53 (11), 2005

Propagation models



$$E_{zz} = \frac{j\omega\mu_0 I_0 l_z e^{jk_i\rho}}{4\pi\rho} \text{ (V/m)}$$



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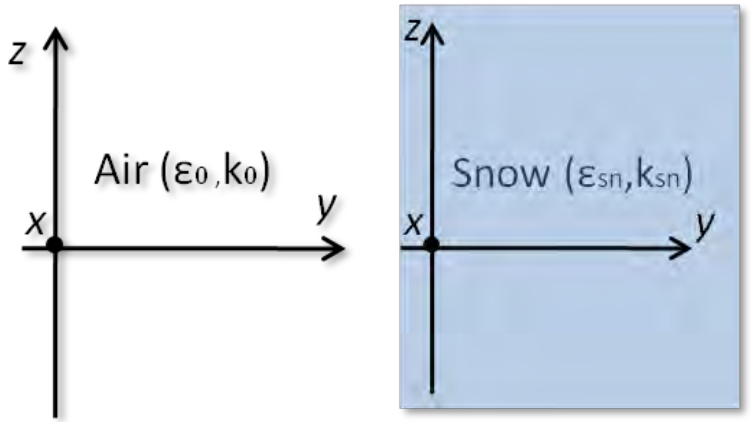

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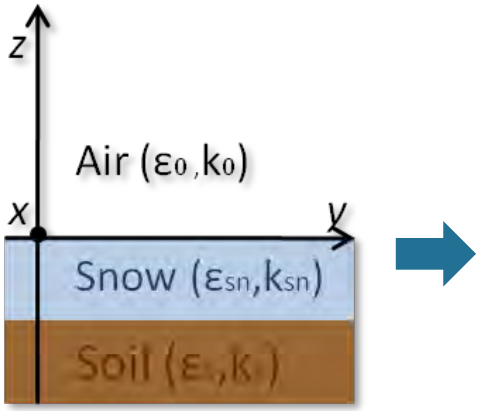


$$E_{zz} = -\frac{\omega\mu_0 I_0 l_z}{8\pi}\int_0^\infty f_{zz}(k_\rho)e^{jk_{oz}z}dk_\rho \text{ (V/m)}$$

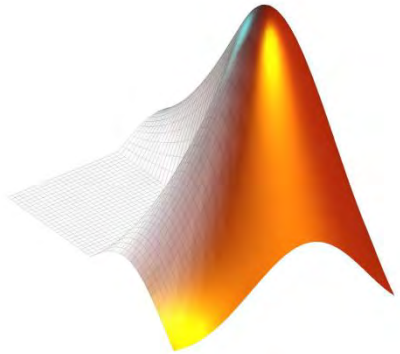
D. Liao and K. Sarabandi, Near-Earth Wave Propagation Characteristics of Electric Dipole in Presence of Vegetation or Snow Layer, *IEEE Transactions on Antennas and Propagation*, 53 (11), 2005

Solving methods

Numerical solution of exact propagation expressions (MATLAB)

Geometrical optics

Finite element method (COMSOL)



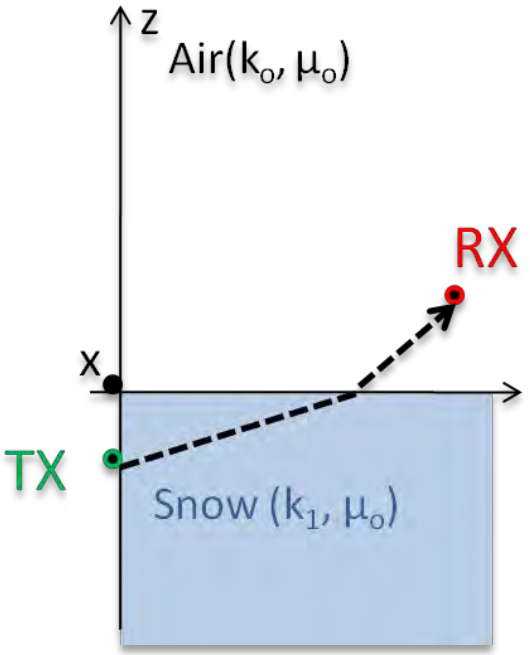
```
er1=2.72+j*0.02;

% SUELO
sig2=30e-6;
%er2=24+j*sig2/w/eps0;
%er2=10.3532 + 0.3743*j;     %suelo
%er2=25.9421 + 1.0825*j;     %suelo
er2=17.3522 + 0.6520*j;     %suelo 3
%er2=8+j*sig2/w/eps0;

% CONSTANTES DE PROPAGACION EN CADA
k0=w*sqrt(eps0*mu0);
k1=k0*sqrt(er1);
k2=k0*sqrt(er2);
k0=k0+j*1e-6;

% DISTANCIAS en más detalle los primeros metros
D=logspace(log10(2),log10(80),100);

% Factor delante de las integrales
F=w*mu0*I0*Ldip/(8*pi);

Ez1=zeros(1,100);
Ez2=zeros(1,100);
Prx1=Ez1;
Prx2=Ez2;
for n=1:100
    rho=D(n);

    % CAMPO DIRECTO
    %Ezd=1i*w*mu0*I0*Ldip*exp(1i*k0*rho)/(4*pi*rho);
    Ezd=(j*w*mu0*I0*Ldip*exp(j*k0*rho)/(4*pi*rho*(k0^2)))*((k0^2-((j*k0)/rho)-1/(rho^2))-((z-zpr)^2)*((k0/

    % PROPAGACIÓN EN ESPACIO LIBRE
    Ez0(n)=Ezd;
```

Solving methods

Numerical solution of exact propagation expressions (MATLAB)

Geometrical optics

Finite element method (COMSOL)



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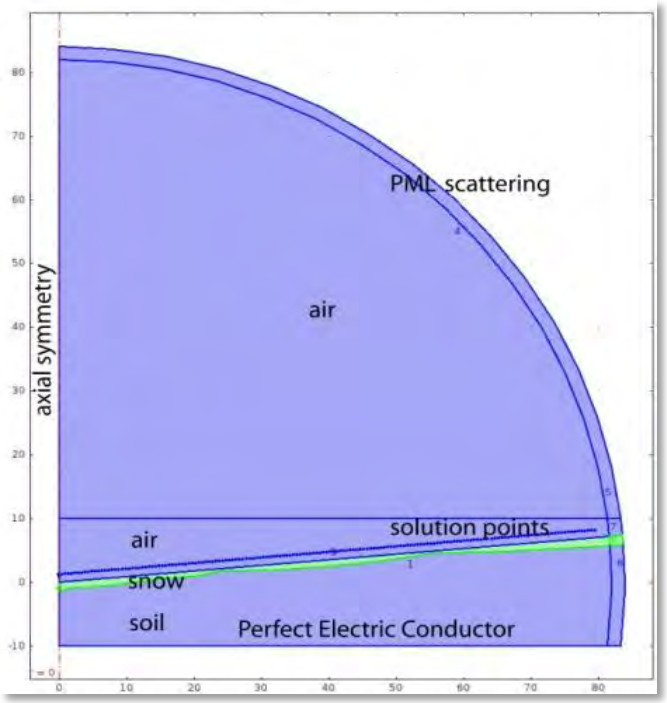
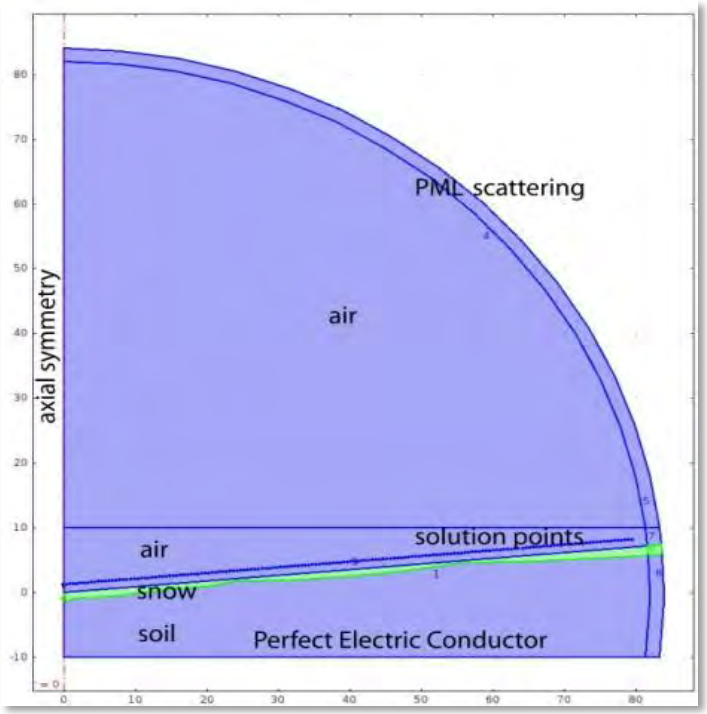


COMSOL model



2D axialsimetry

Truncated geometry

- Perfect match layers
- Scattering boundary conditions

Underlying soil truncated

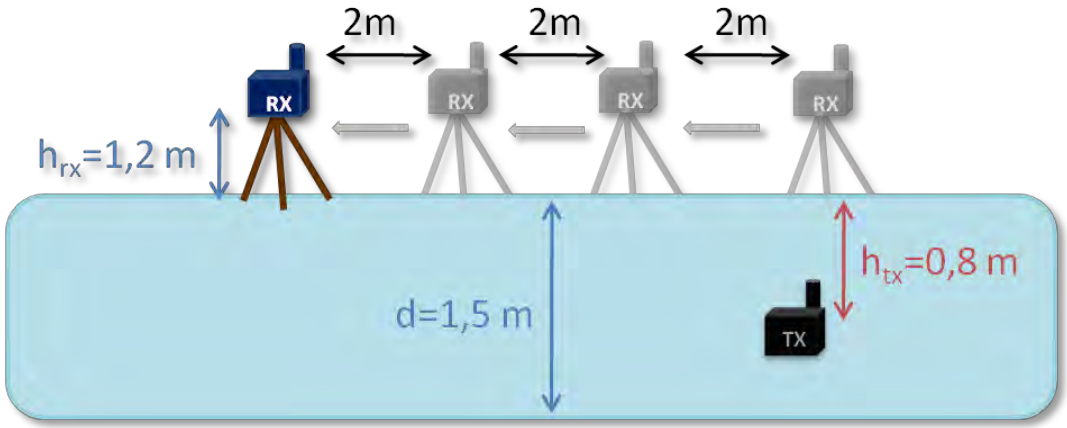
- Perfect electric boundary condition

Magnetic current point

Solution points

Field test

Formigal Ski Resort (Huesca, Spain)



- RF-explorer module (433 MHz)
- IEEE 802.11 node (2.45 GHz)

Field test

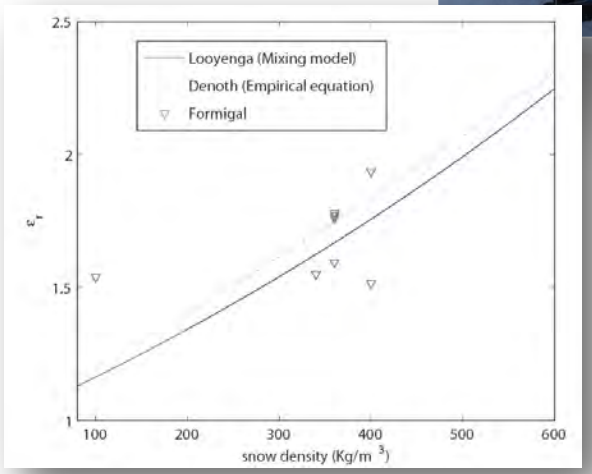
Snow and soil characterization by TDR

- **Measured parameters**

Medium	433 MHz	2.45 GHz
Snow	2.72-j0.02	2.69-j0.1
Soil	10.35-j0.37	5.26-j0.58

- **Simulated parameters**

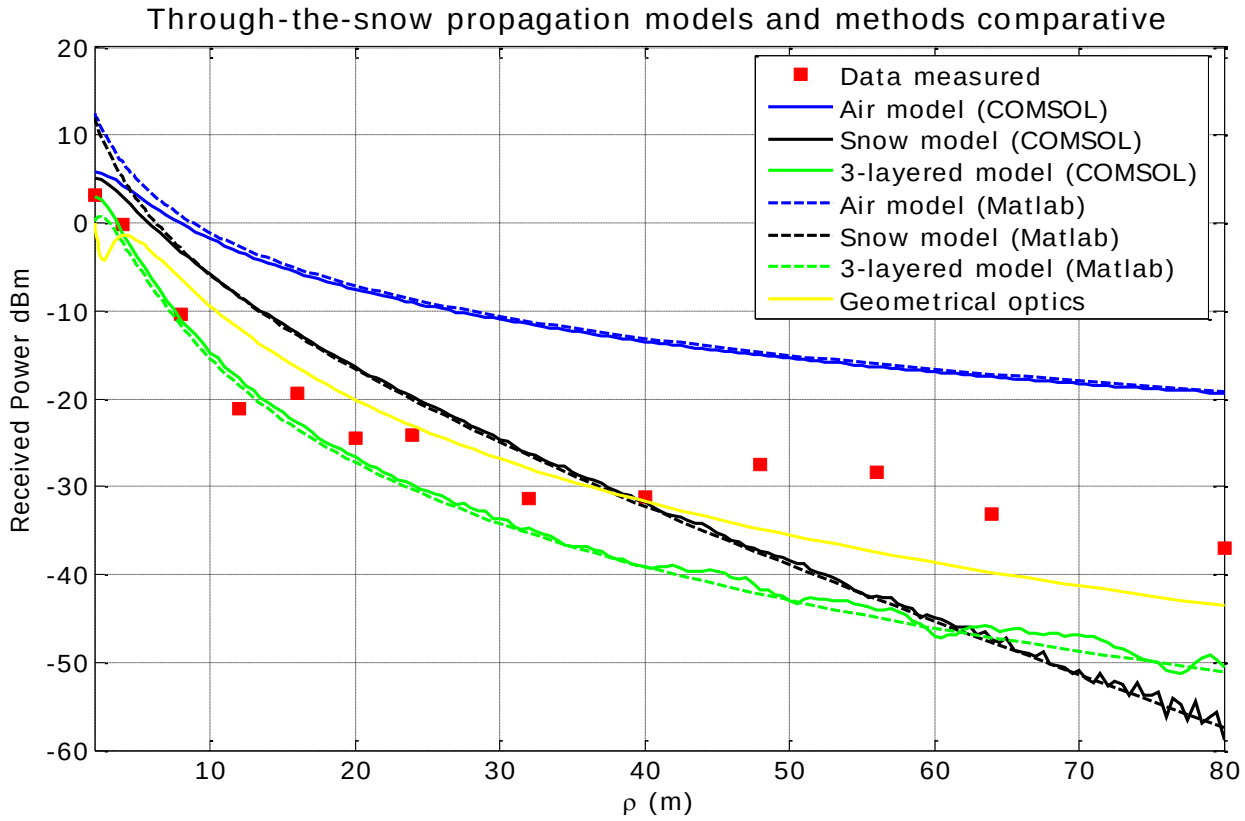
Medium	433 MHz	2.45 GHz
Dry snow	1.129-j0.0001	1.12-j0.0001
Wet snow	3.37-j0.0324	3.2-j0.067
Dry soil	17.35-j0.693	3.33-j0.172
Wet soil	35.64-j1.523	9.98-j1.76



H. Looyenga, Dielectric constants of heterogeneous mixtures, *Physica*, 31,401-406, 1965

Experimental results

Through-the-snow propagation models at 433 MHz



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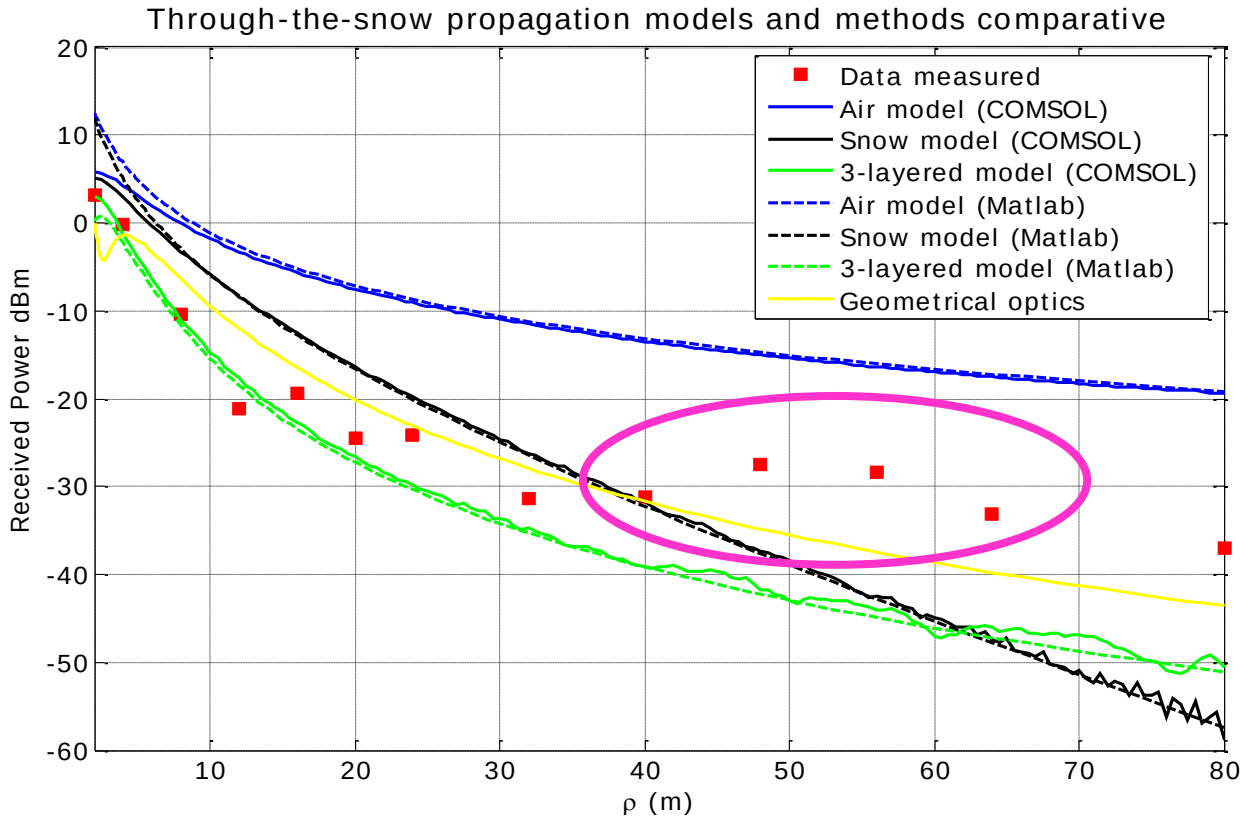
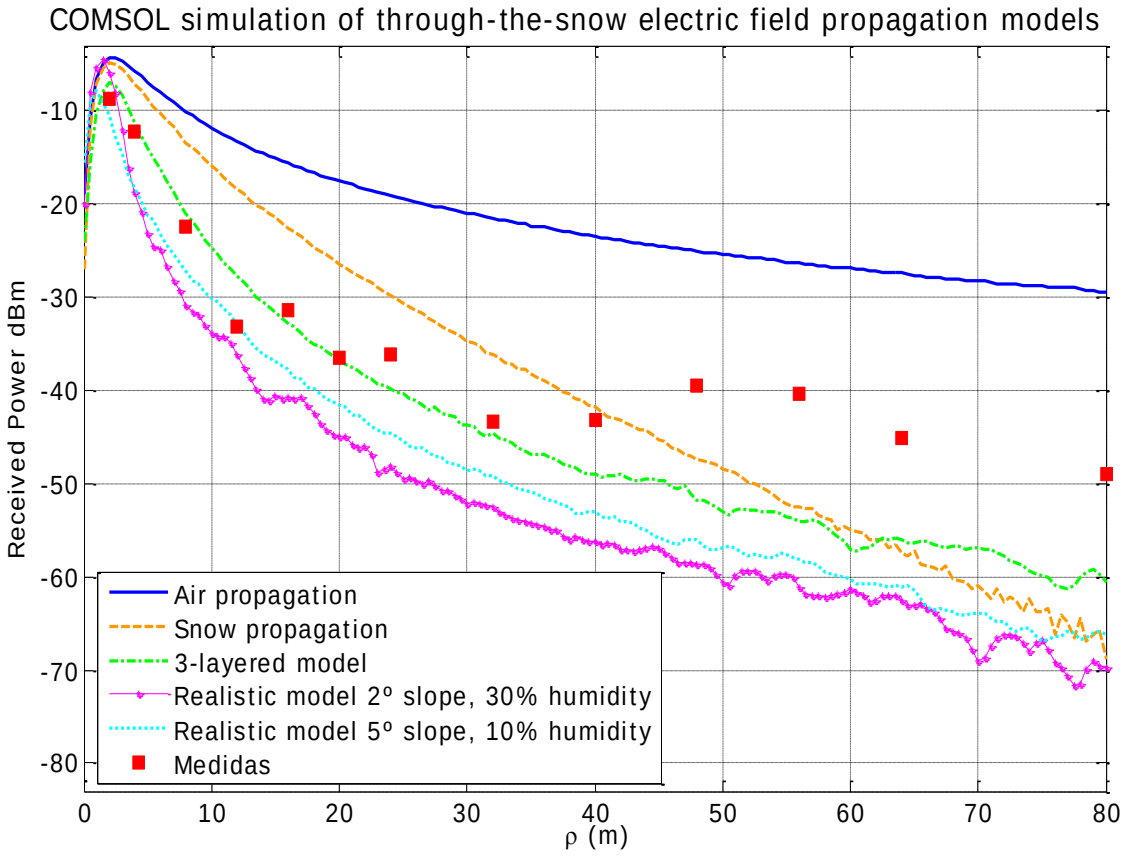


Experimental results (II)

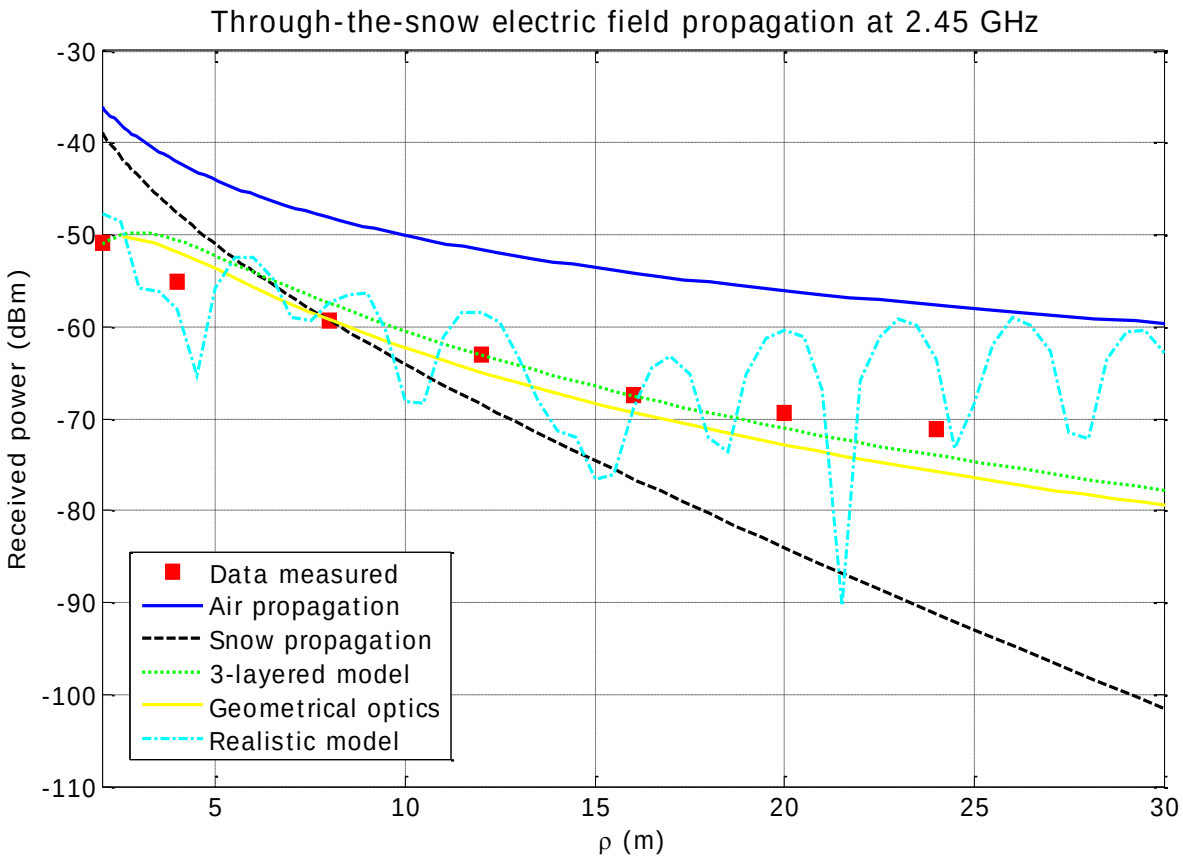
Realistic COMSOL model

- Snow depth
- Soil slope
- Soil humidity



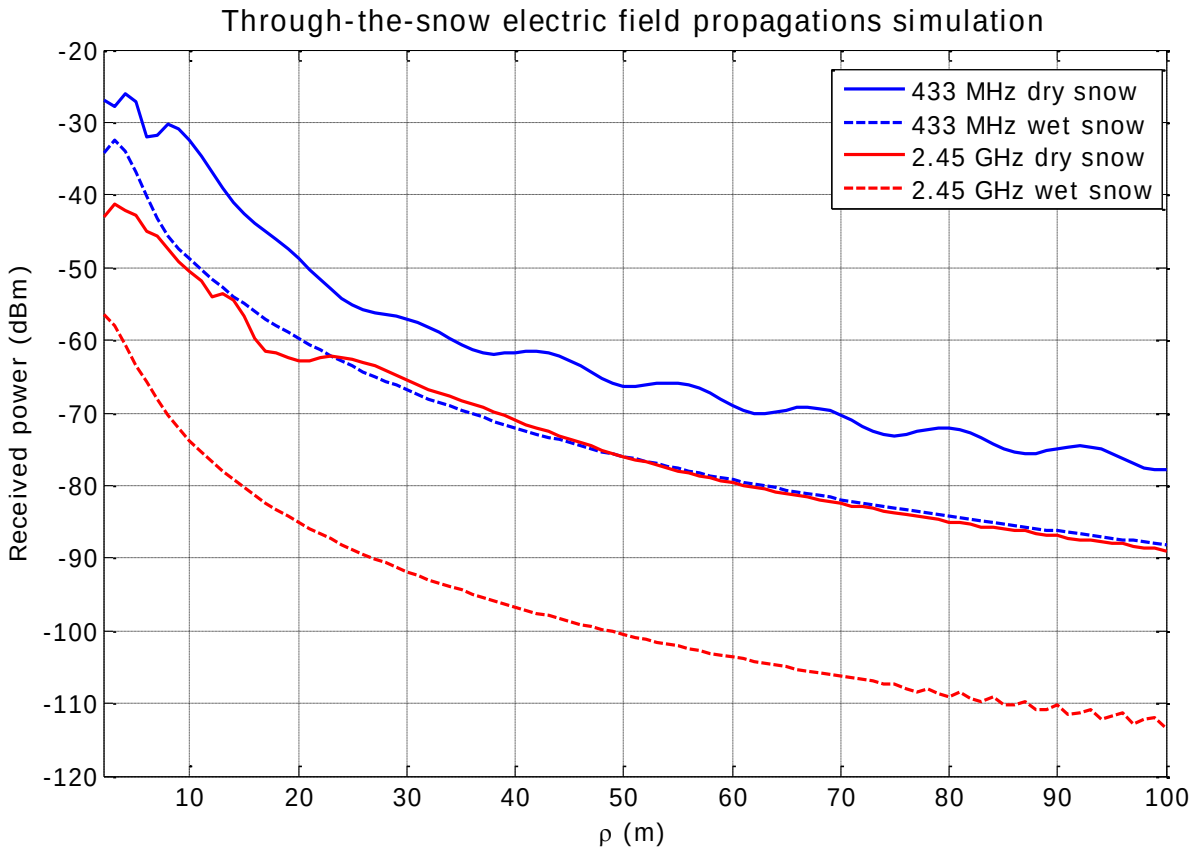
Experimental results(III)

Through-the-snow propagation models at 2.45 GHz



Experimental results(IV)

Through-the-snow propagation comparative



Conclusions and future work

Conclusions

- **Channel model for through-the-snow propagation**
- **Realistic model in COMSOL**
- **433 MHz vs 2.45 GHz**
  - Lower snow attenuation
  - Lower sensibility to snow conditions

Future work

- **3D COMSOL model with digital terrain map**
- **Different dipole orientations**
- **Field tests with more controlled soil topology**

Thank you for your attention

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