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L-Band emission of rough surfaces: comparison between experimental data and different modeling approaches

H. Lawrence[1,2], F. Demontoux[1], J.-P. Wigneron[2], A. Mialon[3], T.D. Wu[4], V.L. Mironov[5], L. Chen[6], J.-C. Shi[6], Y. Kerr[3]
heather.lawrence@ims-bordeaux.fr
[1]MCM department, IMS Laboratory UMR 5218, University of Bordeaux 1, France , [2]INRA-EPHYSE Laboratory, Villenave d'Ornon, France, [3]Centre d'Etudes Spatiales de la Biosphère (CESBIO), Toulouse, France, [4]Department of Electrical Engineering National Taiwan Ocean University, Keelung, Taiwan, [5]Kirensky Institute of Physics, Siberian Branch, Russian Academy of Sciences, Russia, [6]Institute for Computational Earth System Science, University of California, Santa Barbara, USA

Introduction

SMOS Mission

The SMOS mission will measure the brightness temperature, T_B, at 1.4 GHz in order to retrieve soil moisture over land and salinity over oceans. The soil moisture will be retrieved using an algorithm based on the LMEB (L-Band Microwave Emission of the Biosphere) model.

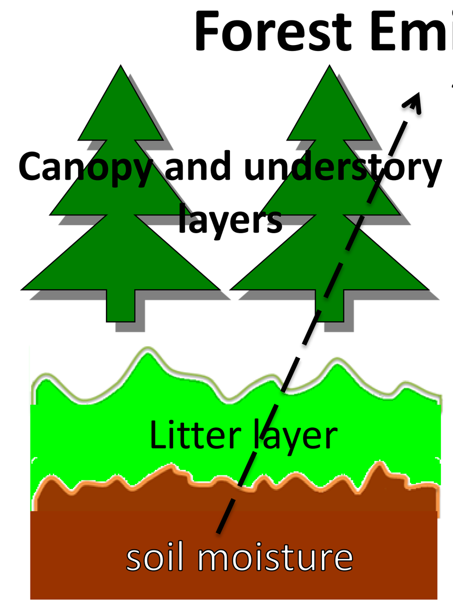
Brightness Temperature:

In the microwave region, the Rayleigh-Jeans approximation applies:

$T_B = eT_o$ — T_B=brightness temperature, T_o=ground temperature, e= system emissivity

In forests the soil emission is affected by many different layers

Forest Emission



T_B measured by SMOS

CANOPY
τ- ω model
LITTER ROUGHNESS
?
LITTER
?
SOIL ROUGHNESS
Q/H model
SOIL LAYER
Dobson model
Mironov model

What effect does the litter layer and surface roughness have on the signal from the ground?

Objectives

1. Create a 3D numerical model that calculates the emissivity of the 2-layer soil-litter system as a function of many different parameters, including surface roughness, soil moisture, layer depth, angle and polarization.

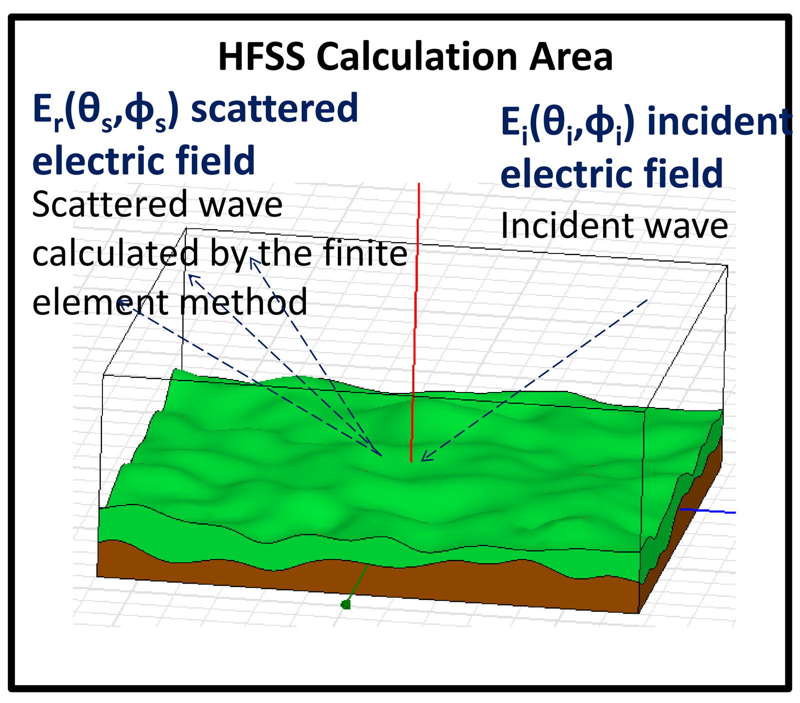
2. Validate this model by comparing against known methods, such as the Method of Moments, as well as experiments.

3. Use this model to study the L-Band emission of the soil-litter system in order to develop and validate the SMOS mission LMEB inversion algorithm over forests.

Numerical Modeling Approach based on the Finite Element Method

Model Set-Up

Using Ansys' HFSS software:



Randomly Rough surfaces
- Created using R software©
- measurement profiles

Soil and Litter moistures inputted as a function of the permittivity constant. This relationship is found using the Mironov model (soil) or measurements (soil,litter)

Boundary conditions

Radiation conditions at the sides and top and layered impedance on the bottom, to prevent edge effects

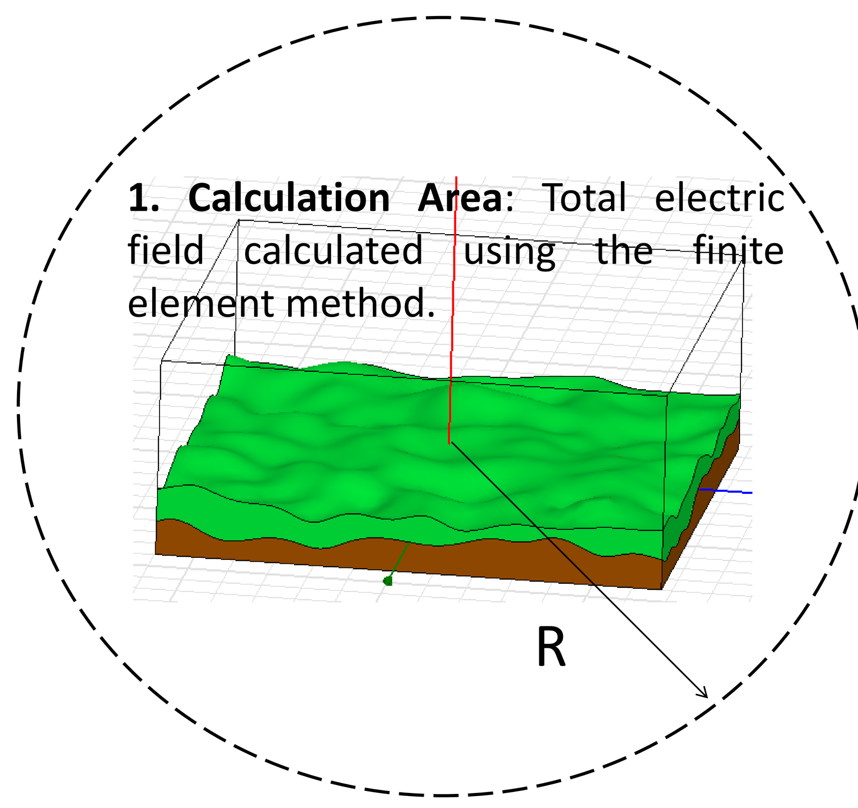
Further Applications: Heterogeneous Media

This set-up can be extended to model heterogeneous media relatively easily, including for example multiple layers and inclusions.

Future Development

Currently working on the integration of a continuous moisture gradient

Calculation and Results Analysis



1. Calculation Area: Total electric field calculated using the finite element method.

2. Near-to-Far Field transformation: The scattered electric field is calculated in the far-field region, at a distance R from the surface, **$E_r(\theta_s,\phi_s)$.**

3. Calculate the Emissivity from the scattered field, $E_r(\theta_s,\phi_s)$, averaged over approximately 20 surfaces

1. Bistatic scattering coefficient

$$\sigma^0_{tr}(\theta_s,\phi_s;\theta_i,\phi_i) = \frac{4\pi R^2 |E_r(\theta_s,\phi_s)|^2}{A_{eff}|E_i(\theta_i,\phi_i)|^2}$$

Back scattering coefficient, $\sigma^0(\theta,\phi)$: bistatic scattering coefficient for $(\theta_s,\phi_s) = (\theta_i,\phi_i)=(\theta,\phi)$

2. Reflectivity

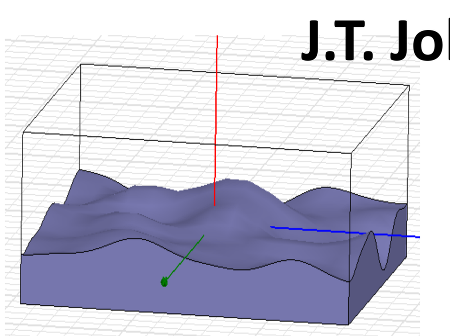
$$\Gamma = \iint_{\substack{Upper \\ Hemisphere}} \frac{\sigma^0_{tr}+\sigma^0_{rr}}{4\pi\cos\theta} d\Omega_s$$

3. Emissivity

$$e(\theta,\phi) = 1-\Gamma_r(\theta,\phi)$$

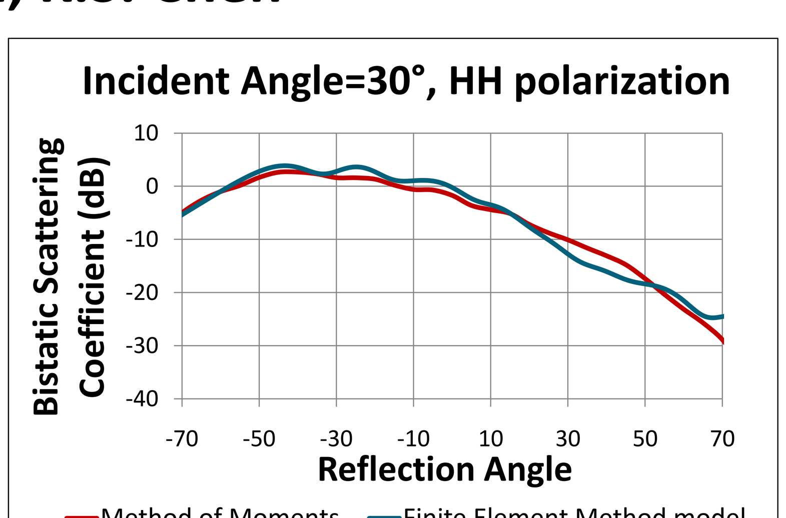
Model Validation: A bare soil layer with a rough surface

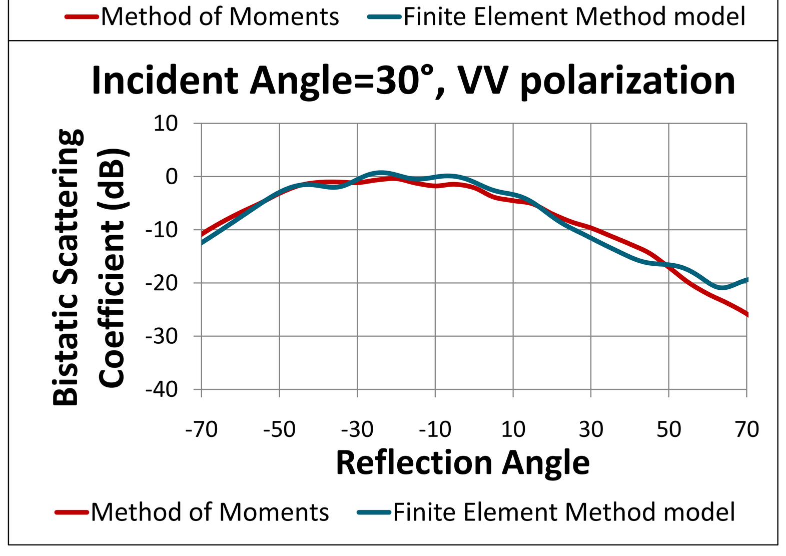
Validation against Method of Moments ref. H.T. Ewe, J.T. Johnson, K.S. Chen[1]



Calculation Conditions

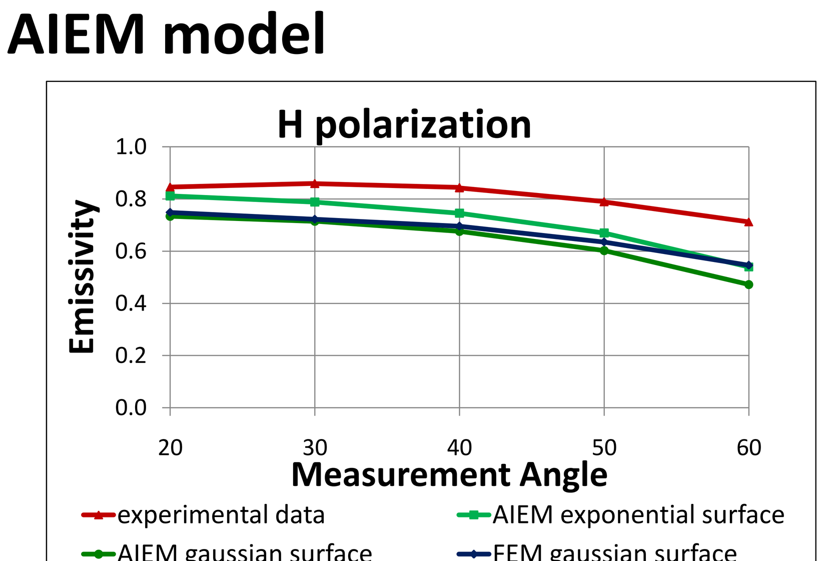
Frequency	1.4 GHz
[kσ, klc]	[1, 6]
number of surfaces	14
surface size	1.27m x 1.27m
number of points on a surface	128 x 128
Relative permittivity constant	4+1j
Gaussian wave constant, g	0.4m

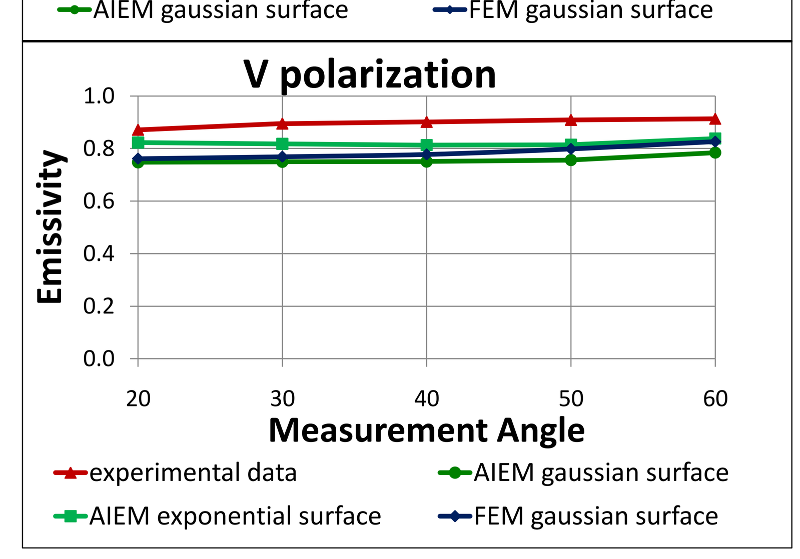




Comparison with experimental data SMOSREX 2006 and the AIEM model

30% soil moisture
σ = 2.8 cm
L_c = 7.1cm
Gaussian/ Exponential autocorrelation functions





[1]"A Comparison Study of the Surface Scattering Models and Numerical Model" Presentation, IGARSS 13 July 2001

Conclusions and Perspective

- Good agreement between results of the Method of Moments and the Numerical Model based on the Finite Element Method

Next Steps:

- Validate the model for a two layer soil-litter system, comparing against measurements
- Create a database of the emissivity of the soil-litter system in forests, to be used to develop and validate the LMEB model for forests