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Numerical modeling of the L-Band emission and scattering of a rough soil layer covered with a grass litter layer- consideration of Moisture and Temperature gradients

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ABSTRACT - *We have developed a new approach for the calculation of rough surface scattering and emission at L-band. It has recently been validated for the case of scattering from a single layer rough surface of Gaussian autocorrelation function. This approach relies on the use of ANSOFT's numerical computation software HFSS (High Frequency Structure Simulator), which in turn solves Maxwell's equations using the Finite Element Method (FEM). The interest of this approach is that it can be extended to calculate the emission of complicated multilayer media, including features such as volume effects, gradients effects and inclusions, as well as rough surfaces. This is therefore especially useful for the problem of the emission from soil-litter systems in forests.*

In this paper we present the work we done to use FEM method to compute thermal effects and water infiltration effects in ground. Coupling electromagnetic and thermal computation we will be able to study scattering of media such as permafrost or effects of rapid changes in temperature condition. It can be very useful for global observations with a frequent repeat coverage (future NASA Soil Moisture Active/Passive mission SMAP). In the present study we present water infiltration in ground effects (as moisture gradients) on the emissivity and bi-static coefficient of soil.

1. INTRODUCTION

In the context of the European Space Agency's (ESA) Soil Moisture and Ocean Salinity (SMOS) mission, we present a study of the emission of rough surfaces at 1.4 GHz and the effects on this emission of a grass litter layer covering the surface. Surface roughness has been studied in some depth in the literature as it is a key influencing parameter on ground emission. A litter layer has also been shown to greatly affect the L-band emission of forests, making it difficult to retrieve soil moisture from space-based radiometer measurements over forests, [1] - [2], but the effects of this layer on the overall forest emission have been little investigated and are not yet well understood.

A new approach for the calculation of rough surface scattering and emission at L-band has recently been validated for the case of scattering from a single layer rough surface of Gaussian autocorrelation function [3], [4]. This approach relies on the use of ANSOFT's numerical computation software HFSS (High Frequency Structure Simulator), which in turn solves Maxwell's equations using the Finite Element Method (FEM). The interest of this approach is that it can be extended to calculate the emission of complicated multilayer media, including features such as volume effects, gradients effects and inclusions, as well as rough surfaces. This is therefore especially useful for the problem of the emission from soil-litter systems in forests.

We have validated this numerical approach and demonstrated its capability of calculating the L-band emission of the soil-litter forest system [5]. To do this we have compared results of the approach with experimental emissivity data, firstly for the case of the emissivity of a bare soil with a rough surface

In this paper we present the work we done to use FEM method to compute thermal effects and water infiltration effects in ground. Coupling electromagnetic and thermal computation we will be able to study scattering of media such as permafrost or effects of rapid changes in temperature condition. It can be very useful for global observations with a frequent repeat coverage (future NASA Soil Moisture

Active/Passive mission SMAP). In the present study we present water infiltration in ground effects (as moisture gradients) on the emissivity and bi-static coefficient of soil.

2.METHOD

In the context of active and passive remote sensing analysis of soil, the moisture and temperature gradients must be took into account.

In order to complete our model we have worked to take into account these gradients in our multi layer model of soil.

Our electromagnetic model solves Maxwell's equations using the finite element method (FEM). We also use this method to solve other equations. It enables the creation of moisture or thermal profiles in our structures.

The process can be divided into three steps. Initially, applying boundary conditions to our structures, we solve the equations related to thermal phenomena or diffusion of water in our layers. This resolution achieves to the creation of a 3D numerical meshing of the multilayer structure profiles (temperature or moisture).

The second step deals with the replacement the moisture and temperature variables in each cell of the system by the permittivity of the material according to the temperature or moisture value. This is possible using the curves of permittivities (Figure 1 and 2) measured in the laboratory using the wave guide experimental set-up presented in [2] or computed with estimating soil permittivity model (Mironov) [6] [7].

The last step deals with the integration of these permittivity profiles (Figure 3 and 4) in our model to solve Maxwell's equations. This allows us to calculate the emissivity or the bi-static coefficients of the structures.

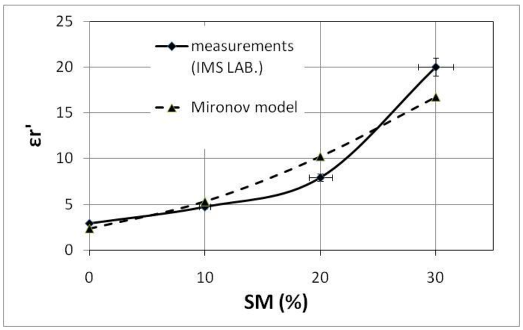

Fig 1 : Real part of the permittivity vs SM(%) Measurement and Mironov model computation

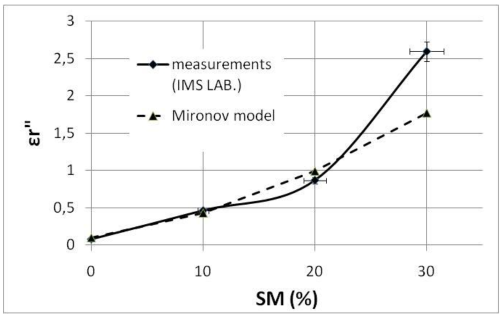

Fig 2 : Imaginary part of the permittivity vs SM(%) Measurement and Mironov model computation

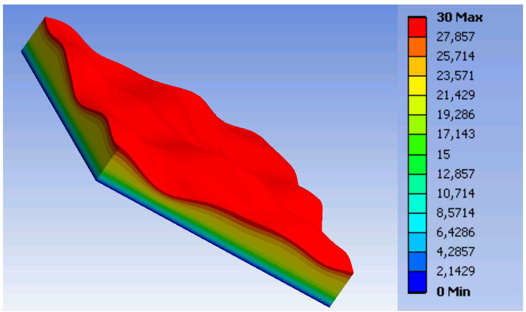

Fig 3 : Soil moisture profile 1 introduced in the model. Surface soil moisture = 30 % - Deep soil moisture [15cm] = 0%

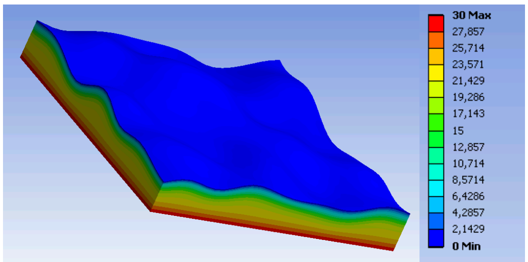

Fig 4 : Soil moisture profile 2 introduced in the model. Surface soil moisture = 0 % - Deep soil moisture [15cm] = 30%

3.RESULTS

To present the first results of our approach we focus in this paper with the study of the moisture gradients. These were created by applying moisture gradients between the soil surface and in depth of the layer (15cm). A diffusion equation yielded profiles of Figures 1 and 2. Note that these gradients are not realistic but will allow us to highlight the inclusion of profiles in our model.

Soil moisture was initially regarded as homogeneous. We calculated the bistatic coefficient and emissivity of soil from the site SMOSREX on which we had already performed validation of our model (soil texture = [17% Clay 36% Sand] Roughness [kσ = 1, kLc = 6]). The results are shown in figures 5 and 6.

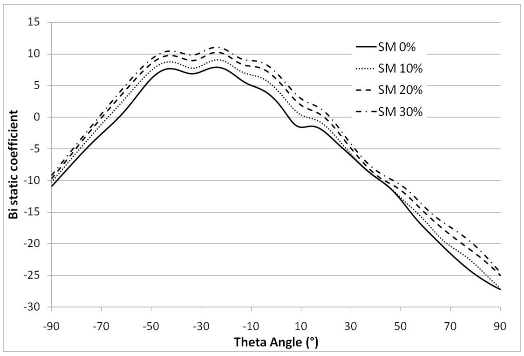

Fig 5 : Bi-static coeff. of soil layer with rough surface Frequency=1.4GHz, Incident angle phi=0° Theta=30°, Observation angle phi=0°, HH polarization, soil texture = [17% Clay, 36% Sand], Roughness [kσ=1,klc=6], Homogeneous soil temperature=25°C, Homogeneous soil moisture profile [0%,10%,20%,30%].

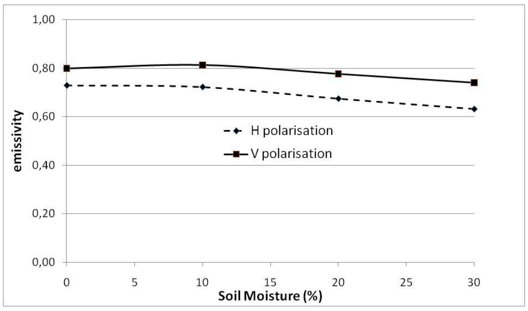

Fig 6 : Emissivity of soil layer with rough surface Frequency=1.4GHz, Observation angle phi=0°, H and V polarization, soil texture = [17% Clay, 36% Sand], Roughness [kσ=1,klc=6], Homogeneous soil temperature=25°C, Homogeneous soil moisture profile [0%,10%,20%,30%].

In a second step, the inhomogeneous soil moisture profiles were incorporated into our model. To focus on the effect of the presence of moisture gradients we have chosen to present the difference between the bi-static coefficient at moisture treated and bi-static coefficient at 0% moisture (see Figure 7). In this figure we observe the effects of moisture gradients. For profile 1 (30% for the surface moisture and 0% at 15 cm depth) the value of the bi-static coefficient computed fluctuates between the coefficients calculated for 30% and 20% moisture.

The effect is more pronounced for the profile 2 (0% for surface moisture and 30% at 15 cm depth).

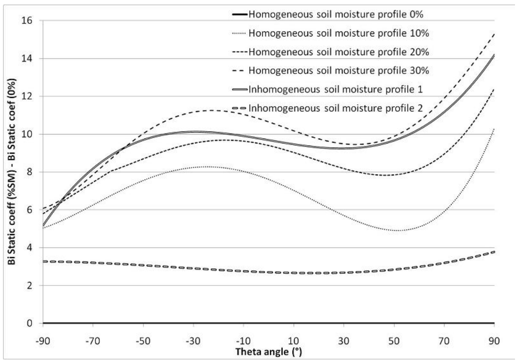

Fig 7 :Bi-static coefficient (%SM) - Bi-static coefficient (0%)
Frequency=1.4GHz, Incident angle phi=0° Theta=30°, Observation angle phi=0°, HH polarization, soil texture = [17% Clay, 36% Sand], Roughness [kσ=1,klc=6], Homogeneous soil temperature=25°C, Inhomogeneous [profile 1 & 2] and Homogeneous soil moisture profile [0%,10%,20%,30%].

4.CONCLUSION

These studies on unrealistic moisture profiles were designed to ensure correct inclusion of profiles into our model. These promising results will be followed by a validation stage. To do that, we have experimental data sets. We have moisture measurements (with the presence of gradients) and emissivities from the site of SMOSREX (nearly no temperature gradients). On the other hand, we have measurements of high temperature gradients, moisture, emissivity and bi coefficients from a measurement site in Siberian [8].

The profiles of humidity and temperature will be integrated into our model and results will be compared with experimental data to validate the introduction of moisture and temperature gradients into our model.

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