L-BAND EMISSION OF A BARE SOIL ROUGH SURFACE AND A ROUGH SOIL SURFACE COVERED WITH A GRASS LITTER LAYER: COMPARISON BETWEEN EXPERIMENTAL DATA AND A NUMERICAL MODELING APPROACH

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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. However there remains a need to further develop our understanding and modeling of its effects. 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] - [3], 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 presented, and validated for the case of scattering from a single layer rough surface of Gaussian autocorrelation function [4], [5]. 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 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 aim to further validate this numerical approach and demonstrate its capability of calculating the L-band emission of the soil-litter forest system. To do this we compare results of the approach with experimental emissivity data, firstly for the case of the emissivity of a bare soil with a rough surface and secondly for the emissivity of a slightly rough soil surface covered with a grass litter layer.

For the bare soil we compare experimental results of rough surface L-band emission from the Surface Monitoring Of the Soil Reservoir Experiment (SMOSREX) 2006 campaign [6], [7] with numerical model predictions. This is done for a soil moisture value of 30% and a range of roughness conditions, including values of standard deviation of surface heights, σ, and autocorrelation length, L_c, in the ranges σ= 5 – 35 mm and L_c= 70 – 125 mm. The permittivity value equivalent to 30% soil moisture, required as an input parameter in the numerical modeling approach, was calculated using the Generalized Refractive Mixing Dielectric Model (GRMDM) developed by Mironov et al. [8]. Numerical model calculations were performed for rough surfaces of both Gaussian and Exponential autocorrelation functions. Results show a good general agreement between the model and experimental data, with model predictions being slightly lower than experimental results. It was found that model predictions were closer to experimental results when calculations were performed for surfaces of Exponential autocorrelation function. This corresponds to previously reported results showing that natural rough surfaces tend to have autocorrelation functions that are closer to Exponential than Gaussian in form.

For the case of a slightly rough soil surface covered with a grass litter layer we compare results of the numerical approach with data from an experiment performed on the SMOSREX site, near Toulouse, France, during the period October 2009 – January 2010. The bare soil on this site, which had a slightly rough surface, was covered with a layer of dead grass. Brightness temperature measurements were then taken at 1.4 GHz, H and V polarization, and an angle of 40° using the L-band radiometer for Estimating Water In Soils (LEWIS) installed on a 13.7m tower on the site. Regular measurements of soil and litter moisture, ground temperature, litter density (weight/m^2) and soil and litter surface roughness were also taken. Calculations were then done using the numerical model for the emissivity of a two layer system for the same values of roughness and soil and litter moisture and results of this were compared with the experimental dataset. The numerical model required input values of soil permittivity and litter permittivity. Soil permittivity was calculated using the GRMDM and

litter permittivity was calculated from litter moisture using a relationship determined experimentally. This relationship was determined by measuring the permittivity of samples of litter from the SMOSREX site at different moisture values, using the wave guide experimental set-up presented in [3]. Results show good general agreement between measurements and model predictions, demonstrating the usefulness of this numerical approach as a technique to calculate the L-band emission of soil-litter layers in forests.

REFERENCES

[1] J. P. Grant, J.-P. Wigneron, A. A. Van de Griend, A. Kruszewski, S. Schmidl Søbjærg, and N. Skou, "A field experiment on microwave forest radiometry: L-band signal behaviour for varying conditions of surface wetness," *Remote Sens. Environ.*, vol. 109, no. 1, pp. 10–19, Jul. 2007.

[2] M. Schwank, M. Guglielmetti, C. Mätzler and H. Flühler, "Testing a new model for the L-band radiation of moist leaf litter," *IEEE Trans. Geosci. Remote Sensing* 46 (7), pp. 1982-1994, Jul. 2008

[3] F. Demontoux, B. Le Crom, G. Ruffié, J.P. Wigneron, J.P. Grant, V.L. Mironov and H. Lawrence, "Electromagnetic characterisation of soil-litter media: Application to the simulation of the microwave emissivity of the ground surface in forests," *EPJ Applied Physics*, vol. 44, no. 3, pp. 303-315, Dec. 2008

[4] H. Lawrence, F. Demontoux, J.-P. Wigneron, P. Paillou, T.-D. Wu and Y. H. Kerr, "A New Numerical Approach for Modeling the 3-Dimensional Scattering and Emission of a Rough Surface," *submitted IEEE Trans. Geosci. Remote Sensing Lett., Oct. 2009*

[5] H. Lawrence, F. Demontoux, J.-P. Wigneron, Y. Kerr, T.-D. Wu, P. Borderies, P. Paillou, L. Chen and J.-C. Shi, "Modeling the Effect of surface roughness on the back-scattering coefficient and emissivity of a soil-litter medium using a numerical model,"proc. Igarss 2009

[6] P. de Rosnay, J. Calvet, Y. Kerr, J. Wigneron, F. Lemaître, M. Escorihuela, J. Sabater, K. Saleh, J. Barrié, G. Bouhours et al., "SMOSREX: A long term field campaign experiment for soil moisture and land surface processes remote sensing," *Remote Sens. Environ.*, vol.102 (n 3-4), pp. p377-389, 2006.

[7] A. Mialon, J.-P. Wigneron, P. de Rosnay, M.J. Escorihuela, Y. Kerr, “Continuous monitoring of surface roughness changes over a bare soil field using L band brightness temperature”, *presentation Microrad* 2008

[8] V.L. Mironov, L.G.Kosolapova, and S.V. Fomin, "Physically and Mineralogically Based Spectroscopic Dielectric Model for Moist Soils," *IEEE Trans. Geosci. Remote Sens.*, vol.47, no.7, pp.2059-2070, July 2009.