STUDY OF MAIZE PLANTS EFFECTS IN THE RETRIEVAL OF SOIL MOISTURE USING THE INTERFERENCE PATTERN GNSS-R TECHNIQUE

N. Rodriguez-Alvarez[§], A. Camps[§ρ], M. Vall-llossera[§ρ], A. Aguasca[§], X. Bosch-Lluis[§], R. Acevo[§], I. Ramos-Perez[§], E. Valencia[§], J. F. Marchan-Hernandez[§]

[§]Remote Sensing Lab, Dept.Teoria del Senyal i Comunicacions, D3, Universitat Politècnica de Catalunya and IEEC CRAE/UPC, 08034 Barcelona, Spain.
[ρ]SMOS Barcelona Expert Centre. Pg. Marítim de la Barceloneta 37-49, 08003 Barcelona, Spain
Tel. +34+934017362, E-mail: nereida@tsc.upc.edu

The use of Global Navigation Satellite Signals Reflections (GNSS-R) techniques to retrieve geophysical parameters from surfaces has been increased in the recent years. These techniques have resulted in suitable tools to obtain information about the sea state of oceans, which is very useful to improve the ocean salinity retrieval [1-3], and also, information about the soil moisture [4-6] of lands.

The present work focuses on the use of the Interference Pattern Technique (IPT) [7-9], a particular type of GNSS-R technique, to study vegetation-covered soils. The IPT consists mainly of the measurement of the interference pattern between the GPS direct and reflected signals, after they impinge over the ensemble soil surface and vegetation layer. The measured interference signal provides information on the soil moisture of the surface and also, on the vegetation height. A previous study [10], showed that this kind of retrievals can be performed over wheat and barley fields, where plants reach 60 cm height and their dominant structure is vertical. This work presents the results for maize-covered fields whose height reaches up to 250 cm and their structure is mostly vertical, but also due to the long leaves, they have a significant horizontal component, they are density packed, and the vegetation water content is higher.

The paper is divided in three main parts. First the theoretical aspects of the IPT measurements over a maize scenario are presented. To develop these theoretical points it is necessary to use an electromagnetic model capable to describe the interactions of the electromagnetic signals and the ensemble soil surface + maize. A software package developed at the Universitat Politècnica de Catalunya [11, 12] is used to model the scattering of the GPS signals. The vegetation is modeled using L-systems [13] (Fig. 1) and trunk, leaves and fruits have their particular scattering models.

(a) (b) (c) (d)

Figure 1. Maize plant structure. (a) and (b), photographs of maize plants in two different growth stages, and, (c) and (d), software package [11, 12] simulated plants for these two growth stages.

A full set of simulations has been performed considering different maize plant heights, soil surface roughness, and soil moisture values, producing a wide range of reflectivities. The IP technique is then analyzed theoretically to find ways to perform the soil moisture retrieval under the presence of maize.

The second part of the paper presents the experimental measurements carried out to prove the theoretical model developed. The SMIGOL Reflectometer [9, 10] will be deployed in a field campaign over a maize field from March to October 2010, in Lleida, Spain, covering different growth stages of the maize, from no vegetation up to 230 - 250 cm vegetation height, including the dry up process of the maize.

The third part of the paper will present the conclusions obtained by comparing these measurements to the theoretical results, in terms of soil moisture retrieval in the presence of maize plants, taking into account the different parameters that influence the measurements, as soil surface roughness and vegetation height.

REFERENCES

[1] Zavorotny, V.U. and Voronovich, A.G. "Scattering of GPS signals from the ocean with wind remote sensing application," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 35 (3), pp. 951-964, 2000

[2] Rius, A., J.M. Aparicio, E. Cardellach, M. Martín-Neira, and B. Chapron, "Sea surface state measured using GPS reflected signals," *Geophysical Research Letters*, Vol. 29 (23), pp. 2122, December 2002.

[3] Marchan-Hernandez, J.F., N. Rodríguez-Álvarez, A. Camps, X. Bosch-Lluis, and I. Ramos-Perez, "Correction of the Sea State Impact in the L-band Brightness Temperature by Means of Delay-Doppler Maps of Global Navigation Satellite Signals Reflected over the Sea Surface," *IEEE Transactions on Geoscience and Remote Sensing*, Vol. 46 (10), part 1, pp. 2914 - 2923, October 2008.

[4] Masters, D., V. Zavorotny, S. Katzberg and W. Emery, "GPS signal scattering from land for moisture content determination," *Proceedings of the IEEE International Geoscience and Remote Sensing Symposium 2000*, Vol.7 pp. 3090-3092, July 24 - 28, 2000, Honolulu, HI, USA.

[5] Gleason, S., "Detecting Bistatically Reflected GPS Signals from Low Earth Orbit Over Land Surfaces," *Proceedings of IEEE International Geoscience and Remote Sensing Symposium 2006*, pp. 3086 – 3089, July 31 - Aug. 4 2006, Denver, Colorado.

[6] Masters, D, "Surface Remote Sensing Applications of GNSS Bistatic Radar: Soil Moisture and Aircraft Altimetry," *Ph. D. dissertation*, University of Colorado, 2004.

[7] Kavak, A., G. Xu, , and W.J. Vogel, "GPS multipath fade measurements to determine L-band ground reflectivity propierties," *Proceedings of NAPEX XX*, pp. 257-263, 1996.

[8] Kavak, A., W.J. Vogel, and G. Xu, "Using GPS to measure ground complex permittivity," *Electronic Letters*, vol. 34 (3), pp. 254-255, February 1998.

[9] Rodriguez-Alvarez, N., Bosch-Lluis, X., Camps, A., Vall-llossera, M., Valencia, E., Marchan-Hernandez, J.F., Ramos-Perez, I.; "Soil moisture retrieval using GNSS-R techniques: experimental results over a bare soil field," *IEEE Transactions on Geoscience and Remote Sensing*, Vol. 47 (11), pp. 245-248, November 2009.

[10] Rodriguez-Alvarez, N., S. Monerris, X. Bosch-Lluis, A. Camps, J. F. Marchan-Hernandez, I. Ramos-Perez, E. Valencia, M. Vall-llossera, J.M. Nieto, "Soil Moisture Retrieval using GNSS-R: Vegetation Effects" International Geoscience and Remote Sensing Symposium 2009, IGARSS 2009, Cape Town, South Africa.

[11] Martinez-Vazquez, A., Camps, A., Duffo, N., Vall-llossera, M., Lopez-Sanchez, J.M., "Full polarimetric emissivity of vegetation-covered soils: vegetation structure effects". *Proceedings of the IEEE Internacional Geoscience and Remote Sensing Symposium 2002*, vol.6, pp. 3542-3544, 2002.

[12] Martinez-Vazquez, A., Camps, A., Lopez-Sanchez, J.M., Vall-llossera, M., Monerris, A., "Numerical Simulation of the Full-Polarimetric Emissivity of Vines and Comparison with Experimental Data," *Remote Sensing*, 1 (3), pp. 300-317, July 2009.

[13] Salomaa, A. and Rozenberg, G. "The mathematical theory of L systems," Pure and applied mathematics, a series of monographs and textbooks. New York: Academic Press, 1980.