BOREALSCAT: A TOWER EXPERIMENT FOR UNDERSTANDING TEMPORAL CHANGES IN P- AND L-BAND BACKSCATTERING FROM A BOREAL FOREST

Lars M.H. Ulander [(1)], Maciej J. Soja [(1)], Albert R. Monteith [(1)], Leif E.B. Eriksson [(1)], Johan E.S. Fransson[(1)], and Henrik J. Persson[(2)]

[(1)] Chalmers University of Technology, Dept. of Earth and Space Sciences, SE-412 96 Gothenburg, Sweden, Email: lars.ulander@chalmers.se, maciej.soja@chalmers.se, monteith@chalmers.se, leif.eriksson@chalmers.se
[(2)] Swedish University of Agricultural Sciences, Dept. of Forest Resource Management, SE-901 83 Umeå, Sweden, Email: johan.fransson@slu.se, henrik.persson@slu.se

ABSTRACT

This paper describes the tower-based radar BorealScat, which is being developed for polarimetric, tomographic and Doppler measurements at the hemi-boreal forest test site in Remningstorp, Sweden. The facility consists of a 50-m high tower equipped with an antenna array at the top of the tower, a 20-port vector network analyser (VNA), 20 low-loss cables for interconnection, and a calibration loop with a switching network. The first version of BorealScat will perform the full set of measurements in the frequency range 0.4 – 1.4 GHz, i.e. P-band and L-band. The tower is currently under construction at a forest stand dominated by Norway spruce (*Picea abies* (L.) Karst.). The mature stand has an above-ground dry biomass of 300 tons/ha. Data collections are planned to commence in autumn 2016.

1. INTRODUCTION

Spaceborne mapping of forest biomass is an active research topic due to the lack of accurate estimates of global forest carbon stock, as well as the lack of suitable instrumentation for deforestation and forest degradation monitoring [1]. In May 2013, the BIOMASS mission was selected by the European Space Agency (ESA) to become the 7th Earth Explorer [2-4]. Equipped with the first P-band (432-438 MHz) synthetic-aperture radar (SAR) in space, the main objective of BIOMASS will be near-global monitoring and estimation of forest biomass and disturbance. During a dedicated phase at the beginning of the mission, BIOMASS will operate in a repeat-pass tomographic mode, giving information about the vertical distribution of backscattering in forests. However, due to ITU (International Telecommunication Union) regulations, BIOMASS coverage will be restricted over Europe and North America, leaving large areas of boreal forests unmonitored. To improve boreal forest mapping, ESA is currently investigating the implementation of a passive companion satellite to the Argentine SAOCOM-1B L-band (1250-1300 MHz) SAR satellite. The SAOCOM-1B companion satellite (SAOCOM-CS) mission will focus on mapping of the boreal forests using SAR tomography [5-6].

Among the greatest challenges in forest parameter estimation from P- and L-band SAR imagery is the modelling and mitigation of moisture effects [7-11]. An uncompensated moisture signal will introduce bias in biomass estimates and make them less reliable. Forest monitoring is also one of the objectives of the European C-band Sentinel-1 SAR systems operating with a center frequency of 5405 MHz. It is well-known that C-band forest signatures are also affected by moisture variations and temporal decorrelation affects repeat-pass interferometry [12-14]. Therefore, it is of importance to improve the understanding of these effects at P-, L-, and C-band.

In tropical forests, moisture effects in a French Guianese forest have been investigated during the TropiScat campaign [15-16], in which temporal changes were studied using a tomographic radar with 20 antennas mounted on a 55-m high tower. Diurnal cycles and rain episodes were observed and it was concluded that temporal coherence is highest at dusk and dawn. In the AfriScat campaign, a similar experiment is being conducted in an African tropical forest in Ghana.

In order to investigate the effects of temporal changes in boreal forests on the P-, L-, and C-band signatures, a tower-based radar, BorealScat, is being developed by Chalmers University of Technology in co-operation with the Swedish University of Agricultural Sciences (SLU). The test site chosen for the tower radar is Remningstorp in southern Sweden which has been used for several remote sensing experiments in the past, e.g. the BioSAR-1 [17] and BioSAR-3 [18] airborne SAR campaigns in 2007 and 2010 funded by ESA.

2. BOREALSCAT

A dedicated 50-m high tower is currently being constructed in the Remningstorp test site. The tower will be located at a mature forest stand dominated by Norway spruce (Picea abies (L.) Karst.) and which has an above-ground dry biomass of 300 tons/ha. Data collections are planned to commence in autumn 2016.

The tower radar equipment consists of a 20-channel vector network analyser (VNA) from Rhode & Schwarz

(ZNBT8, covering 9 kHz-8.5 GHz), an antenna array mounted close to the top of the tower, and 20 low-loss cables for interconnection as illustrated in Fig. 1. External calibration will be performed using a permanently installed trihedral corner reflector. An internal calibration loop with a switching network (not shown in Fig. 1) is also included.

In the first version of BorealScat, the antenna array will consist of 20 log-periodic dipole array antennas with weather-proof radomes (Rhode & Schwarz HL040E), which cover the 0.4-6 GHz frequency range. The antennas will be arranged in four vertical columns of five antennas, i.e. with separate columns for transmission and reception as well as for H- and V-polarisation as illustrated in Fig. 1. The geometrical configuration is similar, but not identical, to that used in TropiScat [15-16] and will enable polarimetric, tomographic and Doppler measurements at P- and L-band. Polarimetric and Doppler measurements will also be possible at C-band but not tomographic measurements due to grating lobes in elevation. In a second version of BorealScat, we plan to add a second antenna array optimised for C-band tomography.

A dedicated weather station will be installed in close proximity of the tower. The system will be connected to the internet via a 4G broadband link. A dedicated webpage (www.borealscat.se) will also be maintained. *In situ* field measurements and terrestrial lidar scanning (TLS) surveys will be conducted by SLU.

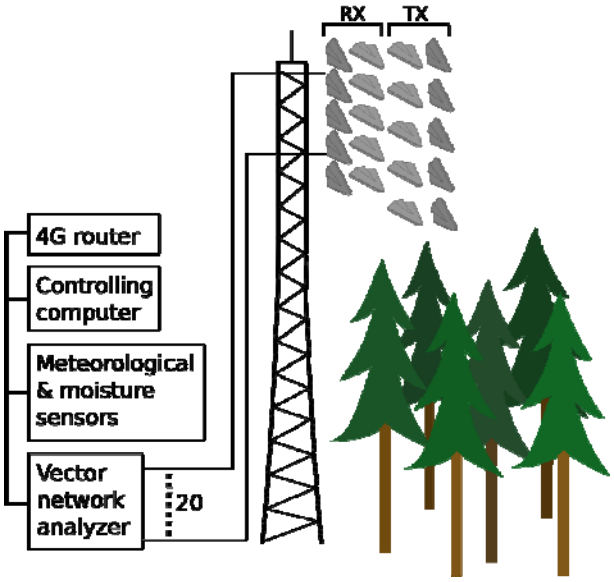

Figure 1. Conceptual design of BorealScat with the principle system blocks, including the tomographic and polarimetric array consisting of four columns with five wideband log-periodic dipole array elements.

3. CONCLUSIONS

A tower-based radar facility is being developed and will be installed at the Remningstorp forest site. In the first version, it will enable polarimetric, tomographic and Doppler measurements at P- and L-band. It will be used to investigate the effect of changing environmental conditions (moisture, wind etc) on the radar data. Data collections are planned to commence in autumn 2016. Polarimetric and Doppler measurements will also be possible up to C-band but not tomography which is planned to be added in a future upgrade.

4. REFERENCES

1. IPCC (2013). *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

2. Le Toan, T., Quegan, S., Davidson, M.W.J., Balzter, H., Paillou, P., Papathanassiou, K., Plummer, S., Rocca, F., Saatchi, S. Shugart, H. & Ulander, L. (2011). The BIOMASS mission: Mapping global forest biomass to better understand the terrestrial carbon cycle, *Remote Sensing of the Environment*, **115**(11), 2850-2860. doi: 10.1016/j.rse.2011.03.020

3. ESA. (2012). *BIOMASS, Report for Mission Selection*, SP-1324/1, European Space Agency, Noordwijk, The Netherlands.

4. Heliere, F., Fois, F., Arcioni, M., Bensi, P., Fehringer, M. & Scipal, K. (2014). Biomass P-band SAR interferometric mission selected as 7th Earth Explorer Mission, *Proc. 10th European Conference on Synthetic Aperture Radar (EUSAR 2014)*, Berlin, Germany, 3-5 June 2014, pp. 1152-1155.

5. ESA. (2014). *SAOCOM Companion Satellite Science Report*, EOP-SM/2764/MWJD-mwjd, European Space Agency, Noordwijk, The Netherlands.

6. Gebert, N., Carnicero Dominguez, B., Davidson, M. W. J., Diaz Martin, M. & Silvestrin, P. (2014). SAOCOM-CS -- A passive companion to SAOCOM for single-pass L-band SAR interferometry, *Proc. 10th European Conference on Synthetic Aperture Radar (EUSAR 2014)*, Berlin, Germany, 3-5 June 2014, pp. 1251-1254.

7. Santoro, M., Fransson, J.E.S., Eriksson, L.E.B., Magnusson, M., Ulander, L.M.H. & Olsson, H. (2009). Signatures of ALOS PALSAR L-band backscatter in Swedish forest, IEEE Transactions

on Geoscience and Remote Sensing, 47(12), 4001-4019. doi: 10.1109/TGRS.2009.2023906

8. Sandberg, G., Ulander, L.M.H., Holmgren, J., Fransson, J.E.S. & Le Toan, T. (2011). L- and P-band backscatter intensity for biomass retrieval in hemiboreal forest, *Remote Sensing of the Environment*, **115**(11), 2874-2886. doi: 10.1016/j.rse.2010.03.018.

9. Neumann, M., Saatchi, S.S., Ulander, L.M.H. & Fransson, J.E.S. (2012). Assessing Performance of L-band and P-band Polarimetric Interferometric SAR Data in Estimating Boreal Forest Aboveground Biomass, *IEEE Transactions on Geoscience and Remote Sensing*, **50**(3) 714-726. 10.1109/TGRS.2011.2176133

10. Soja, M.J., Sandberg, G. & Ulander L.M.H. (2013). Regression-based Retrieval of Boreal Forest Biomass in Sloping Terrain using P-band SAR Backscatter Intensity Data, IEEE Transactions on Geoscience and Remote Sensing, 51(5), 2646-2665. doi: 10.1109/TGRS.2012.2219538

11. Sandberg, G., Ulander, L.M.H., Wallerman, J. & Fransson, J.E.S. (2014). Measurements of Forest Biomass Change Using P-band SAR Backscatter, *IEEE Transactions on Geoscience and Remote Sensing*, **52**(10), 6047-6061. doi: 10.1109/TGRS.2013.2294684

12. Hagberg, J.O., Ulander, L.M.H. & Askne, J. (1995). Repeat-Pass SAR Interferometry over Forested Terrain, *IEEE Transactions on Geoscience and Remote Sensing*, **33**(2), 331-340. doi:10.1109/36.377933

13. Askne, J.I.H., Dammert, P.B.G., Ulander, L.M.H. & Smith, G. (1997). C-band Repeat-Pass Interferometric SAR Observations of the Forest, *IEEE Transactions on Geoscience and Remote Sensing*, **35**(1), 25-35. doi: 10.1109/36.551931

14. Santoro, M., Shvidenko, A., McCallumb, I., Askne, J. & Schmullius, C. (2007). Properties of ERS-1/2 coherence in the Siberian boreal forest and implications for stem volume retrieval, *Remote Sensing of Environment*, **106**(2), 154–172. doi:10.1016/j.rse.2006.08.004

15. Albinet, C., Borderies, P., Koleck, T., Rocca, F., Tebaldini, S., Villard, L., Le Toan, T., Hamadi, A. & Ho Tong Minh, D. (2012). TropiSCAT: A Ground Based Polarimetric Scatterometer Experiment in Tropical Forests, *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, **5**(3), 1060-1066. doi: 10.1109/JSTARS.2012.2201917

16. Ho Tong Minh, D., Tebaldini, S., Rocca, F., Le Toan, T., Borderies, P., Koleck, T., Albinet, C., Hamadi, A. & Villard, L. (2014). Vertical Structure of P-Band Temporal Decorrelation at the Paracou Forest: Results From TropiScat, *IEEE Geoscience and Remote Sensing Letters*, **11**(8), 1438-1442. doi: 10.1109/LGRS.2013.2295165

17. Hajnsek, I., Scheiber, R., Ulander, L., Gustavsson, A., Sandberg, G., Tebaldini, S., Monte Guarnieri, A., Rocca, F. Bombardini, F. & Pardini, M. (2008). *BIOSAR 2007 Technical Assistance for the Development of Airborne SAR and Geophysical Measurements during the BioSAR 2007 Experiment, Final report without Synthesis*, ESA Contract No.: 20755/07/NL/CB.

18. Ulander, L.M.H., Gustavsson, A., Flood, B., Murdin, D. Dubois-Fernandez, P., Dupuis, X., Sandberg, G. Soja, M.J., Eriksson, L.E.B., Fransson, J.E.S., Holmgren, J. & Wallerman, J. (2011). *BioSAR 2010: Technical Assistance for the Development of Airborne SAR and Geophysical Measurements during the BioSAR 2010 Experiment, Final Report*, ESA contract no. 4000102285/10/NL/JA/ef.