VEGETATION EFFECTS AT FROZEN ENVIRONMENT BY SIMULATION AND TRUCK-MOUNTED MICROWAVE RADIOMETER

Zhongjun Zhang[1], Lixin Zhang[2,3], Shaojie Zhao[2,3],Xin Liu[1], Guoqing Sun[4]

1. College of Information Science and Technology, Beijing Normal University, Beijing 100875, China
2. State Key Laboratory of Remote Sensing Science, Beijing 100875, China
3. School of Geography and Remote Sensing, Beijing Normal University, Beijing 100875, China
4. Department of Geography, University of Maryland, College Park, Maryland 20742, USA

1. INTRODUCTION

Passive microwave remote sensing techniques can be used to monitor freeze/thaw at frozen soil surface. Researches found that the negative spectral gradient at 19GHz and 37GHz was a good criteria for decision of frozen soil[1]. At vegetated area, to make the algorithm simple, vegetation scattering were ignored, only their attenuation were considered, which were kept constant, regardless of vegetation species, height etc.

Many studies on microwave properties of vegetation showed that there exist big difference of scattering and attenuation of vegetation between different kinds of vegetation. The behaviors of lower grass are quite different from that of shrub or trees at 19GHz and 37GHz. Up to now to eliminate vegetation effect at frozen environment, the scattering and attenuation of vegetation are not exactly known.

In this paper, a Matrix-Doubling (there after M-D)microwave emission model is used to evaluate vegetation effects at cold environment at Ku-band(18.7GHz) and Ka-band(36.5GHz). This model is based on ray tracing technique, of which multiple scattering inside vegetation layer and that between vegetation and surface could be considered.

To verify the simulations of the M-D microwave emission model, a multi-channel truck-mounted radiometer, was employed to collect microwave emission data at a young forest stand at NE of CHINA during Jan. 2008, and a cole stubble area at Heihe River Basin during Chinese WATER (Watershed Airborne Telemetry Experimental Research) campaign on Mar. 2008, respectively. Comparisons between simulation results by M-D model and field experiments were good. Then we used the model to establish a database with a variety of parameters to simulate microwave emission of vegetated surface at frozen environment. Due to the complexity of M-D model, the results from the database were matched with that from a simple model (τ-ω model) at the same environment by least-square error, so as to retrieve scattering and attenuation of vegetation at Ku- and Ka-band at cold environment.

2. THE MODELS

To monitor the boundary of frozen/thaw by microwave emission, typically the Brightness Temperature of vegetated frozen soil is represented as:

$$T = T_0(1 - L^2\gamma_s) \qquad (1)$$

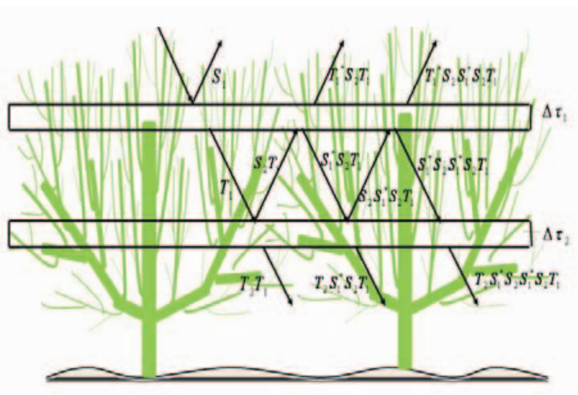
where L is vegetation transmissivity. γ_s is soil surface reflectivity, T_0 is Brightness Temperature of vegetation and surface (assuming equal). Equation (1) is actually a simplified form of τ-ω model[2]:

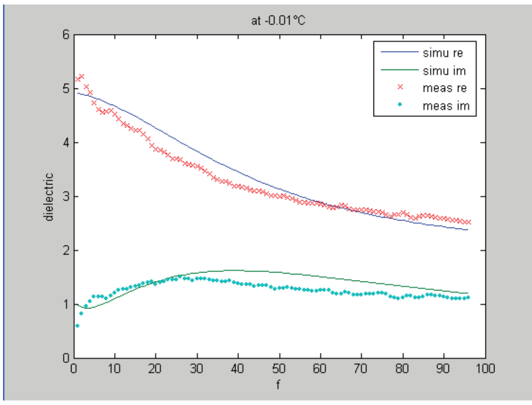
$$T = T_c(1-\omega)(1-e^{-\tau}) + T_c(1-\omega)(1-e^{-\tau})\gamma_s e^{-\tau} + (1-\gamma_s)T_s e^{-\tau} \quad (2)$$

where τ_p and ω are vegetation opacity and single scattering albedo at *p* polarization, respectively. At the frequencies of the negative spectral gradient of 19GHz and 37GHz, Equation (2) is not appropriate since it was obtained under C-band for grass or crops. In our research, to simulate emission at Ku and Ka bands, we used M-D algorithm[3], where the ground surface model IEM was substituted by AIEM. The theory is shown in figure 1. At cold environment the vegetation samples were measured in the lab by AGILENT microwave network analyzer E8362B, and the dielectric constant of vegetation was modified from its earlier version[3] as :

$$\varepsilon = 0.02494(1+1.405m_d)\varepsilon_{sw} + 7.672 - 15.04m_d \quad (3)$$

where $m_d = 1 - m_g, m_g$ is vegetation water content. ε_{sw} is dielectric constant of saline water. Equation (3) and measurements at -0.01°C are shown in figure 2.





(Left)Fig. 1 Theory of Matrix-Doubling algorithm

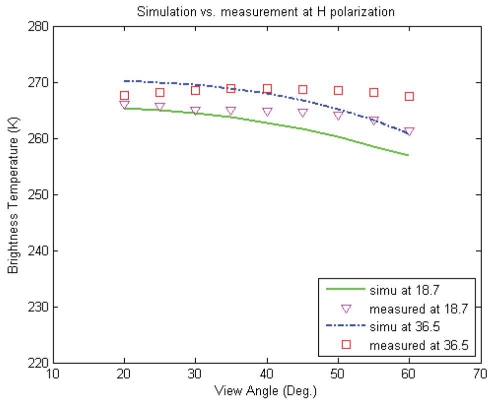
(Right)Fig.2. Comparison of dielectric constant of measured vegetation sample vs. equation (3) when environment is 0.01° C below zero.

3. SIMULATION AND FIELD EXPERIMENTS

To verify the microwave emission simulated by M-D model, we did two field experiments. One was taken at QingYuan at Hebei Province of China (N 38°44’53”, E 115°28’10”) on a young tree stand in Jan. 2008 (Fig.3). The other was taken on a cole stubble area in Mar. 2008 at Heihe River Basin during WATER campaign. At both frequencies the comparison at H pol is illustrated in figure 4.

4. RETRIEVAL OF SCATTERING AND ATTENUATION OF VEGETATION

Since M-D model is complicated which involves lots of parameters, it is difficult to relate microwave emissivity (i.e. satellite data) to the characteristics of frozen soil directly. To use equation (2) at Ku and Ka band to eliminate vegetation effect at cold environment, our method is to match the total emission from M-D model to the results from τ-ω model at the same condition by least-square error, so as to get the effective scattering and attenuation characteristics of vegetation at these frequencies[4]:



(Left)Fig. 3 Experiment on young forest stand at QingYuan, Hebei Province in Jan. 2008

(Right)Fig.4. Comparison of emission simulation and measurement at H polarization at 18.7GHz and 36.5GHz of a young tree stand.

$$\sigma = \sqrt{\sum_{1}^{N}(e_{i1} - e_{i2})^2} \qquad (4)$$

where e_{i1} and e_{i2} is emission from M-D model and τ-ω model, respectively. N is the number of simulation.

5. PRELIMINARY CONCLUSIONS

At 18.7GHz and 36.5GHz, we found that microwave characteristics of grass land at cold environment could be neglected, due to its shortage of water content, which means grass land at frozen area could be treated as bare soil. As to the young forest of about 3 meters high, vegetation emission could be ignored, but their transmissivity at frozen environment is not a constant as used in equation(1). it decrease from 0.9 down to 0.6 as view angle increasing from 20°to 60°Deg. Due to multiple scattering effect increasing greatly at 18.7GHz and 36.5GHz, no obvious polarization difference of transmissivity are found at each frequency. More results will be presented at the full paper.

6. REFERENCES

[1] Zuerndorfer B, England A W, "Radiobrightness Decision Criteria for Free/Thaw Boundaries", *IEEE Transactions on Geoscience and Remote Sensing*, Vol.30 No.1, pp. 89-102, 1992.

[2] T.J. Jackson and T.J. Schmugge, "Vegetation effects on the microwave emission from soils", *Remote Sensing of Environment*, Vol.36, pp. 203－210, 1991.

[3] Matzler, "Microwave(1-100GHz) Dielectric Model of Leaves", *IEEE Transactions on Geoscience and Remote Sensing*, Vol.32 (5), pp.947-949, 1994.

[4] P. Ferrazzoli and L. Guerriero, "Passive microwave remote sensing of forests: a model investigation", *IEEE Transactions on Geoscience and Remote Sensing*, Vol.34, pp.433–443, 1996.

[5] P. Ferrazzoli, Leila Guerriero, and J.P. Wigneron, "Simulating L-Band Emission of Forests in View of Future Satellite Applications", *IEEE Transactions on Geoscience and Remote Sensing*, Vol.40, No.12 pp.2700-2708, 2002.

RESUME

Zhongjun Zhang, Ph.D. Associate Prof. in Beijing Normal University, CHINA. His research interest is microwave remote sensing, signal processing. He was a visiting scientist at USDA Hydrological Remote Sensing Lab during 2006.