Chapter 8

Conclusion and Future prospects

8.1 Summary

The primary purpose of the work presented in this thesis is to investigate the computational efficiency of the electromagnetic scattering model to simulate complex bistatic scattering phenomena from vegetated land on the basis of physics, their structural properties, and mathematics. An indigenous polarimetric bistatic scatterometer device was adapted to measure bistatic scattering from vegetated lands to validate the scattering model simulation. This chapter summarizes the findings and key contributions described in the research work presented in this thesis.

✓An indigenous bistatic specular polarimetric scatterometer system was designed for the scientific objectives of land bio-geophysical monitoring and retrieval.

✓The temporal bistatic scattering response of vegetated lands in a specular direction was measured for X, C, and L bands over a wide specular incidence angular range (i.e., varying from 20° to 60° at intervals of 10°)

✓The temporal and multiangular bistatic scattering coefficient (σ^0_{pq}) curves for different microwave bands and polarization were found sensitive to vegetation biophysical and land surface parameters.

✓The temporal curves of σ^0_{pq} decreased with the increase in the vegetation biophysical parameters for the X and C bands and vice versa. Thus, we can conclude that the canopy parameters influence the temporal curves of σ^0_{pq}. However, the influence of volumetric soil moisture content (m_v) was seen dominant in the temporal curves of σ^0_{pq} for the L band.

✓The correlation analysis between the measured values of σ^0_{pq} and vegetation and land surface parameters can act as a viable choice to find the optimum parameters (i.e., incidence angle, polarization, and frequency band) for the bistatic scatterometer system to monitor land bio-geophysical parameters.

✓In Chapter 4, The co-polarized bistatic scatterometer measurements at the X and C bands were investigated during a growing rice crop season. The 40° specular incidence angle was highly correlated with the vegetation biophysical parameters (i.e., LAI and PWC). The radiative transfer theory-based vegetation scattering model has been used to explore the insights of microwave interaction with the vegetation constituents (i.e., rice crop). The complexities of modeling vegetation and water surface beneath vegetation scattering were reduced by introducing parametrized VPF and BRDF, respectively. In addition, the empirical relation between VOD and vegetation biophysical parameters was used to modify the radiative transfer model, which is also helpful in retrieving vegetation growth parameters information. The retrieval of LAI and PWC from model inversion shows high accuracies for the X band compared to the C band.

✓In Chapter 5, the parameters for specular scattering models are evaluated for co-polarized L and X bands bistatic scatterometer measurements of a wheat field during a growing season. The measurements at 40° were found to have the highest correlations with the crop LAI and m_v. This chapter considers the coherent and incoherent rough surface scatter and incoherent vegetation scattering. The Kirchhoff rough surface scattering theory is employed for the surface models and a modified Henyey-Greenstein phase function for the vegetation scattering. No significant coherent scattering was observed at X band. The

model inversion shows that the LAI retrieval accuracies were best at VV polarization for X band. However, the retrieval accuracies of m_v were best at HH polarization for L band.

✓In Chapter 6, the fully-polarimetric bistatic scatterometer measurements at C band were evaluated for rough vegetated land. The measurements at 30° were found to have the highest correlations with the crop PWC and m_v. The first-order radiative transfer model was used to comprehend the insight of microwave scattering phenomena with the temporal change in the vegetation biophysical and land surface parameters. The Kirchhoff rough surface scattering theory is employed for the surface models and a Rayleighs phase function for the vegetation scattering in this study. The decomposition of scattering components contributions utilizing the first-order radiative transfer model and their dominance provides insights into interaction phenomena at different phenological stages of the vegetation biophysical parameters. The simulation of co-polarized bistatic scattering coefficients using a first-order radiative transfer model was found to be in good agreement with bistatic scatterometer observations.

✓In Chapter 7, the potential of the machine learning technique, namely, Support vector regression using linear, polynomial, and radial kernels, were evaluated for paddy crop information (i.e., LAI, FBm, VWC, and PH) retrieval at optimized parameters of bistatic scatterometer system for X and C bands. The retrieval of the vegetation growth parameters of paddy crop by the developed SVR model using radial kernel provided better results than linear and polynomial kernels for LAI, FBm, and VWC at C band and PH at X band using bi-spec scatterometer data.

The bistatic scatterometer measurements for land bio-geophysical parameters retrieval were found to have excellent potential using both the developed bistatic microwave scattering model and machine learning algorithms. In general, the retrieval accuracies using a high-frequency band were found to derive canopy information best. However, lower band frequencies were found best to derive soil parameters information.

8.2 Future prospects

The development of a bistatic radar system or a concept of companion satellite to an existing sensor for earth exploration is an emerging technique in the field of microwave remote sensing. Therefore, the measurements of bistatic observable quantities for different targets with high precision are necessary to increase knowledge of the microwave signatures. The following point can be considered for future study to upgrade the microwave scattering algorithm for target information retrieval and advance the understanding of target bistatic scattering.

✓The assessment of bistatic radar returns from different targets such as forest, wetland, ocean, vegetation, and bare land surfaces over a wide azimuthal angular range is also essential to determine the most sensitive bistatic geometric configurations.

✓The multiple measurements of the same target may raise the degree of trust in the precise gathering of information regarding the target.

✓The investigation of the cross-polarized radar returns from the target may provide a better understanding of microwave interaction with the target.

✓The accurate interpretation of time-series bistatic radar returns of the time-varying targets based on physics, their geometry, and mathematics would provide the confidence in announcing the result globally.

✓The development of simulating tools for various scientific objectives in the cryosphere, biosphere, and solid earth research domains facilitates the acquisition of necessary target information, which may aid in comprehending the environmental dynamics on a local and global scale.

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