CHAPTER - 8

CONCLUSIONS AND RECOMMENDATIONS

Remote sensing technique is basically based on the accurate interpretation of interaction mechanism of electromagnetic waves with different features of the earth surface. The interaction mechanism depends on the system parameters (frequency, polarization and look angle etc.) and target parameters (geometry, dielectric constant etc.). In our thesis, the estimation of crop growth variables and soil moisture were done using bistatic scatterometer measurements at different growth stages by artificial neural techniques.

The microwave scattering response of growth variables of different crops and soil moisture depends on the frequency, polarization and look angle of the incident microwave and the phenological changes (leaf area index, biomass, crop height, crop water content etc.) and dielectric constant of the crops at various growth stages and the soil surface parameters.

In the present thesis work, the bistatic scatterometer measurements were carried out to examine the microwave response using different system parameters (frequency, polarization and incidence angles) of slightly rough bare soil surfaces and four different crops (Rice, Kidney bean, Wheat and Chickpea) at various growth stages. The method or process was developed for the retrieval of soil moisture from slightly rough bare soil surfaces and crop variables of these crops. The interaction of electromagnetic waves with the soil surfaces and crops is nothing but simply the physics of radio wave propagation and its interaction with these mediums. The microwave scattering/ reflection phenomenon is highly influenced by the system's parameters, target's characteristics, environmental and climatic conditions. The bistatic scattering coefficient is key to understand and evaluate the target characteristics in the active microwave remote sensing.

On the basis of above interaction mechanism, the angular variation of bistatic scattering coefficient for slightly rough bare soil surface were found to increase with the percentage of soil moisture content at various soil moisture conditions at HH- and VV- polarizations. The bistatic scattering coefficient was found to decrease with the incidence angle in the range of 20° to 70° at VV- polarization, whereas it was found to increase at HH-polarization. According to Fresnel reflection theory for the slightly rough surface, the reflectivity in specular direction was found to increase with the

incidence angle at HH-polarization. However, it was found to decrease until the Brewster angle was reached and then after increased slightly in the case of VV-polarization.

In case of crop variables retrieval, the angular variation of the bistatic scattering coefficients showed decreasing behaviour at vegetative and reproductive stage and then after found increasing behaviour at ripening stage (maturity) in the entire angular range of incidence angles at both the like polarizations. As the incidence angle were increased, the magnitude of bistatic scattering coefficients were found to decrease because the slant range of the microwave signal increases in the vegetation medium and resulted in volumes scattering and absorption in the vegetation medium.

Polarization of a microwave is sensitive to the shape, size and orientation of the targets elements. The horizontal polarization gives the measure of the horizontal dimension, while the vertical polarization gives the measure of the vertical dimension of the scattering elements (Prasad et al. 2009). Thus, the microwave response of different incidence angles due to the change in leave size, its orientation with respect to incidence angle can be used for the effective monitoring of the growth stages of a crop (Chakraborty et al. 2005). There are two types of crops namely broad leaf crop and narrow leaf crop used in our study. The bistatic scattering coefficient showed a faster decay at VV-polarization than HH-polarization for narrow leaf crop. The attenuation due to vertical cylinders (vertical leaves) at vertical polarization (VV-) was higher than the horizontal polarization (HH-) (de Matthaeis and Lang 2005; De Matthaeis et al. 1994; Lin et al. 2009; Liu et al. 2008).

8.1 ADVANTAGES AND DISADVANTAGES OF BISTATIC SCATTEROMETER DATA OVER MONOSTATIC SCATTEROMETER DATA

In monostatic radar system, the transmitting and receiving antennas are placed at the same location and receive the back scattered power from the target of interest.

In case of bistatic radar system, the transmitting and receiving antennas are placed opposite to each other and receive the signal in forward direction. The advantages and disadvantages of bistatic radar system over mono static radar system are given below,

1. The bistatic scattering coefficient does not exhibit severe saturation effects and shows a better sensitivity to biomass at higher frequencies than backscattering coefficient.
2. The bistatic scattering echoes can provide multidimensional information on land surface in comparison to backscattering configuration due to the diversity of geometry provided by the transmitting and receiving antennas. Bistatic scattering coefficient is more sensitive to the vegetation parameters than the backscattering configuration.
3. Sometimes the targets are designed to minimize back scattering coefficient. Under this situation, the monostatic radar system couldn't detect the target. Whereas, the bistatic/multistatic radar system can detect such targets due to detection of multiple reflection/scattering from the target by placing receiving antennas at various places. Hence, capability of bistatic/multistatic radar system can improve the counter stealth ability of radar systems.
4. The main drawback of bistatic radar system is the difficulty to focus the transmitting and receiving antenna beams on the target of interest simultaneously.

The results obtained for the estimation of some crops variables and soil moisture from slightly rough bare soil surface using bistatic scatterometer data and ANN, following conclusions may be drawn:

1) The higher sensitivity of bistatic scattering coefficient for the soil moisture is found at lower incidence angle. Whereas, the higher sensitivity of bistatic scattering coefficient for the crop growth variables is found at higher incidence angle.

2) The higher sensitivity of bistatic scattering coefficient for the soil moisture from slightly rough bare soil surface is found at 25° incidence angle and VV-polarization.
3) The simple ANN structure (1×3×1) is found suitable for the estimation of soil moisture from slightly rough bare soil surfaces using bistatic scatterometer data.
4) The ANN model provided slightly better performance than the LRM model for the estimation of soil moisture. The LRM model may be the best choice for the estimation of soil moisture using bistatic scatterometer data.
5) The angular trend of bistatic scattering coefficient is found decreasing as the crop grows at all the incidence angles.
6) The crop growth variables (VWC, LAI, PH and SPAD value) of all the crops (rice, kidney bean, wheat and chickpea) showed increasing trend with the age of the crop.
7) The higher sensitivity of bistatic scattering coefficients for the rice growth variables is found at 30° incidence angle for HH- polarization.
8) The ANN structure (2×10×4) is found more suitable than (1×10×1) structure for the estimation of rice crop variables.
9) The higher sensitivity of bistatic scattering coefficients for the kidney bean growth variables is found at 50° incidence angle for VV- polarization.
10) All the kidney bean crop variables are well fitted by the Gaussian curve with the age of kidney bean crop after date of sowing.
11) The ANN structure (1×10×4) is found more suitable for the estimation of kidney bean crop variables.
12) The higher sensitivity of bistatic scattering coefficients for the wheat growth variables is found at 40° incidence angle for HH- polarization.
13) The higher sensitivity of bistatic scattering coefficients for the chickpea growth variables is found at 50° incidence angle for VV- polarization.
14) The ANN structure (1×10×1) is found more suitable for the estimation of wheat and chickpea crop variables.

15) The gradient descent algorithm is found suitable for the training of back propagation of ANN model for the estimation of soil moisture and crop variables.