EFFECT OF CROP (WHEAT) HEIGHT AND CROP COVERED SOIL MOISTURE ON MICROWAVE SCATTERING FOR REMOTE SENSING

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Abstract :

An outdoor observation has been carried out for response of crop (wheat) height and crop covered soil moisture on microwave by an X- band scatterometer. Penetration of microwave into crop depends upon crop covered soil moisture, moisture content in crop, density of the crop, crop height and frequency of incident wave. When crop is green (wet) and lust i.e. the moisture content in the crop is height, the penetration depth is low. But, when crop is dry (i.e. fruit filling stage), the moisture content is low, the microwave penetrates more deeply. Microwave penetrates both the surface soil and crop. Scattering depends strongly on the surface features as well as moisture content in the soil. The soil moisture of ground and moisture content of the crop changes as the crop grows. Therefore its dielectric properties changes. This change in dielectric shows a relation with scattering coefficient. In this paper, it is attempted to highlight the effect of crop height and crop covered soil moisture on microwave scattering. An empirical relation has been developed for calculating the scattering coefficient. The angular dependence has been also observed, which indicates that, when incidence angle is less than 30^0 then crop (wheat) covered soil moisture is well observed, whereas, the incidence angle is greater than 30^0, crop effect is more dominant at the X- band.

1. Introduction :

The capability of active and passive sensors to measure soil moisture content of bare and crop covered fields has been the subject of extensive research, which has been carried out in order to able to understand the underlying physical principle and to determine the optimum observation parameters, as well as the achievable accuracy of these measurements. This type of work intends to offer a comparative evaluation of the potential of active and passive microwave sensors, estimating crop height and soil moisture etc [1].

Using a bistatic scatterometer system, we have carried out the crop signatures study for several growth stage of wheat. This crop bed was specially prepared for the remote sensing measurements. Bistatic scatterometer measurements of wheat for different stage of growth were carried out at almost every fortnightly to get the signature of crop at X-band, for observing the angular and polarization effect. The linear regression analysis has also been carried out, for observing the effect of crop height and crop covered soil moisture on scattering coefficient. It is also tried to highlight the most suitable incidence angle for observing crop (wheat) covered soil moisture and wheat effect itself.

2. Theoretical approach :

A crop canopy consists of a volume of scattering elements bounded by air top and by scattering soil surface at the bottom. Generally, the scattering coefficient (σ^0) is governed by the scattering properties of the crop/vegetation elements and the soil surface, as well as by the interaction between the crop volume and soil surface in the form of multiple scattering. If the crop cover is sparse, as in early growth stage, the scattering coefficient may be expressed in the form [2]

$$\sigma^0(\theta) = [1 - A(\theta)]\,\sigma^0_{bare} + A(\theta)\,\sigma^0_{can} + [1 - A(\theta)]\,\sigma^0_{int} \quad (1)$$

where, $A(\theta)$ is the fraction of the illuminated area that is the crop covered when observed along the direction (θ), σ^0_{bare} is the scattering coefficient of the exposed surface, σ^0_{can} is the scattering coefficient of canopy which may include contributions from crop covered and from the underlying surface, and σ_{int}^0 is an interaction component accounting for multiple scattering.

For wheat canopy, the stalk is considered to represent the major scattering component of the canopy, and the scattering component may ignore the leaves and concentrate on stalk [3], and this type of canopy treated as a collection of lossy dielectric cylinders. A more simpler approach, for modeling the scattering coefficient from crop canopy was proposed by [4]. The crop volume is assumed to consist of identical scatters that are uniformly distributed throughout the volume. Ignoring, multiple scattering and assuming that the soil scattering contributions are added in coherently to the crop contributions, the canopy scattering coefficient may be expressed as

$$\sigma_{can}^0(\theta) = \sigma^0_c(\theta) + \frac{\sigma^0_s(\theta)}{L^2(\theta)} \quad (2)$$

where, $\sigma^0_c(\theta)$ is the scattering coefficient observed by the crop, $\sigma^0_s(\theta)$ is the scattering coefficient obtained by the soil and $L^2(\theta)$ accounts for the two way attenuation loss experienced by the wave due to propagation through the lossy crop layer. It depends upon crop parameters (i.e. crop height and crop water content, etc.) and incidence angle. It is given by,

$$L(\theta) = \exp(B_1\, m_v\, h \sec\theta) \quad (3)$$

where B_1 is a constant at a given frequency, that may be different for different crop geometries, m_v is volumetric content in crop, h is a crop height, and θ is incidence angle.

If the crop cover is sparse, during early growth stage of crop wheat, a simple and linear empirical model has been proposed, on the basis of these dependent variables

$$\sigma^0_{can}(\theta) = K + \frac{d\sigma^0}{dh} \times h + \frac{d\sigma^0}{dm_g} \times m_g \quad (4)$$

where, m_g is percentage of crop covered gravimetric soil moisture, and K is a constant which depends upon stalk, size of leaves, frequency, polarization, etc. $\frac{d\sigma^0}{dh}$ and $\frac{d\sigma^0}{dm_g}$ are the sensitivity of σ^0 on the plant height and crop covered soil moisture, respectively.

3. Results and discussion :

Botanically, the wheat is a narrow leaf crop. It had attained a maximum average height of around 72 cm during the experiment. The crop (wheat) leaves were narrow in shape but long in size. Due to normal crop density for better yield, the whole ground was not covered by this crop on which it was grown. Therefore, the overall effect of microwave scattering at 9.5 GHz could not be exclusively from wheat. It must have some effect of uncovered ground surface as well. The observation was taken by the X- band scatterometer [5] for various growth stage of wheat and soil moisture, before the fruit filling stage. Fig. 1 and 2 show the angular variation of scattering coefficient for HH- and VV-pol. respectively. In these Figs., it is clearly observed that, at the early age of crop(i.e. when plant height is small) the variation in σ^0 is more in comparison to that at the latter age of crop. It may be due to that, at this time, the crop covered soil moisture effect is more in comparison to the crop effect, and penetration is more. The variation in σ^0 for VV-pol is larger than HH-pol., in all stages of crop.

Table 1. shows the different values of the regression parameters for σ^0 on crop covered soil moisture (m_g), when crop height is kept as a constant, for both like polarizations (i.e. HH- and VV-pol.) The slope, which predicts about the sensitivity of σ^0 on m_g, is positive for both like polarizations. It means that the value σ^0 increases as the m_g increases. But, it is clearly observed that σ^0 is more sensitive at the lower angle of incidence (i.e $\theta < 30^0$) than that at higher angle of incidence, for observing crop covered soil moisture at X- band for both like polarizations. In the same table, it is also confirmed by the value of coefficient of determination (r^2), standard error (SE) and standard error of estimate (SEE). The value of r^2 is high for lower angle of incidence than the higher angle of incidence. But, the value of slope and r^2 is greater for VV- polarization than HH-polarization. It concludes that, VV-pol. gives much better result than HH-pol., for observing m_g at X-band. Table 2. shows different values of regression parameters for σ^0 on crop height (h), when m_g is kept constant for both like polarizations. It is observed that as the angle of incidence increases, the value of slope also increases up to 40^0 angle of incidence. If we consider the r^2, SE and SEE values in the table, we confidently said that the higher angle of incidence (i.e $\theta > 40^0$) is more sensitive to observe the crop height effect on σ^0 at X- band. In this case,VV-pol. also gives much better result than HH-pol, which confirms the experimental results.

4. Conclusion :

When electromagnetic waves incident on the terrain, their scattering depend upon the system and target parameters. The system parameters include wave length, polarizations and incidence angles, whereas the target parameters include shape, size, dielectric properties of the target, etc. In this paper, it is tried to observe the crop height and crop covered soil moisture effects on scattering coefficient and also its dependence upon system parameters (i.e. polarizations and incidence angle) at X-band. It is found that the lower angle of incidence (i.e. $\theta < 30^0$) is more suitable for observing crop (wheat) covered soil moisture, whereas higher angle of incidence (i.e. $\theta > 40^0$) is more suitable for observing the crop (wheat) effect up to the crop height 72 cm, and the before fruit filling stage. VV-pol. gives much better results than HH-pol. at X-band. The results of this paper can be helpful for predeciding the system parameters of space or air-borne radars, as the need and facility available.

References :

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Table 1. Regression parameters of scattering coefficient Vs.% of crop covered soil moisture, when crop height is kept constant at various incidence angle for X-band.

Angle	Slope	r^2	SE	SEE	Pol.
20	0.86	0.81	0.132	0.069	HH
30	0.76	0.72	0.153	0.14	HH
40	0.62	0.61	0.184	0.184	HH
50	0.51	0.58	0.238	0.21	HH
60	0.46	0.52	0.282	0.23	HH
70	0.39	0.49	0.292	0.24	HH
20	0.92	0.86	0.12	0.092	VV
30	0.8	0.77	0.133	0.105	VV
40	0.65	0.63	0.164	0.142	VV
50	0.56	0.61	0.208	0.182	VV
60	0.49	0.53	0.25	0.192	VV
70	0.43	0.51	0.282	0.223	VV

Table 2. Regression parameters of scattering coefficient Vs. crop height, when crop covered soil moisture is kept constant at various incidence angle for X-band.

Angle	Slope	r^2	SE	SEE	Pol.
20	0.51	0.52	0.182	0.152	HH
30	0.62	0.59	0.176	0.14	HH
40	0.76	0.72	0.164	0.111	HH
50	0.73	0.68	0.179	0.135	HH
60	0.7	0.67	0.196	0.165	HH
70	0.68	0.63	0.201	0.179	HH
20	0.58	0.56	0.152	0.143	VV
30	0.66	0.63	0.142	0.131	VV
40	0.81	0.79	0.13	0.099	VV
50	0.76	0.71	0.136	0.11	VV
60	0.74	0.7	0.141	0.118	VV
70	0.64	0.65	0.148	0.128	VV

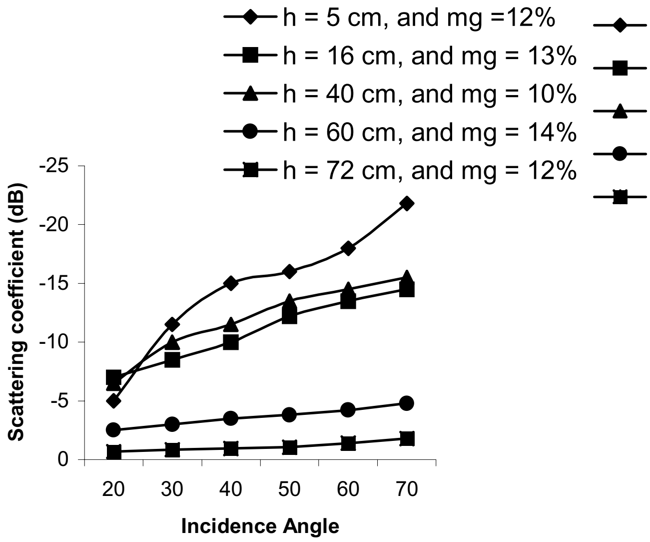

Fig. 1. Angluar variation of scattering coefficient at different crop (wheat) height and crop covered soil moisture for HH-pol. at X-band

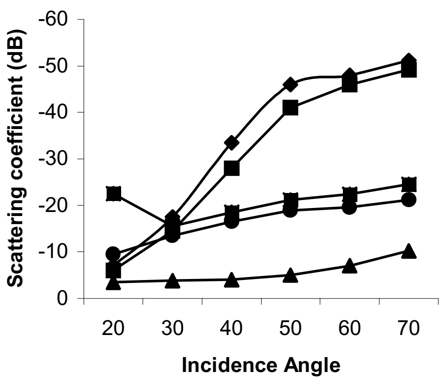

Fig. 2. Angular variation of scattering coefficient at different crop (wheat) height and crop covered soil moisture for VV-pol. at X-band