Preliminary Results On Radar Measurement Of Paddy Field Using C-Band Scatterometer System

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Abstract: A ground-based, C-band full polarimetric mobile Scatterometer system has been developed in Malaysia with collaboration between Malaysian Centre for Remote Sensing (MACRES) and Multimedia University (MMU). The main purpose of this system is to measure and monitor backscattering coefficient, σ^0, for earth terrain such as paddy fields, forest and soil surfaces. This paper describes the preliminary results on radar backscatter measurement from paddy field using the mobile C-band Scatterometer system. The measurement campaign was conducted at Sungai Burung area in April 2003. Real time data were collected using four polarization modes (HH, HV, VV and VH), at various incidence angles ranging from 0^0 to 60^0. The measurement data show consistent results as compared to other reports, which verify the capability of this Scatterometer system as a useful tool for remote sensing.

Keywords: Remote Sensing, Microwave, Sensor, Scatterometer.

1. Introduction

Instead of using traditional method, Malaysian researchers are motivated to use appropriate remote sensing technology to increase the rice crop production [1]. The development of a mobile C-band Scatterometer system in 1997 was in line with the objective to measure *in situ* backscatterer characteristics of extended and discrete targets on earth terrain for remote sensing applications [2]. This system consists of four major subsystem namely antenna, radio frequency (RF) section, intermediate frequency (IF) section, and PC-based data acquisition unit, mounted on a boom-truck platform. The system, operating at 6.0GHz center frequency, is a short range radar with full polarization capability. The system has been tested in an outdoor environment and the performance clearly indicates its capability as a useful tool for measuring the backscattering or reflective properties of surfaces and volumes.

2. Procedures And Ground Truths

In April 2003, the first field measurement campaign was conducted at Sungai Burung paddy field area. The monitored paddy species was the MR219 type, using broadcasting plantation technique, and the age is about 60 days. The life cycle of the paddy is about 100 days.

The main objectives of this campaign were to gain experiences for field measurement, and to collect preliminary data for system verification. Each measurement was collected using four polarization modes (HH, HV, VV and VH), at various incidence angles θ, ranging from 0^0 to 60^0 at 10 degree interval. The optimum measurement range for this system was between 20 m to 100 m. Far-field region had been considered for this particular measurement to minimize the taper in the phase fronts impinging on the target [3]. The far-field region is fixed at 20 m. The height of the antenna was adjusted accordingly to get the corresponding θ at fixed range of 20 m. Fig.1 shows the measurement setup of the mobile C-band Scatterometer system.

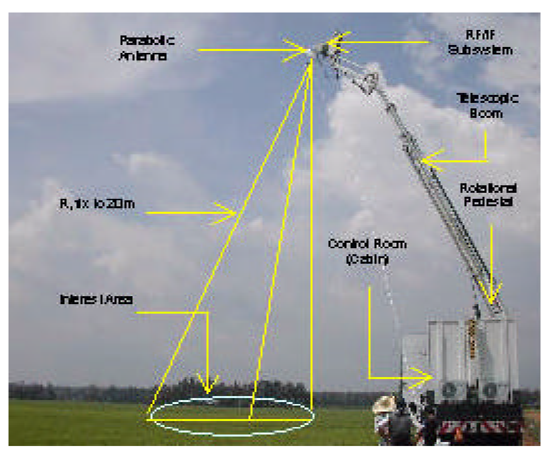

Fig.1.Measurement Setup of the Mobile C-Band Scatterometer System

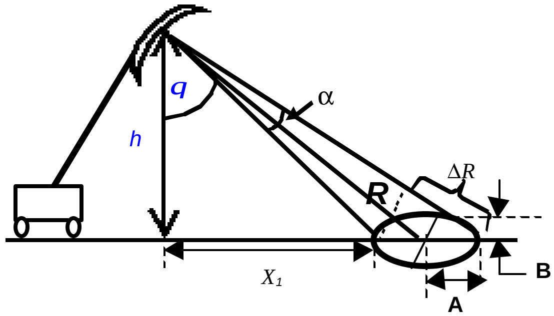

Fig.2.Geometry illustration for height, incident angle and area of Illumination

Prior to geometry illustration in Fig.2, equations (1) – (3) are used to compute the height, h, area of illumination, A, and backscattering coefficient, σ^0.

$$h = R\cos\theta \qquad (1)$$

$$A = h/2\{\tan(q + \alpha/2) - \tan(q - \alpha/2)\}, \text{ where } \alpha = 3° \qquad (2)$$

$$B = \tan(\alpha/2)\,\{\sqrt{h^2 + (A + h\tan(q - \alpha/2))^2}\,\} \qquad (3)$$

Note that the paddy field under observation is an area-extended target. The projected area on the ground, called the effective area of illumination, is given by

$$A_{ill} = \pi AB \qquad (4)$$

Meanwhile, radar backscattering coefficient is given by

$$\sigma° = [\,\{P_r\,(4\pi)^3 R^4\} / \{P_t\, G^2\, l^2 A_{ill}\}] - C \qquad (5)$$

where $\sigma^0 = \sigma / A_{ill}$ and C = correction factor

Ground truth measurements had been carried out simultaneously to ensure timely and localized information. During the measurement, it was observed that the plant moisture contents were about the same and stable. The boom was rotated on a turntable while independent samples were collected up to 20 sets for each incidence angle θ. An encoder that fixed on the jib boom joint was used to display the antenna elevation angle.

The measurement started with delay line calibration, point target measurement, and followed by error correction procedures as described in [4]. A 100ns delay line was incorporated for internal calibration to compare the measured target's response with the delay line response. Internal calibration is necessary to verify the functionality and stability of the RF and electronics components in the system and it had been repeated for every 5 - 6 data sampling interval. External calibration was carried out for the purpose of eliminating system bias and absolute errors of the antenna and receiver. The correction factor, C was used to convert the relative measurement to absolute measurement, where C value was approximately –30dB.

The data collected were processed off line. The radar signal processing involved power spectral density estimation, statistical analysis, radar cross section (RCS) calculation and polarization synthesis.

3. Results and Analysis

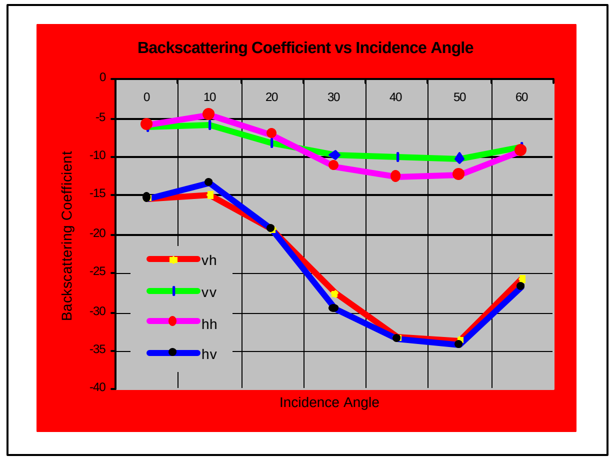

Fig.3. Backscattering coefficient, s^0 vs incidence angle, q

Fig 3 shows the results of the measured backscattering coefficient, σ^0, of the paddy at various incidence angles, θ. Each point on the graph represents a mean of 20 independent measurements, taken at different azimuth positions. From the observation, this preliminary result shows that the backscattering coefficient increases at incidence angle close to nadir and then decreases until certain point and increases again. This trend is similar to the results reported by other research groups [5].

At incidence angle 10^0 and 60^0, the backscattering coefficient shows increasing behavior. In this particular position, the orientation of the target is orthogonal to the wave propagation as shown in Fig. 4. This scenario is influenced by the wind speed which contributes to the leaf-angle distribution. Microwave backscatter is highly dependent on the orientation and distribution of the scattering elements present within the region. Consequently, some of the paddy leaf-angle causes direct backscattering from plants and hence contributes larger scattering [6]. For intermediate angles 20^0 – 50^0 for both co-polarized and cross-polarized, the trend of the backscattering coefficient decreases exponentially [5].

The upper two curves with higher backscattering coefficient values represent the HH and VV polarizations, while the lower two curves show the VH and HV polarizations. Co-polarized has high backscattering value due to quasi vertical structure of paddy plant. The difference between cross-polarized and co-polarized backscattering coefficients is about 10dB. Both VH and HV show approximately same value while VV and HH show a slight difference.

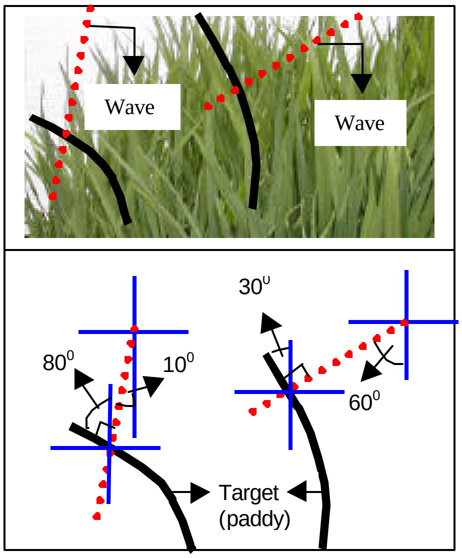

Fig. 4 Leaf-angle distribution of paddy plant

4. Conclusions

A measurement campaign has been conducted at Sungai Burung paddy field area by using a ground-based mobile C-band Scatterometer system. The measurement results show a typical response of backscattering coefficients as compared to other reports. It is known that the backscattering depends on the sensor and the scatterer characteristics. The sensor characteristics are primarily defined by the incidence angle, polarization and frequency. Scatterer parameters include dielectric properties, roughness, shape, and orientation. With this preliminary results we have shown that this system is capable to be one of the useful and reliable tool for remote sensing in Malaysia. Further ground truth measurement verification will be carry out before using this radar as the basis of an operational monitoring system in Malaysia. In future, this system will be used to develop theoretical model for major crops such as paddy, oil palm and rubber.

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References

[1] Saiful Bahri, A.B, 1999. Monitoring of Wetland Paddy Fields using Microwave Remote Sensing Data, Master of Engineering Science, MMU.

[2] Koo, V.C., B.K., Chung, H.T., Chuah, 1999. Design and Development of a Scatterometer System for Enviromental Monitoring, *Proceeding of IGARSS'99 Symposium, Hamburg Germany*.

[3] Knott, E.F, 1993. Radar Cross Section Measurements, *Elsevier, NY*, chap 1.

[4] Koo,V.C., B.K.Chung, and H.T.Chuah, 2000. Calibration and Field Experiment of a C-band Polarimetric Scatterometer, *Proceeding of IGARSS 2000 Symposium, Honolulu Hawaii USA.*

[5] Soo Bum Kim, Byung Wook Kim, Young Kyun Kong, and Young-Soo Kim, 2000. Radar Backscattering Measurements of Rice Crop Using X-band Scatterometer, *IEEE Trans. Geosci. Remote Sensing, Vol 38, pp 1467-1471*.

[6] F.T. Ulaby, R.K. Moore, and A.K.Fung, 1986. Microwave Remote Sensing Active and Passive : From Theory to Applications, Volume III pp 1856.