Retrieval of Modulation Transfer Function using SAR: Ocean Wave Imaging Scheme

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Abstract:

This paper proposes an over view of the estimation of Modulation Transfer Function (MTF) for the wave imaging mechanism. MTF correlates interaction of electromagnetic waves with dynamics of ocean surface waves. This approach is suitable for the estimation of wave parameters in the large oceanic regions. Main phenomenon occurred in between sea surface and electromagnetic waves interaction are known as Bragg scattering mechanism based-on the various sub-phenomenon such as velocity bunching , hydrodynamic, tilt and orbital velocity modulation existed during the interaction. Bragg scattering assumes the radar cross section of a patch of ocean is estimated strictly by amplitude of small waves called Bragg wave. Bragg waves are the surface waves which have wavelength equal to the projection of the SAR electromagnetic wavelength over the local ocean surface and which propagates either towards or away from the sensor direction. The mechanism is dependent on incidence angle of the satellite SAR sensor. The usefulness of this model for interpreting SAR signatures specially in near-shore region where the backscattering response is higher as compared to the deep ocean.

Key Words: Modulation Transfer Function, Ocean Wave Imaging, SAR, Microwave

I. INTRODUCTION

Microwave Radio Detection and Ranging (RADAR) systems application plays an important role in various oceanographic phenomena such as estimation of wave parameters, detection of targets in huge oceanic regions, current determination. Ocean waves play a vital role in environment for the various maritime activities globally [1]. Space-borne Synthetic Aperture Radar (SAR) system is an efficient technique to monitor variations of dynamic ocean surface phenomena as well as to acquire high resolution surface images at any time and irrelevant of environmental conditions. The two-dimensional SAR image can observe spatial distribution of sea surface that arise from small gravity waves and capillary waves, the main sources of backscattered energy. Various ocean surface phenomena that affect the amplitude or spectral distribution of these waves will be visible on the radar images [2,3]. These phenomena include surface swells, internal waves, currents, wind cells, eddies, ship wakes, and oil spills. The retrieval of Modulation Transfer Function (MTF) has been carried out in this paper in order to show the SAR ocean wave imaging mechanism [4]. Main cause of ocean wave imaging is due to the interaction of SAR signals with ocean surface waves which causes the doppler shift phenomena between the movement of ocean surface along with the microwave signal interaction [5,6].

II. BACKGROUND

The interaction between the SAR pulse of microwave energy and the ocean surface is complex, dependent on wavelength, polarization, geometry, environmental conditions and the electrical properties of the ocean surface. SAR energy is primarily scattered from the ocean surface by the presence of small (mm- to cm-scale) wind-induced surface waves called *Bragg waves*. SAR is particularly sensitive to the Bragg waves in which the wavelength is matched to the projection of the SAR electromagnetic wavelength onto the local ocean surface [7]. A Bragg wave on the ocean surface will cause all of the electromagnetic wave fronts scattered from its different portions to be in phase (i.e., they travel an integral number of wavelengths) and add constructively. Bragg waves are ocean surface waves which have wavelength equal to the projection of the SAR electromagnetic wavelength onto the local ocean surface and which are propagating either directly toward or away from the look direction of the sensor. This can be expressed by $\lambda_B = \dfrac{\lambda_R}{\sin\theta}$ where θ is the local incident angle of the ocean surface, λ_B is the wavelength of the Bragg wave, and λ_R is the SAR electromagnetic radiation wavelength.

III. METHODOLOGY

The calculation of tilt, hydrodynamic, and velocity bunching modulation values have been estimated for the various angle of incidence of SAR sensor. The basic flow chart can be seen in Fig.1

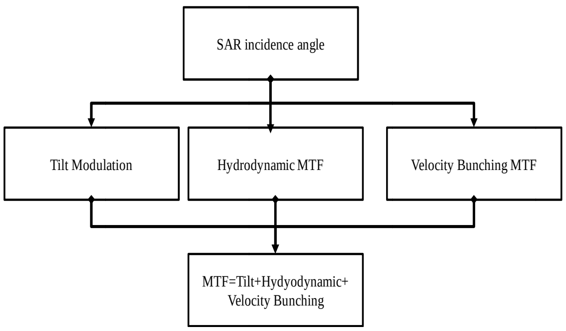

Fig. 1. Flow chart for estimation of MTF using tilt, hydrodynamic, and velocity bunching mechanism of the SAR-ocean waves interactions.

Tilt, hydrodynamic and velocity bunching modulation index algorithms can be written as

$$T_k^{\ tilt} = -4ik_y \frac{\cot\theta}{1+\sin^2\theta} \qquad (1)$$

$$T_k^{\ hydr} = 4.5\omega \frac{k_y^{\ 2}(\omega - i\mu)}{k(\omega^2+\mu^2)} \qquad (2)$$

$$T_k^{\ vb} = -ik_y \cot\theta \qquad (3)$$

Equations 1, 2 and 3 indicates the variation of all three modulation transfer functions with respect to SAR incidence angle along with the variation in wave numbers towards range directions.
The total modulation function can be retrieved by addition of equations 1, 2 and 3.

$$T = T_k^{tilt} + T_k^{hydr} + T_k^{vb} \qquad (4)$$

IV. RESULTS AND DISCUSSION

Figure 2, 3 and 4 shows the variation of Bragg wavelength with the incidence angle of SAR look from 0 to 90 degrees. Since Bragg wave length phenomena is the important for the SAR wave imaging techniques before the discussion with various MTFs. It can be observed that, for L-band radar, the maximum wavelength of 750m can be obtained at the incidence angle of 50 degrees while for the C band radar the maximum wavelength of 920m were obtained at incidence angle of 25 degree.

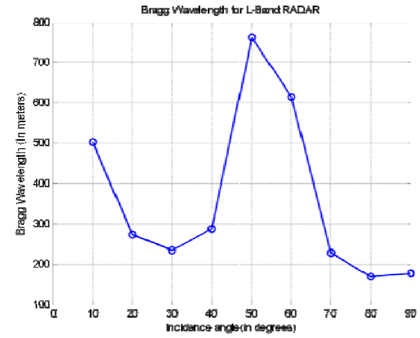

Fig.2. Variation of Bragg wavelength with incidence angle for L-Band Radar

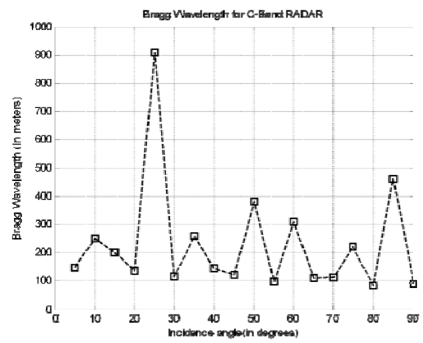

Fig.3. Variation of Bragg wavelength with incidence angle for C-Band Radar

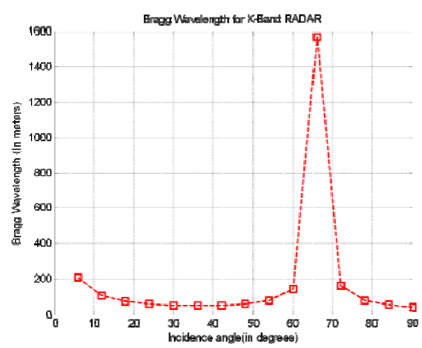

Fig.4. Variation of Bragg wavelength with incidence angle for X-Band Radar

Similarly, for X-band radar, maximum wavelength of 1800m were estimated incidence of 65 degrees. Since Bragg wave imaging mechanism depends on the Bragg wave imaging value. Hence it can be seen that L-band radar shows the suitable response for the image formation because of the moderate wavelength at moderate angle of incidence as compared to the other two types of imaging radar datasets.

CONCLUSION

The various aspect of the SAR imaging mechanisms have been presented in this paper based on three modulation functions. The variation of bragg wavelength with angle of incidence were presented and it can be concluded that, L-band radar has more suitability in SAR ocean imaging due to moderate value of wavelength at significant incidence angle. The variation of MTF along with the incidence angles are under process. It can be seen that, the imaging phenomena is depends on the incidence angle of SAR sensor as well as the various oceanographic phenomena such as wave length, wave number, wave time period.

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