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Review Article

# A case study of tsunami detection system and ocean wave imaging mechanism using radar

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**Abstract**

Tsunamis are the seismic generated waves, which causes the huge displacement of water volume in ocean from deep water to the coastal regions. Tsunami detection and investigation of its early warning is the very important issue nowadays, which supports our existing system more precise. This paper proposes a case study of the mathematical models of the ocean wave imaging schemes and the Tsunami detection system model for the Japan's region where Tsunamis hits on March 11, 2011. Tsunami detection function ($q$-factor) was developed which is well known as $q$-factor estimates. $q$-factor works on the principle of selected radar band threshold. The tsunami reaches around an hour afterward the earthquake, as specified through the relationship in the velocities in altered bands. These effects in a high-pitched upsurge in the $q$-factor, descriptive the tsunami appearance. This radar functions for only 40 min in the hour, causing in the 20 min gaps noticeable in plots. The entrance of the tsunami is specified by relationship between velocities in altered bands early about 2.5 $h$ afterward the volcanic activity. $q$-factor demonstrates a sudden conversion in magnitude about 8 min afterward the start of the velocity relationships. At this point, the velocity is declining, representing that the tsunami is stirring offshore, subsequent in the negative $q$-factor. The future improvements in integrated tsunami detection systems can also be easily incorporated in this technique in order to obtain better detection capabilities.


*Keywords:* Tsunami detection; RADAR; Waves modulations.

## 1. Introduction

Waves are the ocean's most important features, which transport energy from one place to other. Wavelengths can vary from few centimeters to hundreds of meters and wave heights may vary from tiny perturbation in ocean surface to tens of meters. Measuring the ocean waves from space is the key contribution towards the satellite remote sensing. If the wave attributes such as wavelength, wave height and direction of propagation can be found effectively, this information may recover our acceptance values towards the distinctive compelling towards the ocean.

RADARSAT-2 is the Earth Observation Satellite (EOS) that was successfully launched on 14 December 2007 with the unique collaboration of the Canadian Space Agency (CSA) and the industry MacDonald, Dettwiler and Associated Ltd. (MDA), Canada. It carries a C-band (5.40 GHz) SAR instrument in order to achieve good resolution imageries. RADARSAT-2 has been designed with significant and powerful technical advancements that include high-resolution imaging, left and right-looking imaging options, superior data storage and more precise measurements of spacecraft position and attitude.

Fig. 1 illustrates the imaging capabilities of RADARSAT-2 sensor which involves the different imaging modes of operation. Table 1 gives the specification of RADARSAT-2 sensor in terms of its imaging mode of operation, swath width, resolutions, polarizations and incidence angles. The satellite is placed over an altitude of approximately 792 *Km* above the earth surface.

Current tsunami sentry structures are created on computational databases that counsel alongside the probability of seismic activity-produced tsunami influences, and effort to

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Table 1
Imaging mode characteristics of RADARSAT-2 [5].

| Imaging mode | Nominal swath [km] | Resolution (range × azimuth) [m] | Polarization | Incidence angle [°] |
|---|---|---|---|---|
| Standard | 100 | 25 × 28 | Quad | 20–49 |
| Wide | 150 | 25 × 28 | Quad | 20–45 |
| ScanSAR wide | 500 | 100 × 100 | Quad | 20–49 |
| ScanSAR narrow | 300 | 50 × 50 | Quad | 20–47 |
| Standard quad-polarization | 25 | 25 × 28 | Quad | 20–41 |
| Fine quad-polarization | 25 | 11 × 9 | Quad | 20–41 |
| Ultrafine | 20 | 3 × 3 | Quad | 30–50 |

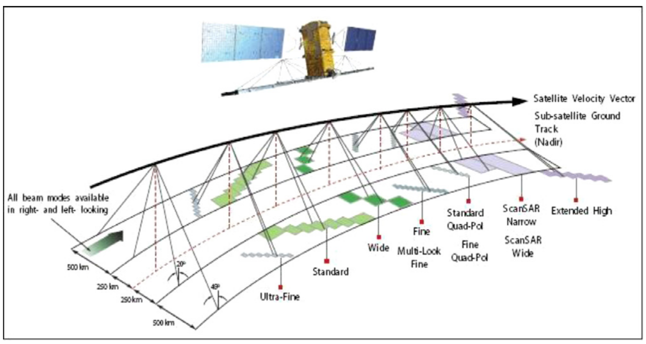


Fig. 1. Schematic diagram for the different modes obtained by RADARSAT-2 sensor [5].

forecast their power and influx times verses site built on the seismic activity appearances [6,7]. These computational models comprise ocean-size shoreline and bathymetry geometries. A procedure exists for sudden dissemination of earthquake datasets and tsunami model early investigations in between foreign administrations but there are no structure exists for native recognition of an real inward wave with the substantial early warning competences [8,11]. Tide-gauge sea heights at seaside locations nearer to the epicenter and do deliver useful measurable data for sites additional downstream, if they would able to transmit the datasets [2]. Tsunami which hited Japan in March 2011, the signal was detected by many high frequency radars round the Pacific ocean with strong consequences from locations in United States, Japan, and Chile [9]. The high frequency radar systems currently function endlessly from numerous seaside sites around the world, measuring the ocean surface currents and waves. The radar locations around the globe are accessible on http://www.codar.com/seasonde_world_locations.shtml.

Barrick [10] initially suggested the utilization of coastal based radar instruments for tsunami early monitoring. Furthermore, the investigation refined this idea and radar period pattern algorithm was proposed [1,8] which can be further be engaged using a single radar to detect a tsunami signals among the background wave currents. This algorithm was depends on the evidence that when wave velocity mechanisms perpendicular to the water depth contours are conquered by the tsunami waves, they will be intelligible over area bands parallel to the water depth subzones. The arrival of the tsunami is indicated by the commencement of distinctive current velocity oscillations.

When water depth reduces, the height of tsunami decreases gradually, as the inverse 1/4th order of water level. The Eigen function orbital velocity upsurges with higher values swiftly, as the inverse 3/4th order of water level. Water wavelength reduces with the quantity of square root to the water depth.

As under the discussion and part of the tsunami working group, the tide gauge data was collected and compiled about40-50 tide gauge records in to region of Indian Ocean to analyze maximum amplitude and spectral components**.** Sea-level monitoring of the oceanographic activities have been developed known as Global Sea Level Observation System (GLOSS) and is located in Australia, The pacific and Atlantic oceans recorded the 2004 tsunami [12].

Tsunami execution and propagation was also measured on hydrophones or seismometers in which the analysis have been carried out to provide a wide range of time of arrival about 90 to 3000 s. The aspect of Global Positioning Systems (GPS) measurements of tsunamis and its surveys have also been carried out this research categories based on the societal responses [14,16].

The real-time justifications and monitoring of the tsunami have been incomplete to deep-water bottom pressure instrument interpretations of variation in sea level changes. The coastal based radar monitoring systems are implemented in various countries to detect the tsunami wave's arrival near to the coast and to analyze and present the report to the disaster management team for the quick and sudden action to save various lives.

Numerous models have been proposed in order to retrieve the wave parameters either in exposed sea or in coastal sea waters. The sea state can be completely characterized by the directional wave spectrum, which describes the distribution of wave energy with respect to the wave propagation and wave numbers. Retrieval of the ocean wave parameters by SAR depends on sea state conditions.

Beckmann and Spizzichino [17] discussed the idea of electromagnetic waves interaction with ocean waves with the use of Maxwell's equation and they intimate the theory of Kirchhoff's approximation which was valid for longwave. Elachi and Brown [15] described some of the mechanism of SAR-ocean interaction with the development of linear transform equation. The detailed study about the sea scattering mechanism can be found in [3]. Sea surface back scattering response sensed by the sensors are more dominantly affected by the surface scattering phenomenon between the interactions of electromagnetic and sea surface waves.