Advance Prediction of Tsunami by Radio Methods

Sheenu.P
Department of Electrical & Electronics
Mar Baselios College of Engineering & Technology Nalanchira, Thiruvananthapuram
Kerala, India

Dr. MJS Rangachar
Department of Electronics and Communication Engineering
Hindustan Institute of Technology & Science (HITS)
Chennai, Tamil Nadu, India

Abstract- Tsunamis represents as an ever-present threat to lives and property along the coasts of most of the world's oceans that cause considerable destruction and kills people. As the Sumatra tsunami of 26 December 2004 revealed the fact that we must be more proactive in developing ways to reduce their impact on our global society. This paper provides an overview of the state of knowledge of tsunami presents some challenges confronting advances in the field and identifies some promising frontiers leading to a global warning system. This paper compares the different schemes for the detection of tsunami signals. Overviews of the signals and their characteristics have done. This overview is then used to develop guidelines for advancing the science of forecasting. High-frequency (HF) surface wave radars can also provide a unique capability to detect targets far beyond the conventional microwave radar coverage. This capability also could contribute to the development and improvement of Tsunami Early Warning Systems. This paper concludes that surface wave radar systems can be used to detect tsunamis well before their arrival at a coastline. We should create a world that can coexist with the tsunami hazard.

Keywords – Remote sensing, modeling, DART Systems, BPR Systems, and HF surface radar.

I. INTRODUCTION

No instantaneous happening for any event. That is an important fact of life. There are "time constants" involved for all events. The light and sound difference in air is about a million. The above idea can be considered for the prediction of tsunami so that there will be enough time for the authorities to move people to safer locations in order to prevent loss of life. If tsunami can be predicted in advance of its occurrence that will help in taking preventive measures. About 72 percent of the surface of Earth is covered with water-the three Oceans (Indian, Atlantic & Pacific oceans). Earth Quakes occurring in Oceans floor around 6(Richer Scale) and above, can cause upheavals in the water volume directly above it and which results in Tsunami. The resulting water waves may reach height as much as 100 feet and above. These waves travel towards coast and cause destruction to people who are unprepared or unaware of its arrival. Radar is an acronym for Radio Detection and Ranging. Majority of Radars used by Air force, Airport authorities including weather Radars are LOS systems. These radars may/may not be used in prediction of arrival of Tsunami. A special category of radar called "Surface Wave Radars" Which may have to be operated in VLF/LF bands may do the job.

Tsunamis waves propagate near the ocean surface. Tsunamis are distinct due to their mode of generation, their characteristic period wavelength and velocity. The meaning of Tsunami is 'harbor wave'. A tsunami is characterized by its wavelength of very long value that is generated by sudden displacement of the sea floor or disruption of any body of standing water. Generally the danger of a tsunami occurring exists where geological faults occurs like earth- and lake-quakes are possible, tectonic plates collision etc. Usually beaches and coastlines are more affected by tsunamis. Tsunami's most frequently occur in the Pacific region , particularly along the "Pacific Ring of Fire "and are the geologically most active fields of the earth. Scientists are constantly trying to learn new ways to predict the behavior of tsunamis. Most related works so far are particularly interested in the inundation and run-up features after the waves strike land. Most common Centers continuously monitoring seismic events and changes in the tide level are the Pacific Tsunami Warning Centre (PTWC) and West Coast & Alaska Tsunami Warning Centre (ATWC).Tsunamis are usually generated when earth plate boundaries abruptly move and vertically displace the overlying water and they are a series of waves. So all earthquakes will not cause tsunamis. For this reason it must be determined at sea level itself whether or not an earthquake has actually triggered the deadly wave. A tsunami has a much smaller wave height offshore, and a very long wavelength of about hundreds of kilometers. That is why they generally pass unnoticed at sea. This wave travels at a speed over 800 km/h, but due to the enormous wavelength this wave has amplitude less than 1 m. So it is very hard to detect tsunamis over deep water. When the tsunami approaches the coast (shallow water), due to wave shoaling the wave is compressed and its speed slows down to 80 km/h. More over in shallow water its wavelength diminishes to less than 20 km and its amplitude grows enormously so it becomes a distinctly visible wave. We can also include the high frequency surface wave radar (HFSWR) for the improvement of Tsunami Early Warning Systems. The HF radar that is based on surface wave propagation along salty water will detect targets far beyond the conventional microwave radar coverage. HF radars usually provide a large coverage area using the frequency band of 3-30 MHz that could extend up to more than 200 kilometers in Tsunamis waves propagate near the ocean surface. Tsunamis are distinct due to their mode of generation, their characteristic period wavelength and velocity. The meaning of Tsunami is 'harbor wave'. A tsunami is characterized by its wavelength of very long value that is generated by sudden displacement of the sea floor or disruption of any body of standing water. Generally the danger of a tsunami occurring exists where geological faults occurs like earth- and lake-quakes are possible, tectonic plates collision etc. Usually beaches and coastlines are more affected by tsunamis. Tsunami's most frequently occur in the Pacific region , particularly along the "Pacific Ring of Fire "and are the geologically most active fields of the earth. Scientists are constantly trying to learn new ways to predict the behavior of tsunamis. Most related works so far are particularly interested in the inundation and run-up features after the waves strike land. Most common Centers continuously monitoring seismic events and changes in the tide level are the Pacific Tsunami Warning Centre (PTWC) and West Coast & Alaska Tsunami Warning Centre (ATWC).Tsunamis are usually generated when earth plate boundaries abruptly move and vertically displace the overlying water and they are a series of waves. So all earthquakes will not cause tsunamis. For this reason it must be determined at sea level itself whether or not an earthquake has actually triggered the deadly wave. A tsunami has a much smaller wave height offshore, and a very long wavelength of about hundreds of kilometers. That is why they generally pass unnoticed at sea. This wave travels at a speed over 800 km/h, but due to the enormous wavelength this wave has amplitude less than 1 m. So it is very hard to detect tsunamis over deep water. When the tsunami approaches the coast (shallow water), due to wave shoaling the wave is compressed and its speed slows down to 80 km/h. More over in shallow water its wavelength diminishes to less than 20 km and its amplitude grows enormously so it becomes a distinctly visible wave. We can also include the high frequency surface wave radar (HFSWR) for the improvement of Tsunami Early Warning Systems. The HF radar that is based on surface wave propagation along salty water will detect targets far beyond the conventional microwave radar coverage. HF radars usually provide a large coverage area using the frequency band of 3-30 MHz that could extend up to more than 200 kilometers in range. So they are used for many applications that include ship detection, tracking, guidance, distribution of pollutants, fishery, oceanography etc. These radar systems recently became an operational tool in coastal monitoring worldwide. The HF radar can be used to identify a tsunami wave travelling towards the coast at long ranges. The Bragg-resonant back-scattering by ocean waves with half of the electromagnetic wavelength allows measuring the radial components of ocean surface currents at far distances. We can extend the radar systems that have already been installed at the coast by adding just a software package enable support for tsunami detection.

The rest of the paper is organized as follows. Proposed embedding and extraction algorithms are explained in section II. Experimental results are presented in section III. Concluding remarks are given in section IV.

II. Tsunami-Description of the Event

A tsunami is a shallow-water ocean wave and the cause that producing it may be any undersea seismic actions. These waves can travel even across the deepest ocean basins. It is also called as "shallow water" since it is always feeling and responding to the bottom depth. Typical tsunami periods may vary within 30 minutes with wavelengths in deep water is of range 600km and with propagation speeds as high as 700 km/hour (nearly supersonic). However, in deep water, the height of a killer tsunami is only 50 cm, not enough to ever be felt by someone sitting in a boat while the tsunami passes over the course of a half hour. Everything changes as this tsunami moves up onto the continental shelf, into shallow water. The height of the wave changes inversely as its depth. But when the depth changes from 4000 m to 2 m, the height increases from 50 cm to ~3.5 m. As the depth gets shallower yet, that is called its "run-up phase", nonlinear energy/momentum transfers can cause this wave to rise up to 10 meters or more, a catastrophically damaging event. The HF radar does not see the tsunami wave itself. More over every shallow-water wave has a "particle current" attached to it. In deep water, the particle of water at the surface orbits around in a circle whose radius is the amplitude of the water wave. In shallow water, the particle translates back and forth, as though the circular orbit were squashed down to a straight horizontal line. Short Bragg waves that the radar observes are translated towards the shore on top of the tsunami crest, and back away from the shore in its trough. The radar measures the velocity of these particle-like Bragg waves arrayed over the surface of the tsunami wave. Since the tsunami height increases slowly as depth decreases, the particle/Bragg velocity increases as much faster as the inverse three-quarters power of the depth. So as the water gets shallower, the velocity seen by the radar begins to stand out from the background circulation in that region. Any wave that moves into very shallow water refracts, so that it advances very nearly perpendicular to the bottom contours, or isobaths. In most cases, these isobaths are parallel to the coast. Small features in the isobaths contours do not matter. Because the tsunami wavelength even in shallow water is tens of kilometers, a bathymetry feature must be at least 30 - 40 km to cause much of a deviation in direction. Tsunami Characteristics

Tsunamis are primarily associated with the occurrence of earthquakes. The energy generated travels out in all direction when an earthquake occurs. An example for this is throwing a pebble into a small, still pond where the pebble represents a meteorite or some other energy source and the pond represents the ocean. And the ripples that travel out in all directions from the point where the pebble hit the water represent the energy that creates a sea wave or tsunami. More over waves as they reach the shore becomes larger where the water is shallower. Detecting tsunamis is a very difficult task to handle, because when a wave begins in the deep ocean waters, the height will be of about twelve to twenty-three inches and look like nothing more than the gentle rise and fall of the sea surface. Tsunamis are characterized as shallow-water waves where they are different from the wind-generated waves that many of us have observed from the beach. Wind-generated waves generally have a period (the time between two successive waves) of five to twenty seconds and a wavelength (the distance between two successive waves) of about 330 to 660 feet (100 to 200 meters).Tsunamis in deep water can have a wavelength greater than 300 miles (482 kilometers) and usually have a period of about an hour. But the normal California tube is having a wavelength of about 330 feet (100 meters) and a period of about ten seconds. As mentioned above, tsunamis are shallow-water waves, which mean that the ratio between water depth and wavelength is very small. The deeper the water, the wave will be faster and shorter. At this speed, the wave can compete with a jet airplane, since they can travel across the ocean in less than a day. Since a wave loses energy at a rate inversely related to its wavelength, so tsunamis can travel at high speeds for a long period of time and they lose very little energy in the process[1].

RADAR RELEVANTTSUNAMI SIGNATURES

In this section we review, from a radar remote sensing viewpoint, all known tsunami-related signatures. Each sensor relies on at least one principle of detection but, obviously, one sensor can combine more principles of detection.

A. Tsunami wave height

Wave height is the most intuitive physical feature of an ocean wave and can be measured by tide gauges at shore, ocean bottom pressure sensors off shore and, lately, tsunami wave height measurements were recorded by satellite-borne altimeters. Satellite altimetry relies on nadir pointing radars carried onboard a number of satellite missions like ESA’s ERS-1, ERS-2, ENVISAT, SENTINEL and the series of US-French satellites Topex/Poseidon, Jason-1 and Jason-2. On Boxing Day 2004, a number of altimeters accidentally overflew the tsunami wave and provided the scientific community with valuable measurements. Following this accidental data-takes, concepts were put forth for tsunami early warning from space. The proposed concepts envision a number of LEO microsatellites carrying altimeters. Since tsunami wave heights in the open ocean are expected to be far below 1 m, detecting such a small change will certainly be a challenge. The Topex/Poseidon and Jason-1/2 altimeter measurements already showed that averaging over long times is required to resolve these changes, and it might become impossible for low amplitude tsunamis, especially under bad weather conditions where the ocean is already very rough. However, one advantage, which is true for all signatures mentioned in this section, is that tsunamis are extremely large-scale phenomena and that the changes, although being very small, apply for very large areas in the order of hundreds times tens of kilometers or even more. By continuously monitoring these large areas and by adequate averaging and filtering, it should be possible to extract even small changes from the overall statistics.

B. Tsunami orbital velocities

As with every ocean wave, tsunami propagation relies on the Elliptical movement of water masses. Even though the group velocity of the wave is generally high (700 km/h in the open ocean, slows down with shallower bathymetry) the horizontal orbital velocities of water masses accomplishing tsunami propagation are extremely small. The horizontal orbital velocity of a tsunami wave U_h can be calculated using the following formula

$U_h = A\sqrt{\frac{g}{D}}$ Where A is the wave amplitude, g is the gravitational constant and D is the ocean depth. For the Sumatra Boxing Day tsunami in 2004, which had amplitude of 0.7m in the open ocean with a depth of 4000 m, the horizontal orbital velocity U_h results to 3.5 cm/s. This value clearly indicates the upper bound of expected velocities; smaller (average) tsunamis should be in the range of 1–2 cm/s. These orbital velocities are amplified by shallow bathymetric features and might reach tens of cm/s or even m/s in coastal areas. Tsunami orbital velocities might be detected by along-track interfero-metric SAR systems and HF surface wave radars.

C. Tsunami shadows

Tsunami shadows are spatially extended alterations of the radar cross section of the ocean surface. Observations of tsunami shadows, that is, extended darker strips on the ocean surface along the front of a tsunami wave were first reported by the pilot of an aircraft overflying the 1946 Aleutian tsunami (Perkins, 2004). Later, observations were reported by eye-witnesses located at different points along the shore of the island of Oahu, Hawaii, coinciding with the arrival of a small tsunami triggered by the 1994 Shikotan earthquake. Besides optical observations, tsunami shadows were also observed at microwave frequencies by satellite altimeters overflying the Boxing Day tsunami. This unique data-take confirmed the presence of relevant (a few dB) variations of the ocean surface radar cross section (RCS) associated with the tsunami wave front. However, the physical mechanisms causing tsunami shadows are not yet entirely understood. The most likely explanation is that the orbital velocities of the tsunami wave cause modulations of wind velocity over the sea surface and thus cause variations of the intensity of short surface waves. These observations suggest that satellite altimetry, synthetic aperture radar (SAR), scatter meters and radiometers might have good tsunami detection capabilities. The tsunami shadows propagate at a known and very distinct speed, which allows for their unambiguous differentiation from other features on the ocean surface. Therefore these shadows appear to be the most promising detectable signature for the near-field problem and for tsunami detection in the open ocean in general. Further research is however needed to evaluate the time needed for tsunami shadows to build up after the tsunami inception [2].

D. Tsunami-induced internal waves

Tsunamis are long gravity waves and, like tides, have the capability of triggering internal waves under given oceanographic conditions. Even though internal waves appear as radar cross section variations of the ocean surface, it is worth reminding that the generating mechanism and the spatial scale of these features are completely different from tsunami shadows. All these features are ocean surface physical features, and might be detectable by satellite borne sensors (SAR, satellite altimeters, scatter meters and radiometers). Indeed, a number of mechanisms (either known or unknown) might contribute to tsunami-induced radar cross section modulations and chances are that these effects are strong enough to be used as principles of detection by future tsunami warning systems. This involves not only detection but also an estimate of the tsunami magnitude. Ultimately, a stationary sensor has the possibility to learn normal patterns and detection and/or magnitude estimation can be achieved by comparing pre- and post-quake patterns.

III.TSUNAMI PREDICTION METHODS

The main detection schemes include the following:

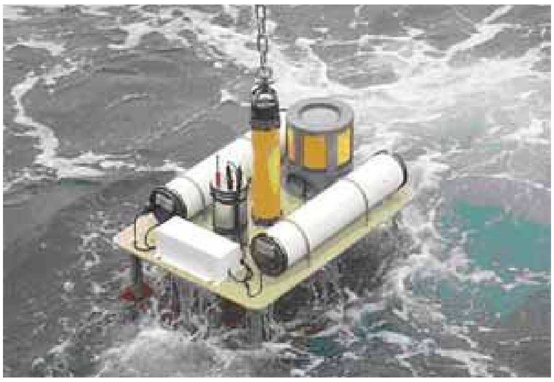
- Deep-Occean Assessment and Reporting Of Tsunamis (DART systems)
- Buoy-Bottom Pressure Recorder System(BPR)
- Satellite Detection System
- Global Earth Observation Systems of systems(GEOSS)
- Using Surface wave radars (Radio Method).

A. Deep Ocean Tsunami Detection Buoys

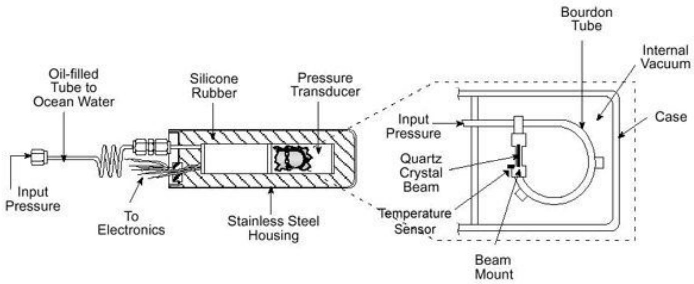
Deep-ocean tsunami detection buoys are instruments that are used by the Bureau of Meteorology (Bureau) to confirm the existence of tsunami waves generated by undersea earthquakes. The function of these buoys is to observe and record changes in sea level out in the deep ocean. This enhances the capability for early detection and real-time reporting of tsunamis before they reach land. A typical tsunami buoy system mainly comprises of two components. They are the pressure sensor anchored to the sea floor and the surface buoy. The sensor on the sea floor measures the change in height of the water column above by measuring associated changes in the water pressure. After that this water column height is communicated to the surface buoy by acoustic telemetry and then relayed via satellite to the tsunami warning centre [3].

B. Buoy-Bottom Pressure Recorder System (BPR)

The bottom pressure recorder (BPR), is a critical component of the tsunameter system and it includes a Digiquartz® Broadband Depth Sensor, a computer, data logger and an acoustic transducer to communicate with the surface buoy.



Tsunameter BPR



Digiquartz® Bourdon Tube Broadband Depth Sensor

The main sensing element in the bottom pressure recorder is the Digiquartz® Broadband Depth Sensor. This sensor monitors pressure continuously and if the pressure reading changes above a set threshold, then the tsunameter automatically transmits data to a surface buoy. The surface buoy makes a satellite connection to Tsunami warning centers that evaluate the threat and issue a tsunami warning. The most important sensing requirement is the detection of very small pressure changes at water depths up to 6000 meters. The change in water depth due to a tsunami in the open ocean is generally less than one centimeter. The resolution capability of Digiquartz® Broadband Depth Sensors makes it possible for tsunameters to detect water level changes of less than one millimeter at the deployed depth of 6,000 meters (one part in six million). Digiquartz® Broadband Depth Sensors employ a Bourdon tube as the pressure-to-load generator. Pressure applied to the Bourdon tube generates an uncoiling force which applies tension to the quartz crystal. The change in frequency of the quartz crystal oscillator is a measure of the applied pressure. The transducers are hermetically sealed and evacuated to eliminate air damping and maximize the Q of the resonators. The internal vacuum also serves as an excellent absolute pressure reference. The high performance of the Digiquartz® Instruments is achieved through the use of a precision quartz crystal resonator whose frequency of oscillation varies with pressure induced stress[4].

C. Satellite Altimetry measurements

In some exceptional cases another useful measurement of the sea level variation can be performed by means of the Satellite Altimetry. Altimeters (e.g. ERS-1, ERS-2, JASON-1 and TOPEX/POSEIDON missions) are nothing but sensors that use microwave radar to determine the distance between the satellite and the sea surface directly below. Although watching for tsunamis is beyond the scope of ongoing altimetry missions, tsunamis can be detected by the change in height of the sea surface during oceanographic monitoring missions, provided that they have the right tracks. Satellite altimetry has the potential to detect large tsunamis, but no tsunami had been detected clearly from space until the 2004 Indian Ocean tsunami event. Actually, only with the aid of sophisticated techniques is possible at times to retrieve the tsunami signal; in fact some of the detection problems are the unfavorable source directivity in the geometry of existing satellite tracks and the high level of noise at frequencies and wavelengths of interest for tsunamis – including various effects due to oceanographic, meteorological, geodetic, and seismic phenomena – that blur the tsunami signal if the wave amplitude is not so much high. However, since satellite altimetry measurements are carried out in the open sea, they have the same advantage of the oceanic bottom-pressure gages because the local coastal effects do not affect the propagating tsunami waves [6].

D. GPS data

GPS (Geodetic Positioning System) provide crustal measurements that reveal a number of tectonic phenomena, such as co seismic and post seismic displacements due to earthquakes, offering a good constrain regarding the rupture process that generates the tsunami. However, geodetic measurements are limited to land and therefore the slip distribution is poorly resolved offshore, though well constrained in the landward areas. These measures are characterized by a very high precision, and the diffusion of these instruments increases day by day. Nevertheless the spatial coverage of these sensors is not always good around the world. Only in some regions, for example in Japan, the instrumental distribution is excellent.

E. RADIO METHODS: SURFACE WAVE RADARS

The most effective means to predict major tsunamis is to predict major earthquakes. However this ambitious objective to say the least, and despite the research of many decades of earth scientists this remains a grand challenge problem, on which major progress will take much time. The question remains, however, as to find credible aspects of tsunami prediction on which mathematicians can contribute. It seems to me that there are many important open questions in the modeling of (1) tsunami wave generation in the event of a major earthquake, (2) wave propagation across the Open Ocean, and (3) wave impact upon the coastlines affected by the event. Indeed the design of tsunami early warning systems or some of its components involves mathematical modeling of solutions of the partial differential equations describing ocean wave dynamics, and computer simulation of solutions which, if they are to be an effective warning, must be performed in faster than real time. It is also an important problem to be able to clarify the character of tsunami waves, in particular those features of the waves as they impact on coastal areas which can affect tsunami safety codes in engineering and architecture. In light of the events of the 2004 tsunami in South Asia, there has been an increasing concern about future tsunami threats, and with it, growing interest in tsunami detection and prevention systems. Part of my task was to research existing tsunami detection systems, consider their effectiveness and feasibility and also to theorize new systems and ways of improving existing ones. Majority of Radars used by Air force, Airport authorities including weather Radars are LOS systems. These radars may not be used in prediction of arrival of Tsunami. Special type of radar called "Surface Wave Radars" Which may have to be operated in VLF/LF bands may do the job. Even HF radars propagating through Ionospheric layers may be helpful in the prediction of Tsunami. It is learned that Indian Navy is using a Radio transmitter at about 10 KHz to contact submarines and surface vessels in and around Indian Ocean Region-Arabian Sea and Bay of Bengal section. The transmitter is located at Tirunelveli. If this transmitter is employed as a surface wave Radar the "Return" from the sea will be "Strong" during Tsunami and it should be possible to predict the incoming Tsunami quite before its arrival at the shore and prevent destruction and damage at the shores. Existing tsunami watch systems are based on computer modeling programs that warn against the possibility of earthquake-generated tsunami impacts, and attempt to predict their strength and location. Before the tsunami occurred, there was the naturally occurring circulation pattern, dominated by tides, wind-driven flows, and the strong Western Boundary current called the Gulf Stream. All of these current contributors are added in, on top of the tsunami pattern. Finding the tsunami pattern within the obscuring background is facilitated by capitalizing on two factors:

• The background currents don't change very much over time periods of 1 – 2 hours, while the tsunami currents change a lot over that time. Therefore we calculate continuously an average background flow and subtract it from the latest incoming radial pattern.

• Devise an algorithm that looks for onshore vectors that are nearly constant within strips parallel to the bathymetry contours, but are allowed to vary with distance from shore [7].

A surface wave can follow the contours of the Earth due to the process of diffraction, .The wave tends to curve or bend around the object as long as when a surface wave meets an object and the dimensions of the object do not exceed its wavelength. But weakening or attenuation of the wave takes place as long as it moves away from the transmitting antenna since the induced voltage takes energy away from the surface wave. The amount of induced voltage must be reduced in order to reduce the attenuation. This can be done by using vertically polarized waves that minimize the extent to which the electric field of the wave is in contact with the Earth. And the electric field of the wave is parallel with the surface of the Earth and it will be in contact with it as long as a surface wave is horizontally polarized. Then the wave is said to be completely attenuated within a short distance from the transmitting site. But when the surface wave is vertically polarized, that wave becomes out of the Earth's surface. So we can say that vertical polarization is superior to horizontal polarization for surface wave propagation. Another major factor that affects in the attenuation of surface waves is its frequency. The higher frequency wave will have shorter wavelength. These high frequencies, with their shorter wavelengths, are usually absorbed by the Earth at points relatively close to the transmitting site. More rapidly the surface wave will be absorbed, or attenuated, by the Earth as long as the frequency of a surface wave is increased. So the surface wave is impractical for long distance transmissions usually where the frequencies are above 2 megahertz. But as long as the frequency of a surface wave is low enough to have a very long wavelength, the Earth looks like very small, and diffraction is enough for propagation well beyond the horizon. So by lowering the transmitting frequency into the very low frequency range and using very high-powered transmitters, we can propagate the surface wave at great distances. The major application area involves the Navy's extremely high-powered very low frequency transmitters that are actually capable of transmitting surface wave signals around the Earth and so they can provide coverage to naval units operating anywhere at sea. This idea can be extended for the prediction of tsunami [8].

The high frequency (HF) surface wave radar could also contribute to the improvement of Tsunami Early Warning Systems. The HF radar, which is based on surface wave propagation along salty water, uses the frequency band of 3-30 MHz to provide a large coverage that could extend to more than 200 Kilometers in range. These maximum range values are of high interest for many applications including ship detection, tracking, and guidance, as well as search and rescue, distribution of pollutants, fishery and oceanographic research. These radar systems recently became an operational tool in costal monitoring worldwide. No one can afford to wait for a major tsunami in order to have relevant data sets for analyses. Hence we must use simulations for continuing optimization efforts, as well as for examining new processing, pattern-recognition, and decision-making algorithms. This will ensure the best, most relevant outcomes. Radar Remote Sensing of ocean surface waves may in general be defined as measuring characteristics of the sea surface by means of electromagnetic waves so that the sea surface is itself not disturbed. The electro-magnetic waves transmitted by the radar antenna are scattered back from the sea surface, modulated in amplitude and phase or frequency by the interaction with the sea surface in motion. This modulation carries information about sea-surface characteristics, surface waves and currents. Oceanographic data is extracted from the backscatter signal by sophisticated signal processing and data analysis.

IV. CONCLUSION

Tsunami forecasts should provide site- and event-specific information about tsunamis well before the first wave arrives at a threatened community. The only information forecasted at present is the tsunami arrival time based on indirect seismic information about the source. Real-Time Tsunami Forecasting of all critical tsunami parameters (amplitudes, inundation distances, current velocities, etc.) are done based on direct tsunami observations. There are many technical obstacles of achieving this. Accuracy, speed, and robustness are the three important factors. In this paper we attempt to consolidate the important milestones in the development of tsunami signal detection by reviewing the major works done so far. Tsunamis are originated by relative movement of the 'tectonic plates' or the segments of the earth's crest under the sea. In common terms 'an earthquake' at the bottom of the ocean causes Tsunami. Today there is no full proof 'Tsunami detection' system operational in any part of the world. Most reliable detection is claimed with the help of buoys which are equipped with water velocity sensors and data transmitting electronics. However their capability is limited to the local area. Therefore very large numbers of such buoys would be required to cover a large ocean area. The sea state monitoring radars have a potential of detecting Tsunamis from a distance of about 300 to 400Km. This capability makes these radars a promising option for the 'Tsunami disaster warning system'. It is important to understand the oceanic current patterns during Tsunami. Relative tectonic plate movement initiates a burst or wave of surface current which is 50 to 200 Km wide. In other words the wave becomes very high at the coasts where the sea is shallow. These wavelength give enhanced 'Bragg scattered' radar echoes in the HF range. The period of tsunami waves is invariant over changes in bathymetry and is in the range 2 to 30 minutes. High frequency (HF) coastal ocean radar is well conditioned to observe the surface current bursts at the edge of the continental shelf and give a warning of 40 minutes to 2 hours when the shelf is 50 to 200 km wide. The capability of the radar to detect Tsunami is translated to the capability of resolving the sea echoes in terms of Range or the distance and Doppler or the velocity of the target. Thus the surface wave radar could contribute to the improvement of Tsunami Early Warning Systems. If a well functioning and efficient warning system is in work, warning and escape are probably the best way to prevent loss of life due to geohazards. Care must be taken in interpreting coastal sea level data, as the signal may only represent the local response rather than offshore tsunami wave characteristics, hence the requirement and implementation of far deeper ocean tsunameters in recent years.

REFERENCES

[1] Bernard, E.N. (1991): Assessment of Project THRUST: Past, present, future. Special Issue on Tsunami Hazard (E.N. Bernard, ed.), *Nat. Hazards, 4*(2,3), 285–292.

[2] Zielinski, Adam and Saxena, Narendra. Tsunami Detectability Using Open-Ocean Bottom Pressure Fluctuations. IEEE Journal of Oceanic Engineering. Vol OE-8, No.4, pg 272, 1983.

[3] Eble, M.C., and F.I. González (1991): Deepocean bottom pressure measurements in th northeast Pacific. *J. Atmos. Ocean. Tech., 8*(2),221–233.

[4] González, F.I., E.N. Bernard (1988): Deepocean tsunami and seismic wave observations:Three recent gulf of Alaska events. Presented at U.S. Japan Earthquake Prediction Seminar, 11-15 Sept. 1988, Morro Bay, CA, USA.

[5] Wallendorf, Louise. Solutions to Coastal Disasters 2008 Tsunamis. American Society of Civil Engineers. 2008. Page 146.

[6] Yamazaki, F., Matsuoka, M., Warnitchai, P., Polngam, S., Ghosh, S. *Tsunami Reconnaissance Survey in Thailand Using Satellite Images and GPS*. AJG. 2005.

[7] T. Buffard, T. Gallou¨et, and J. M. H´erard. A naive Godunov scheme to solve the shallow water equations. CR Acad. Sci. Paris., 1(326):885–890, 1998.

[8] Looking at the Sea, Physical Features of the Ocean. http://www.mos.org/oceans/planet/features.html. The Museum of Science, 1998.