UNDERWATER ACOUSTICS

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Contents

Summary

Underwater acoustics is an important science with significant practical application, especially for the application in ocean. Electro-magnetic waves, which are strongly absorbed by water, have their limits in propagation range in water. Therefore, acoustic waves play an important role on the navigation, underwater communication, underwater detection, and investigation in ocean research.

The ocean is an inhomogeneous medium with various sound velocity profiles that vary with depth because of changes in temperature, hydrostatic pressure and salinity. Due to these sound velocity profiles, acoustic wave propagation in ocean results in several interesting phenomena such as surface duct, shadow zone, SOFAR (deep sea) channel, etc. These phenomena all have practical application in underwater communication and detection. Theoretical models and their numerical algorithms for wave propagation are developed to describe the complicated ocean phenomena of wave propagation. Some of these models, such as: acoustic ray model, normal mode model, PE (parabolic wave equation) models are described in this section.

Sonar equations comprise a group of parameters, which considers the phenomena and effects of the underwater sound. The effects of the medium, the target, and the equipment are all considered as the parameters available to the engineer for underwater sound application.

There are three paragraphs in this section to describe the general pictures of ocean acoustics: The first paragraph, titled as an acoustic view of oceanography, covers the history regarding to research and investigation of underwater acoustics. Then, the sound

velocity profile, which is an important factor for acoustic wave propagation at sea, is also described. In addition, the approaches for measurement of the speed of sound in water are also discussed and are categorized into two kinds of methods. Furthermore, acoustic phenomena in ocean are covered. The phenomena of wave propagation in ocean acoustics, such as: surface duct, shadow zone and SOFAR channel, are discussed in terms of their occurrence and application.

In the second paragraph, propagation wave models for various ocean environments are discussed. Three sophisticated propagation models which are acoustic ray model, normal mode model and PE (parabolic wave equation) model will be discussed.

The final paragraph titled as "the application in ocean acoustics" will cover the application of sonar equations, the application of echo sounder for detection of fish and depth of ocean bottom as well as the bioacoustics of marine life and other applications of underwater acoustics in the ocean.

1. An Acoustical View of Oceanography

In contrast to electromagnetic waves which are strongly absorbed by water, acoustic waves can propagates over hundreds, even thousands, of miles through the ocean under the proper conditions. Therefore, at ocean depth greater than 100 m, humans without searchlight are blind even in the cleanest water. A bat, which is blind in the air, can sense their prey and their surroundings by acoustic echo ranging. Likewise, humans need echo sounder to navigate and communicate in the ocean. In ocean acoustics most physicists or engineers restrict themselves to a vaguely defined band of frequencies f lying somewhere between 1Hz and 100 kHz. At the high-frequency end, sound absorption by sea water is very high. There are a small number of very special applications at the high frequency such as acoustic image-makers and side-looking sonars, which are used for very short-range studies. On the other hand, applications of sound transmission are limited to frequencies less than a few tens of kilocycles. At the low-frequency end, below 1Hz, one has great difficulty in generating sound except with earthquakes and very large explosions.

2. The History of Research on Ocean Acoustics

Researches on ocean acoustics are triggered by the collision of the steamship Titanic in 1912, with an iceberg and the subsequent loss of hundreds of lives. A patent was applied for underwater acoustic echo ranging by L. R. Richardson in Great Britain and R. A. Fessenden in United States to use sound for sensing in the sea. The first applications of underwater sound to submarine detection were made in 1915-16 during World War I by Constantin Chilowsky and Pierre Langevin in France and Robert W. Boyle in Great Britain. Subsequent advances such as echo sounder were made in use of the sound to determine water depth and to find schools of fish. An intense effort to study underwater sound phenomena was performed by several groups in the United States. Their efforts culminated in the publication of "Physics of sound in the Sea" [1946], a remarkable summary of the state of the art in underwater sound which is still a useful reference today. The most significant finding of this period was the discovery of SOFAR (Sound Fixing And Ranging) channel by W. Maurice Ewing and John L.

Worzel [1948] in the United States and Leonid M Brekhovskikh and co-workers [1980, 1991] in the Soviet Union.

In the postwar period, significant efforts on ocean acoustics were developed all over the world to study the complexity of ocean environment. With the development of electronics, all the acoustic sensors became more effective, and with the growing knowledge of acoustic signal processing and display, greater ranges could be achieved and smaller targets could be identified. Now, acoustics has finally provided eyes to sense the sea, its inhabitants, its plant life and its garbage, and the surface and bottom that contain them. High frequency sonar can count marine life even millimeters in dimension, and low frequency sounds can be identified at ranges of thousands of miles.

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Biographical Sketch

Gee-Pinn James Too received PhD from the School of Mechanical Engineering, Georgia Institute of Technology in 1991 and is now Professor in the Department of Naval Architecture and Marine Engineering, National Cheng Kung University