UNDERWATER SHIP RADIATED NOISE MODEL

[1]V. M. Kumbhar, [2]S.S. Jagdale, [3]R. K. Shastri
Department of E&TC, VPCOE, Baramati,
Email:[1]Vidyakumbhar72@gmail.com, [2]shantanujagdale@gmail.com,
[3]rajveer.shastri@vpcoe.org

Abstract— An Underwater noise becomes a field of growing concern because of the possible interaction with sound vocalization of marine mammals. An ambient noise may have different non- electrical origins which are generated due to natural and anthropogenic noise sources. The low frequency radiated noise is the type of an ambient noise which masks the original sound signals transmitted in the ocean and hence it widely affects the detection capabilities of wide range of underwater sensors and SONAR. To improve the system performance significantly, the modeling of radiated noise is necessary which may give the better prediction of the noise. In this paper, the radiated ship noise model is used for analyzing the noise level for the frequencies varying from 100 Hz to 5 kHz. The result shows that noise level is dominant at low frequencies.

Index Terms—Modeling, Radiated ship noise spectrum, underwater radiated noise sources

I. INTRODUCTION

By ambient noise we mean the prevailing, sustained unwanted background of sound at some spot in the ocean [1]. There are varieties of natural and anthropogenic ambient noise sources and they are dominant in each of three frequency bands: low (10 to 500 Hz), medium (500 Hz to 25 kHz) and high (>25 KHz). Anthropogenic sources are dominant at low frequency in which shipping traffic and distant shipping is included. The low-frequency sound experiences little attenuation, allowing for long-range propagation due to shipping noise sources contribute to ambient noise across ocean basins [2].

The sound generated by a ship is broadband component which is originates from propellers, shafts, propulsion machinery and auxiliary machinery [3]. This paper attempt to describe the underwater radiated noise sources, spectrum of ship radiated noise and model of ship radiated noise.

A. Underwater Radiated Noise

Ship, submarines and torpedoes are significant sources of underwater sound. Radiated noise is of particular importance for passive sonar, which is designed to exploit the peculiarities of this form of noise in which it is normally observed.

The sources of the noise on ships, submarines and torpedoes can be grouped into the three major classes such as machinery noise, propeller noise and hydrodynamic noise.

1. Machinery noise:

Machinery noise comprises that part of the tonal noise of the vessel cause by the ship machinery. Machinery noise originates as mechanical vibrations of the many and diverse parts of the moving vessel. Machine noise is independent of speed, main frequency of machine noise are usually accompanied by their harmonics. The manner of mounting of the machine and the resulting vibration of the hull are determining the factors in the radiation of sound. Because of this various effects, the harmonic structure of radiated noise is complex.

2. Propeller noise:

Propeller noise is hybrid form of noise having features and an origin common to both machinery and hydrodynamic noise. The source of the propeller noise is principally the noise of cavitations induced by the rotating propellers. The production and the collapse of the cavities formed by the action of the propeller is called propeller cavitation. Propeller cavitation may be subdivided into tip-vortex cavitation and blade surface cavitation shown in Fig.(1a) and (1b).

Fig.1 (a) Tip vortex cavitation (b) Blade surface cavitation

Because cavitation noise consists of large number of random small burst caused by bubble collapse, it has a continuous spectrum and it is a non linear phenomenon.

3. Hydrodynamic noise:

Hydrodynamic noise originates in the irregular and fluctuating flow of fluid past the moving vessel. The pressure fluctuations associated with the irregular flow may be radiated directly as sound to a distance or more importantly, may excite portions of the vessel into vibration. The noise created by the turbulent boundary layer is sometimes called flow noise. The excitation and re-radiation of sound by various structures of the vessel are an important source of hydrodynamic noise.

Of the three major classes of the noise just described, machinery noise and propeller noise dominates the spectra of radiated noise under most conditions.

B. SPECTRUM OF RADIATED NOISE

The summary of characterization of each component is presented by the spectrum. At high frequencies, its spectrum level decreases with frequencies at the rate of about 6dB/octave, or about 20dB/decade. At low frequencies, the spectrum level of cavitation noise increase with frequency [4]. The peak in the spectrum of cavitation noise which is for ship and submarines usually occurs within the frequency decade 100to1000 Hz. Fig (2) shows diagrammatically cavitation noise spectra for three combinations of speeds and depth for a hypothetical submarine.

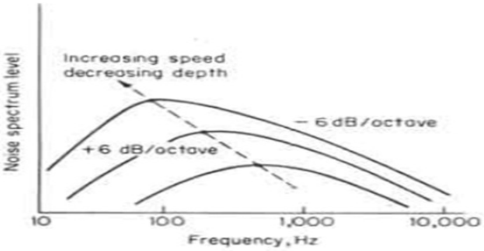


Fig. (2) Variation of the spectrum of cavitation noise with speed and depth

The behavior of the spectra peak is associated with the generation of larger cavitation bubbles at the grater speeds and the lesser depths and with the resulting production of greater amount of low frequency sound. At low frequency at the end of the spectrum, propeller noise contains discrete spectra blade rate components occurring at multiples of the rate at which any irregularity in the flow pattern into or about the propeller is intercepted by the propeller blades.

Fig.3, which shows the characteristics of the spectrum of submarine noise at two speeds one is low speed and other is high speed.

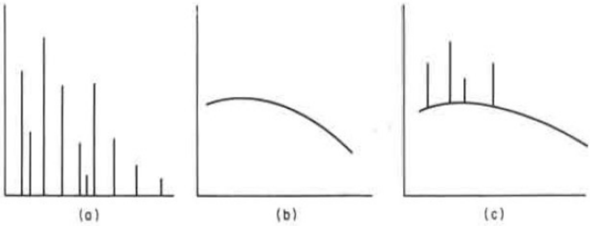


Fig.(3) Spectra of submarine noise

Fig 3 (a) and 3 (b) are diagrammatic spectrum at a speed when propeller cavitations have just begun to appear. Machinery lines, together with the blade rate lines of the propeller, dominate the low frequency end of the spectrum. At a higher speeds Fig. 1.3(c), the spectrum of propeller noise increases and shifts to lower frequencies. At the same time some of the line component increases in both level and frequency.

II. MODELING

Modeling is a method for systematize the knowledge build up through observations or deduced from underlying principles also modeling is a mechanism by which researchers and analyst can simulate sonar performance in laboratory conditions. Modeling is necessary to analyze the data collected in field experiments and forecast acoustic conditions for planning at sea experiment [5]. The modeling is distinguished into physical modeling and mathematical modeling. Physical modeling associated to theoretical or conceptual representation the physical processes occurring within the ocean and the term analytical model is sometimes used synonymously. Mathematical models include both empirical models (those based on observations) and numerical models (those based on mathematical representations of the foremost physics).

Mathematical models of noise in the ocean involve ambient noise models. Ambient noise models forecast the mean levels sensed by an acoustical receiver when the noise sources include surface weather, biologics and such commercial activities as shipping and oil drilling.

So in this paper we are dealing with empirical model which is the type of mathematical model for modeling of underwater ship radiated noise.

A. SHIP RADIATED NOISE MODEL

A continuous broadband background is presented by the spectrum of the ship radiated noise, the level of which increases with ship speed [6]. The Fig 4 shows the spectrum of ship radiated noise, it is maximum around 100 Hz.

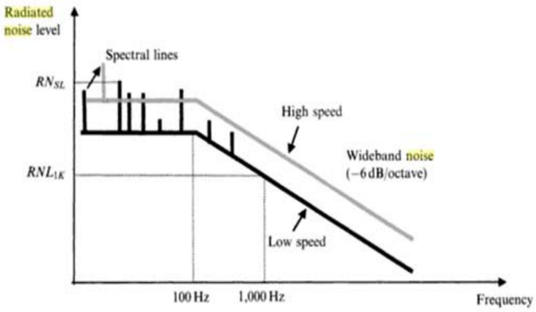


Fig.4 spectrum of ship- radiated noise

The radiated noise level RNL_{1K} at 1 KHz is know then the noise at the other frequencies is calculated from the below equation;

$$RNL(f) = RNL_{1K} - 20*\log(f/1000) \qquad (1)$$

III. RESULTS

From the audio library of web resource DOSITS[7], the real time samples of radiated noise for large commercial ship, merchant vessel and tug boat was collected. The spectral analyses of all these samples were carried out in matlab the results are shown below

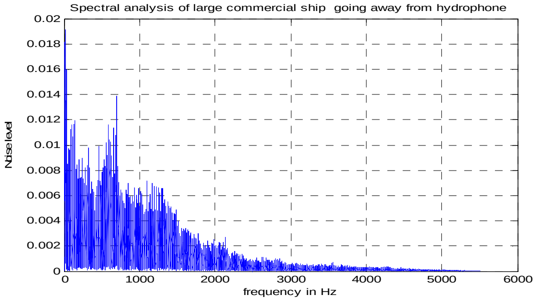


Fig 5.1 Spectrum of radiated noise by large commercial ship

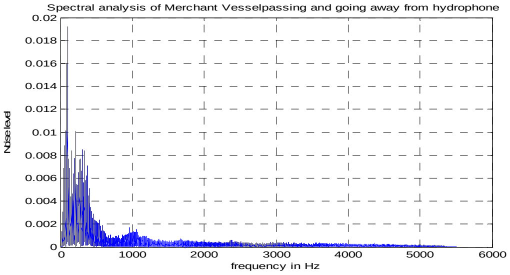
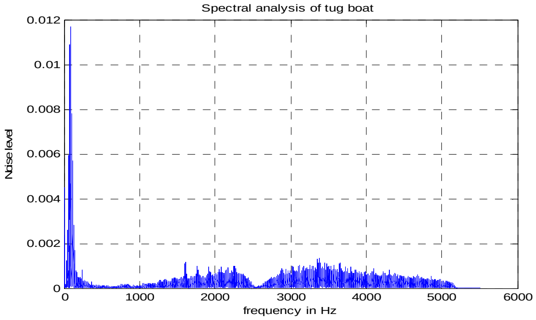


Fig 5.2 Spectrum of radiated noise by Merchant Vessel



5.3 Spectrum of radiated noise by tug boat

The Table 5 shows the values for radiated noise level at 1K for different types of submarines [6] and one tug boat,

Type	RNL_{1K}
Recent SSBN	100
Modern submarine electric	80
Submarine electric	120
Tug boat	170

Table 5 Noise radiated by different types of submarines and a tug boat

The significance from the Table 3.1 was used to estimate the noise radiated by the individual type of submarines and a tug boat at various frequencies using the equation (1), the modeled plots are as shown in Fig. (5.4, 5.5, 5.6, 5.7)

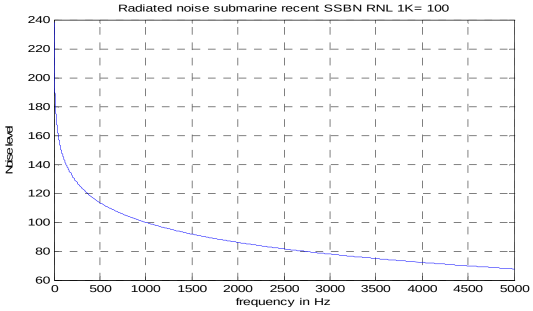


Fig 5.4 Estimated radiated noise for recent SSBN

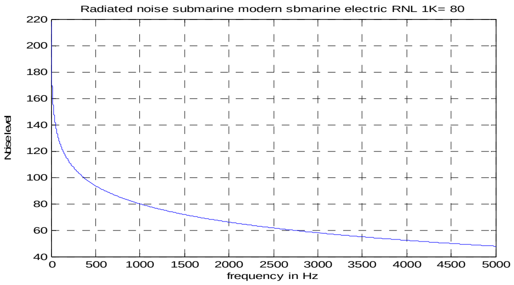


Fig 5.5 Estimated radiated noise for modern submarine electric

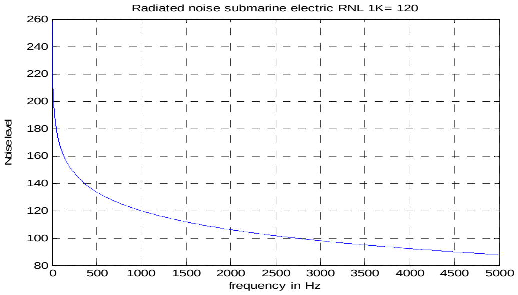


Fig 5.6 Estimated radiated noise for submarine electric

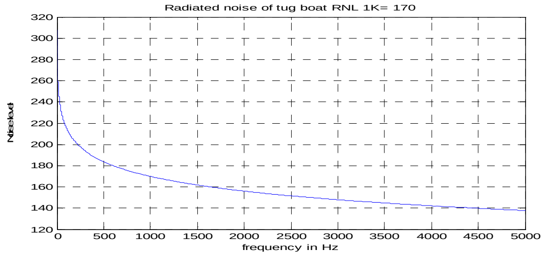


Fig 5.7 Estimated radiated noise for tug boat

IV. CONCLUSION

Using the mathematical Radiated noise model, if RNL_1K is known then we can easily estimate the component of noise at other frequencies as shown in Fig (5.4, 5.5, 5.6, and 5.7). The spectral analysis (Fig 5.1, 5.2 and 5.3) shows that the radiated noise is dominant in the frequency range upto 5 KHz. This spectral analysis using real time data shows that noise is dominant at low frequencies and at higher frequencies noise level decreases.

REFERENCES

[1] P. H. Dahl, J. H. Miller, D. H. Cato, R. K. Andrew, “Underwater Ambient Noise”, Acoustics Today, Jan. 2007.
[2] J. A. Hildebrand, “Anthropogenic and natural sources of ambient noise in the ocean”, Marine Ecology Progress Series, vol. 395, pp. 520, Dec. 2009.

[3] Stephen C. Wales and Richard M. Heitmeyer, “An ensemble source spectra model for merchant ship-radiated noise”, J. Acoust. Soc. Am. 111 (3), March 2002

[4] R. J. Urick, “Principles of Underwater Sound”, New York: McGrawHill, 1983.

[5] Paul C.Etter, “Underwater Acoustic Modeling Principles, Techniques and Applications” McGrawHill, New York, NY, USA, 3rd edition, 1983.

[6] Xavier Lurton, “An introduction to Underwater Acoustics: Principles and Applications”by Springer science and business media, 2002.

[7] “DOSITS: Home.”. http://dosits.org/