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# Assessment on source levels of merchant ships observed in the East China Sea

Zilong Peng, Bin Wang *, Jun Fan

*Collaborative Innovation Center for Advanced Ship and Deep-Sea Exploration, State Key Laboratory of Ocean Engineering, Shanghai Jiao Tong University, Shanghai 200240, People's Republic of China*

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ABSTRACT

During the past decades, the impact of shipping noise on marine ecology has always attracted more and more interest of the global researchers. Some empirical ship source level models have been proposed. Whether these models can be used to model the underwater radiated noise (URN) of merchant ships transiting near China remains to be examined. The URN of 57 merchant ships was measured with an opportunistic bottom-mounted acoustic observatory in the East China Sea at least one day in each month from Jan. 2015 to Nov. 2016. The propagation losses (PLs) of transiting ships were modeled using Normal Modes combining with the realistic geoacoustic parameters. The corresponding uncertainties were also analyzed, and the bottom type and the source depth were the major factors. Based on PL computations, the Spectral Source Levels (SSLs) of 57 ships were obtained. By comparing with the estimations using empirical models, the discrepancies indicated that the median estimation errors using RANDI-3 model and Ross's model were 0 ( ±7.1) dB and 6.8 ( ±3.2) dB, respectively. Furthermore, the trends with speed and length at different frequency ranges were also compared with Ross's model. These results might be helpful to develop a more precise model for the further research.

## 1. Introduction

It is well known that noise levels in the sea began to increase steadily with the onset of industrialization in the mid-nineteenth century, and this trend may be continued in recent times but lack of enough scientific evidence. It is an important research task to evaluate the human and natural contributions to marine ambient noise and describe the long-term trends in ambient noise levels, especially from human activities (NRC, 2003). Vessel noise from a range of different ship types substantially elevated ambient noise levels across the entire recording from 0.025 to 160 kHz at ranges between 60 and 1000 m (Hermannsen et al., 2014). Ross analyzed the noise levels measured in the mid-20th century, and suggested that the low-frequency noise was increasing rapidly at an average rate of about 0.5 dB per year (Ross, 2005). He also postulated this trend would not be sustained and this rate was later proved to be 0.2 dB/yr (Chapman and Price, 2011). Most recently, Andrew, Howe and Mercer's measurement in the Northeast Pacific showed a level or slightly decreasing trend in low-frequency noise (Andrew et al., 2011). To make it clear whether the low-frequency trends still exist in other regions, Miksis-Olds and Nichols examined the rate and magnitude of change in low-frequency sound (5–115 Hz) over the past decade in the South Atlantic and Equatorial Pacific Oceans. The observations showed that sound levels over the past 5–6 yr in the above regions had decreased (Miksis-Olds and Nichols, 2016). By far, the major component of the low-frequency (<500 Hz) ambient noise field is the noise generated by ship traffic (Breeding et al., 1996). Even very distant shipping noise can dominate and become the main background disturbance for the active sonar or passive sonar. For the above reasons, extensive concern has been made on the studying of ambient noise.

By so far, many empirical models have been proposed. The comparisons of different models (Urick, 1983; Ross, 1976; Wales and Heitmeyer, 2002; Hamson and Wagstaff, 1983; Breeding et al., 1996; Wittekind, 2014; Audoly and Rizzuto, 2015) are summarized in Table 1.

Among the above models, the two earliest models were proposed by Ross (1976) and Urick (1983), respectively, in which the SSLs of merchant ships or naval vessels can be expressed as a function of ship length, draught and speed. Wales and Heitmeyer (2002) proposed the mean spectrum model describing the source spectra between 30 Hz and 1200 Hz of 54 ships in the Mediterranean Sea and the eastern Atlantic Ocean. The RANDI-2 model (Hamson and Wagstaff, 1983) and RANDI-3 model (Breeding et al., 1996) are based on a reference ship SSL. Thus, the individual SSL can be calculated as a function of its speed and length. At

* Corresponding author.
*E-mail address:* w89986581@sjtu.edu.cn (B. Wang).

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**Table 1**
Comparison of different URN models.

| Model | Urick | Ross | W&H | RANDI-2 | RANDI-3 | Wittekind | AQUO |
|---|---|---|---|---|---|---|---|
| Speed dependence | ✓ | ✓ | × | Related to category | Related to category | ✓ | ✓ |
| Size dependence | ✓ | ✓ | × | Related to category | Related to category | ✓ | ✓ |
| Frequency (Hz) | 100~10 k | 100~10 k | 30~1.2 k | 10~1 k | 10~10 k | 10~10 k | 10~10 k |
| Methodology | Statistical | Statistical | Statistical | Statistical | Statistical | Mechanism | Mechanism |

present, the RANDI-3 model has been used in modeling the ambient noise from traffic and providing the reference for assessing the impact on marine ecology from shipping noise (Gordon et al., 2003; Simard et al., 2016; Hom et al., 2016). But it should be noted that the RANDI-3 model is only introduced in the NRL report and lack of peer reviews, which needs to be further verified compared with the measured data.

Different from the above models, both the Wittekind's model (Wittekind, 2014) and the AQUO project's model (Audoly and Rizzuto, 2015; Audoly et al., 2017) consider the radiated noise should be decomposed into three components. In the AQUO project's model, the parameters can be obtained by the numerical process of minimizing target function, which requires at least two different speeds.

In addition to the above models, in recent years, with expanded use of controllable pitch propeller (CPP), a new model "3P (Three-parameter) model" was proposed by Traverso et al. (2015, 2017), based on Ross model and Lurton model (Lurton, 2010).

To build URN models, the reliable data must be obtained as input at first. A series of radiated noise measurement standards have been proposed by some organizations such as ASA (ANSI/ASA, 2009), DNV (2010), ICES (1995) and ISO (ISO 17208-1, 2016), of which the most widely used standard is the "ANSI/ASA, S12.64–2009". In 1975, the U. S. Navy initiated a new program for accurate narrow-band measurements of merchant ship noise, jointly sponsored by Naval Research Laboratory (NRL) and Naval Ocean Research and Development Activity. In 1980, the radiated noise of M/V HARRIETTE was measured by Arveson and Vendittis (2000) sponsored by NRL, which was considered as one of the most accurate measurements.

Until now, the shipping noise of the main channels and waters around the world has been measured. The measured sites are concentrated on the busy channels such as the Mediterranean, the north Atlantic oceans near Europe, U.S.A., Canada, the north Indian oceans, etc. In the past ten years, with the development of polar scientific research, the measurement of shipping noise in the Arctic Ocean was also conducted (Roth et al., 2013). Scrimger and Heitmeyer (1991) estimated the SSLs of 50 ships approaching or departing from the Mediterranean port of Genoa (Italy) in the frequency band 70 Hz–700 Hz. By measuring the SSLs of 593 container ships at the Santa Barbara Channel, McKenna et al. (2013) studied the relationship of SSLs with ship-type, operating parameters and oceanographic conditions.

In recent years, sponsored by several large cooperation projects including SILENV (Ship Innovative soLutions to rEduce Noise and Vibrations) (SILENV, 2012), AQUO (Achieve QUieter Oceans) (Audoly and Rizzuto, 2015), SONIC (Suppression Of underwater Noise Induced by Cavitation) (Brooker and Humphrey, 2016) and MEPC (Marine Environment Protection Fund) (Robinson et al., 2011), the scientific research teams studied the radiated noise of the vessels at the north Atlantic Oceans. Brooker measured the radiated noise of a small research vessel with three hydrophone arrays deployed at shallow water sponsored by SONIC project (Brooker and Humphrey, 2016). Furthermore, some recent works were published. Simard analyzed and modeled 255 sources levels of merchant ships from an acoustic observatory along St.Lawrence Seaway (Simard et al., 2016). Jansen and de Jong measured the shipping noise around the Port of Rotterdam and obtained the acoustic monopole source levels of 23 ships. Besides, they compared the source levels of different ship types (Jansen and de Jong, 2017).

To model the shipping noise, the expensive measurements and reliable noise data are essential. The measurement not only must be carried out adhering to the measurement standards as much as possible, but also has the sufficient funding support for the long-term plan. However, as suggested by Arveson and Vendittis (2000), "*At some level of detail, more precise measurements and theoretical analysis will become too expensive, and further progress in fleet noise predictions must revert to semi-empirical*

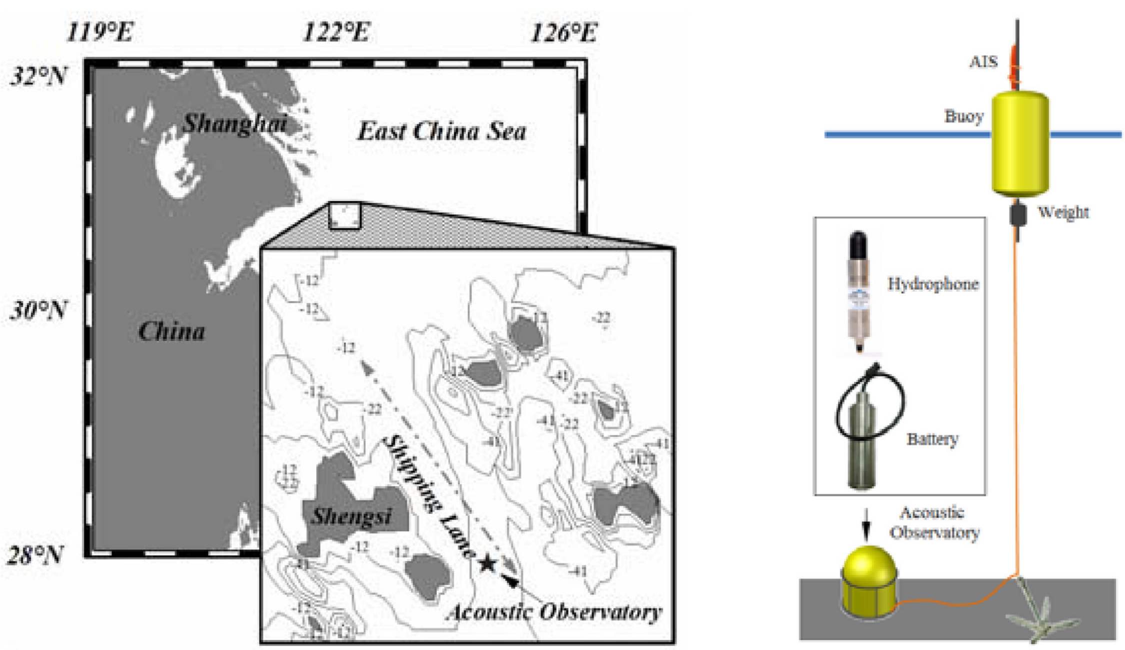


**Fig. 1.** Sketch of the layout of the opportunistic acoustic observatory.