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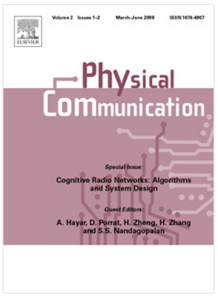

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Determination of the Best Carrier Frequency Based on the System and Environmental Parameters in Underwater Acoustic Systems

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Abstract

One of the most challenging features of underwater acoustic (UWA) channel in comparison with its terrestrial radio frequency counterpart is highly frequency-dependent path loss. Thus, utilizing efficient carrier frequencies in UWA systems can considerably reduce the path loss. In this context, this paper presents an approximate formula for determining the best carrier frequency based on both the system and environmental parameters. To achieve this goal, this research first addresses a simple algorithm including general steps for tuning the parameters of Francois and Garrison (FG) formula in the frequency range of 10 to 100 kHz based on the appropriate experimental data which can be acquired from any interest region. Second, for a more accurate modeling of path loss, this paper considers the loss due to the reflections of sound from both the rough surface and bottom of the sea by employing the ray theory. Third, this study presents a general algorithm for modification of the power spectral density (PSD) of ambient noise based on Wenz formula in the frequency range of 10 to 100 kHz and the required experimental measurements which can be simply collected from any interest channel. Moreover, it is mathematically demonstrated that the ambient noise in the frequency range of 10 to 100 kHz, can be generally approximated with a strict sense stationary (SSS) colored normal stochastic process which is ergodic not only in mean and covariance but also in distribution. Finally, an approximate formula for the best carrier frequency is derived by maximizing the sound to noise intensity ratio (SNR). To verify the validity of simplifications and approximations utilized in this study and to assess the performance of our proposed algorithms and formulas, experimental results obtained in the Strait of Hormuz (SoH) are compared with the original, simplified, and modified models under different scenarios.

Keywords: Absorption loss, ambient noise, carrier frequency, ray theory, underwater acoustic channel.

1. Introduction

In recent years, design and implementation of efficient underwater acoustic (UWA) systems have been receiving an increasing attention in both military and civilian applications [1]-[4]. In order to design and analyze a UWA communication system, modeling of the channel is a necessary step. In this regard, utilizing suitable models for propagation loss and ambient noise leads to more promising performance [4]-[6]. In literature, there are several empirical formulas for sound speed profile (SSP) as well as absorption coefficient [7]-[11], which are two major characteristics for modeling of propagation loss in UWA channel. Moreover, there is merely an empirical model for power spectral density (PSD) of ambient noise [12], which is widely used in the literature that are not experimental works. Although, empirical models are useful, they result in suitable performance merely in the regions from which they are obtained. Therefore, it is not efficient from an engineering standpoint to utilize empirical models where there is a significant difference between the experimental data of an interest channel and the output of empirical models which are not obtained from that channel. However, modification of classic models based on experimental measurements and utilizing modified models leads to better performance in the appropriate interest channel. In this context, this paper first addresses two algorithms including general steps for parameter-tuning and modification of