Abstract

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Due to the inherent complexity of the underwater acoustic (UWA) channel, the transmission of information is always a difficult task. The primary disadvantage of the UWA channel is that the sound travels at a slower speed. When information is transmitted via radio waves that travel at the speed of light, velocities of a few kilometers per hour do not produce a significant Doppler effect. As a result, Doppler spread contributes a negligible fraction to the center frequency in the radio frequency (RF) case. However, in the case of an acoustic signal transmitted over the UWA channel, movement of a few kilometers per hour may significantly deteriorate the channel condition due to the lower frequency range. The extended delay spread is another effect of the slower sound speed. The delay spread of a channel is related to the channel's frequency selectivity. The larger the delay spread, the smaller the coherence bandwidth and the greater the channel's frequency selectivity within that bandwidth. As a result, the UWA channel is doubly selective, meaning that it is both time selective (due to Doppler spread) and frequency selective (due to delay spread). This thesis focuses on the study and analysis of the UWA channel's communication system. It is demonstrated that when the time reversal mirror (TRM) is used, the channel's delay spread becomes significantly smaller. The more receivers there are, the more improvement in terms of delay spread there will be. This thesis also analyses the properties of the prefix signals to be used in the channel estimation. A detailed comparative analysis of various prefix signals is provided in this work. Prefix signals are compared based on their correlation and spectral properties under the influence of Doppler-induced scaling. We have demonstrated that using hyperbolic frequency modulation (HFM) signal as a probing signal improves channel estimation under the linear Doppler effect in the UWA channel. The hyperbolic time-frequency coupling in the HFM signal also aids in the joint estimation of the Doppler scale and the channel. As a result, we propose a novel algorithm for simultaneously estimating the Doppler scale factor and channel using look-up table (LUT) formation. The underwater channel typically has considerable variation in the received signal Doppler scale value. It is primarily due to the wide range of the angle of arrival of received multipath signals. Traditionally, the communication receiver is designed to compensate for the Doppler effect by considering a single Doppler scale value. However, such a type of receiver produces a sub-optimum result for the channels

with significant Doppler scale distribution. Additionally, designing the receiver to compensate all the Doppler scale values observed in the communication interval would dramatically enhance the receiver's complexity. This thesis proposes a novel scale lag rake receiver based on unsupervised clustering of the estimated Doppler scale factor. It is shown that the proposed receiver provides performance close to the optimum receiver with reduced complexity. Its architecture also incorporates both the TRM and phase-locked loop (PLL). TRM is used to minimize the delay spread of the channel, thereby minimizing the number of equalizer coefficients required. Under time-varying channel conditions, PLL is used to reduce the update rate of the equalizer coefficients. This thesis also examines multi-carrier communication techniques such as orthogonal frequency division multiplexing (OFDM). We demonstrate that using TRM enhances the performance of the OFDM receiver for underwater channel configurations. It has also been shown that the TRM operation makes the effective channel real; hence, the complexity of the receiver can be reduced without compromising the performance.