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Advanced Modulation and Coding Techniques for Underwater Wireless Communications

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Abstract

Underwater communication channels suffer from numerous issues such as low propagation speeds and hence extensive time delays, dispersion, Doppler frequency shifts, limited bandwidth, multipath fading and time varying parameters. Many researchers have attempted to solve one or more of these problems by using advanced modulation and coding techniques. The different modulation and coding methods are characterized by different advantages and disadvantages.

This thesis discusses, at the start, the different problems of underwater communication channels and the typically used modulation and coding techniques which have been used to overcome some of the problems of these channels. These methods are then compared with each other to determine which one is the best for a given underwater environment in terms of minimizing the error rate.

Next, the thesis introduces a new modulation/coding technique that can be used to overcome the effects of fading and time variability of the underwater channels and enhances the communication performance and, in the same time, it has an additional advantage of increasing the system security. The suggested technique is an advanced form of Differential Frequency Hopping (DFH) in which the hopped frequencies are extracted from an advanced PN code family known as Spinal Codes (SPC) which results in almost uniformly distributed hopping frequencies. Spinal Codes are subsets of Rateless Error Correcting Codes. They are nonlinear, due to the utilization of hash functions in their generation. These properties make the suggested transmission technique more vulnerable to attacks and interference.

Also, the thesis suggests another new modulation and coding technique suitable for fading channels which is Orthogonal Frequency Division Multiplexing (OFDM) with Spinal Codes as the error correcting coding method. OFDM technique, the main modulation technique used in 4G systems, is characterized by its superior ability to overcome fading by using a group of orthogonal subcarriers and the use of Spinal Codes increases its security properties.

The simulation results prove that the first suggested spreading/coding Differential Frequency Hopping using Spinal codes (DFH-SPC) technique highly improves the communication performance of in short range shallow water channels as compared to conventional DFH based on trellis, and as a bonus, the suggested technique enhances the system security.

Also, the results show that the second proposed technique using OFDM with Spinal codes as the encoding method (OFDM–SPC) gives a highly improved performance of the considered underwater channel, especially when using a channel estimation method to know the state of channel. When the two suggested techniques are compared with each other, the results show that OFDM-SPC have better results in term of error rate as compared to DFH –SPC, but the advantages of DFH-SPC technique is the increased security and the no need of equalizers which make it easier in implementation.