Three-hops UWAC based on SOFAR Plane: A Novel Relay Deployment Technique

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Introduction

In this paper, to improve the underwater communication capacity at a level of thousands of kilometres, we propose a three-hop underwater wireless acoustic communication (3H-UWAC) structure based on the Sound Fixing and Ranging (SOFAR) channel. The proposed 3H-UWAC consists of transmitters, relay stations (RRs), and receivers. RRs are set on the SOFAR plane at a known depth. The transmitter will send the information to the nearest first relay station (NFRS) on the SOFAR plane with a narrow beam width. Then, the NFRS will send the information to the nearest relay station to the receiver on the SOFAR plane with a narrow beam width, which is the nearest second relay station (NSRS). Tools from stochastic geometry are used to model the spatial distributions of transmitters’, receivers’, and RRs’ locations. The coverage probabilities (CPs) of the three hops (transmitter to FRS, FRS to SRS, and SRS to receiver) are analyzed, and the final CP from a transmitter to a receiver through the 3H link is derived.

System Model

Based on experiments, a special channel was found, where the acoustic can propagate similar to a line is named SOFAR Channel (Sound Fixing and Ranging channel). It is defined as a horizontal layer of water in the ocean at which the speed of sound is at its minimum (it will be called the SOFAR plane in this paper). The system model named 3H-UWAC is shown in Figure 1.

Coverage Performance

According to our exploration of the mathematical calculation, SNR of the third hop will be less than the threshold \( \tau \) when the depth of the receiver is greater than 6.8 km. Hence the CP of the third hop will equal 0, and the total CP will go to 0.

- For different values of \( z_r \), with the increase of \( z_r \), CP will rise to the maximum value gradually.
- All the CPs dropped sharply to 0 when \( z_r \) goes to around 6.8 km.

Change the parameters in the same hop (in the first hop) and identify the effects made by the two factors: (i) the depth of the transmitter and (ii) the VDA.

- When \( z_t \) is at a lower level, even if \( \theta_t \) is at a high level, for example, 40°, the CP is still very small.
- Comparing Fig. 5(a) and Fig. 5(b) further, we can find that \( \theta_t \) and \( z_t \) in the third hop affect the maximum CP of the system. Again, when \( z_t \) ups to 6.8 km, SNR of the first hop will lower the decoding threshold so that the CP will be 0.