An Antenna System for Autonomous Underwater Vehicle

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***Abstract*— A multipurpose (Wi-Fi, ISM, GPS, and Iridium bands) antenna system for communications over saltwater is introduced. Three antennas including monopole, dipole, and helix are located close to each other within a resin as a radome. In the proposed antenna design, special considerations are taken into account to not only miniaturize the antenna overall size but also maximize antenna gain in the desired directions. A full wave simulator (HFSS) is used to optimize the antenna radiation patterns and return loss for different levels of the seawater. The simulation results illustrate the effectiveness of our design.**

I. Introduction

Nowadays, Autonomous Underwater Vehicles (AUVs) are becoming more popular in both commercial and military areas due to their wide range of applications such as oil and gas explorations, discovering and terminating underwater mines, and oceanography [1]. Although an AUV conducts missions underwater, due to underwater communication issues [2, 3], it usually comes to the surface and exposes its antenna above the surface to communicate its collected information with the surface.

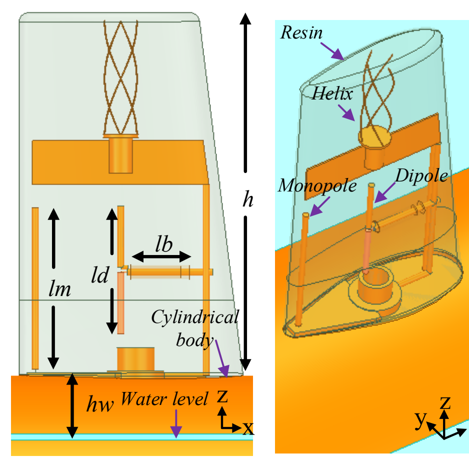
There have been efforts to mount antennas on AUV in the recently published literature [4, 5]. However, the dynamic nature of the environment such as time-variant antenna height in addition to the saltwater effects on the antenna performance has not been studied in these works. In this paper, we presents an antenna system comprises of three different antennas including a monopole antenna for the ISM band (902 MHz to 928 MHz), a dipole antenna for the Wi-Fi band (2400 MHz to 2500 MHz), and a helix antenna for the GPS (1575.42 MHz) and Iridium (1621 MHz) bands. Special considerations have been taken into account to increase the angle between pattern null and the desired radiation direction in presence of the seawater. In addition, we have considered height variations in the simulations.

II. Antenna Desing And Simulation Results

As depicted in figure 1, An aerodynamically designed polyurethane resin with a relative dielectric constant of 2.65 is used to cover the structure. The antenna system should be able to communicate with other radio stations located on the shore or over the seawater at the ISM and Wi-Fi bands. As a result, we need to optimize the monopole and dipole antennas to have omnidirectional patterns with maximum radiation in the *xy*-plane. On the other hand, the helix antenna with maximum gain toward the *z*-axis is located on top of the structure to receive the GPS and Iridium satellite signals.

We have considered a cylindrical shape AUV with a radius of 90 mm in our design. A variable height, *hw*, PEC sheet (shown with blue color in figure 1) is assumed to model the effect of the saltwater. In addition, a cylindrical section is added to the structure to ease its connection to the AUV body. It provides a path for coaxial cable connections as well. It is worth mentioning, although miniaturization is important in the proposed structure, we haven't used small antennas in our design to avoid problems such as low gain and narrow bandwidth [6, 7].

The antenna and its image, with respect to saltwater as the conducting surface, create an array of two elements. Increasing the antenna height creates nulls in the receiving direction (θ=90°) which is not desired. As a result, the monopole and dipole antennas are located as close as possible to the bottom of the structure. On the other hand, the helix antenna is located on top because its pattern looking toward the *z*-axis and the effect of the saltwater to the helix antenna is negligible.



(a) (b)

Fig. 1. Proposed structure. a) Side view and b) 3D view (dimensions in mm: *h* =123, *lm* = 55, *ld* = 43, and *lb* = 20).

As is shown in figure 1 the cylindrical body operates as a part of the ground plane for the monopole antenna as well. However, in the cases in which the saltwater is closer to the bottom of the structure, *hw* = 0, saltwater by itself is considered as a ground plane. To decrease the mutual coupling between the monopole antenna and other antennas, it is located as close as possible to the left side of the structure. High-Frequency Structure Simulator (HFSS) software is used to simulate and optimize the structure for different values of *hw* (3 mm, 25 mm, and 50 mm). To maintain an acceptable return loss and a reasonable gain in the ISM band, all dimensions are optimized simultaneously and are given in the caption of figure 1. As given, length of the monopole antenna, *lm*, is equal to 55 mm which shows 30% miniaturization is obtained compared to the monopole antenna radiating in free space.

Figure 2 shows the return loss of the monopole antenna for three different values of *hw.* As illustrated, appropriate return loss (-14 dB) is obtained in the desired frequency ranges. Antenna 2D patterns, at 915 MHz, are plotted in figures 3-*a* and *b* for $\varphi = 0°$ and $\varphi = 90°$, respectively. The maximum and minimum gains are simulated to be 8.32 dBi and 4.44 dBi which shows an omnidirectional pattern with 4 dB variation. It should be mentioned that the infinite ground plane is considered in the HFSS simulations to model the saltwater.

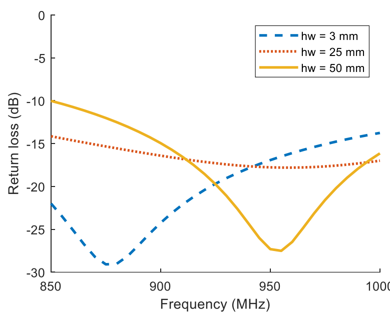
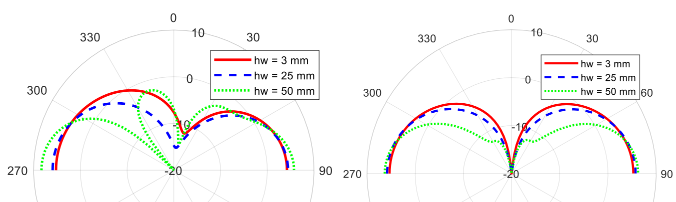


Fig. 2. Antenna return loss at the ISM band for different water levels.



(a) (b)

Fig. 3. ISM band antenna 2D patterns at a) φ = 0 and b) φ = 90.

The resin deteriorates the dipole antenna pattern more than the monopole antenna because the dipole antenna radiates at higher frequencies. Then, the dipole antenna is located at the center to avoid deteriorating its omnidirectional pattern. However, still, the dipole antenna is surrounded by the resin asymmetrically due to the resin wideness in the *x*-direction. Simulation results show the dipole antenna pattern is squeezed in $\varphi = 90°$ plane because of the asymmetric radome. To compensate for this issue, a metallic rod is placed in the right side. This rod along with the monopole antenna in the left side play destructive effect in $\varphi = 0°$ plane leading to decrease the gain in this plane. To feed the helix antenna located on the top, a coaxial cable is used instead of a rod.

As shown in figure 1, a balun is used to prevent current following on the exterior surface of the coaxial cable. Length of the balun along with other dimensions are tuned to match the dipole antenna. Figure 4 shows the return loss for different values of *hw* when the balun length is 20 mm. As depicted, the return loss lower than -10 dB is obtained in the desired frequency ranges for all cases.

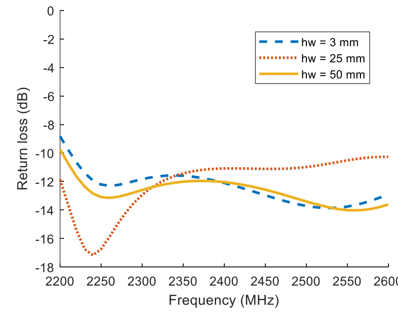
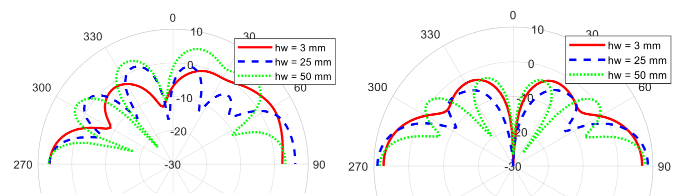


Fig. 4. Antenna return loss at the Wi-Fi band for different water levels.

Finally, the radiation patterns of the dipole antenna are given in figures 5-*a* and *b* at $\varphi = 0°$ and $\varphi = 90°$ planes, respectively. In this case, the maximum and minimum gains are simulated as 8.96 dBi and 2.34 dBi, respectively.



(a) (b)

Fig. 5. Wi-Fi band antenna pattern at a) φ = 0 and b) φ = 90.

For the GPS and Iridium bands, the M1600HCT-P-UFL circularly polarized helix antenna from Maxtenna company has been chosen. The reader can refer to the product datasheet for more information. To have a more accurate model for dipole and monopole antenna, the structure of the helix antenna is included in the HFSS simulations as well.

III. Acknowledgment

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