International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 12, December - 2017

Underwater Antenna Design and Analysis at ISM Band Frequency

Sathyakumari Ganta, Akhila. S
Department of Electronics & Communication Engineering,
BMS College of Engineering,
Bangalore-19

Abstract**— Acoustic waves are used in underwater communication. But acoustics limits the data rates and also distance of communication. Sound waves propagate at very lower speed therefore the channel latency increases and hence higher data rates with acoustic waves cannot achieved. Acoustic waves are more sensitive to the reflection and refraction than Electro-Magnetic waves. Radio waves travel with the speed of light, and hence provide higher data rates and bandwidth. Electro-Magnetic waves perform better in shallow waters and air-water interface than acoustics. To operate with Electro-Magnetic waves in underwater, the foremost requirement is antenna with high gain. Preferable antennas for underwater communication are loop antennas, long wires and bow-tie antenna. Bow-tie antenna is a wide band micro-strip antenna which are compatible with Integrate Circuits(IC), hence highly robust, compact and relatively light.**

Designing bow-tie antenna for under water communication requires detailed insight of the electro-magnetic wave's behavior in water. A detailed study of antenna dimensions with equations are provided. In this work, Bow-tie antenna is proposed for short range underwater applications. Return loss, impedance of the bow-tie antenna simulated in pure water and sea water at 2.4GHz are analyzed.

I. INTRODUCTION

Short range and high-bandwidth communications are gaining more prominence in digital world. Demand for reliable connectors and short range data links is increasing due to the introduction of modernized technologies in military operations, oil industry and navigation. Investigation of electromagnetics for short range applications revealed that addition of digital technology and signal compression makes electromagnetic signals suitable for underwater applications.

In unmanned underwater vehicles, electromagnetic signal based navigation systems uses signal strength as a measure to move in a particular direction to reach the beacon. Therefore electromagnetic signal based navigation system enables very simple and robust control loop. Distributed transducers are another most advantageous application of the electromagnetic signals in underwater. Distributed cables are designed to radiate electromagnetic signal along their length, and there is no equal substitute in acoustics for distributed cables. These distributed cables provide short range navigation and reduces the required range for mobile communications. Tram-lines can be formed using distributed cables to track unmanned underwater vehicles. A continuous tram-line can be easily intercepted on the unmanned underwater vehicles return by allowing periodic excursion using distributed cables.

II. BOW-TIE ANTENNA DESIGN

The two triangular patches of the bow-tie antenna are manufactured on a single substrate. Bow-tie antenna is attractive because of its compactness similar to rectangular patch and broadband nature similar to biconical antenna. The relation of resonant frequency and side arm length of the bow-tie strip can be given as[12],

$$f_r = \frac{2c\sqrt{m^2 + mn + n^2}}{3a\sqrt{\varepsilon_r}} \qquad (1)$$

where,

f_r- resonant frequency of the antenna.
c – Velocity
m , n – mode numbers
a – side arm length of the bow-tie strip

This relation is best suitable for the triangular resonator surrounded by the perfect dielectric. There are some suggestions provided in [15]. The first suggestion is replacing side length with its effective value and keeping relative permittivity unchanged. And the second suggestion is to replace both the side length and the relative permittivity with their respective effective values. The resonant frequency of the dominant mode i.e., TM 10 mode is:

$$f_{10} = \frac{2c}{2f_r\sqrt{\varepsilon_r}} \qquad (2)$$

And also side length of the strip is:

$$a = \frac{2c}{2f_r\sqrt{\varepsilon_r}} \qquad (3)$$

The effective side length and relative permittivity are given as [15]-

$$a_{eff} = a + \frac{h}{\sqrt{\varepsilon_r}} \qquad (4)$$

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 12, December - 2017

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{4\sqrt{1 + \frac{12h}{a}}} \qquad (5)$$

where, h is the thickness of the substrate.

After finding the dominant frequency from equation (2), the resonant frequencies of the higher modes can be calculated by using equation (3), which will be get modified as:

$$f_{mn} = f_{10}\sqrt{m^2 + mn + n^2} \qquad (6)$$

III. Bow-tie Antenna Simulated in Underwater Environment

Bow-tie antenna is a flat version of bi-conical antenna with feed at its vertex. Bow-tie antenna is designed at ISM (Industrial scientific and Medical) band of frequency. To design antenna at 2.4GHz, the substrate thickness should be in the range of 0.2mm to 0.5mm and the dimensions of the patch can be 25mm to 62mm. Therefore 1mm thickness Duroid substrate is used in this work. And the bow-tie antenna dimensions are chosen as 30 mm and 10mm as shown in the figure (1). A copper cladding layer is formed on the substrate to create bow-tie arms and finite conductivity boundary is assigned. Initially a rectangle feed cut is formed on the substrate, and then the bow-tie antenna arms created with the dimensions given in figure (2).

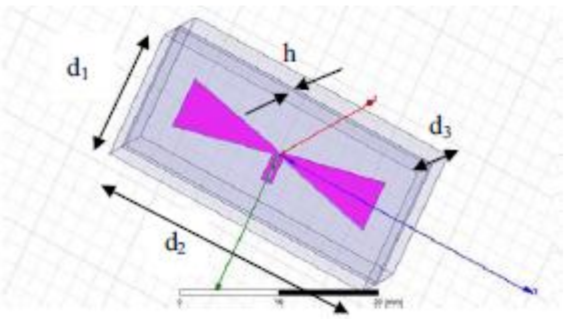

Figure 1 Bow-tie micro strip antenna with dimensions d1=14mm, d2=30mm, h=1mm, d3=10mm.

A lumped port connection is formed for excitation. The antenna is then analyzed for the frequency range 1GHz to 10GHz and therefore 10mm radiation boundary has been formed around the antenna. The antenna is simulated in the underwater environment with relative permittivity = 81, relative permeability = 0.999991 and conductivity = 4 S/m and linear step frequency sweep from 1GHz to 10 GHz.

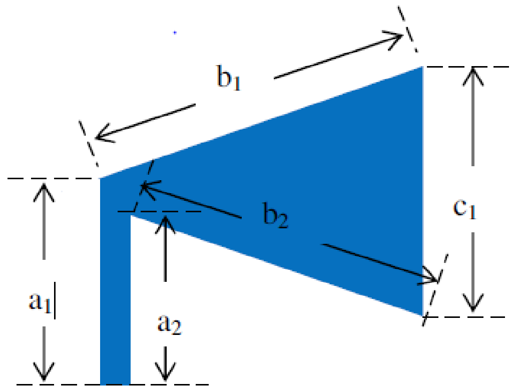

Figure 2 Bow-tie antenna arm with dimensions a1=3.5mm, a2=3mm, b1=11.39mm, b2=10.99mm, c1=5.6mm.

IV. RESULTS AND ANALYSIS

A) Bow-tie antenna simulated in Underwater Environment

1) S-parameters

S-parameters can be calculated for any electrical network, which gives the relationship between input and output ports. In a communication system, transmitter and receiver are viewed as two ports of the network, then S12 is the power transmitted from port-2 to port-1. In the similar way S21 gives the power transferred from the port-1 to the port-2. S11 represents the power delivered by the port-1 to itself, known as reflected power. Therefore S11 called reflection co-efficient gives the measure of the power reflected from antenna, also known as return loss (RL).

The resonant frequency of the antenna is a frequency, at which antenna radiates at its maximum power. From figure.3, designed antenna is radiating maximum power at 2.2GHz, with reflection co-efficient S11 = -6.11dB. The antenna radiates minimum at 4.75 GHz, with peak reflection co-efficient S11 = - 4dB. Reflection co-efficient is less than -5dB for the frequency ranges from 1.2GHz to 3GHz. Fig. 3 shows almost flat curve from 3GHz to 6.8GHz.

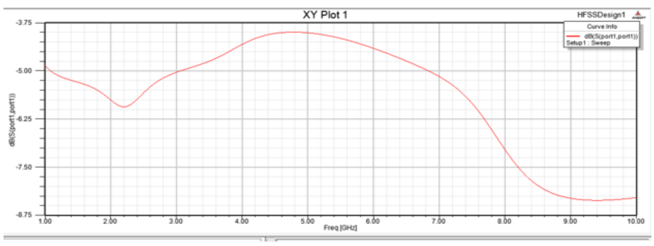

Figure 3 S11 of the designed antenna in sea water

2) Z-parameters

Antenna impedance gives the measure of resistance of the electrical signal in an antenna. It is a very important factor of the antenna, as it represents the power absorbed by the antenna as well as the power radiated in the form of electro- magnetic waves. At different wavelengths or frequencies, antenna exhibits different impedance values. Antenna impedance can be complex. When the voltage and current in the antenna are not in in-phase, the antenna results complex impedance. The real part of the antenna impedance represents the power absorbed or

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 12, December - 2017

radiated by the antenna. And the imaginary part represents non-radiated power stored in the near-field of the antenna.

Designed antenna has input impedance of 15.5 ohm at resonant frequency 2.2 GHz. It is exhibiting the input impedance less than 20 ohm till 7.8 GHz and less than 15 ohm in the frequency range 3GHz to 6.5 GHz. The imaginary part of the impedance is negligible below 10 ohm till 5GHz and it is less than 5 ohm from 1.4 GHz to 4 GHz. At the resonant frequency 2.2 GHz, it has very negligible value of 2 ohm.

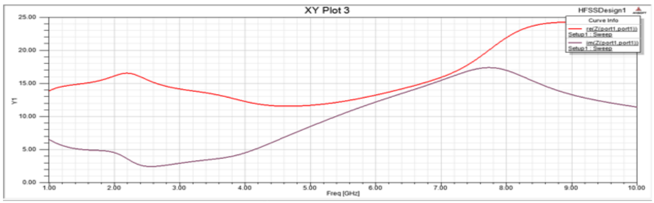

Figure 4 Input impedance of the designed antenna in sea water

3) Gain

The main objective of the work is to design low cost, low profile and monolithic compatible antenna for underwater communication. The antenna should have a gain more than 1dB. Gain for the antenna gives the ability to direct its all electro-magnetic energy in one direction. Typically it is measured in decibels (dB). Antenna gain is the relative measure with the isotropic antenna. Gain of 3dB means the power received by the antenna is 3 dB more than what it would have received from an isotropic antenna. It is often measured as a function of angle. Radiation pattern is a plot of antenna gain in decibels as a function of angle. And it is noted as a single value in peak gain direction.

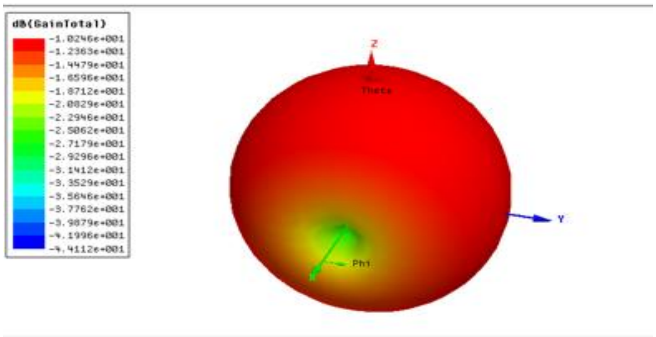

Figure 5 Gain of the designed antenna in sea water.

B) Bow-tie antenna simulated in Distilled Water.

The same antenna simulating in pure water exhibits different behavior. Pure water has zero salinity, but the sea water has salinity of 35 parts per thousand. Salinity of the water is a measure of the dissolved salts in the water. These dissolved salts induce some amount of conductivity in the sea water but pure water has zero conductivity or minimal conductivity. Because of salinity, electro-magnetic signal experience more attenuation in sea water than in pure water. Therefore, antenna shows different behavior while operating in pure water. Salinity of the water also affects the permittivity of the medium. Propagation speed in a medium is indirectly proportional to the permittivity of the medium. Consequently the time taken by the signal to reach receiver or the data rates are different in distilled water compared to the sea water.

1) S-parameters

In pure water, antenna resonates at 2.2 GHz, but exhibits improved reflection co-efficient. In pure water antenna radiates maximum power at 2.2GHz with reflection co-efficient s11 = -8.9 dB and radiates minimum at 4.4 GHz with s11 = -3.6 dB. The plot also shows almost flat curve between 3.8GHz to 7GHz. Reflection co-efficient is improved in distilled water compared to the sea water.

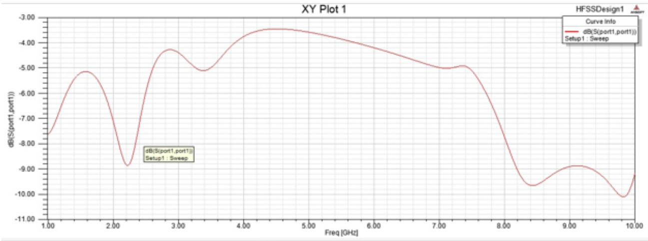

Figure 6 S11 parameter of the Bow-tie antenna simulated in Distilled water environment

2) Z-parameters

Simulating antenna in pure water augmented the impedance of the antenna. The real part of the input impedance of the antenna is 23 ohm at resonant frequency 2.2GHz. Imaginary part of the input impedance is showing a dip in pure water. At resonant frequency antenna, imaginary part of the input impedance is around 1 ohm and it has less than 5 ohm till 1.8 GHz.

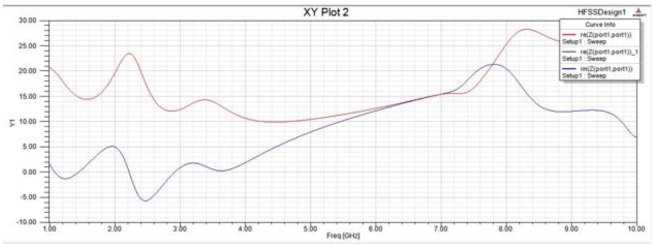

Figure 7 Input impedance of the Bow-tie antenna simulated distilled water environment.

V. CONCLUSION

Designing a patch antenna includes calculation of the patch at a frequency. Therefore, attention has been given to bow-tie antenna design considerations. With the help of the results arrived, it shows that electro-magnetic waves can be used in underwater communication by considering underwater environment effects on antenna design. Using bow-tie structure, monolithic, compatible, low cost and light weight antenna can be designed for underwater applications. Also bow-tie antenna can be successfully used for underwater short range applications with good return loss and impedance characteristics.

REFERENCES

[1] Evangelia A. Karagianni, "Electromagnetic Waves under Sea: Bow-Tie Antenna Design for Wi-Fi Underwater Communications", in Progress in Electromagnetics Research M, Vol. 41, 189–198, 2015.

[2] Mr. Rajesh Kumar, Neha Thakur, Vijay Thakur, "An overview of sonar andacoustic underwater communication", in International Journal of Advanced Research in Electrical, Electronics and Instrumentation EngineeringVol. 2, Issue 5, May 2013.

[3] Mohd Ansor Bin Yusof and Shahid kabir, "Underwater communication systems: a Review", in Progress in Electromagnetics Research Symposium Proceedings, Marrakesh, Morocco, Mar.20-23, 2011.

[4] Shan Jiang, Stavros Georgakopoulos, "Electromagnetic Wave Propagation into Fresh Water", in Journal of Electromagnetic Analysis and Applications, 2011, 3, 261-266.

[5] Richard K. Moore,The theory of radio communication between submerged submarines, 1st edition, Cornell University, June, 1951.

[6] A. A. Abdou, A. Shaw, J. Cullen, S. Wylie, A. Mason, and A Al-Shamma, "A Review of Underwater EM Wave Propagation to Investigate the Development of a Through Water WSN," 6th Built Environment And Natural Environment, 2011, pp. 1–6.

[7] Nisha George, Ganesan R., Dinakardas C. N, "Design of Wide Band Antenna for Ocean Communication: Review", in International Journal of Advanced Computer Research, Volume-4 Number-1 Issue-14 March-2014.

[8] Aleix Garcia Miquel," UWB Antenna design for underwater communications , Master Thesis, 2009.

[9] Kenneth P. Hunt, James J. Niemeier, AntonKruger, "Short Paper: Antennas for Mussel-BasedUnderwater Biological Sensor Networks in Rivers"WUWNET, ACM, 2010.

[10] A A Abdou, A Shaw, A Mason, A Al-Shamma'a,J Cullen, S Wy lie and M. Diallo ,"A matchedBow-tie antenna at 433MHz for use inunderwater wireless sensor networks", Sensors &their Applications XVII ,Journal of Physics,2013.

[11] MKA Rahim, MZA Abdul Aziz, C.S.Goh, "Bow-tie microstrip antenna dessign", IEEE Xplore conference: Networks, pp 4244-4247, 2005.

[12] Stuntebeck, E., D. Pompili, and T. Melodia, "Wireless under-ground sensor networks using commodity terrestrial motes," 2nd IEEE Workshop on Wireless Mesh Networks, 2006.

[13] Rhodes, M., "Electromagnetic propagation in seawater and its value in military systems," SEAS DTC Technical Conference, Edinburg, UK, 2007.

[14] Kerim Guney, Transactions on antennas and propagation, vol. 42, pp. 1363-1635, september 1994