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An Efficient Hemispherical Antenna Design for Wideband Applications

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Abstract: Liquid antennas are the type of antenna which utilize fluid to transmit and receive radio signals. Two types of liquid antennas are widely investigated: liquid metal antennas and water-based liquid antennas. As a special type of liquid antennas, water antennas are one of the most popular. They have attractive features such as: a) low-cost and readily accessible; b) compact size - water is a high permittivity material. This paper describes a hemispherical antenna made of pure water. The water hemispherical antenna is realized by replacing the metallic arm of a conventional hemispherical antenna with a plastic tube of circular cross section and filled with pure water. The axially symmetric TM01 mode is excited along the water arm and accounts for the wave propagation and radiation. Circular polarization is achieved by choosing a proper dimension of the water helix. The hemispherical antenna exhibits polarization-reconfigurable capability over a wide frequency band. The proposed antenna is designed and simulated using HFSS software design tool by forming virtual radiation.

Index Terms: Hemispherical antenna, polarization reconfigurable antenna, water antenna.

I.INTRODUCTION

Liquid antennas, especially the non-metal liquid antennas, have drawn more and more attentions in recent years due to the potential in reconfigurability and the virtue of flexibility, transparency, together with the low price, etc. Several kinds of non-metal liquid antennas have been proposed or demonstrated. The first type is to use sea water, saline water or distilled water to build the radiation structure. For instance, to form a monopole or a dielectric resonator antenna. The second idea is to substitute some part of the conventional antenna to make a new one. The water patch microstrip antenna is one of the examples. A wideband hybrid rectangular water antenna for DVB-H (Digital Video Broadcasting - Handheld) applications was developed. The hybrid structure combined a dielectric resonator antenna and a monopole antenna to effectively double the available bandwidth without compromising other characteristics. A transparent water dielectric patch antenna fed by an L-shaped probe was proposed. In contrast to other reported water antennas, the proposed design had the operation mechanism similar to the conventional metallic patch antenna.

A mechanically reconfigurable frequency-tunable microstrip antenna that uses a liquid actuator as the dielectric layer to reduce the size is reported. The dielectric liquid is encapsulated in the polymer to form an actuator, which can change the liquid thickness. Thus, the resonant frequency of the fabricated antenna can be changed. A sea water monopole antenna consists of a feeding probe and a sea-water cylinder held by a clear acrylic tube for maritime wireless communications was presented to demonstrate the feasibility of liquid antenna. Measurement shows that the proposed sea-water antenna has high radiation performance. A Compact dual-feed water-based antenna for hand portable systems was developed, and a ground defect structure was employed to provide a decoupling path between the antenna ports. A Sea-Water Half-Loop Antenna was designed for maritime wireless communications, which could generate a new antenna when needed with the help of a pump in the ocean environment. An antenna consisted of a cylindrical conducting monopole antenna, saline-water and a biocompatible shell was designed for Industrial, Science and Medical (ISM, 2.45 GHz) band.

The miniaturization of a liquid-based DRA due to the high relative permittivity of water was demonstrated. Furthermore, a DRA-based technique was proposed for measuring liquid permittivity [8]. A hybrid antenna with solid and liquid materials was discussed [9], with the focus of the influence of the feeding locations and the distribution of the liquid. The water antennas are designed according to different working mechanisms. By tuning the salt concentration, integrating the radiating and feeding structure or using water as a load, the water antenna can be considered as a conducting antenna, a hybrid antenna, or a water loaded antenna.

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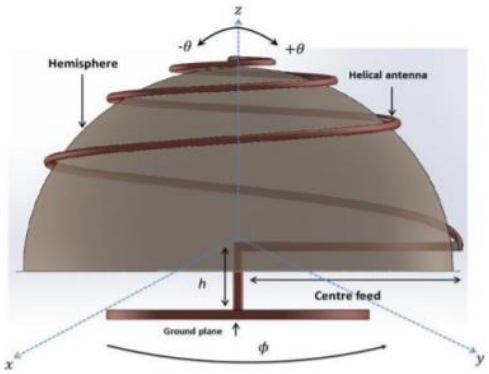

Fig. 1 Water Hemispherical Antenna

II.WATER ANTENNA DESIGN

In this section, a water monopole antenna is designed with a layer of foam with relative permittivity = 1 and relative permeability = 1 to isolate the water from the ground plane. The cross-section view is shown in Fig. 2. For a 1.8 GHz antenna, we choose the following parameters: the water antenna height = 50 mm, seawater relative permittivity = 81, relative permeability = 1, conductivity = 4.7 S/m (as seawater) A PVC tube is used to hold the water whose relative permittivity = 4, conductivity = 0, and relative permeability =1, and the tube height = 100 mm and diameter = 25 mm, and conducting ground plane thickness = 1 mm. A foam base is applied to maximise its bandwidth. Compared with traditional structure, the new water antenna has the outer conductor of co-axial feed substituted by the ground plane. The simulatedS11, efficiency are shown in Fig. 3 and Fig. 4 respectively. The new design has a very broad bandwidth: from 0.8 to 2.56 GHz for S11 < -10 dB (the fractional bandwidth > 95%), and the efficiency is above 50% from 1.2 GHz to 2.2 GHz.

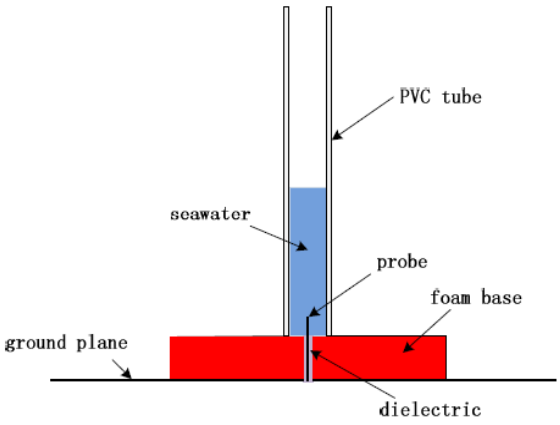

Fig. 2 Geometry of water antenna

The dielectric foam base is needed in the water antenna to avoid short circuit. And the material of the base has a great effect on antenna bandwidth. Fig. 5 depicts the simulated S11and efficiency for foam, teflon and paxolin base. The relative permittivity of the three materials are 1, 2.1 and 5.5 respectively. From the figure, we can see that foam base has the widest -10 dB bandwidth and highest efficiency. The value of relative permittivity increases, the radiation efficiency decreases.

In a Water Loaded Antenna Water is a kind of high dielectric material and usually considered for compact designs. However, the bandwidth may be sacrificed for a high Q factor. In [10], a 3D folded monopole antenna was presented for DVB-H Applications as depicted on Fig. 5, employing the idea of effective relative permittivity. By mixing the high dielectric material (such as water) and the air, the equivalent relative permittivity is reduced, which does not reduce the bandwidth significantly but reduce the size of the antenna considerably (a trade-off).

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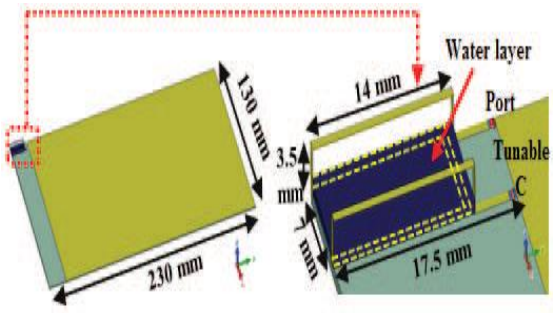

Fig. 3 3D folded monopole antenna design:
(a) top view, (b) zoom-in view

III.PROPOSED SYSTEM

This project describes about a novel hemispherical antenna made of pure water. The water hemi spherical antenna is realized by replacing the metallic arm of a conventional helical antenna with a plastic tube of circular cross section and filled with pure water. The axially symmetric TM01 mode is excited along the water arm and accounts for the wave propagation and radiation. Circular polarization is achieved by choosing a proper dimension of the water helix. Measured results show that the proposed water helical antenna has an overlapping impedance bandwidth (|S11| <-10 dB) and axial ratio (AR) bandwidth from 1.27 GHz to 2.13GHz, or 50.6% fractional bandwidth.

Our water hemispherical antenna employs a water arm of circular cross section. By properly choosing the water arm dimensions, circularly polarized radiation can be obtained over a wideband. By controlling the water flow between the arms, the polarization of the antenna can be selected between right-hand circular polarization (RHCP) and left-hand circular polarization (LHCP). The proposed water antenna with wideband width can be potentially very useful in global positioning system, radar, and satellite communication systems due to its excellent radiation performance and good reconfigurability.

IV. SIMULATED RESULTS

The water antenna has been designed and simulated report can be obtained by using HFSS software by forming virtual radiation.

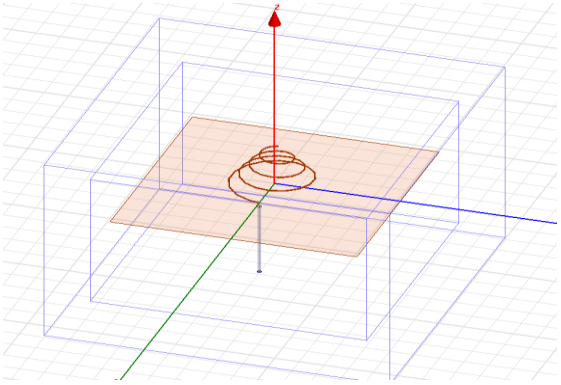

Fig. 4 Proposed Water Hemispherical Antenna Design

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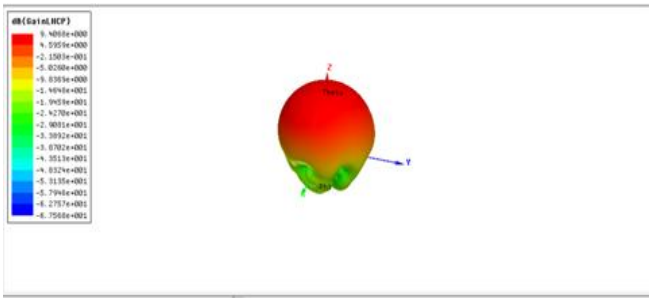

Fig. 5 Simulated gain of the water hemispherical antenna with RHCP polarization

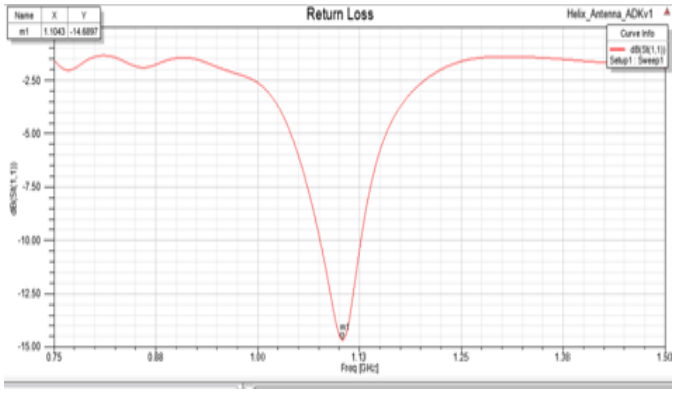

Fig. 6 Simulated Return loss of Water Hemispherical Antenna Design

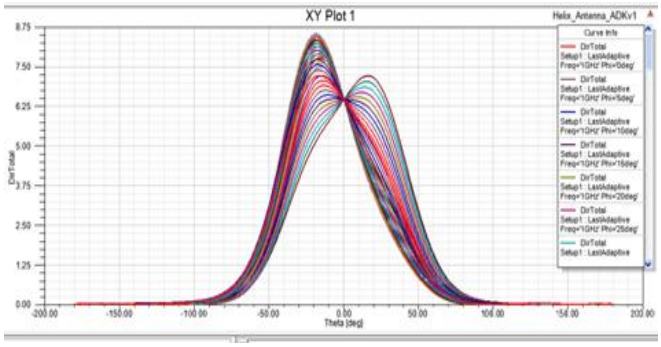

Fig. 7 Simulated Directivity of Water Hemispherical Antenna Design

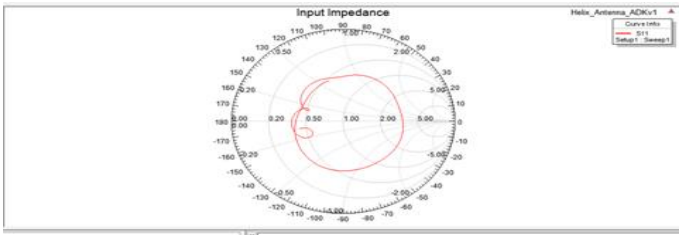

Fig. 8 Simulated Input Impedance of Water Hemispherical Antenna Design

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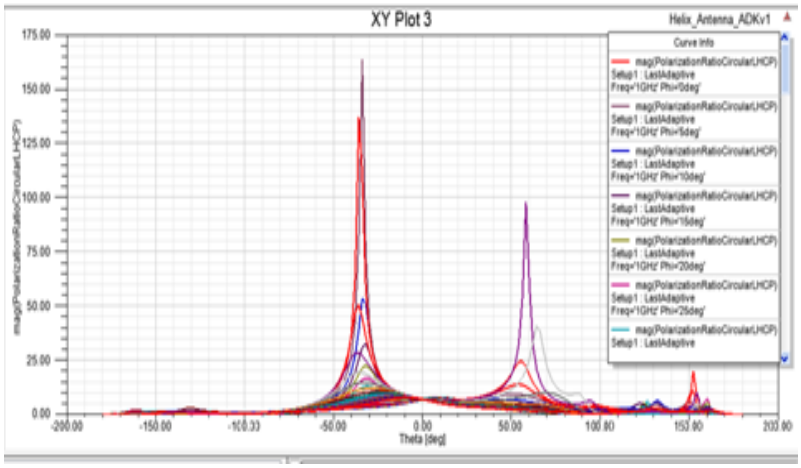

Fig. 9 Polarization ratio of Water Hemispherical Antenna Design

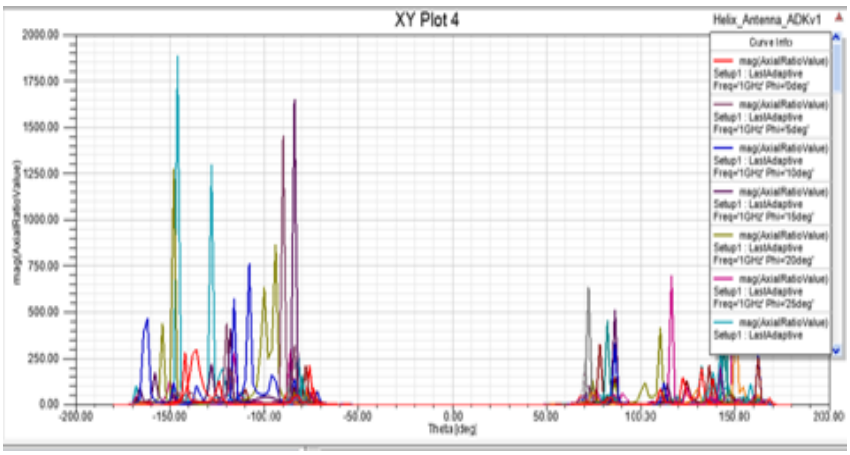

Fig. 10:Axial ratio of Water Hemispherical Antenna Design

V.PERFORMANCE ANALYSIS

The figures given below show that the gain and bandwidth of water helical antenna on implementation results have been increased when compared to the existing system.

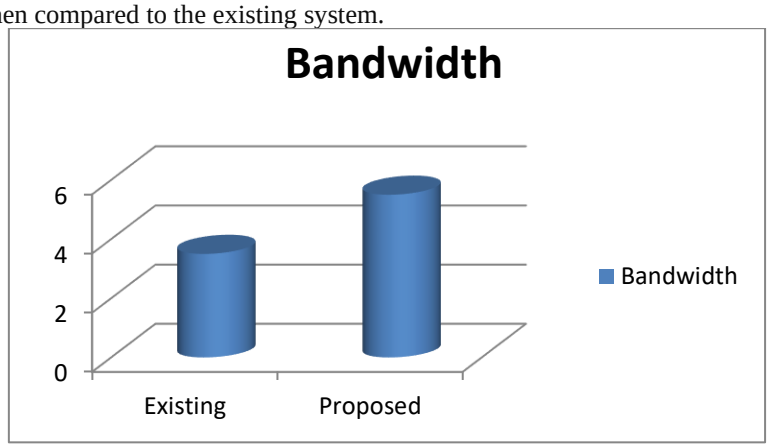

Fig. 11 Performance Result of Bandwidth

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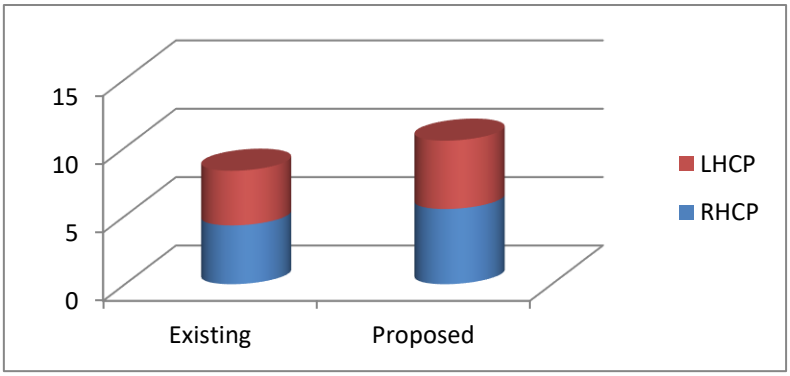

Fig. 12 Performance Result of Gain

TABLE I BANDWIDTH ANALYSIS

S.No	Parameter	Existing	Proposed
1.	Bandwidth	400 MHZ	600 MHZ

VI.CONCLUSION

In this paper, A novel hemispherical antenna made up of pure water have been designed . It has been found that the proposed antenna is able to achieve a broad bandwith circular polarization by choosing proper dimensions of the helix. Based on the design, a prototype has been designed and tested. Measured and simulated results are in good agreement. The measured results show that the proposed water helical antenna is able to obtain a wide impedance bandwidth of AR < 3 dB, a realized gain up to 7.5 dB are achieved. Based on the structure, a polarization reconfigurable antenna which can switch between RHCP and LHCP have been designed.

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