Design of Water Hemispherical Antenna for Wide Band Applications

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ABSTRACT:Liquid antennas are a type of antenna utilizing 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 project 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 TM01mode 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 system is designed and simulated using HFSS software design tool by forming virtual radiation.The proposed work increases a gain and bandwidth by using circular polarization technique.

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.

The rest of the paper contains the related works in the section 2 and the proposed methodology of water antenna illustrates in section 3. In section 4, the simulation and the design results of screenshot are presented and the performance analysis is given in section 5. Finally paper concludes in section 6.

II. RELATED WORK

Min Wang et al [1] is presented coaxial dual-tube monopole water antenna with high efficiency and wideband characteristics. Zhenxin Hu et al [2] is presented a novel circularly polarized water spiral antenna with polarization reconfigurability and low profile. It is basically an Archimedean spiral antenna with two water arms and fed by a parallel strip line. Gerard J. Hayes et al [3] is described a flexible microstrip patch antenna that incorporates a novel multi-layer construction consisting of a liquid metal (eutectic gallium indium) encased in an elastomer. Ya-HuiQian et al [4] is presented broadband hybrid water antenna operating at` very high frequency (VHF) band, in which a simple seawater monopole is loaded with two distilled water cylinders working as dielectric resonators (DRs).

Huang et al [5] is presented a microfluidically reconfigured wideband frequency-tunable liquid-metal monopole antenna. The antenna operation relies on continuous moving of the liquid-metal volume over the capacitively coupled microstrip line feed network with a micropump unit. Jin Tak et al [6] is presented broadband hybrid water antenna at very high frequency band. The proposed antenna is composed of a seawater monopole and a distilled-water ring antenna. Shen Song et al [7] is presented broadband circularly polarized (CP) antenna using organic ionic liquid resonators in this communication for the first time. The antenna is excited by inserting a new feeding structure into the liquid which is relatively simple but significantly improves the bandwidth and CP performance of traditional single probe-fed dielectric resonator antennas (DRAs).

Changzhou Hua et al [8] is presented a dynamic-type sea-water monopole antenna of high efficiency by using a new shunt-excited feeding structure .Changzhou Hua et al [9] is presented a study of sea-water monopole antenna at very high frequency (VHF) band for maritime wireless communications. The sea-water monopole antenna consists of a feeding probe and a sea-water cylinder held by a clear acrylic tube. Lingnan Song et al [10] proposed a wideband frequency reconfigurable patch antenna with switchable slots (PASSs) based on liquid metal manipulation in 3-D printed micro fluidic channel.

III. PROPOSED SYSTEM

In this paper, a novel hemispherical antenna made of pure water. The water helical 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.

The 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 wide band. 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 wide bandwidth can be potentially very useful in global positioning system, radar, and satellite communication systems due to its excellent radiation performance and good reconfigurability.

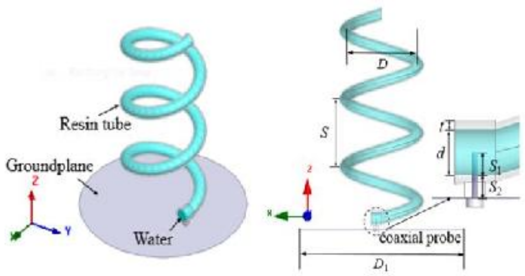

Fig 3.1 water hemispherical antenna

Fig 3.1 shows the configuration of the hemispherical antenna made of pure water and its detailed dimensions are shown in Table I. It is basically a helix with a water arm of 3 turns. The water arm has a circular cross-section of diameter *d*. The pitch spacing and diameter of the helix are *S* and *D*, respectively. The pitch angle is α = tan-1 ($S / \pi D$). A coaxial probe is protruding into the water arm by a height of *S*1 to feed the water arm. A circular metallic ground has a diameter of *D*1, which is around 0.75λ at the center frequency, and is separated from the water arm by a small distance of *S*2.

The dielectric constant of pure water is 78.7 at the centerfrequency of 1.7 GHz. It is known that the electrical properties of water vary with the temperature, pressure, and frequency. Therefore, the electrical properties of pure water used here are characterized by using a coaxial line reflection method [31] to obtain an accurate antenna design at the desired frequency. When the water cylinder is wounded into a form of helix, it can be treated as a dielectric helical antenna. In order to achieve circular polarization, the diameter and pitch angle of the water helixes should follow the same guidelines for conventional helix antenna made of conductors:

$$0.78 \le \frac{\pi D}{\lambda} \le 1.33, \qquad 12^\circ \le \alpha \le 18^\circ \quad \textbf{(1)}$$

It is known from optical fibers that leaky modes can travel along a dielectric rod and can leak power into space as radiation. Just like leaky wave antennas, leaky mode in optical fiber appears when a fast wave is excited where the phase constant is less than the free-space wave number. In order to gain insight into our water helix antenna's operating principle,

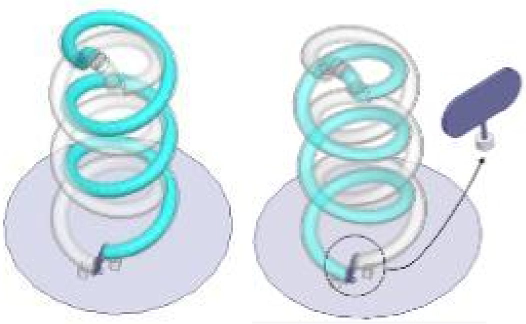

Fig 3.2 Configuration of the proposed LHCP to RHCP water hemispherical anenna

Fig.3.2 shows the phase change along a long straight water rod, a conducting cylinder, and in free-space. It can be seen that the phase difference of waves travelling in water rod is smaller than in free-space. Hence, a fast wave is excited. The magnitude of the electric field distribution along long straight water and metallic cylinders with the same thickness and feed structure as the proposed water helical antenna. The magnitude and direction of the electric field along the water helix at the antenna's center frequency of 1.7 GHz. The magnitude distribution of the electric field along the water arm of this antenna at time = 0, T/4, T/2 and3T/4, where T is the period of time. It can be seen that a travelling wave is propagating along the water arm and leaking into space as radiation in the same time.

3.1 POLARIZATION RECONFIGURABILITY

Due to the fluidity of liquid, a water antenna can be easily reconfigured. Two helixes with the same dimensions but opposite wound directions are connected in parallel and intertwined together.Only one helix is working at a time. A metallic disk is employed to feed the two helixes and block the water flow. In order to reduce the fabrication cost, we choose a white resin to process the twin helical tubes and its transparency can still be achieved if we choose transparent resin as the prototype helix shown in Section II. By controlling the water flow between two helixes, we can choose the excited arm and the polarization of the antenna can then be tuned between RHCP and LHCP. It should be mentioned that the structure occupies half of the space of a traditional parallel-fed hemispherical antenna with two polarizations and it does not need any circuit for the control of the feeding. Thus, the proposed LHCP-to-RHCP water helical antenna is very convenient to form an array.

IV. SIMULATION RESULTS

In this section, the water hemispherical antenna has been designed and simulated report can be obtained by using HFSS software by forming virtual radiation.

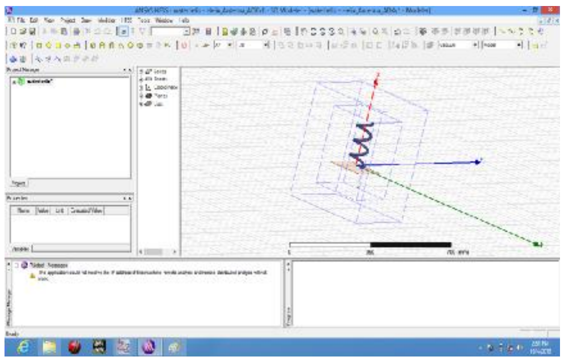

Fig 4.1 Design of the water hemispherical antenna

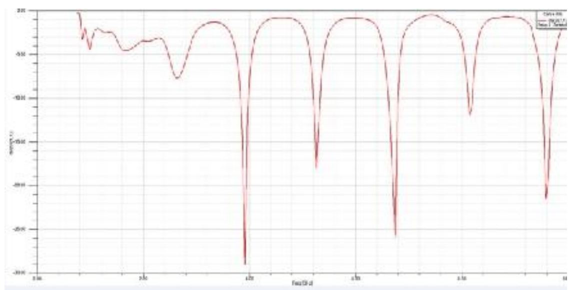

Figure 4.2 Return Loss With Multiple Resonant Frequencies

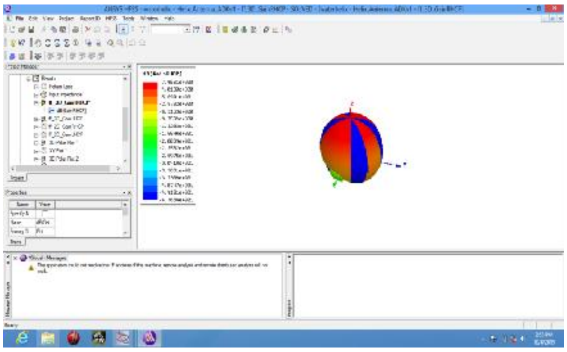

Fig 4.3 Simulated gain of the water hemispherical antenna with RHCP polarization

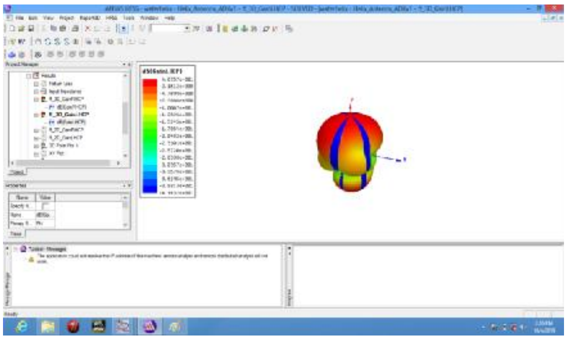

Fig 4.4 Simulated gain of the water hemispherical antenna with LHCP polarization

GAIN ANALYSIS

Table 4.1 Comparision Table

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

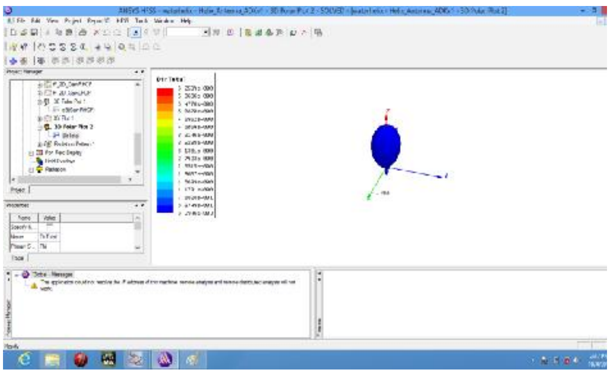

Figure 4.5 Directivity the of water hemispherical antenna

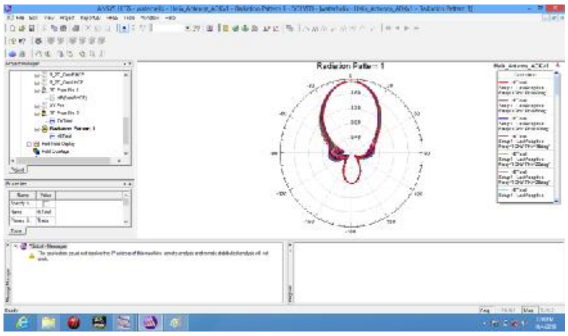

Figure 4.6 Radiation pattern of the water hemispherical antenna

BANDWIDTH ANALYSIS

Table 2 Comparision Table

S.No	Parameter	Existing	Proposed
1	RHCP	6	7.456
2	LHCP	3	4.6757

V. PERFORMANCE ANALYSIS

The Figure given below is shown that increases a gain and bandwidth of water helical antenna on implementation results which have been done by using HFSS software.The proposed system increases a gain and bandwidth when compared to the existing system.

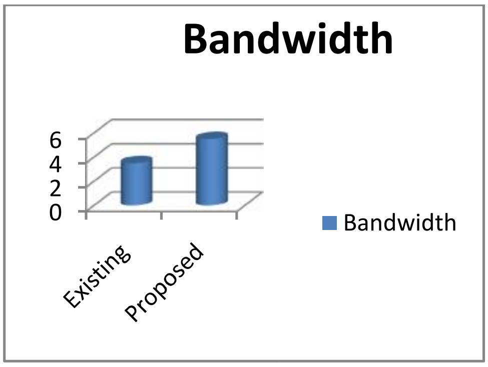

Fig 5.1 Performance Result of Bandwidth

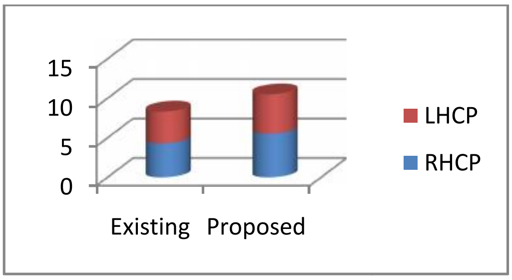

Fig 5.2 Performance Result of Gain

VI. CONCLUSION

The hemispherical antenna made up of pure water has been designed in this project. It has been found that the antenna is able to achieve a broad band with circular polarization by choosing proper dimensions of the helix. Based on the design, a prototype has been designed and tested. 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 dBi are achieved. Based on the structure, a polarization reconfigurable antenna which can switch between RHCP and LHCP is designed.

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