

Reconfigurable Water Antennas

(Invited Paper)

Changzhou Hua, Zhenxin Hu, and Zhongxiang Shen

School of Electrical and Electronic Engineering

Nanyang Technological University

50 Nanyang Avenue, Singapore, 639798

ezxshen@ntu.edu.sg

Abstract— This paper introduces two types of reconfigurable water antennas. One is a water-grating leaky-wave antenna and the other is a sea-water monopole antenna. The water-grating leaky-wave antenna consists of a parabolic reflecting surface-wave launcher and a periodic water-grating structure, which is designed for wide-angle beam-scanning. While the sea-water monopole antenna mainly comprises of a Teflon container and a sea-water stream supplied by a water pump, which is very suitable for maritime wireless communications.

Keywords—Leaky wave; reconfigurable; sea-water monopole; water antenna; water grating.

I. INTRODUCTION

In recent years, liquid antenna has been becoming an interesting topic that is receiving growing affection. As a special case of fluid antenna, water antenna is probably the most popular, due to its low cost and easy access. Many kinds of water antennas have been reported so far [1]–[3]. A simple broadband monopole water antenna was presented in [1]. The performance of this antenna was carefully studied by dissolving salt into pure water. Another monopole water antenna was presented in [2] by inserting a dielectric base between water and the ground plane to maximize the bandwidth. In [3], a rectangular dielectric resonator (DR) water antenna with compact size was designed due to high permittivity and low loss of the pure water at the low frequencies.

This paper summarizes our latest research work on water antennas. The applications of water in the design of reconfigurable antennas are presented. Two reconfigurable water antennas are introduced. One is a water-grating leaky-wave antenna for wide-angle beam-scanning and the other is a sea-water monopole antenna for maritime wireless communications.

II. ELECTRICAL PROPERTIES OF WATER

The electrical properties of water can be described by its complex relative permittivity $\epsilon = \epsilon' - j\epsilon''$, where the real part ϵ' is the dielectric constant, and the imaginary part ϵ'' is the loss factor. Further, the loss factor can be expressed as $\epsilon'' = \sigma/\omega\epsilon_0$, where σ is the conductivity of water. Both the real and imaginary parts of the complex permittivity will vary with the operating frequency and water's temperature. Fig.1 shows the

variation of ϵ' and ϵ'' with frequency for pure water [4].

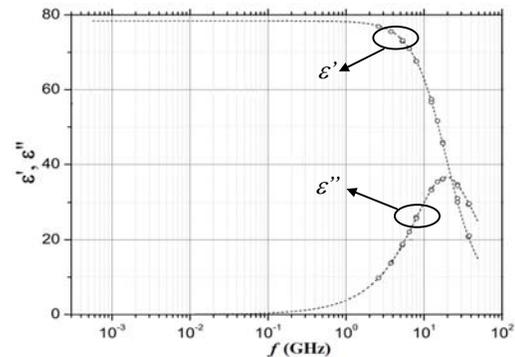


Fig. 1. Complex permittivity of pure water at 25 °C.

III. WATER-GRATING LEAKY-WAVE ANTENNA

It's well known that, water has a very high dielectric constant ($\epsilon_r \approx 78$), taking advantage of that a reconfigurable water-grating leaky-wave antenna is designed [5].

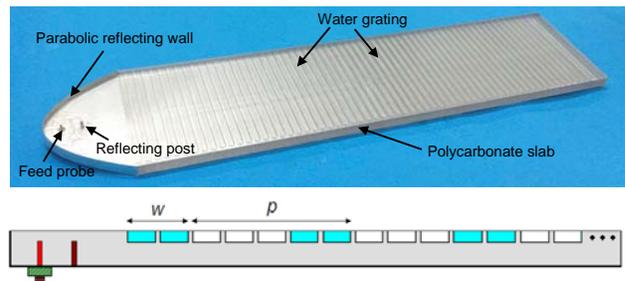


Fig. 2. Reconfigurable water-grating leaky-wave antenna.

The water-grating leaky-wave antenna consists of a surface-wave launcher and a periodic water-grating structure, as shown in Fig. 2. The feeding probe protrudes into the Polycarbonate slab ($\epsilon_r = 2.8$ and $\tan\delta = 0.006$), lying at the focus of the parabolic reflecting wall, exciting cylindrical electromagnetic waves in the slab. The direct forward waves are suppressed by the reflecting post and the backward waves will be reflected by the parabolic reflecting wall and then transformed into plane waves propagating in the Polycarbonate slab. The thickness of the slab is carefully

chosen to ensure that only the TM_0 mode can propagate. The grating structure consists of periodic narrow rectangular grooves filled with pure water. Between the adjacent grooves, there is a very thin Polycarbonate wall. The adjacent water-filled grooves are assumed to be connected to form one larger water grating since the thin Polycarbonate wall between them has an insignificant effect on the radiation performance of the antenna. By properly choosing the water flow among grooves, the beam angle of the antenna can be tuned by varying the width (W) and period (P) of the water gratings. In practical application, a water piping system can be designed to connect all the grooves for filling and emptying water in the grooves.

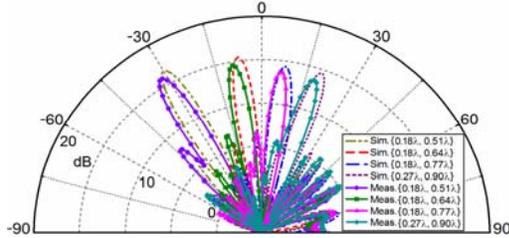


Fig. 3. Measured and simulated E-plane patterns at 5.5 GHz.

Fig. 3 shows the measured and simulated E-plane patterns of the reconfigurable water-grating leaky-wave antenna at 5.5 GHz. Measured results show that the beam angle can be tuned from -32° to 18° within a gain ripple of 2.2 dB by controlling the water grating. It can be predicted that if the groove is made even narrower, the radiation beam can be tuned more smoothly.

IV. SEA-WATER MONOPOLE ANTENNA

So far, most of the early designs of water antennas were based on fresh water [1]–[3]. However, in a maritime environment, sea water is more readily available than fresh water. Therefore, a reconfigurable sea-water monopole antenna is proposed.

Fig. 4 shows a photograph of the sea-water monopole antenna and its simulation model as well. As shown, the sea-water monopole antenna mainly consists of a Teflon container and a sea-water stream supplied by a water pump. The feeding probe is directly inserted into the water through the ground plane to feed the antenna. To achieve the desired excitation of TM mode, the container and the feed probe are concentric to maintain its structural symmetry. When the antenna is activated, the sea water is first pumped into Teflon container through the pipe, and then water stream shoots out from the container to form a monopole antenna. In comparison to the static-type water monopole antenna in [1]–[3], this antenna can be turned off in real time. Meanwhile, it is clear that the sea-water monopole antenna can be reconfigurable which means that its operating frequency and bandwidth can be adjusted by changing the height and width of the sea-water stream.

A comparison of the measured and simulated reflection coefficients and realized gain of the sea-water monopole antenna are made in Fig. 5. It is seen that the measured reflection coefficient is better than -10 dB over the frequency

range from 20 to 58 MHz. Meanwhile, the measured realized gain is larger than -10 dB over the frequency range from 46.5 to 160 MHz. It can also be seen that, reasonable agreements between the measured and simulated results are observed, with the discrepancy mainly caused by the differences between the simulation model and the actual one.

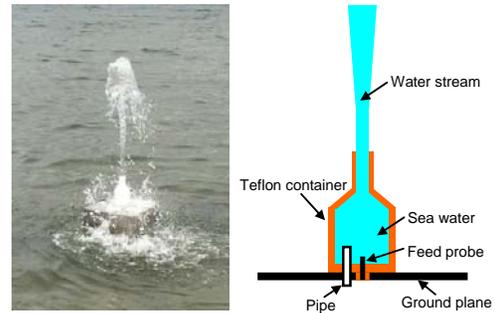


Fig. 4. Reconfigurable sea-water monopole antenna.

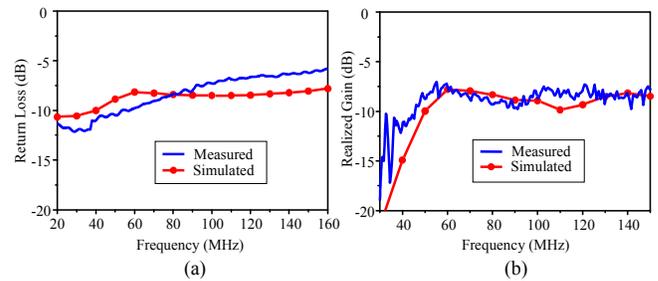


Fig. 5. Measured and simulated reflection coefficients (a) and gain (b).

V. CONCLUSION

Two types of reconfigurable water antennas have been designed, fabricated, and tested. Measured results show good agreement with simulated ones, which demonstrate their good reconfigurability. The water-grating leaky-wave antenna is appropriate for wide-angle beam-scanning. The sea-water monopole antenna is suitable for maritime wireless communications. More details of the antennas will be present at the conference.

REFERENCES

- [1] H. Fayad and P. Record, "Broadband liquid antenna," *Electron. Lett.*, vol. 42, no. 3, pp. 133–134, 2006.
- [2] L. Xing, Y. Huang, S. S. Alja'afreh, and S. J. Boyes, "A monopole water antenna," in *Proc. IEEE Antennas Propag. Conf.*, Loughborough, UK, Nov. 2012, pp. 1–4.
- [3] R. Zhou, H. Zhang, and H. Xin, "A compact water based dielectric resonator antenna," in *IEEE AP-S Int. Symp. Dig.*, Charleston, USA, Jun. 2009, pp. 1–4.
- [4] E. Levy, A. Puzenko, U. Kaatzte, P. B. Ishai, and Y. Feldman, "Dielectric spectra broadening as the signature of dipole-matrix interaction. I. Water in nonionic solutions," *The Journal of chemical physics*, vol. 136, pp. 114502(1-6), 2012.
- [5] Z. Hu, Z. Shen, and W. Wu, "Reconfigurable leaky-wave antenna based on periodic water grating," *IEEE Antennas Wireless Propag. Lett.*, vol. 13, pp. 134–137, 2014.