一般社団法人　電子情報通信学会
THE INSTITUTE OF ELECTRONICS,
INFORMATION AND COMMUNICATION ENGINEERS

信学技報
IEICE Technical Report
A･P2021-92(2021-10)

High Gain Leaky-Wave Antenna Using Deionized Water

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Abstract In this report, a high-gain leaky-wave antenna using deionized water is evaluated. Experimental results of the leaky-wave antenna using lossy deionized water as the dielectric substrate are presented and are compared with numerical results. 2.7 dB increase of actual gain at 0.91 GHz is obtained and it is found that the water is applicable as a superstrate of leaky-wave antenna at around 1 GHz.

Keywords Leaky-Wave Antenna; electromagnetic band gap (EBG); patch antenna

1. Introduction

Leaky wave antenna (LWA) with high relative permittivity superstrates placed in front of planar antennas is reported [1]. The high gain can be easily realized by covering planar antennas with a dielectric plate, and also the gain increase as the relative permittivity increase. As an example of a material with a high relative permittivity, water is the representative material, but it has not been studied as a superstrate for leaky wave antennas because of its large loss. Considering that the conductivity of water decreases as the frequency decreases, it can be considered useful as a material of superstrate in the low frequency band.

In this report, the LWA structure with lossy deionized water as a dielectric superstrate, named as the water Leaky wave antenna (WLWA) is evaluated in a frequency range of 0.5 GHz to 1.5 GHz. Gain of the LWA are evaluated by experiments and are compared with numerical results.

2. Experimental Setup

The structure of leaky-wave antenna using deionized water is shown in Figure 1. There was a method involving the addition of a superstrate or cover layer over the substrate to significantly improve gain was proposed [1]. By choosing the thicknesses h and the height d appropriately by

$$d = \frac{m\lambda_0}{2} \tag{1}$$

$$h = \frac{(2n-1)\lambda_0}{4\sqrt{\varepsilon_r}} \tag{2}$$

where m, n are positive integers. In this report, deionized water is placed at a distance d = 150 mm, from the ground plane and is used as a superstrate. A square patch with a length L_p = 130 mm is placed at a distance g = 10 mm from the ground plane. A rectangular plastic box is used as a container for carrying the water. h represents the height of the water injected into the container.

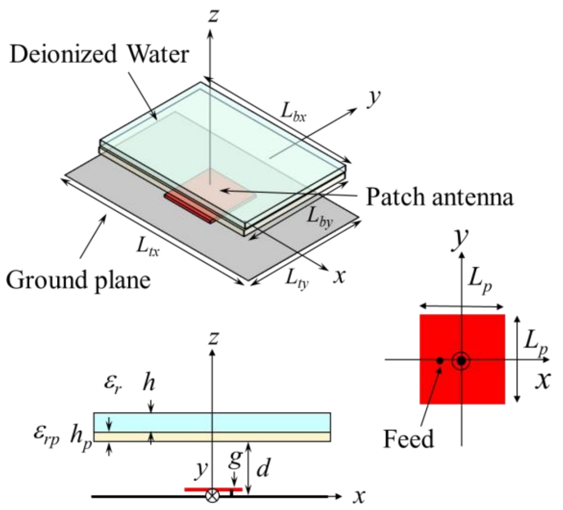

Fig. 1. Leaky-wave antenna with water superstrate.

The experimental setup is shown in the Figure 2. Two patch antennas operating at 1 GHz are separated H=1.74 m apart. The transmitting patch antenna is connected to Port 1 of the vector network analyzer E5071C and the receiving patch antenna is connected to Port 2. Water is gradually injected into the contained up to different heights from 5 mm to 20 mm and the actual gain was calculated for each height with 1 mm intervals. The height H with far field condition is around 2.4 m and H=1.74 m is not satisfied a little.

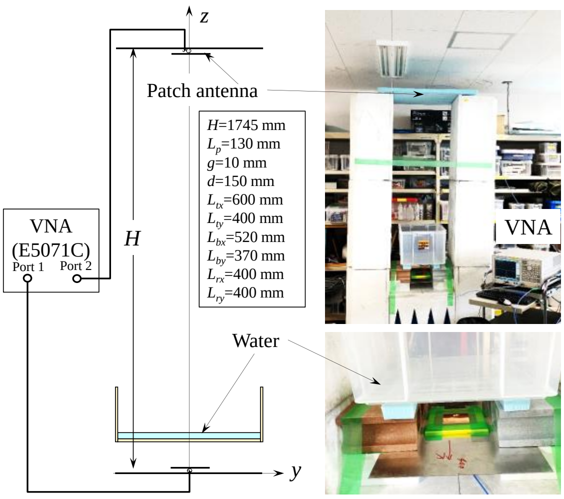

Fig. 2. Experimental Setup.

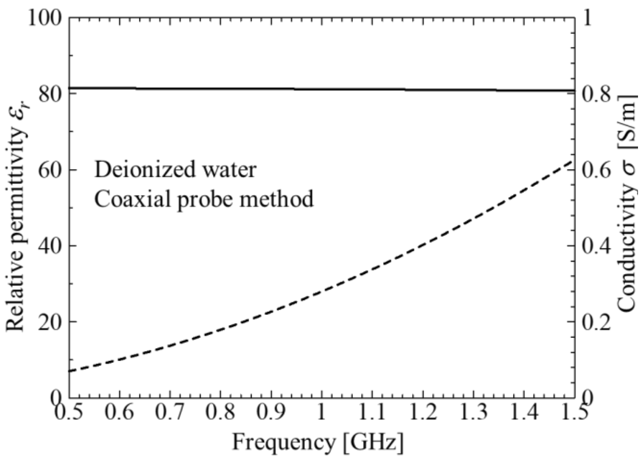

Fig. 3 Relative permittivity and conductivity of deionized water measured by coaxial prove method.

3. Results and discussion

In order to evaluate the effect of loss of water, the numerical analysis using FDTD method with considering the dispersive effect of deionized water was also performed. Figure 3 shows the relative permittivity and the conductivity of deionized water measured by using the coaxial probe method. Each value of relative permittivity and conductivity at 1 GHz are 80 and 0.3 S/m.

Figure 4 and Figure 5 are S_{11} of WLWA when h=14 mm. Almost good agreement was observed. It is observed that the return loss in the case of WLWA is significantly larger than that of a regular patch antenna used as a reference. In Figure 5, the return loss with loss of water were slightly decreased which will be caused by the reduction of quality factor of resonance, however, it is not observed in the experimental results.

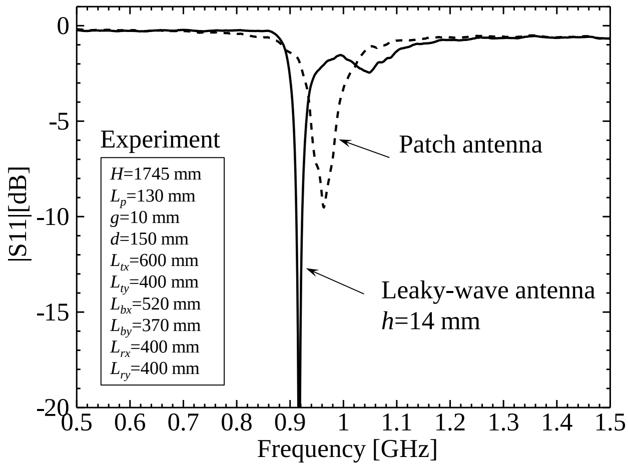

Fig. 4. Reflection coefficient S_{11} (Experiment, h=14 mm).

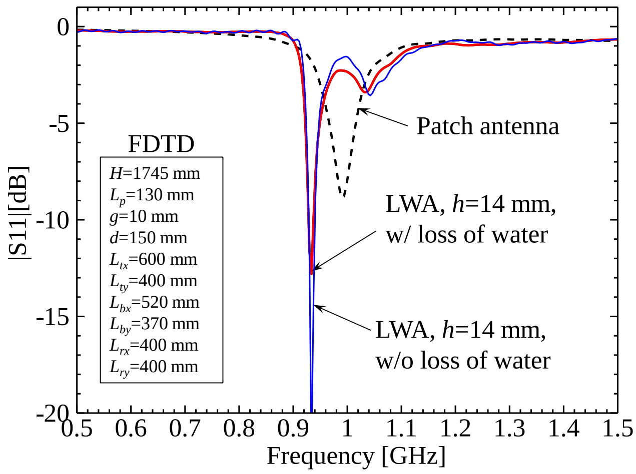

Fig. 5. Reflection coefficient S_{11} (FDTD analysis, h=14 mm).

The actual gain of the WLWA when h=14 mm was compared with a regular patch antenna and are shown in Figure 6 and Figure 7. It is observed that the actual gain increases by the presence of deionized water as the superstrate. The actual gain at h=14mm reaches 10 dBi at 0.91 GHz and increase of 2.7 dB compared with the gain of patch antenna as 7.3 dBi at 0.96 GHz. The actual gain with and without loss are compared in FDTD analysis and is shown in Figure 7. The actual gain of 11.6 dBi at 0.94 GHz without loss and 11.2 dBi at 0.93 GHz with loss, difference is only 0.4 dB, were observed. Gain of numerical value of 11.2 dBi is higher than that of 10 dBi observed in the experiment.

Figure 8 shows the resonant frequency and the actual gain corresponding to the experiment and FDTD calculations at different heights of the water. It is observed the actual gain reaches the highest value of 11.17 dBi at h=14mm in the FDTD results. On the other hand, in the

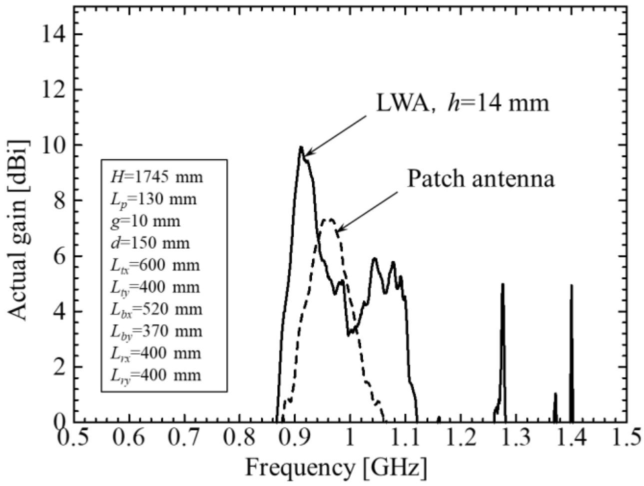

Fig. 6. Actual gain (Experiment, h=14 mm).

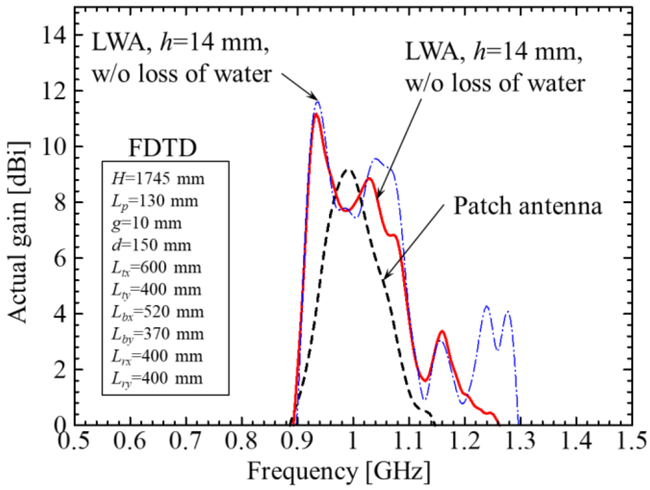

Fig. 7. Actual gain (FDTD analysis, h=14 mm).

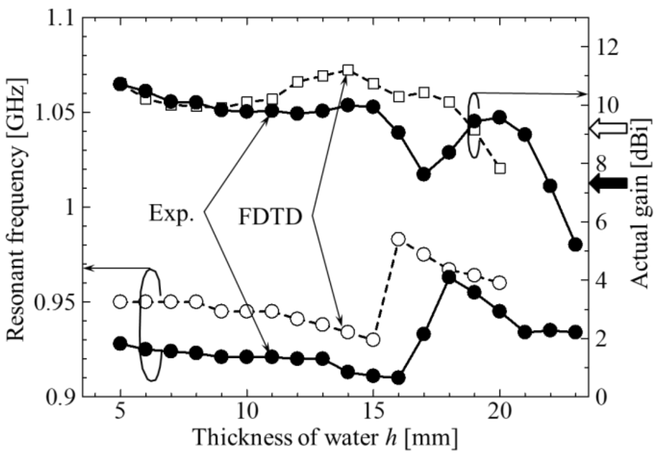

Fig. 8 Resonant frequency and actual gain as function of thickness of water h.

experimental results, the actual gain does not change much in a range from 5mm to 15mm and are in about 10dBi, slight increase was observed at 14mm. This trend agrees with that of FDTD results. It is observed that the gain can be increased in the range of 5mm to 20mm, and the maximum gain when h=14mm, in both experiments and FDTD calculations.

4.Conclusion

In this report, a LWA using deionized water as a superstrate dielectric layer was evaluated. 2.7 dB increase of actual gain at 0.91 GHz was obtained and it is found that the water is applicable as a superstrate of leaky-wave antenna at around 1 GHz.

References

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