Study and Design of a 2×2 Water Dielectric Patch Antenna Array for Wi-Fi Application

By

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Abstract: A kind of 2×2 water dielectric patch antenna array for Wi-Fi communication application is presented. The special feature of the antenna is using pure water to replace the top metallic patch of the traditional microstrip antenna. The water antenna is aperture coupled fed so that it is easy to integrate a feed network for the antenna array. Simulation is conducted with a commercial solver and a prototype is fabricated to verify the correctness as well. A measured impedance of 17.21% from 2.23 to 2.65 GHz for $|S_{11}|<-10$dB, a gain up to 12.8 dBi and a good stable radiation pattern with low cross polarization and low backlobe are achieved. The result shows that the water antenna has similar performance as the usual metallic microstrip antenna at the lower microwave frequencies.

Keywords: Pure water; water dielectric patch; antenna array; H-shaped aperture coupled feed; Wi-Fi communication.

References:

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Design Background
Background

1. Dense dielectric patch antenna (DDPA)

1.1 Replacing traditional metallic radiation patch with a thin dielectric patch of high permittivity.
1.2 Waves can be controlled between the dense dielectric patch and the ground plane.
1.3 A cavity mode $TM_{11}$ can be excited.
1.4 It is expected this kind of antenna has higher radiation efficiency than metallic patch antenna especially at higher frequency.

Performance: Operating at 3.98GHz with an impedance of 1% and a gain of 5.6 dBi.

Figure 1. Geometry of dense dielectric patch antenna

2. Water Characteristic

2.1 Advantages: transparent, easy available, liquidity and so on.

2.2 Permittivity and loss tangent of pure water:

From Figure. 2, we can see that at 15°C and at 2.4GHz, the dielectric constant and loss tangent for pure water is about 81 and 0.125 respectively.

So at lower frequency, pure water has relative high dielectric constants which can serve as a good choice for DDPA.

Figure. 2. The dielectric constant and dielectric loss of pure water

3. Previous water patch antenna design

3.1 Design Feature:
1. Patch antenna
2. L-probe feed

3.2 Performance
Bandwidth: 7.05% from 0.89 to 0.95 GHz for $|S_{11}| < -10$ dB
Gain: varies between 5.5 dB to 6.5 dB
Radiation Pattern: cross-polarization $<-20$ dB

Water patch antenna has the similar performance as the usual metallic patch antenna

3.2 Disadvantage:
Difficult to form array structure due to the use of L-probe.

My Design of Water Dielectric Patch Antenna Design
Design of Unit Water Dielectric Patch Antenna

**Objective:** 1) Design a water dielectric patch antenna working at Wi-Fi frequency (2.4GHz to 2.5GHz)  
2) Convenient to form array structure.

1. **Antenna structure:**
   1.1 Aperture coupled feed without touching water directly
   1.2 H-shaped slot to enhance the front-to-back ratio
   1.3 Plexiglass (dielectric constant equals to 3.4)

Fig. 4. Geometry of unit pure water dielectric patch antenna: (a) side view, (b) 3D view
Design of Unit Water Dielectric Patch Antenna

2. Analysis of radiation process:

2.1 From Figure 4.(a), the energy transmitted through the H-shaped slot and concentrated between water patch and ground plane. Finally, the energy radiates from the two slots into free space.

2.2 From Figure 4.(b), the fundamental mode $TM_{10}$ is excited which is same as the usual metallic microstrip patch antenna.

![Figure 5](image)

Figure 5. Simulated electric field distribution: (a) Magnitude of electric field. (b) Vector of electric field
Design of Unit Water Dielectric Patch Antenna

3. Simulated results:

3.1 $S_{11}$ and Gain

Bandwidth: 23.6% from 2.05 GHz to 2.6 GHz for $|S_{11}| < -10$ dB

Gain: varies between 5.5 dB to 6.5 dB

3.2 Radiation patterns

Figure. 6. Simulated performance: (a) $S_{11}$ and Gain (b) Radiation pattern at 2.45GHz
Design of a 2×2 Water Dielectric Patch Antenna Array for Wi-Fi Application

1. Antenna structure

Whole size: 230.6 mm×232.6 mm×14.07 mm

Figure 7. Geometry of 2×2 water dielectric patch antenna array: (a) top view of feeding network, (b) 3D view
Design of a 2×2 Water Dielectric Patch Antenna Array for Wi-Fi Application

2. Simulated and measured performance

Bandwidth: 17.21% from 2.23 to 2.65 GHz for $|S_{11}| < -10$ dB

Gain: varies between 11 to 12.8 dBi

Figure. 8. Simulated and measured performance: (a) $S_{11}$ and Gain, (b) radiation pattern at 2.45GHz
Design of a $2 \times 2$ Water Dielectric Patch Antenna Array for Wi-Fi Application

3. Photo of fabricated $2 \times 2$ water dielectric patch antenna array

Figure. 9. Photo of $2 \times 2$ water dielectric patch antenna array
Conclusion

1. Introduce some relevant fundamental concepts such as dense dielectric patch and water characteristic.
2. Have a review of previous water patch antenna design.
3. Describe my design of water dielectric patch antenna array using aperture coupled feed and give the corresponding performances.
Thank you!
Q & A