A Hybrid Antenna with Solid and Liquid Materials

Chenglong Lin[1], Gaosheng Li[1,2]*, MIEICE & MIEEE, Peiguo Liu[1], MIEEE, Yujian Qin[1],
and Yi Huang[2], SMIEEE & FIET
1College of Electronic Science and Engineering, National University of Defense Technology, 410073, Changsha, China
2Department of Electrical Engineering and Electronics, University of Liverpool, L69 3GJ, Liverpool, United Kingdom

***Abstract* – The performance of a hybrid monopole antenna with solid and liquid materials is investigated. Sea water, distilled water and oil are injected into a dielectric structure, respectively. The influence of the feeding location, the distribution of the liquid, the length of the probe and other relevant factors are studied. The simulation results demonstrate that this antenna has a very good performance and could offer more design freedom than the conventional metal or dielectric antennas.**

***Index Terms* —Hybrid Antenna, Dielectric Resonator Antenna (DRA), Liquid Antenna, Reconfigurable Antenna.**

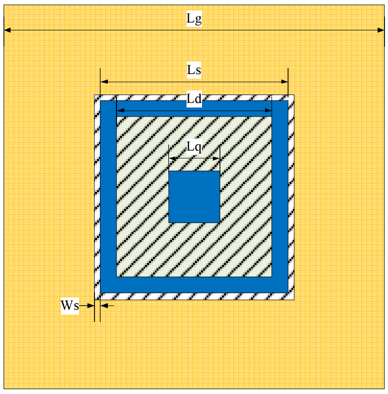
1. Introduction

The liquid antennas have attracted growing attentions in recent years due to the flexibility, reconfigurability, conformal, cost and so forth. Monopole water antennas [1], liquid metal antennas [2], hybrid water antennas [3], and transparent antennas [4] have been reported recently.

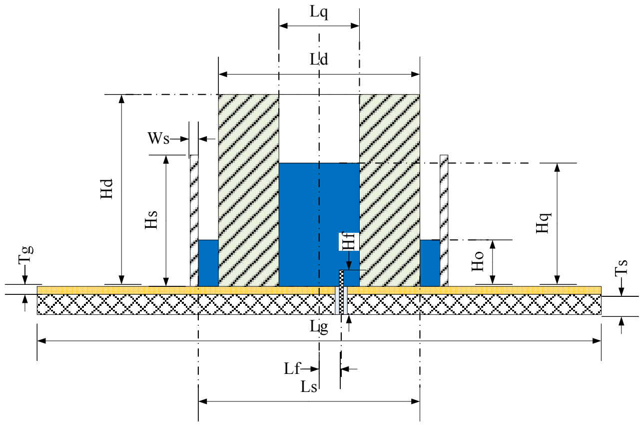
Based on previous work, a further study is carried out a hybrid antenna with a combination of solid and liquid materials to achieve better performance than the conventional design for various wireless systems.

2. Structure of the Antenna

Monopole is a popular antenna, thus we will focus on this type of antenna. But the DRA monopole has a limited bandwidth. This study is aimed at broaden the DRA bandwidth by employing liquid to make the DRA antennas. We will use both solid dielectric and liquid materials to make the antenna to which may also offer the benefit in the reduction of volume and weight, which is essential for certain system. The geometry of the proposed antenna is shown in Fig. 1. A square substrate with length L_g =200 mm that has copper (thickness T_g = 0.035mm) on the surface. The radiation structure consists of solid and liquid materials. The former could be various dielectrics and glass or ceramic materials while the latter could be sea water, oil and some other fluid mixture. The heights of the inner (H_q) and the outer liquid (H_o) are related to keep the total volume as a constant. The heights of the inner and outer dielectrics are H_d = 50 mm, H_s =30 mm, respectively. And the lengths are 40 mm (L_d) and 54 mm (L_s), with the shell thickness of the outer dielectric W_s =2 mm. Thus, the planar size of the inner and outer liquid is 20 mm (L_q) and 5 mm.



(a)



(b)

Fig. 1. Structure of the antenna.(a)top view. (b)side view.

A coaxial feeding port is fixed at the bottom of the substrate with a probe stretching into the liquid. The original length of the feed into the liquid is 3 mm.

3. Simulations and Analysis

(1) Comparison of the Bandwidth

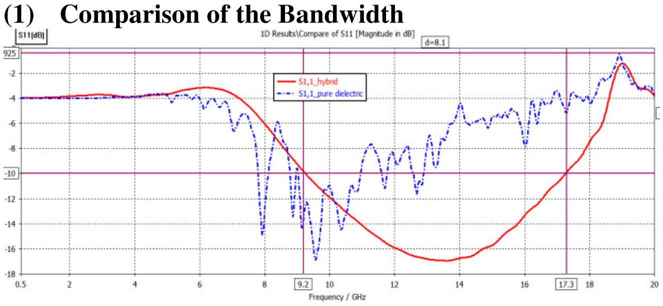


Fig. 2. S11 of single dielectric and hybrid of solid and liquid.

*corresponding author, E-mail: gfkdlgs@163.com

The reflection coefficients (S11) of a single dielectric and the hybrid antenna with solid and liquid are shown in Fig. 2. It can be seen clearly that the bandwidth of the hybrid one is very broad with S11<-10 dB in the frequency band of 9.2-17.3 GHz out of 0.5-20 GHz that calculated, while the pure dielectric one has only several narrow frequency gaps between 7.8-13 GHz available. As the valley of the S11 curve is 13.6GHz, the relative bandwidth is about 59.6%. This supports the potential flexibility for the hybrid antenna to expand its bandwidth.

(2) Influence of the Feeding Locations

Rogers RT6010 with the permittivity epsilon of 10.2 and sea water of 74 are applied as the radiation materials first. The feeding point is put on the Axis x, and we can get the VSWR curves as shown in Fig. 3, with the location (L_f) changes from 2.5 mm to 10.0 mm by step of 2.5mm, which can reflect the matching situations of the different configurations. It can be seen that the first three agree well while the last one shows obvious but not large increase due to the change of material from water to RT6010. Here, we choose the frequency band of 10.5GHz to 17.7GHz, which is 13.6/1.3 GHz and 1.3*13.6 GHz, respectively.

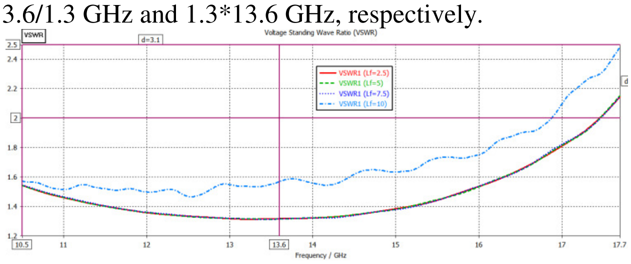


Fig. 3. The VSWR of different feeding positions.

(3) Influence of the Distribution of the Liquid

The distribution of the liquid inside of the dielectric structure will influence the radiation and the matching performance. We changed the height of the inner liquid and the calculated results are shown in Fig. 4, with the height (H_q) of 5, 30 and 48mm, respectively. It is almost the same for the latter two. The curve indicates that tiny amount of liquid will influence the flatness of the S11 curve.

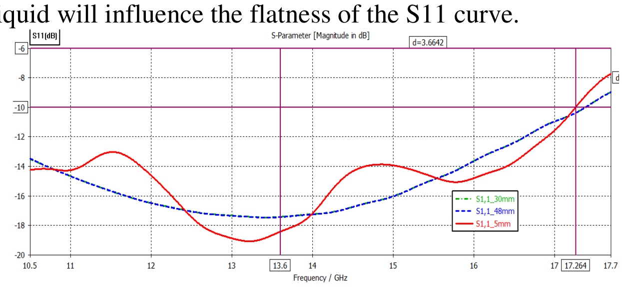


Fig. 4. S11 of different inner liquid heights.

(4) Curves of Different Liquids

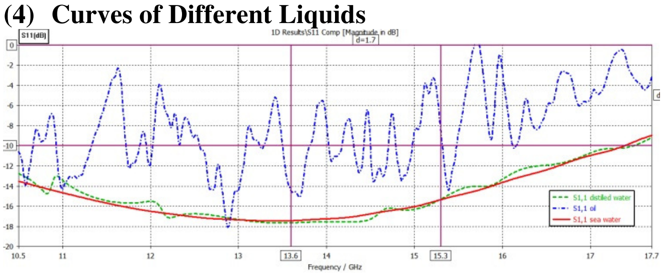


Fig. 5. S11 of sea water, oil and distilled water.

When we change the liquid from sea water to distilled water (epsilon 78.4) or oil (epsilon 2.33) without changing other parameters, the calculated reflection coefficients can be seen in Fig. 5. The curve of sea water has the best flatness. It is not so good for oil in this structure, but we can improve it by changing the parameters of the substrate or other relevant factors.

(5) Influence of the Length of the Feeding Probe

We changed the length of the feeding probe from 1mm to 5mm, which is among the range of 1/22 to 1/4, considering that the wavelength of the signal of 13.6GHz is 22mm.

The substrate of F4BT-1 with epsilon of 2.94 is used first. Computation results of S11 with different thickness (T_s) are displayed in Fig. 6(Hf=3.035 means the height of the probe is 1mm while 7.035 means 5mm). Slight differences can be seen from the results which reveal that no important influence will be settled on the matching performance in these conditions.

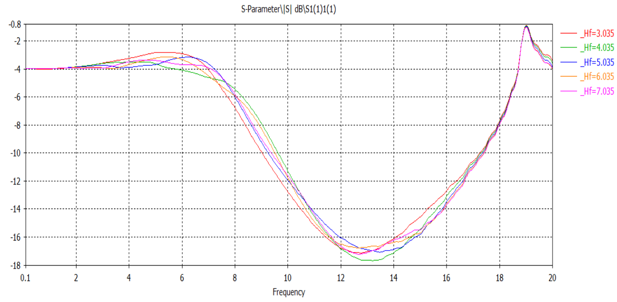


Fig. 6. The reflection coefficients VS. length of the probe.

By the way, we simulated the influence of the upper lid to hold the liquid. It is exactly the same for the structure to have or have not a thin lid on it. The maximal gain difference is about 0.5 dB between them referring to a thickness of 2 mm.

4. Conclusion

A preliminary study of a hybrid monopole antenna was proposed for broadband applications. Simulation results have been produced and analyzed. Fairly good performance was obtained after optimization. The simulation results indicated that to make use of the shell of common liquid antenna can benefit both the design and performance improvement, owing to the additional degrees of freedom. Furthermore, to change the shape of the dielectric and the liquid or the substrate will introduce new performance of the antenna. We will try to figure out a method to change the distribution of the liquid with convenient and carry out measurement of the parameters of the antenna.

References

[1] Changzhou Hua, Zhongxiang Shen, “High Efficiency Sea-water Monopole Antenna for Maritime Wireless Communications,” *IEEE Antennas and Wireless Propa. Lett.* , vol. 15, pp. 174-177, 2016.

[2] A. Ha, K. Kim, “Frequency Tunable Liquid Metal Planar Inverted-F Antenna,” *Electronics Letters* , vol. 52, pp. 100-102, 2016.

[3] Lei Xing, Yi Huang, Qian Xu, “A Broadband Hybrid Water Antenna for Hand-Portable Applications,” *IEEE Antennas and Wireless Propa. Lett.* , vol. 15, pp. 174-177, 2016.

[4] Yujian Li, Kwai-Man Luk, “A Transparent Water Dielectric Patch Antenna,” in *Proc. IEEE 4th Asia-Pacific Conference on Antennas and Propa. (APCAP)*, 2015, Bali, Indonesia, pp. 319-320.