Bi-functional Saltwater-based Structure as UHF Antenna and EMI Shielding Window

Duy Tung Phan [(2)], Tien Dat Nguyen [(1)], Ping Jack Soh [(2)], and Changwon Jung [(1)]

(1) Graduate School of NID Fusion Technology, Seoul National University of Technology, 172, Gongneung-ro, Nowon-gu, Seoul, 139-743, Korea.

(2) Centre for Wireless Communications, University of Oulu, Pentti Kaiteran katu 1, 90570 Oulu, Finland.

***Abstract*—This paper presents a transparent saltwater in glass structure working simultaneously as a UHF antenna and EMI shielding window. The proposed structure has high transparency (> 91%), which is achieved through the use of salt water as a conductive medium held between two clear glass layers, allowing its use as an optical window. On one hand, the saltwater in the glass structure functions as an EMI shielding window, with a shielding effectiveness above 20 dB. On the other hand, the proposed structure works as a transparent UHF antenna by adding only a feeding port.**

***Keywords*— transparent antenna; EMI shielding; liquid antennas; shielded windows.**

I. Introduction

The rapid development of wireless technologies with higher data-rate requires new classes antenna to meet new requirements. For example, the design of antennas for UHF band are challenging because internal antennas with limited space and electromagnetic interference have low performance, whereas external antennas are not conformal and aesthetic due to its relatively big size. Many types of solid transparent antennas have been extensively studied using solid transparent thin films [1-3]. Due to the low transparency, most previous transparent antennas are designed to work at a high frequency to reduce the size and fit specific applications [2-3]. On the other hand, the development of wireless technologies also give rise to an unwanted EM waves, which causes EM interference (EMI). These EM waves potentially cause electronic device failures and their radiation may raise the risk of cancer, asthma, heart disease, migraine, and even miscarriage [4]. Therefore, the EMI shielding technologies have become more critical to prevent EMI pollution.

In this paper, we demonstrate a highly transparent structure which can work as a UHF antenna and EMI shielding window at the same time. The structure consists of a saltwater layer held between two clear glass layers. To the best of our knowledge, there is not any similar design reported so far.

II. Results and Discussion

A. Concept and Schematic of Antenna

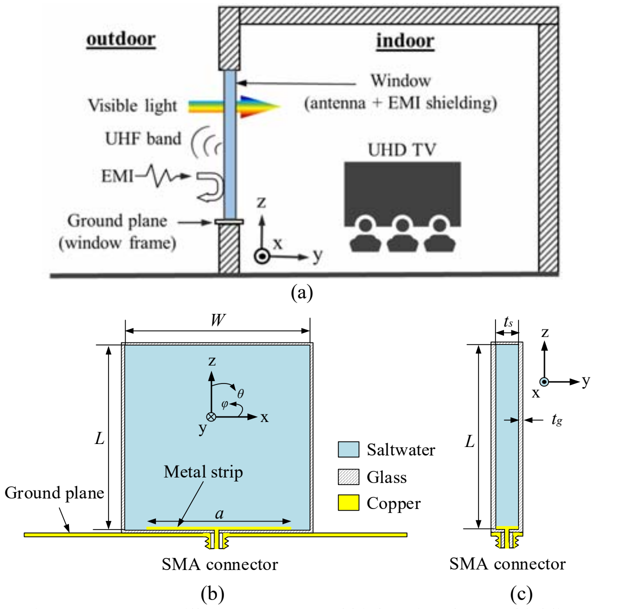
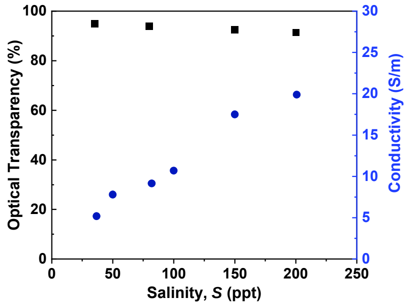


Fig. 1. (a) Concept illustrates proposed bi-functional EMI shielding window and UHF antenna; Schematic of the liquid antenna: (a) front view, (b) side-view.

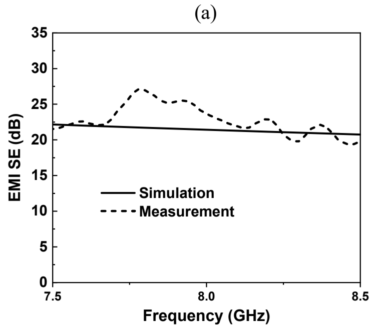
Fig. 1(a) illustrates the concept of the proposed structure working as a bi-functional device: the UHF antenna and EMI shielding window. Due to its high optical transparency, the structure allows visible light to pass through unchanged; therefore, alternating as a conventional window. For the shielding function, the conductive salty water layer will serve as a radiation barrier to block EM interference from outside. Therefore, radiation essentially cannot penetrate to interfere with electronics in the room. On the other hand, by introducing a feeding port, the proposed structure can be used as an antenna to transmit/receive desired RF waves for certain wireless communication applications, e.g., the UHF band for broadcast television applications. The schematic of proposed structure when operating as a transparent liquid antenna with different configurations is shown in Figs. 1 (b) and (c). The dimensions of the proposed antenna are optimized to work in the UHF band with $W = L = c = 15$ cm, $t_s = 3$ mm, and $t_g = 2$ mm.

B. Optical, Electrical and Shielding Performance Analysis

Fig. 2(a) shows the measured optical transparency and conductivity of the saltwater at various salinity levels ranging from 35 to 200 parts per thousand (ppt). Results show that the conductivity of saltwater is significant improved while the optical transparency slightly decreases when the salinity increases. To prevent the saltwater from becoming saturated, 200 ppt saltwater is used in this structure. Fig. 2(b) shows the measured EMI shielding effectiveness (SE) of the proposed structure, which is in good agreement with the simulated result. Results showed at least 20 dB of SE from 7.5 to 8.5 GHz. Due to the limitations of measurement instruments, the performance of this antenna only evaluated in this band.



(a)



(b)

Fig. 2. (a) Measured optical transparency and conductivity of saltwater layer versus salinity; (b) Measured EMI SE of the proposed structure.

C. Antenna Measurement

Fig. 3 shows the simulated and measured reflection coefficients of the structure when operating as an antenna. The measured -6 dB bandwidth of the antenna ranges from 350 to 680 MHz (330 MHz; 64%). This bandwidth nearly meets the requirement for ultra-high-definition TV (UHD TV) applications. The antenna radiation patterns shown in Fig. 4 indicate a good agreement between simulation and measurement results. The antenna shows an omnidirectional

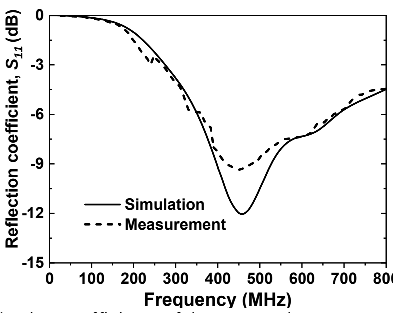
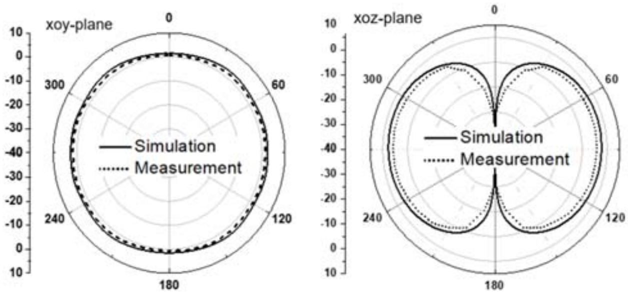


Fig. 3. Reflection coefficients of the proposed structure working as an antenna.



(a) (b)

Fig. 4. Radiation pattern of the antenna in (a) xoy-plane and (b) xoz-plane.

characteristic in the *xoy*-plane and a directional radiation pattern in the *xoz*-plane, similar with a typical monopole.

Table I summarizes the performance of the proposed structure when operating as an antenna and EMI shielded window. The antenna structure shows typical monopole-like performance with an average gain and radiation efficiency of 1.73 dBi and 69% in the UHF band, respectively. At the same time, it featured a good shielding level with an average of 21.8 dB.

TABLE I. SUMMARY OF MEASURED RESULTS

Antenna performance			Shielding performance
BW (MHz)	Gain (dBi)	Radiation efficiency (%)	EMI SE (dB)
330	1.73	69	21.8

III. CONCLUSION

This paper presents a highly optical transparent saltwater in glass structure which can work simultaneously as an antenna and EMI shielding window. The overall transparency of the structure is over 91% with a shielding effectiveness of above 20 dB, allowing it to be used as an EMI shielding window. When operating as an antenna, the structure shows typical monopole-like performance with an average gain and radiation efficiency of 1.73 dBi and 69%, respectively in the UHF band. Results demonstrate that the proposed structure can be used as a bi-functional device in practical applications.

ACKNOWLEDGMENT

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