착용환경을 고려한 안테나 설계와 손 부착 시 HAC 지수의 관찰

강승택*, 최동근**, 전진수*, 박정훈*

A Handset Antenna Design with the Real-Portable Mock-Up and Its HAC with the Hand-Effect

Sungtek Kahng*, Dong-Geun Choi**, Jinsu Jeon*, Jeong-hoon Park*

요 약

본 논문에서는, 이중대역 안테나를 가진, 인체 거치용 단말장치 모사구조의 HAC(보청기 EMC) 지수가 실재환경으로부터 받는 영향에 대한 관찰이 이뤄진다. 첫째, 부착형 이동통신 장치에 필수적인 인접 구조를 고려한 이중대역 내장형 안테나가 설계된다. 이 설계는 모사구조의 제작을 통해 실제의 모습을 갖춘다. 둘째, 이 장치의 HAC 지수는 손에 부착하기 전과 후에 대해 모의시험 및 측정을 통해 얻어진다. 특히, 실재 장치의 전자장 모의시험 결과는 표준 측정법에 의해 타당성이 확인된다. 마지막으로, HAC 기주는 대역, 실장환경, 손(인체) 효과의 관점에서 분석된다.

Key Words : Mobile Phone, Human-Body Effect, Hearing-Aid Compatibility(HAC), Hand-Effect, SAR

ABSTRACT

In this paper, we investigate the realistic environment influence on the Hearing-Aid Compatibility(HAC) of the body-held device mock-up with a dual-band antenna. In detail, first, a dual-band internal antenna is designed considering the neighboring objects essential to a real attachable mobile device. This comes to reality by making its mock-up version. Second, the HAC of this device is simulated and measured for `stand alone`, and `hand-held` cases. Particularly, the electromagnetic simulation of the designed antenna in the real device is verified by the standard measurement. Finally, the evaluated HAC is analyzed in terms of the relations with the bands, the mock-up environment and the hand effect.

Ⅰ. INTRODUCTION

The modern society sees the increasing population of those who have difficulties in hearing, wear hearing-aids, resulting from the aging and growing levels of noise and the number of hearing-problem holders increases annually by over 10%. Namely, the number of hearing aid users is not a small fraction of the World population.

Hearing aids are electronic devices. They may be disturbed by the near-zone fields from mobile phones and the GSM burst noises. For their safety or meeting the requirements from the IEEE ANSI[1], the HAC needs to be considered for antenna and phone designs. As a part of the HAC, the electric field of RF emission should be controlled under the maximum limits 1122 V/m, and 354.8 V/m for 835 MHz and 1.765 GHz, respectively, at the 1.5 cm distance from the surface of the loudspeaker of a phone with AWF 0.

As early as [2-4], it is demonstrated the models of their wireless devices can electromagnetically interfere with hearing aids. Going further from the aforementioned work, Hayes et al suggest two ways to constrain the current that leads to the radiated emission and negative influence on the HAC[5-6].

In this paper, instead of using simple and ideal antenna and phone models without hand effects and counting on only the calculation as before, we design and fabricate a dual-band antenna embedded in a pseudo-real -phone(PRP), and conduct the measurement of the HAC by a standard test equipment as well as the field analysis

※ 본 연구는 인천대학교의 자체 연구비 과제 지원으로 수행되었음.
*인천대학교 정보통신공학과 전파공학 및 전파환경 연구실 (s-kahng@incheon.ac.kr), **국립전파연구원
접수일자 : 2014년 3월 7일, 수정완료일자 : 2014년 3월 13일, 최종게재확정일자 : 2014년 3월 14일

on the electromagnetic influence from the PRP on the hearing aid with regard to a case without a hand on and three cases with the hand on the PRP. The band, the PRP, and the hand effect are explained concerned with evaluated HAC levels.

Ⅱ. DESIGN OF A DUAL-BAND ANTENNA IN THE PRP

Before dealing with the PRP environment, an initial dual-band antenna is designed. The target resonance frequencies are 835 MHz and 1.765 GHz. The current path for each resonance is roughly decided as in [7].

$$f_0 = \frac{c}{4(W+L)} \tag{1}$$

where c is the speed of light in free space, f_0 is the desired resonant frequency, and W and L are the width and length of the main radiator. The lengths of the two current paths are obtained as 83.02 mm for 835 MHz and 40.52 mm for 1.765 GHz. These lengths are not used as described but slightly changed as detuning before the objects of the PRP in the vicinity of the antenna are added.

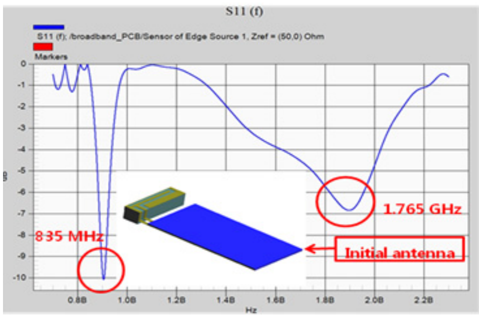


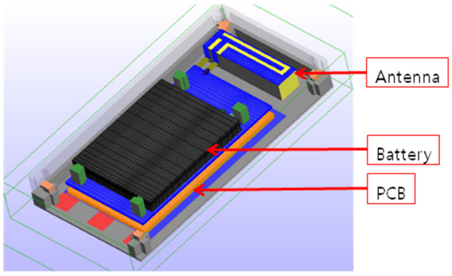
Figure 1. Return loss of the initial antenna(BHz = GHz)

So the return loss of the antenna alone is calculated by the 3D EM simulation that we take advantage of .

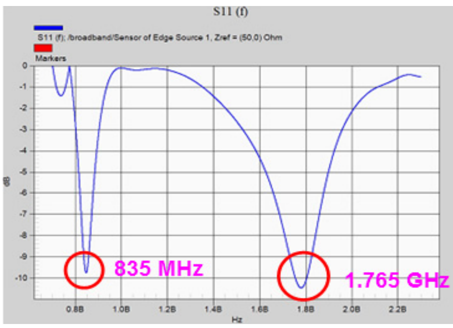
Table 1. Geometrical and material info. on the PRP elements

Distribution	Size [mm] (x* y* z)	Material Parameter (PEC/ε_r/μ_r)	Relative position (mm)
Cover	96.58*49.89*14	Dielectric/3.5/1	31.73
Speaker	7*11*3	PEC	22.93
Display	34*63*1	Dielectric/3.5/1	37.37
Battery pack	36*45*5	PEC	41.84
Wiring	5*3*4	PEC	30.07

It is time to place the objects needed in the PRP near the antenna. Since they change the field distributions from the initial antenna, for the accurate second step design, and simulation, the geometrical and material attributes of the objects(cover, louder speaker, display, battery pack and wiring) are clarified in Table 1 where PEC stands for the perfectly electric conductor. Also, Relative position means the center of an object in terms of the origin of the global coordinates. The necessary objects are put together in the proximity of the antenna in the simulation as illustrated below, and the return loss of this PRP model is obtained.



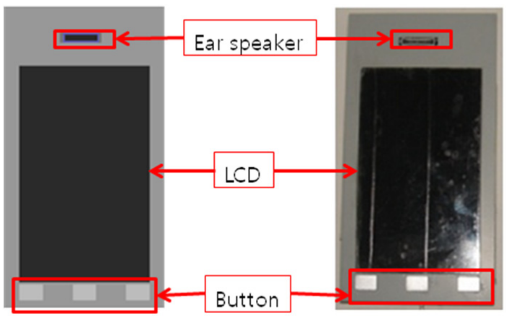
(a) Structure of the PRP



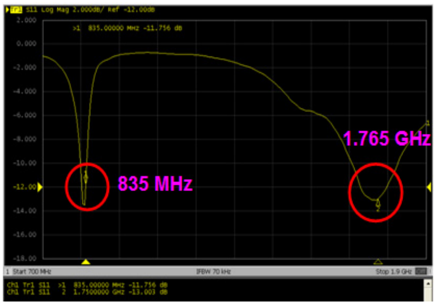
(b) Return loss results of the PRP(BHz = GHz)

Figure 2. PRP in the EM field simulation level and its S11

The return loss result of the PRP model is acceptable with the dual bands. Using the physical dimensions and materials in the EM field simulation above(Table a, Fig. 2(a)), we can make the mock-up of the PRP.



(a) PRP in CAD (b) PRP in the real world(front case)



(c) S11 of the fabricated PRP

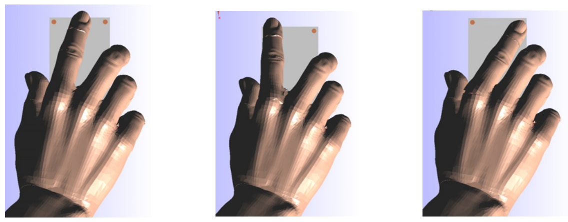
Figure 3. PRP before and after fabrication

If the fabricated PRP is compared to the CAD version, they look the same. However, the return loss of the manufactured PRP is not exactly the same as that of the simulation which might have been caused by the manufacturing tolerance and errors in the material constants. Despite the change in the bandwidths of the frequency bands, the return loss level and the center frequencies have not changed. So we can move on to next step.

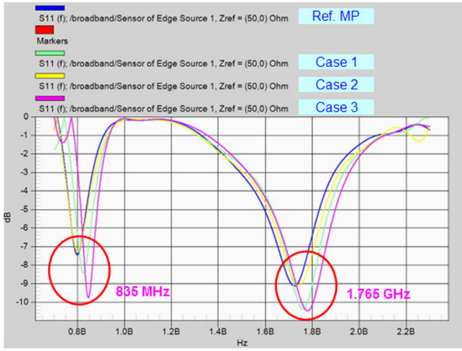
Ⅲ. CONSIDERATION OF A HAND HOLDING THE PRP

Prior to the HAC test, we would like to examine the hand effect on the PRP performance. There are a variety of postures of a hand and hand grips in reality and we set three cases according to the index finger position. This takes into account the human behavior that the index finger moves more often than the other fingers of the hand that holds the phone. The three cases are illustrated as follows.

The three cases are the index finger in the middle of the top edge, on the left of the top edge, on the right of the top edge, when the PRP is held by a hand. The CAD model of the hand is taken from the library of the SEMCAD. The human hand as the surrounding factor to the PRP affects the EM field and impedance matching. So S11 of the 3 cases is changed from Fig. 2(d). The case 2 undergoes the smallest change, since the index finger position is off the antenna. Meanwhile, cases 1 and 3 disturb the near-zone field from the antenna and experience the largest change in S11. The measurement of the 3 cases can be reflected on by the following HAC test and be predicted by the EM simulation that has shown reliability.



(a) Case 1 (b) Case 2 (c) Case 3

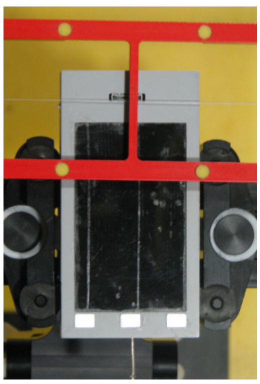


(d) S11 of 3 cases(BHz = GHz)

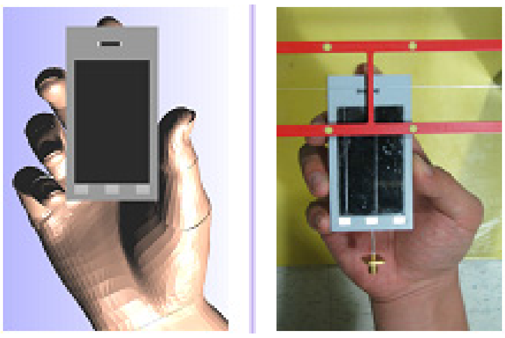
Figure 4.

Ⅳ. HAC TEST OF THE PRP WITH AND WITHOUT THE HAND

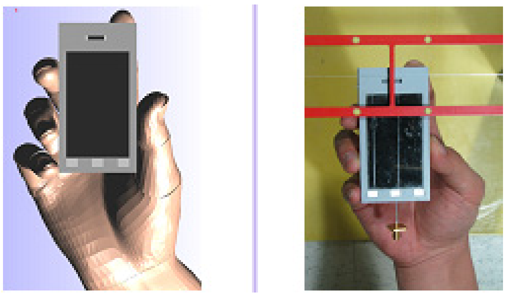
In this section, the HAC of the PRP is simulated by the SEMCAD equipped with the corresponding function, and measured by commercially available DASY4 and ESSAY3 that have become the standard test equipment, regarding 835 MHz and 1.765 GHz. Briefly mentioning the HAC test region, it is represented by a 5 cm × 5 cm square having its center at the loudspeaker hole in the PRP cover. This square is divided into 9 sub grids for the HAC evaluation and it is located 1.5 cm away from the outer surface of the loudspeaker.



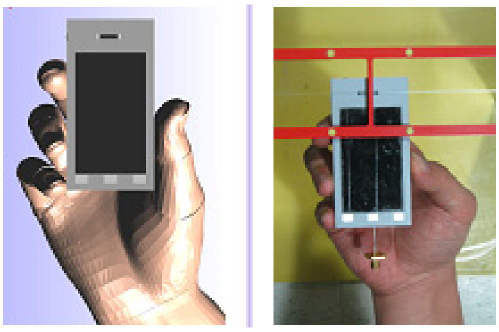
(a) Case 0(Stand-along PRP)



(b) Case 1



(c) Case 2

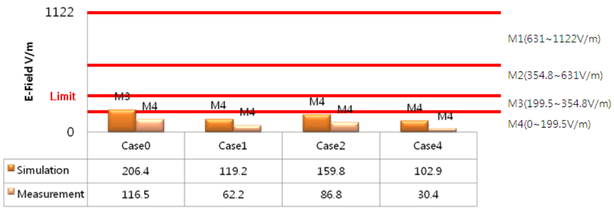


(d) Case 3

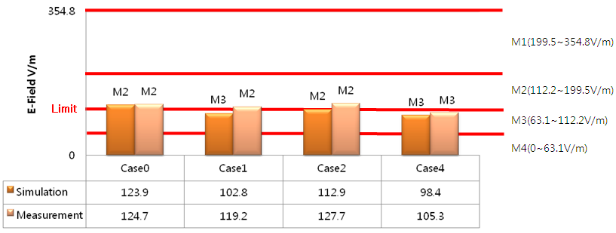
Figure 5. Simulation and Measurement of HAC test

For the measurement, one of the co-authors has volunteered to hold the fabricated PRP in the set-up. Though there is no hand-phantom available in the lab, we can see the trend of the HAC electromagnetically interacting with the hand. Here are the charts as the results of the simulated and measured HAC.

It was checked that the phone antenna has resonance points at 835 MHz and 1.765 GHz for the simulation(Fig. 2) and test(Fig. 3). Fig. 4 presents the return loss in the different cases. It is confirmed that the simulation shows good agreement with the measurement in each test case. And even if the experiment result in the lower frequency(835 MHz) satisfies the HAC specs for all the cases, the experiment result in the higher frequency(1.765 GHz) has a few cases that do not comply with the HAC specifications due to the difference between the CAD hand and the real human hand.



(a) 835 MHz Result



(b) 1.765 GHz Result

Figure 6. Comparison of the simulation and measurement on the dual bands (a) 835 MHz (b) 1.765 GHz

V. CONCLUSIONS

It is found out that the experiment in the lower frequency is more affected by the hand in this study against the general idea that the test in the higher frequency will be more sensitive to the hand. It is observed that the difference of the efficiency from the simulation and the measurement in the lower frequency test on the sample antenna turns out around 200%, with the HAC measurement value as the half of the simulation. It is understood that since the lower frequency has a narrow band which is relatively more vulnerable to the change in the test environment, the resonance frequency of this band is shifted due to the real hand causing unstable postures of the hand and the antenna position. Conclusively, it is believed that securing wide bandwidth for the antenna design like 1.75 GHz frequency band is the important point to improve the HAC from the hand effect. Therefore, the current U.S. requirements on the HAC do not take into consideration the hand effect, but it needs to consider the effect for the HAC study and standardization.

ACKNOWLEDGEMENT

The work was supported by the Incheon national university research grant. And the authors appreciate Dr. Oh with the RRA, Mr. Kwon with EPIK, Mr. Kim with Satimo, Mr. Jeong with LG for their instrumental collaboration on SAR/HAC. Also, the authors are indebted to the SEMCAD for Science Program.

REFERENCES

[1] Standard of Institute of Electrical and Electronics Engineers(IEEE) American National Standards Institute(ANSI), "American National Standard Method of Measurement of Compatibility between Wireless Communications Devices and Hearing Aids", IEEE, New York, USA, C63.19-2007.

[2] M. Okoniewski and M. A. Stuchly, Modeling of interaction of electromagnetic fields from a cellular telephone with hearing aids, IEEE Trans. Microwave Theory and Techniques, vol .46, pp. 1686-1693, 1998.

[3] R. E. Schlegel and F. H. Grant, "Modeling the electromagnetic response of hearing aids to digital wireless phones", IEEE Trans. Electromagnetic compatibility, vol. 42, pp. 347-357, 2000.

[4] K. Caputa, M. A. Stuchly, M. Skopec, H. I. Bassen, P. Ruggera, and M. Kanda, "Evaluation of electromagnetic interference from a cellular telephone with a hearing aid", IEEE Trans. Microwave Theory and Techniques, vol. 48, pp. 2148-2154, 2000.

[5] G. Hayes and S. L. Vance, "Reduction of near field electro-magnetic scattering using high impedance metallization terminations", US Patent, US2006/0035607A1, Feb.16, 2006.

[6] G. Hayes, "Reduction of near field E-M scattering using high impedance coating materials", US Patent, US2006/0029217, A1, Feb.9, 2006.

[7] S. Hong, et al," Design of an Internal Multi-Resonant Monopole Antenna for GSM900/DCS1800/US-PCS/S-DMB Operation," IEEE Transactions on Antennas and Propagation, Vol. 56, No. 5, pp.1437-1443, May 2008.

[8] D. G. Choi, H. T. Oh, S. Kahng, D. H. Kwon, S. G. Kim, C. H. Jeong, Investigating the effect of the electromagnetic field from a mobile phone on the hearing aid, 2010 BEMS., P0A-25, 2010.

저자

강 승 택(Sungtek Kahng) **정회원**

- 2000년 2월 : 한양대학교 전자통신 공학박사
- 2000년 4월 : 한양대학교 산업과학연구소 연구원
- 2004년 2월 : 한국전자통신연구원 통신위성개발센터 선임연구원
- 2004년~현재 : 인천대학교 정보통신 공학과 교수
- 2007년~현재 : 송도 국방벤처 자문교수

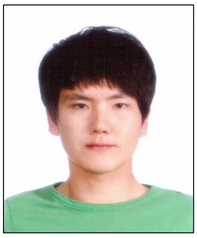
<관심분야> : 전자파 수치 해석 및 응용, EMI/EMC 대책, 초고주파 부품 및 안테나 설계, 메타재질구조 이론 및 응용

최 동 근(Dong-Geun Choi) **비회원**

- 2003년 2월 : 충북대학교 정보통신공학과(공학사)
- 2005년 2월 : 충북대학교 정보통신공학과(공학석사)
- 2006년 7월 ~ 현재 : 국립전파연구원 공업연구사
- 2010년 3월~현재 : 한양대학교 전자컴퓨터통신공학과(박사과정)

<관심분야> : SAR 평가 기술, 전자파 수치 해석, 전자파 인체보호, 안테나 설계

전 진 수(Jinsu Jeon) **비회원**



- 2013년 8월 : 인천대학교 정보통신공학과(공학사)
- 2013년 8월~현재 : 인천대학교 정보통신공학과(공학석사과정)

<관심분야> : 착용형 안테나 설계, 안테나 SAR/HAC 반영 설계, 초고주파 부품 및 안테나 설계, 메타재질구조 이론 및 응용

박 정 훈(Jeong-hoon Park) **비회원**

- 1984년 2월 : 아주대학교 전자공학과(공학사)
- 1993년 2월 : 아주대학교 전자공학과(공학석사)
- 2005년 3월 : 아주대학교 전자공학과(공학박사)
- 1987년 ~ 1992년 : 한국전자통신 연구원
- 1992년 ~ 1994년 : SK 텔레콤 ㈜ 선임연구원
- 1994년 ~ 2012년 : 인천전문대학 정보통신공학과 교수
- 2012년 ~ 현재 : 인천대학교 정보통신공학과 교수, 본 논문 교신저자

<관심분야> : 이동통신, 무선통신