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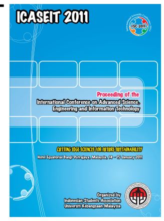

Analysis of Mobile Phone Antenna Performance within the Head and Hand Phantoms

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***Abstract*— This paper proposes the effect of the hand-hold position on the electromagnetic (EM) wave interaction of a candy bar type and clamshell type cellular handset and a human head and hand is investigated. The human hand influences the performance of terminal antennas, and it is the main cause for absorption and detuning. In spite of its importance in mobile-phone design and validation processes, it is still complicated to take it into account because a lack of knowledge in the area. In this paper, a rigorous investigation methodology is described for the study of candy bar, and clam shell mobile phone CAD model is used to numerically investigate the effect of hand phantom of mobile phone antenna radiation performance. The simulation results show that mobile phone grip styles of the hand phantom material properties, wrist and length, and hand phantom sizes and different positions is the important parameter to antenna performance. The grip style has direct implications in the definition of phantom head. The preference of the handset with respect to the side of the user's head depends on the mobile phone form factor and size. The results established high reliability and suitability for providing decision rationale for the design of complex high-end multi-band mobile phones.**

***Keywords*— antenna closeness factors, finite-difference time-domain (FDTD) method, hand phantom, mobile communication.**

I. Introduction

Recently, cellular handset manufacturers producing developed types come in a diversity of shapes, or forms, such as; candy bar, clamshell, slider, swivel and flip-type, where most of these types can adopt either external or built-in antennas. For certain frequency, input power, antenna configuration and handset position with respect to user's head, the induced SAR in head tissues may differ according to handset type. These days, standards do not consider yet a specific "hand phantom" mainly because of the large number of grip positions and practical issues [1], [2]. In the past, the absence of the hand was partly justified for specific absorption rate (SAR) investigations, considering the overestimation of its value in the head, there is conservative view [3], [4]. The human hand consists of several materials that are responsible of electromagnetic (EM) energy absorption [5]. However recent studies showed that the presence of the user hand also changes the RF performance of cellular phones [4-7].Therefore, there is need to include a hand phantom in these tests, with repeatable hand positioning and support to predict mobile phone performance reliably. In order to define the hand phantom geometry and the position of the hand with respect to the head and the phone, detailed investigations of different setups have to be performed.

This led us to perform some preliminary investigations using the finite-difference time-domain method (FDTD), discovering that the grip style strongly influences the communication performances; a comprehensive grip study may be the key to provide more accurate phantom hand models. Handheld units may have different inclinations with respect to the side of the user's head [6-9].

The objectives of this paper, we also present statistics on how people hold mobile phones for talk and data modes, also giving guidelines for further studies concerning the implications in the definitions of a phantom head. Also this paper are to determine the effect of different hand models and use patterns on RF performance in terms on radiation parameters such as efficiency, Total Radiated Power (TRP). The RF dielectric properties and materials composition of the hand, the grip of the hand on the phone and the size of the hand will be investigated.

II. Materials and Method

The FDTD based electromagnetic simulation tool SEMCAD

X was used to perform the evaluations. The software was explicitly developed for the analysis, optimization and synthesis of transceivers in the vicinity of lossy structures. Considering a uniform cubic lattice, a space step size that is equal to 1 mm was chosen, using the perfectly matched layer (PML) absorbing boundary conditions [7]. The handset metallic ground plane was modelled as a perfect electric conductor (PEC) box, with dimensions of 20 × 50 ×110 mm, forcing the tangential electric field components to zero. The planer-inverted F-antenna (PIFA) plate and the quarter wavelength monopole were modelled as a plate and a wire, respectively, being both made of PEC as before. The monopole antenna was $\lambda/4$ long in order to resonate in correspondence of 1800 MHz, and it was placed on the top of the handset (Fig. 1), while the dimensions of the PIFA were adjusted to resonate. The user's head was represented by using the SPEAG phantom that consists of a shell modelled as fibreglass (ε_r =4.6, σ = 0.0 S/m) and a brain/muscle simulating liquid (ε_r =41.0, σ = 1.65 S/m). The dielectric composition of the homogeneous hand has been adjusted to comply with the materials' properties described in Gabrial's study [7] (ε_r =32.6, σ = 1.26 S/m), while VHP heterogeneous hands consisted of several tissues (skin, muscle, bone, etc) according to the data belonging to the visible project (VHP) [5]. The phone was simulated in the right side, 15 degrees tilted position, at homogeneous Specific Anthropomorphic Mannequin (SAM) head phantom according to standardized protocols. Two different hand models were used for this study as shown in Fig. 2: inhomogeneous anatomical hand model with skin, muscle and significant finger and wrist bone tissues, and homogeneous anatomical hand model with homogeneous dielectric constant and conductivity. The material properties of the hand modes are shown in Table 1. RF dielectric properties of the homogeneous hand phantom are based on the human tissue measurement data as described in [5]. In addition a newly developed of hand phantom modelling engine in Fig. 2(c) has been also analysed which allows the user to pose the hand model to obtain appropriate grips on any given phone models with different sizes.

Fig. 1. Multiband phone used in this study: (a) a candy bar phone (b) a clam shell Phone

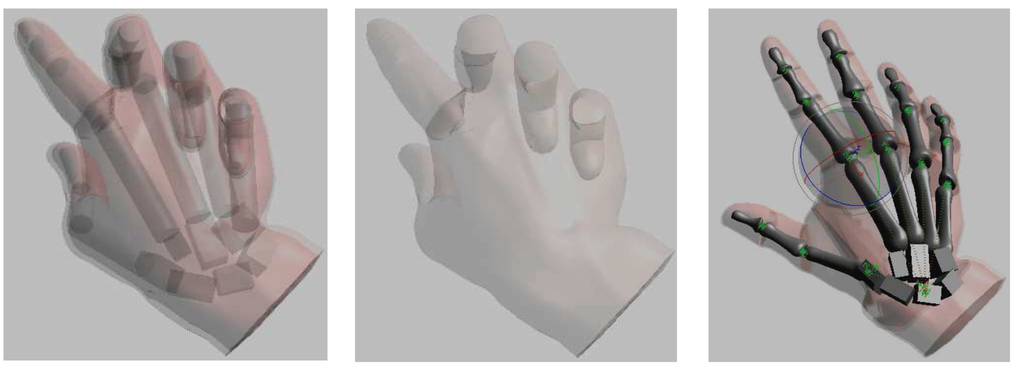

Fig. 2 (a). Homogeneous (H1), and (b) inhomogeneous (H2) hand models; (c) diagram of hand phantom modeling engine.

TABLE 1
MATERIAL PROPERTIES OF HAND AND HEAD MODELS

900 MHz	H1	H2-Skin	H2-Muscle	H2-Bone	H2-Head
ε	36.2	41.41	55.03	12.45	41.5
σ	1.26	1.22	1.39	0.29	1.42
1800 MHz	H1	H2-Skin	H2-Muscle	H2-Bone	H2-Head
ε	32.2	37.95	52.9	11.43	38.5
σ	1.29	1.24	1.41	0.31	1.43

Initial investigations with homogeneous and inhomogeneous hands have shown negligible differences in terms of antenna radiation parameters (Table 2). Therefore the rest of the study was carried out using the homogeneous hand phantom (H1).

TABLE II
COMPARISON OF RADIATION PERFORMANCE OF THE PHONE WITH INHOMOGENEOUS AND HOMOGENEOUS HAND MODELS

	900 MHz		1800 MHz	
	H1	H2	H1	H2
Radiation Efficiency	0.112	0.113	0.108	0.113
TRP (dBm)	19.36	19.51	19.85	19.99
NHRP +/- 30^0	16.20	16.55	16.53	16.81
NHRP +/- 45^0	17.70	18.02	17.99	18.24

III. Simulation Results.

The parameters of the hand phantom on the influence of mobile phone antenna performance are studied thoroughly in this research project. The results are divided into two parts: Firstly, the parameter of the hand phantom with negligible influence on mobile phone antenna performance, which is depends on hand phantom material dielectric properties, hand wrist and length. Secondly, it depends on size of the hand phantom, discussed in this paper the effect of the hand phantom on the peak SAR.

A. Hand Material Properties

The effects of tolerances in dielectric parameters of hand phantom material were investigated by using different permittivity and conductivity to simulate dry and wet hands. The palm of the hand is the tissue most implicated in the interaction. The dielectric properties of tissues correlate strongly with their water content; a contact measurement carried out through the dry surface is dominated by the response of the outermost, low water content and would not be representative of the properties throughout whole thickness of the skin. Moistening evens out the water content of the outer skin layer and reduces the roughness of its surface. The values for dry palm are lower for both permittivity and conductivity reflecting the lower water content of the upper most layers and, to lesser extent, the difficulties of ensuring a good contact. They represent the lower bound of the dielectric properties of the palm. It is interesting this research finding that the average of all tissues fall within the bounds of the two values for palm. In [7], it has been shown that the differences in permittivity and conductivity of dry and wet palms of the order of 35 % of their average. Table 3 shows five sets (M0-M4) of different materials used in the simulations. As Fig. 3 clearly established, the TRP value is not sensitive (‹ 0.5 dB difference) to tolerances in material properties of both frequency bands.

TABLE III
THE INFLUENCE OF THE MOBILE PHONE ANTENNA PERFORMANCE DUE TO THE VARIATIONS OF THE MATERIAL PROPERTIES

	900 MHz		1800 MHz	
	ε	σ	ε	σ
M0	36.2	0.79	32.2	1.29
M1	36.2 #120%	0.79 #120%	32.2 #120%	1.29 #120%
M2	36.2 # 20%	0.79 # 90%	32.2 #120%	1.29 # 90%
M3	36.2 # 90%	0.79 #120%	32.2 # 90%	1.29 #120%
M4	36.2 # 90%	0.79 # 90%	32.2 # 90%	1.29 # 90%

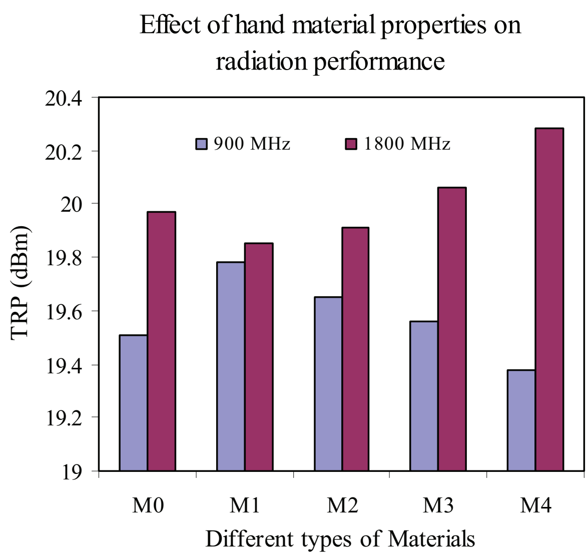

Fig. 3. Effect of hand material properties on radiation performance at 900 MHz and 1800 MHz

To study the effect of the wrist on antenna performance was chosen five different lengths and different tilt angles of hand models as shown in Fig. 4. The simulation results show that there is no significant effect on TRP with wrist of hand model as shown in Fig. 5. This is because the wrist is further away from the antenna and the most of the radiated energy in the direction of wrist is already absorbed by the palm.

(a) (b) (c) (d) (e)

Fig. 4. The hand phantoms with different wrists: (a) no wrist, (b) 3cm long wrist, (c) 10cm long wrist (d) 10cm long 15 degrees tilted wrist, and (e) 10cm long 30 degrees tilted wrist

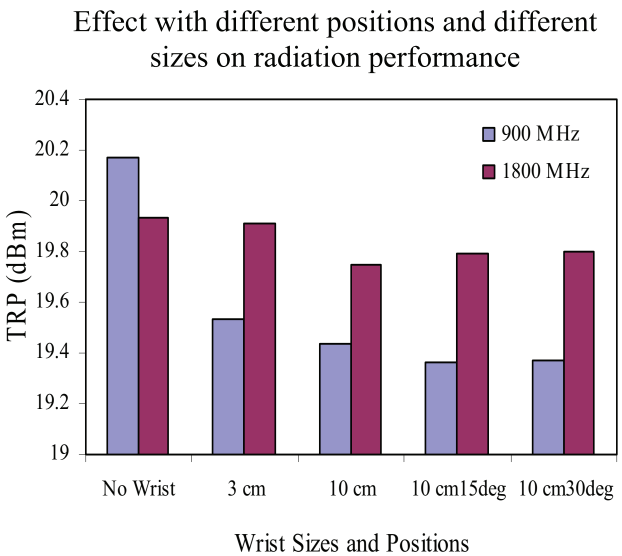

Fig. 5. Effect with different positions and different sizes on radiation performance at 900 MHz and 1800 MHz

B HAND SIZE

The original size of the hand and the palm-phone distance were investigated using commercial phone model. The unique size of the hand model used in this study is chosen to be close to the average of female and male hand sizes, [8]. The smallest female hand and the largest male hand reported in [8] differ by about 20 % from the average hand size. Therefore, the hand models in shown in Fig. 6 are used in the simulations. Therefore five different hand models have been used to illustrate the effects of human hand size and the palm phone distance on antenna performance. The results presented in Fig. 7 reputable that the radiation performance of the antenna is more sensitive to hand size when the antenna is located at bottom of the phone. In interesting that larger hand s do not always result in lower TRP since the antenna performance is also sensitive to the palm-phone distance. Another interesting observation is that in the 900 MHz simulation without the index finger, when the hand is placed at lower positions, the efficiency of the antenna with the hand is higher than that without hand. It is because that has higher frequency, the head phantom also absorbs lower powered compared to without hand.

(a) (b) (c) (d) (e)

Fig. 6. The hand phantom different hand sizes for evaluating the influence of different mobile phone antenna performance: (a) 80 %, (b) 90 %, (c) 100 %, (d) 110 %, and (e) 120 % of the average hand size

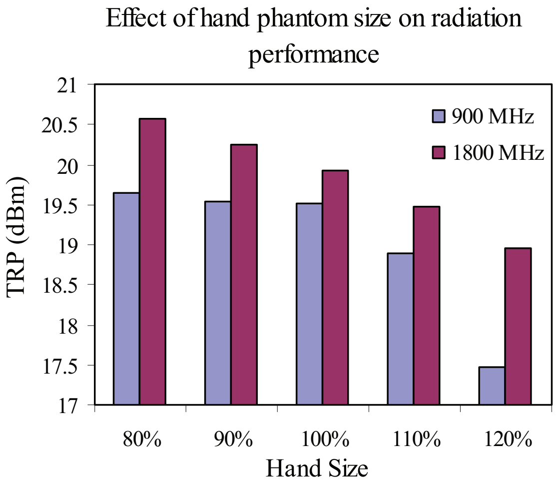

Fig. 7. Effect of hand phantom sizes on radiation performance at 900 MHz and 1800 MHz

IV. CONCLUSION

The influence of the hand on the overall performance of mobile phone antenna is analysed in this paper. Hand material properties, hand wrist and length on the phone different positions, and various types of hand phantom sizes, small affects the radiation performance of the device. A homogeneous and an inhomogeneous, faceted hand model also analysed this paper. Based on analysis, an effective dielectric constant for two cellular frequencies has been determined to ensure a good balance between speed of simulations and accuracy of the results. A three tissue, muscle, skin, and bone tissue has also been studied. However, the hand geometry as well as the exact position of the phone inside the hand must be very precisely defined in order to obtain highly reproducible results in future OTA measurements.

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REFERENCES

[1] P. Futter, N. Chavannes, R. Tay, M. Meili, A. Klingenboeck, K. Pokovic, N. Kuster, “Reliable prediction of mobile phone performance under real usage conditions using the FDTD method”, Proceedings of International Symposium on Antenna and Propagation, pp. 355–358, 2005.

[2] G.F. Pedersen, M. Tartiere, M.B. Knudsen, “Radiation efficiency of handheld phones”, Vehicular Technology Conference Proceedings, pp. 1381–1385, 2000.

[3] K. R. Boyle, “The performance of GSM 900 antennas in the presence of people and phantoms”, Proceedings of International Conference on Antennas and Propagation, pp. 35–38, 2003.

[4] C-M. Su, C-H Wu, K-Lu Wong, S-H Yeh and C-L Tang, “User’s hand effects on EMC internal GSM/DCS mobile phone antenna,” IEEE Antennas and Propagation Society International Symposium, Albuquerque, NM, pp. 2097 – 2100, 9-14 July 2006.

[5] K-Lu Wong, C-H Wu, W.-Yu Li, C.-M. Su; S.-H. Yeh, C.-L. Tang, “Simplified hand model for the study of hand-held device antenna,” IEEE Antennas and Propagation Society International Symposium, Albuquerque, NM, pp. 2101 – 2104, 9-14 July 2006.

[6] M. T. Islam, M. R. I. Faruque, and N. Misran, “Design analysis of ferrite sheet attachment for SAR reduction in human head,” Progress In Electromagnetics Research, PIER 98, 191-205, 2009.

[7] C. Gabriel, “Tissue equivalent material for hand phantoms”, Phys. Med. Biol. 52, pp. 4205–4210, 2007.

[8] T. Greiner, Hand anthropometry of U. S. Army personnel. U. S. Army Natick Res., Development and Eng. Center. Dec. 1991.

[9] M. R. I. Faruque, M. T. Islam, and N. Misran, “Effect of human head shapes for mobile phone exposure on electromagnetic absorption,” Informacije MIDEM, vol. 40, no. 3, 2010.