FDTD Simulation of a Mobile Phone Operating near a One Metal Cell

Nuttaka Homsup, Terapass Jariyanorawiss and Wiroj Homsup

***Abstract*— This paper presents results of placing a one metal cell closed to a mobile phone. The one metal cell is the Yee's cell that has a metal characteristic, with high conductivity and low permittivity. In general, the mobile phone was modeled by a dipole antenna. The one metal cell's characteristic can be model as one Yee's cell [1-3]. This simulation uses Finite Difference Time Domain (FDTD) and its domain is divided into two parts: the physical domain and the artificial domain. First, the physical domain consists of a dipole antenna located at 1 cm from a human head model and a one metal cell varied distance (Δl) from the dipole. In addition, the dipole antenna operated at 900 MHz and 1800 MHz was used in the simulation. Second, the artificial domain is a Perfectly Matched Layer (PML). The PML acts as an electromagnetic field absorbing layer and was backed by a Perfect Electric Conductor (PEC). The Specific Absorption Rate (SAR) was computed and averaged on a tissue mass of one gram and ten grams, SAR 1-g and SAR 10-g, respectively. Also, the average power (P_{avg}) absorbed in various human tissues is computed with a distance between the dipole antenna and the one metal cell as a varying parameter (Δl). There are three reference SAR values: the standard SAR 1-g (FCC, Federal Communications Commission), the simulation in an open area and the simulation with the metal wall. Results from the simulation show that the computed SAR 1-g and SAR 10-g values are not exceed the limitation values established by various standard institutes (1.6 Watt/kg), however, for Δl = 0-5 cm, both of the SAR and the average power absorb are higher than the simulation with the metal wall and the simulation in an open area.**

***Index Terms*— Finite Difference Time Domain (FDTD), Perfectly Matched Layer (PML), One Metal Cell**

I. Introduction

In recent years mobile phones or smart phones have gained popularity because of its versatility: internet capabilities, navigation and cameras. Engineering research on the subject of wireless phones and radio frequency (RF) energy has been conducted worldwide for many years. The Federal Communications Commission (FCC) established RF exposure safety guidelines for wireless phones [1]. Before a wireless phone model is available for sale to the public, it must be tested by the manufacturer and certified by the FCC that it does not exceed limits established by the FCC. One of these limits is expressed as a Specific Absorption Rate (SAR).

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In 1996, the FCC adopted updated guidelines for evaluating human exposure to radio frequency fields from fixed transmitting antennas such as those used for a mobile phone. Also, the new guidelines for a mobile phone are identical to those recommended by the National Council on Radiation Protection and Measurements (NCRP). Furthermore, these guidelines are also similar to the 1992 guidelines recommended by the American National Standards Institute/Institute of Electrical and Electronics Engineers (ANSI/IEEE). In general, IEEE standard required that the SAR 1-g of handheld wireless phones not exceed 1.6 watts/kg, averaged over 1-g mass of tissues [2]. Although the SAR 1-g is determined at the highest power level, the actual SAR 1-g value while operating depends on factors such as the proximity of the antenna to the human head while in use.

The finite-difference time-domain (FDTD) formulation was introduced by Yee in 1966 [3]. Some work has been done in the past to show the capability of FDTD to calculate radiation patterns of mobile telephones [4-5], but extensive work on simulation of a mobile phone operating near a metal wall has never been presented. With the introduction of Perfectly Matched Layer (PML) by Berenger in 1996 [6], many FDTD schemes with PML has been implemented to correctly model today's cellular phones. Moreover, the classical FDTD was modified by using an unsplitting field formulation which can combine the simulated physical domain and an artificial absorbing layer as a single computational domain [7].

This paper presents the simulation of electromagnetic interaction in the human head model using the FDTD with a modified PML. The simulated physical domain contains a dipole antenna, a high-resolution human head model and a metal wall. In the simulation, a dipole antenna acts as a mobile phone operated at 900 MHz and 1.8 GHz. In addition, the time-stepping system resulting from the discretization of the Maxwell's equations is solved by imposing the excitation field as a function of time at the proper cell with initial and boundary conditions. A high-resolution human head model's parameters: Permittivity (ε), Conductivity (σ) and Permeability (μ) were averaged to guarantee the continuity of the tangential E field component [8]. In each simulation, the distance between the metal wall and an antenna is a varied parameter. As the distance gets longer, both the required memory size and CPU's time increase dramatically. Due to these problems, the simulated physical domain was truncated using a truncation method presented in [9-12].

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II. The Reference SAR Values

There are three reference SAR values: the standard SAR 1-g = 1.6 Watt/kg (FCC, Federal Communications Commission), the simulation in an open area (the plastic case) and the simulation with the metal wall (the metallic case)

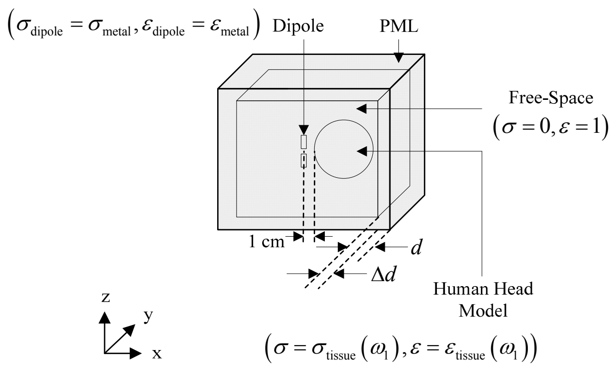

Fig. 1. The simulation in an open area.

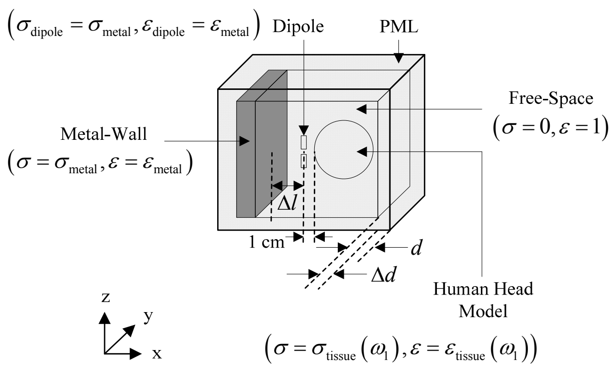

Fig. 2. The simulation with the metal wall.

III. The Simulation Model

This paper sets the one metal cell next to the dipole and varied distance (Δl) between the dipole and one metal cell. For Δl = 0-6 cm, this paper computes the SAR 1-g, the SAR 10-g and the average power absorbed in human head.

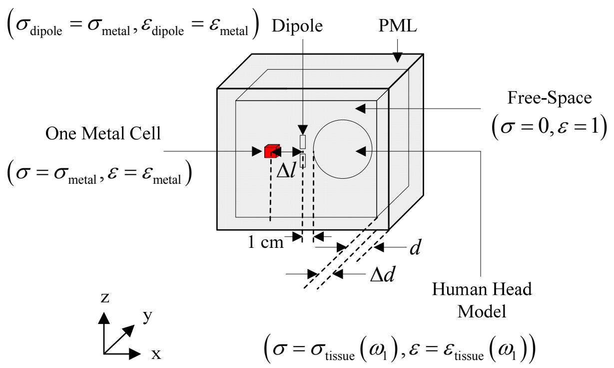

Fig. 3. The simulation with the one metal cell.

IV. The Simulation Result

Table I. The simulation result at 900 MHz

One Metal Cell next to Dipole			
Distance(d)	SAR 1 g	SAR 10 g	Power
(cm)	(Watt/kg)	(Watt/kg)	(Watt)
0	1.50837	1.42997	0.26252
1	1.44871	1.31357	0.21796
2	1.44335	1.30665	0.21494
3	1.44225	1.30457	0.21300
4	1.44164	1.30322	0.21133
5	1.44122	1.30238	0.21003
6	1.44094	1.30195	0.20919
7	1.44077	1.30190	0.20881
8	1.44064	1.30209	0.20884
9	1.44052	1.30245	0.20921
10	1.44038	1.30287	0.20983

* SAR 1-g (Standard) = 1.6 Watt/kg
** SAR 1-g (Open Area) = 1.44307 Watt/kg
*** SAR 10-g (Open Area) = 1.30634 Watt/kg
**** Power Absorbed (Open Area) = 0.21486 Watt

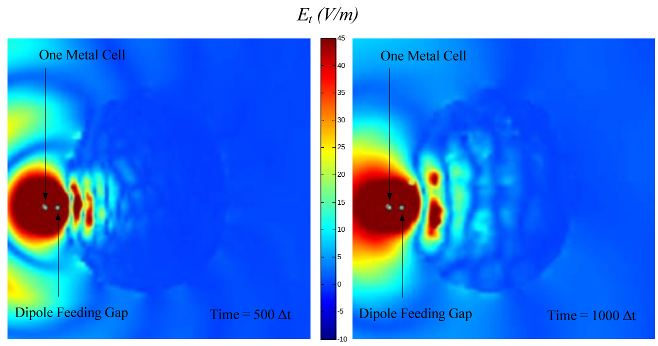

Fig. 4. Top view of E_t
in the simulated physical domain at 900 MHz

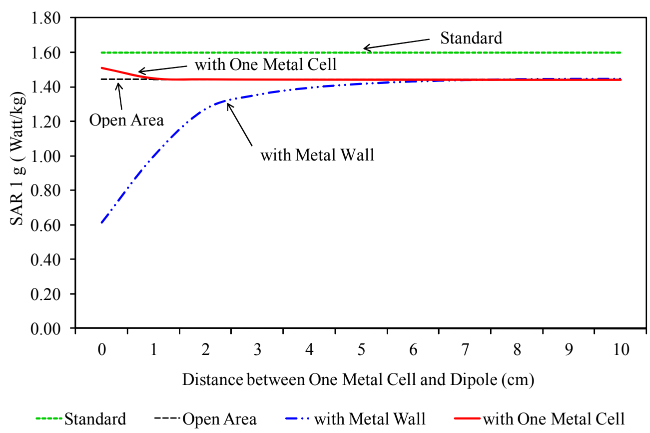

Fig. 5. Spatial-Average SAR 1-g at 900 MHz.

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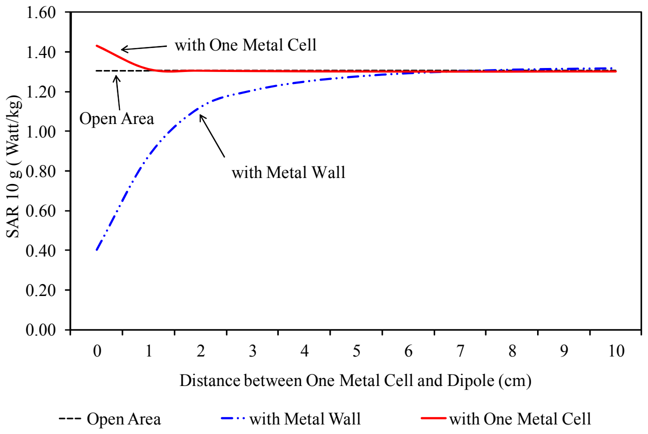

Fig. 6. Spatial-Average SAR 10-g at 900 MHz.

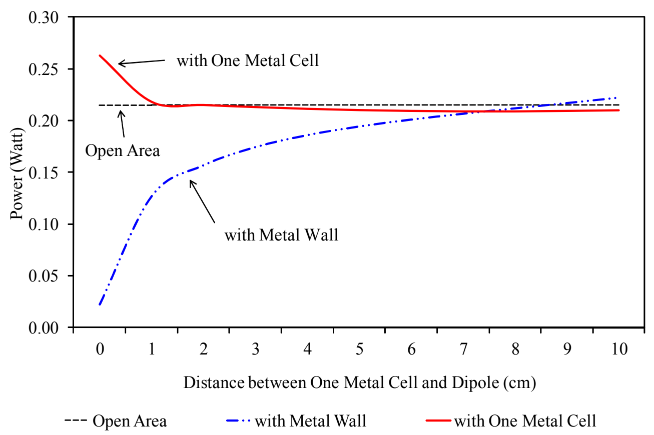

Fig. 7. The average power absorbed in human head at 900 MHz.

Table II. The simulation result at 1800 MHz

One Metal Cell next to Dipole			
Distance(d)	SAR 1 g	SAR 10 g	Power
(cm)	(Watt/kg)	(Watt/kg)	(Watt)
0	1.34737	1.31281	0.15998
1	1.29133	1.17379	0.11768
2	1.28487	1.17086	0.11781
3	1.28145	1.17151	0.11956
4	1.27873	1.17156	0.12156
5	1.27796	1.17088	0.12291
6	1.27975	1.17032	0.12294
7	1.28293	1.17018	0.12179
8	1.28562	1.17058	0.12026
9	1.28658	1.17112	0.11915
10	1.28569	1.17155	0.11887

* SAR 1-g (Standard) = 1.6 Watt/kg
** SAR 1-g (Open Area) = 1.28455 Watt/kg
*** SAR 10-g (Open Area) = 1.17044 Watt/kg
**** Power Absorbed (Open Area) = 0.11773 Watt

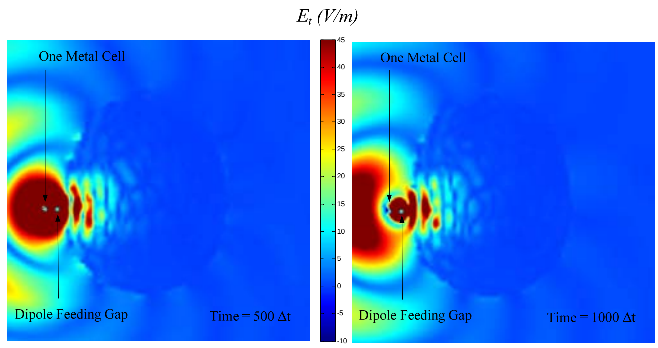

Fig. 8. Top view of E_t in the simulated physical domain at 1800 MHz

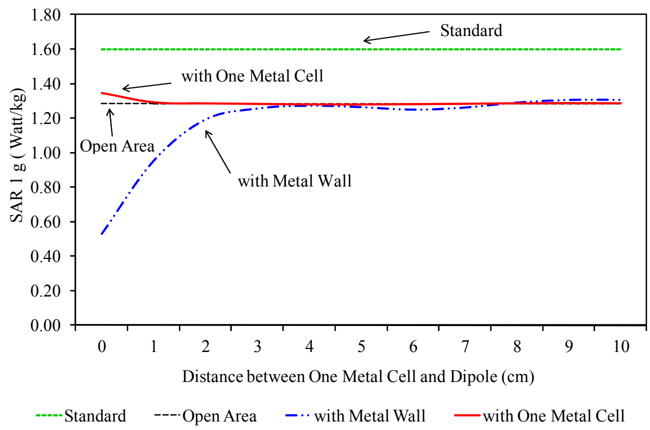

Fig. 9. Spatial-Average SAR 1-g at 1800 MHz.

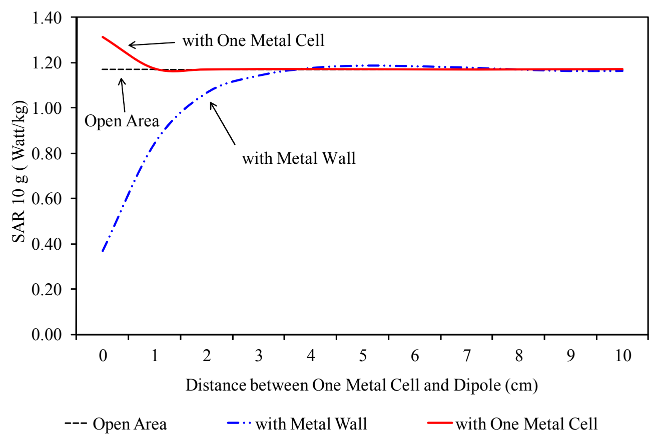

Fig. 10. Spatial-Average SAR 10-g at 1800 MHz.

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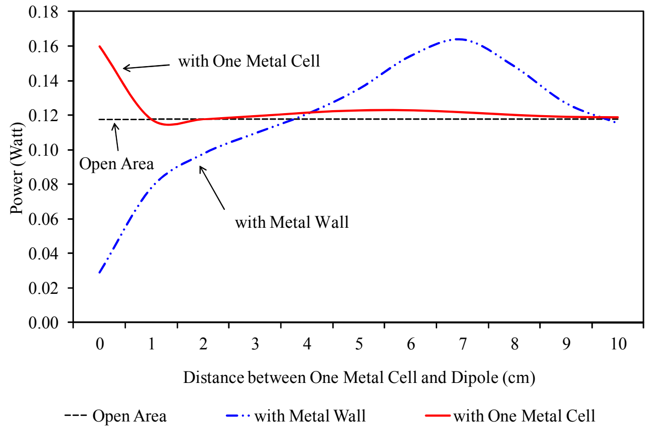

Fig. 11. The average power absorbed in human head at 1800 MHz.

V. Conclusion

The FDTD have been applied to the simulation model and operated frequencies are 900 MHz and 1800 MHz. Results show that SAR 1-g and SAR 10-g do not exceed the ANSI/IEEE standard. Surprisingly, both SARs and the average power absorbed in human head are higher than the simulation with the metal wall.

References

[1] Federal Communication Commission (FCC), "Information on Human Exposure to Radiofrequency Fields from Cellular and PCS Radio Transmitter," *Federal Communications Commission (FCC)*, 445 12th Street, SW Washington, DC 20554. Available Source : http://www.fcc.gov/oet/rfsafety/cellpcs.html, May 03, 2009.

[2] IEEE Standard, "IEEE Recommended Practice for Determining the Peak Spatial-Average Specific Absorption Rate (SAR)in the Human Head from Wireless Communications Devices: Measurement Techniques," *The Institute of Electrical and Electronics Engineers (IEEE)*, New York, USA, pp. 18-19, 2003.

[3] K.S. Yee, "Numerical Solution of Initial Boundary Value Problems Involving Maxwell's Equations in Isotropic Media," *IEEE Transactions on Antennas and Propagation*, Vol.14, pp.302-307, 1966.

[4] N.K. Kouveliotis, P.T. Trakadas and C.N. Capsalis, "Investigation of A Dipole Antenna Performance and SAR Distribution Induced in A Human Head Model," National Technical University of Athens, Athens, Greece.

[5] N. Homsup, T. Jariyanorawiss, and W. Homsup, "Truncation of the Head Model in Cellular Phone Simulations Using a Simple PML Formulation," *Proceedings of the International Conference on Communications and Information Technologies 2004 (ISCIT 2004)*, pp. 793-796, Sapporo, Japan, October 26-29, 2004.

[6] J.P. Berenger, "Three-Dimensional Perfectly Matched Layer for the Absorption of Electromagnetic Wave," *Journal of IEEE Transactions on Computational Physics*, Vol.127, pp.363-379, 1996.

[7] L. Ling, L. Ronglin, X. Suming and N. Guangzheng, "A New Generalized Perfectly Matched Layer for Terminating 3-D Lossy Media," *IEEE Transactions on Magnetics*, Vol. 38, No. 2, pp. 713-716, 2002.

[8] K.W.L. Fabian, *Modeling of Electromagnetic Wave Propagation in Printed Circuit Board and Related Structures*. Ph.D. Thesis, Multimedia University, Malaysia, 2003.

[9] T. Jariyanorawiss and N. Homsup, "Implementation of FDTD Scheme Using PML for Truncation of the Head Model in Cellular Phone Simulations," *Proceedings of the International Conference on International Symposium on Communications and Information Technologies 2005 (ISCIT 2004)*, pp. 623-626, Beijing, China, October 12-14, 2005.

[10] A. Taflove and S. C. Hageness, *Computational Electrodynamics: The Finite-Difference Time-Domain Method*. Norwood, MA: Artech, 2000.

[11] K.S. Kunz and R. J. Luebbers, *The Finite-Difference Time-Domain Method in Electromagnetics*. Boca Raton, FL: CRC, 1993.

[12] S. Watanabe and T. Masao, "An improved FDTD Model for the Feeding Gap of a Thin-Wire Antenna," *IEEE Microwave and Guided Wave Letters*. Vol. 8, pp. 152-154, 1998.

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