American Journal of Engineering Research (AJER)
e-ISSN : 2320-0847 p-ISSN : 2320-0936
Volume-03, Issue-06, pp-92-100
www.ajer.org

Research Paper Open Access

Investigation of Radiation Problem for two Separated Mediums

Yahia Zakaria[1], Burak Gonultas[2]
[1]*Systems and Information Department, Engineering Research Division, National Research Centre*
El-Behoose Street, p.c. 12622, Cairo, Egypt
Yahia.zk82@yahoo.com
[2]*Electrical and Electronics Engineering Department, Nigde University*
Fertek Build, p.c. 51310, Nigde, Turkey
brk_gnlts@hotmail.com

Abstract: The Hertzian potentials are used to determine the electric and magnetic field components. Moreover, it is possible for the radiation to start with the dipole to be observed at much greater distances than would be possible if the waves were generated in an infinite homogeneous medium. In this paper we present the problem of communication of aradiation in a conducting medium. The problem is analyzed in terms of a dipole radiation in a homogenous medium separated by a plane boundary from a dielectric half space. Expressions for the Hertzian potentials of the dipole is reduced to integrals which was obtained by Sommerfeld equations multiplied by an exponential depth attenuation factor. The analysis is described for both magnetic and electric, vertical and horizontal dipolesFinally, accurate numerical analyses are derived to illustrate the above statements.

Keywords: *- Sommerfeld radiation problem, Dipole radiation, Hertzian potentials*

I. INTRODUCTION

The so - called 'Sommerfeld radiation problem' is a well – known problem in the field of propagation of electromagnetic (EM) waves for obvious applications in the area of wireless telecommunications [1], [2]. Furthermore, Sommerfeld expanded his original work to take into account vertical and horizontal, electric and magnetie dipoles above a plane earth. In 1909, Sommerfeld stated the existence of a surface wave in the radiation of a vertical Hertzian dipole over a plane earth [1]. The solution of the boundary value problem was based on the evaluation of Fourier-Bessel integrals which were the solutions of the wave equation. In 1953, Wait discussed an insulated magnetic dipole in a conducting medium, showing that the fields are independent of the characteristics of the insulation for an antenna diameter much less than the radiation wavelength in the conducting medium [4]. Analyzed magnetic dipole solution of a semi-infinite medium including special cases of frequency, antenna depth, and separation between antennas was discussed [5]. It can be noticed from [6], [7] that a horizontal electric dipole in a conducting half space was carried out by a mathematical analysis. Also, the exponential increase of the attenuation with depth was experimentally verified. In [8], [9] the engineering application of the above problem with obvious application to wireless telecommunications was discussed and provided approximate solutions to the above problem, which are represented by rather long algebraic expressions.

II. PREFACE OF RADIATION PROBLEM

The geometry of the problem is given in Figure 1. It is assumed that the dipole is oriented either horizontally in x-direction or vertically in the z-direction. It can be noticed that the important direction for transmitting dipole radiation is directly toward the surface of the sea because of the mode of communication. Furthermore, magnetic and electric fields have been calculated for both the vertical and the horizontal dipoles.

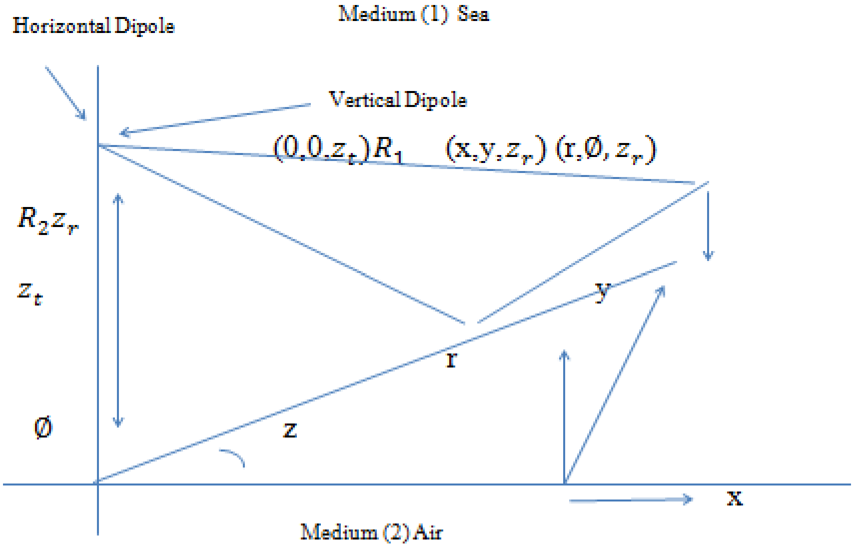

Figure 1. Geometry of the radiation problem considered in this paper

The theory of a conducting half space and electromagnetic radiation in a conducting medium are discussed in [9,10].

III. ANALYSIS OF RADIATION PROBLEM

3.1 The two Hertzian functions for the two mediums have to meet the following conditions, [1]:

$$\Delta\pi_1 + k_1^2\pi_1 = 0\,, \qquad z > 0$$

(1a)

$$\Delta\pi_2 + k_2^2\pi_2 = 0\,, \qquad z < 0$$

$$\pi_1 = \pi_2\,, \; \frac{1}{k_1^2}\frac{\partial\pi_1}{\partial z} = \frac{1}{k_2^2}\frac{\partial\pi_2}{\partial z} \quad at \;\; z = 0$$

(1b)

$$\pi_1 = 0, \quad z > 0, \quad r = \infty\,, \quad z = +\infty$$

$$\pi_2 = 0,\; z < 0,\; r = \infty\;,\; z = -\infty \qquad (1c)$$

where

r = cylinder radius , R = distance of the point from the transmitter which lies on the origin (z = 0 , r = 0). As in Figure 2.

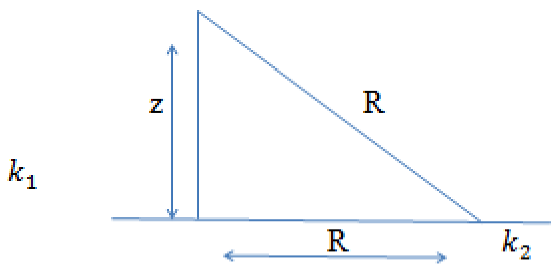

Figure 2. Dipole position

Then, Sommerfeld obtained his well-known solution in the form of the following integral, [2]:

$$\pi_1 = 4\int_0^\infty \frac{(k_1^2 + k_2^2)e^{-z\sqrt{\lambda^2 - k_1^2}}\,(J_0\lambda r)}{3k_1^2\sqrt{\lambda^2 - k_1^2} + k_2^2\sqrt{\lambda^2 - k_2^2}}\lambda d\lambda (z > 0) \qquad (2)$$

1.2 The Maxwell equations for a conducting medium are given by, [2], [3]:

$\nabla^2 E = j\omega\mu\sigma E$ (3)
where
H is the magnetic field and E is the electric field.
Furthermore, by taking into account a plane wave travelling through the positive z-direction we get the following equations

$$E = E_0 e^{-(1+j)z/\delta} \quad , \quad H = e^{-j\lambda/4}\sqrt{2}\frac{n*E}{\mu\omega\delta} \qquad (4)$$

where
n is the unit vector in the direction of propagation

$$\delta = \sqrt{\frac{2}{\mu\omega\sigma}}$$

The Hertzian potentials $\prod$ and $\prod^*$(the Green's function for a dipole source) for the electric and magnetic dipoles respectively, in the infinite, conducting medium are, [2], [11]:

$$\prod = P_1 \frac{e^{-k_1 jr}}{R} \quad , \quad P_1 = \frac{\prod^{em}}{4\sigma\pi} \quad (5)$$

$$\prod^* = P_1^* \frac{e^{-k_1 jr}}{R} \quad , \quad P_1^* = \frac{\prod^{mm}}{4\pi} \quad (6)$$

where
$\prod^{mm}$ is the magnetic moment = NIS
I is the current.
N is the number of turns in the magnetic loop.
S is the loop area vector.
$\prod^{em}$ is the electric moment.
R is the distance from the dipole to the observation point.
In this paper, the Hertzian potentials are used for both the electric and magnetic dipoles. It can be easily found that the electric and magnetic field vectors are functions of the Hertzian potential as follows, [5], [12]:

For the Electric dipole:

$$H_1 = \nabla\sigma * \prod \quad , \quad E_1 = \prod * \nabla\nabla + k_1^2 \prod (7)$$

For the Magnetic dipole:

$$H_1 = \nabla\nabla * \prod^* + k_1^2 \prod^* \quad , \quad E_1 = -j\omega\mu\nabla * \prod^* \qquad (8)$$

where

$$k_1 = \sqrt{-j\omega\mu\sigma}$$

Moreover, the electric and magnetic fields in an infinite, nonconducting medium are as the following equations:
For the Electric dipole:

$$H_2 = \nabla j\omega\epsilon_0 * \prod \quad , \quad E_2 = \prod * \nabla\nabla + k_2^2 \prod \qquad (9)$$

For the Magnetic dipole:

$$H_2 = \nabla\nabla * \prod^* + k_2^2 \prod^* \quad , \quad E_2 = -j\omega\mu\nabla * \prod^* \qquad (10)$$

where
$k_2 = 2\pi/\lambda_0$, is the wave number
λ_0 is free space wavelength

Therefore, the Hertzian potentials in this case for the electric and magnetic dipole respectively, are as the following equations, [4]:

$$\prod_2 = P_2 \frac{e^{-k_2 jr}}{R} \quad , \quad P_2 = j\,\frac{\prod^{em}}{4\omega\pi\,\epsilon_0} \qquad (11)$$

$$\prod^*{}_2 = P_2^* \frac{e^{-k_2 jr}}{R} \quad , \quad P_2^* = \frac{\prod^{mm}}{4\pi} \qquad (12)$$

Then, by taking into account the modification for the case of a source in a conducting half space separated by a plane boundary from a nonconducting half space. Therefore, the source (transmitting dipole) is located in the conducting half space at coordinate position (0, 0, z_t) from the boundary. Similarly, the point of observation (receiving dipole) is located at coordinate position $(r, \emptyset, z_r)$, as shown in Figure 1. Moreover, the Hertzian potentials for the conducting and nonconducting half space must satisfy the wave equation (condition A below), the radiation condition at infinity (condition B) and the radiation condition near the source (condition C) below [1], [13]:

For condition A:

$\nabla^2\prod_1 + k_1^2\prod_1 = 0 \quad, \nabla^2\prod_1{}^* + k_1^2\prod_1{}^* = 0, \; z_r > 0$ sea medium

$\nabla^2\prod_2 + k_2^2\prod_2 = 0 \quad, \nabla^2\prod_2{}^* + k_2^2\prod_2{}^* = 0, \; z_r < 0$ air medium

For condition B:

$\lim_{R\to\infty}\prod_1 = 0 \quad, \quad \lim_{R\to\infty}\prod_1{}^* = 0 \quad, \qquad z_r > 0$ sea medium

$\lim_{R\to\infty}\prod_2 = 0 \quad, \quad \lim_{R\to\infty}\prod_2{}^* = 0 \quad, \quad z_r < 0$ air medium

where

$R = \sqrt{r^2 + (z_t - z_r)^2}$

For condition C:

$$\lim_{R\to 0}\prod_1 = \frac{e^{-jk_1R}}{R} = \lim_{R\to 0}\prod_1{}^*$$

Moreover, the electric and magnetic fields must satisfy the boundary conditions at the surface of the sea. Therefore, the boundary conditions for the components of the Hertzian potentials and their derivatives are as the following described equations, [3]:

$\prod_{z1}{}^* = \prod_{z2}{}^*$

$-jg\prod_{x1}{}^* = \prod_2{}^*$

$$\frac{\partial\prod_{x1}{}^*}{\partial z} = \frac{\partial\prod_{x2}{}^*}{\partial z}$$

$$\frac{\partial\prod_{x1}{}^*}{\partial z} + \frac{\partial\prod_{z1}{}^*}{\partial z} = \frac{\partial\prod_{x2}{}^*}{\partial x} + \frac{\partial\prod_{z2}{}^*}{\partial z}$$

where

$g = \frac{\sigma}{\omega\epsilon_0} = \frac{k_1^2}{k_2^2}$,-jg is an approximation for the complex index of reflection.

By this way, we have to describe that the Sommerfeld has shown that only $\prod_z$ component of the Hertzian potential is required to describe the fields of a vertical dipole [2].

3.3 Related to the integral calculations of Hertzian potential, the Hertzian potential can be obtained in integral form for the four basic dipole configurations: vertical and horizontal, electric and magnetic dipoles. The method used here for obtaining the potential integrals was first used by Sommerfeld [1,3]. Thus, a general Hertzian potential for each of the four dipole configurations is obtained satisfying conditions (A) through (C). So, the Hertzian potentials for the observation point in the sea are presented in integral form for the four basic dipole configurations as follows, [3], [8]:

For vertical dipole:

$$\prod_{z1} = L + I_{a1} \quad , \quad \prod_{z1}{}^* = L + I_{b1} \qquad (13)$$

For horizontal dipole:

$$\prod_{x1} = L + I_{b1} \quad , \quad \prod_{x1}{}^* = L + I_{a1} \qquad (14)$$

where

$$L = \frac{e^{-jk_1R_1}}{R_1} - \frac{e^{-jk_1R_2}}{R_2} \quad , \quad R_1 = \sqrt{r^2 + (z_r - z_t)^2} \quad , \quad R_2 = \sqrt{r^2 + (z_r + z_t)^2}$$

$$I_{a1} = 2\int_0^{\infty} \frac{e^{-FJ_0}}{3F - gjG} \quad , \quad I_{b1} = 2\int_0^{\infty} \frac{e^{-FJ_0}}{4F + G} \quad (15)$$

$$I_{c1} = 2\,(-gj - 4)\int_0^{\infty} \frac{e^{-FJ_0}}{(F - gjG)\,(F + G)} \quad (16)$$

where

$$G = \sqrt{£^2 - k_2^2} \quad , \quad F = \sqrt{£^2 - k_1^2}$$

It should be noticed that the function L has two parts: exp $(-jk_1R_1/R_1)$ which represents the primary source at the position $(0, 0, z_t)$, and exp $(-jk_1R_2/R_2)$ which represents a secondary source at the image position $(0, 0, -z_t)$. Moreover, at the ease of the horizontal electric and the vertical magnetic antennas, the secondary source represents the image of the primary source, but in the case of the vertical electric and the horizontal magnetic antennas, the secondary source represents an image dipole of the opposite polarity. As shown in Figure 1, the primary source radiates over the direct path R_1 , and the secondary source radiates over the reflected path R_2. Consequently, the integral in every case represents the major contribution to the Hertzian potentials if r $>>(z_r + z_t)$. By considering (-jg-1) = -jg as g >> 1 for the frequencies and conductivity in this paper, it can be shown that for $z_r > 0$, $z_t > 0$, [9], [11]:

$$I_{c1} = \frac{\partial}{\partial z_r}\left[-\frac{2}{k_1^2}\frac{e^{-jk_1R_2}}{R_2} + I_{a1}\left\{\frac{1}{k_2^2} + \frac{1}{k_1^2}\right\}\right] \quad (17)$$

$$I_{b1} + \mathrm{jg}I_{a1} = \frac{\partial I_{c1}}{\partial z_r} \quad (18)$$

Also, the integrals I_{c2}, I_{b2} and I_{a2} are interdependent. So, it can be shown that for $z_t > 0$, $z_r < 0$

$$I_{c2} = \frac{1}{k_2^2}\left[\frac{\partial I_{a2}}{\partial z_r} + \frac{\partial I_{a2}}{\partial z_t}\right] \quad (19)$$

$$\frac{\partial I_{c2}}{\partial z_r} = I_{b2} - I_{a2} \quad (20)$$

Furthermore, by taking into account calculating the fields in the sea and at the surface of the sea to concentrate on the integrals I_{b1} and I_{a1}. Moreover, all the fields which will be discussed in this paper can be expressed in terms of integrals I_{b1} and I_{a1}. Then, by replacing I_{b1} and I_{a1} with the two new integrals I_a and I_b as follows, [2], [13]:

$$4\int_0^{\infty} \frac{e^{-Lʒ}\,(\rho\Psi)}{2L - jMg} = I_a \quad (21)$$

$$6\int_0^{\infty} \frac{e^{-Lʒ}\,(\rho\Psi)}{3L + M} = I_b \quad (22)$$

where

$$\rho = \frac{\omega}{c}\,r = r * \frac{2\pi}{\lambda_0} \quad , \quad c = \text{speed of light}\,, \quad \lambda_0 = \text{wave length}$$

$$ʒ = \frac{\omega}{c}\,z = z * \frac{2\pi}{\lambda_0} \quad , \quad \Psi = \frac{c}{\omega}\,ʒ \quad , \quad z = z_t + z_r$$

$$M = \frac{c}{\omega}\,G = \sqrt{\Psi^2 - 1} \quad , \quad L = \frac{c}{\omega}\,F = \sqrt{\Psi^2 + gj}$$

The factors ʒ and ρ are used to express r and z in terms of free space wavelength divided by 2π. So, the electric and magnetic field components in the sea as functions of the integrals I_a and I_b are as follows, [11]:

For the Vertical dipole at Electric dipole, [2]:

$$E_z = \frac{\omega^3}{c^3}\left[\frac{\partial I_a}{\partial z^2}\right] \quad (23)$$

$$H_\varphi = -\frac{\omega^2}{c^2}\,\sigma\,\frac{\partial I_a}{\partial \rho} \quad (24)$$

$$E_r = \frac{\omega^3}{c^3}\frac{\partial^2 I_a}{\partial\rho\partial z} \quad (25)$$

For the Vertical dipole at Magnetic dipole, [6]:

$$H_z = \frac{\omega^3}{c^3}\left[\frac{\partial I_b}{\partial z^2}\right] \quad (26)$$

$$E_\varphi = j\,\frac{\omega^3}{c^2}\,\mu\,\frac{\partial I_b}{\partial \rho} \quad (27)$$

$$H_r = \frac{\omega^3}{c^3}\frac{\partial^2 I_b}{\partial\rho\partial z} \quad (28)$$

For the Horizontal dipole at Electric dipole, [10]:

$$H_r = \frac{\omega^2}{c^2}\,\sigma\sin\varphi\left[\frac{1}{\rho}\frac{\partial^2 I_a}{\partial\rho\partial z}\right] \quad (29)$$

$$H_\varphi = \frac{\omega^2}{c^2}\,\sigma\cos\varphi\left[\frac{\partial^3 I_a}{\partial\rho^2\partial z}\right] \quad (30)$$

$$H_z = -\frac{\omega^2}{c^2}\,\sigma\sin\varphi\frac{\partial I_b}{\partial \rho} \quad (31)$$

$$E_r = -2\frac{\omega^3}{c^3}\cos\varphi\;gj\left[\frac{\partial^2}{\partial \rho^2} + I_b\right] \quad (32)$$

$$E_\varphi = 5\frac{\omega^3}{c^3}\sin\varphi\,gj\left[\frac{1}{\rho} + I_b\right] \quad (33)$$

$$E_z = -\frac{2\omega^3}{c^3}\cos\varphi\frac{\partial^2 I_a}{\partial\rho\partial z} \quad (34)$$

For the Horizontal dipole at Magnetic dipole, [12]:

$$E_r = -j\frac{\omega^3}{c^2}\,\mu\sin\varphi\left[\frac{1}{\rho} + \frac{\partial I_b}{\partial z}\right] \quad (35)$$

$$E_\varphi = -3j\frac{\omega^3}{c^2}\,\mu\,sin\,\varphi\left[\frac{3 I_a}{\partial\rho^2\partial z} + \frac{\partial I_b}{\partial z}\right] \quad (36)$$

$$E_z = j\frac{\omega^3}{c^2}\,\mu\,sin\,\varphi\frac{\partial I_a}{\partial \rho} \quad (37)$$

$$H_r = -\frac{\omega^3}{c^3}\cos\varphi\left[\frac{\partial^2 I_a}{\partial \rho^2} + I_a\right] \quad (38)$$

$$H_\varphi = \frac{\omega^3}{c^3}\sin\varphi\left[\frac{1}{\rho} + I_a\right] \quad (39)$$

$$H_z = -5\frac{\omega^3}{c^3}\cos\varphi\frac{\partial^2 I_a}{\partial\rho\partial z} \quad (40)$$

It can be mentioned from the above equations that the electric and magnetic fields in the air at the boundary can be calculated from the fields in the sea and the boundary conditions. Moreover, the fields are expressed through the boundary conditions as follows, [13]:

$$E_{z2} = -gjE_{z1} \quad , \quad E_{i1} = E_{i2} \text{ as } i = r,\varphi \quad , \quad H_{i1} = H_{i2} \text{ as } i = r,\varphi, z \quad (41)$$

Related to the calculations of the integrals, asymptotic expansions for I_a and I_b can be determined by the method of critical points [12]. In the case of which the source and point of observation both lie on the boundary, it will be possible to reduce the integrals I_a and I_b to those obtained by Sommerfeld [3], [11]. The coordinates of branch points 4 and 2 are given by $\psi = 1 - jx/2$ and $\psi = -1 + jx/2$, respectively. where x is a very small value associated with the conductivity of air. Moreover, the poles occur when (L-gjM) = 0, exactly when, [15]:

$$\psi^2 = \left[1 - \frac{j}{g}\right]\frac{g^2}{1+g^2} \quad (42)$$

where $g \gg 1$ for the conductivity and frequencies considered in this paper. It can be easily found that to evaluate the integrals by contour methods it is convenient to write these integrals in forms such that the path of integration lies along the entire real axis. Therefore, it can be done by the conversion of the Bessel functions of the first kind into Hankel functions of the first kind to become as follows, [10], [13]:

$$\int_{-\infty}^{\infty}\frac{e^{-Lz}J_0H_0}{2L - jMg} = I_a \quad (43)$$

$$\int_{-\infty}^{\infty}\frac{e^{-Lz}J_0H_0}{5L + M} = I_b \quad (44)$$

whereM is a pure imaginary part.

Morefore, it is possible to close a contour by tottering a semicircle, whose radius is unbounded from the positive real axis to the negative real axis through the upper half plane. Then, by taking into account a highly conducting medium, we can observe that the contribution to the integral along branch line 1 is negligible. Furthermore, in order to integrate I_a and I_b with respect to the conductivity and frequency range considered in this case, it can be written such as the following equations, [3]:

$$2e^{(-1-j)\sqrt{g/2z}}\int\frac{H_0^1\,(\rho\Psi)}{2L - jMg} = I_a \quad (45)$$

$$2e^{(-1-j)\sqrt{g/2z}}\int\frac{H_0^1\,(\rho\Psi)}{5L + M} = I_b \quad (46)$$

where

$L = \sqrt{jg}$

Then, as a conclusion in the case examined here, it can be easily realized that I_a and I_b in case of $0<\rho<1$, T=1 can be written as:

$$I_a = 5j\frac{e^{4j\rho}}{2g\rho}\text{T} \quad (47)$$

$$I_b = 8\frac{e^{7j\rho}}{(jg - 3)\rho^3} \quad (48)$$

IV. PHYSICAL INTERPRETATION OF THE DERIVED EXPRESSIONS OF A DIPOLE RADIATION PROBLEM CONSIDERED IN THIS PAPER

1. It is deduced from our analysis that the path of electromagnetic energy between the transmitting and receiving dipoles in the conducting medium is as the following : (a) propagation from the transmitter directly to the surface, (b) propagation along the surface of the medium allowing refraction of the energy back into the homogeneous medium, (c) propagation descending into the inhomogeneous medium to the receiver.
2. From equations (43) – (48), we can realize that the energy traveling directly through the sea between the transmitter and receiver is neglected and the ratio of the magnitude of the direct wave through the sea over the surface wave is of the order of $e^{-\frac{z}{\delta}}$ where z and δ are respectively antenna depth and skin depth.
3. The analysis shows that the main path of communication between antennas is composed of three parts as follows: (a) energy flow from the transmitting dipole directly to the surface of the sea, (b) creation of a wave that travels along the surface refracting back into the sea, (c) energy flow normal of the surface to the receiving dipole. Moreover, from equation (13) – (14), it can be observed that the Hertzian potentials is composed of three components: (a) a primary source function, (b) a secondary source function, and (c) an integral.
4. The boundary conditions in equation (41) state that the magnetic fields and the tangential electric fields in air are equal to those in the sea, and that the vertical electric fields in the air are related to those in the sea by the proportionality constant - jg.
5. The z-components of the fields in the conducting halfspace in sea are small compared with the horizontal components and therefore they have not been included. On the contrary, the z-component of the electric field in the air, for the horizontal dipoles, is the predominant component [15]. Moreover, it can be observed that the fields of the horizontal dipoles are stronger than those of the vertical dipoles, as would be expected because of the vertical nulls in the radiation from the vertical dipoles.

V. CONCLUSION

As a matter of fact, any practical medium even air has some conductivity and therefore the effective permittivity must contain a small imaginary component. Furthermore, each of the field expressions may be considered to consist of 3 parts: a multiplying factor which includes the dipole strength and parameters such as frequency and conductivity of the medimn; an exponential attenuation factor whose exponent is the sum of the distance from the dipole to the surface and from the surface to the point of observation; and a factor associated with variation in the horizontal direction. In this paper analytical expressions of the dipole radiation problem in a conducting half space were introduced. It is obvious from the limits of the integrals that the path of integration must lie along the real axis. Thus, this branch point appears to lie on the real axis because of medium 2 has been assumed to have zero conductivity. Furthermore, as a conclusion in the case described here, it can be easily noticed that the wave propagates at the dipole and proceeds by the shortest path to the surface, then the path of minimum attenuation is refracted at the surface and travels along the surface as a wave in air, then comes to the point of observation by the path of the least attenuation.

VI. FUTURE RESEARCH

In the future, research should be focused on the solution of the corresponding problem for horizontal radiating Hertzian dipole above flat and lossy ground propagation in isotropic and anisotropic crystals.

VII. ACKNOWLEDGEMENTS

The authors would like to express their thanks to Prof. Dr. Elsayed Sallam for his valuable cooperation and instructions.

REFERENCES

[1] A. Sommerfeld, 'The propagation of waves in wireless telegraphy," Ann. der Phys., vol. 28, pp. 665-736; March 1909.
[2] A. Sommerfeld, 'The propagation of waves in wireless telegraphy," Jahrb. d. Drahtl. Tel., vol. 4, pp. 157-176, December 1910.
[3] H. Weyl, "The propagation of electromagnetic waves over a plane conductor," Ann. der Phys., vol. 60, pp. 481-500, November 1919.

[4] Wait, J . R., and L. L. Campbell, The fields of an oscillating magnetic dipole immersed in a semi-infinite conducting medium, Gcophys. Research, 58, No.2, 167- 178 (June 1953).

[5] K. A. Norton, "The propagation of radio waves over a plane earth," Nature, vol. 125, pp. 954-955, June 1935.

[6] K. A. Norton, "The propagation of radio waves over the surface of theearth and in the upper atmosphere," Part I, PROC. I.R.E., vol. 24, pp. 1367- 1387, October 1936.

[7] S. Sautbekov, "The Generalized Solutions of a System of Maxwell's Equations for the Uniaxial Anisotropic Media', Chapter 1 in book Electromagnetic Waves Propagation in Complex Matter, edited by A. A. Kishk, Croatia, pp. 3 – 24, June 2011.

[8] K. A. Norton, "The Propagation of Radio Waves Ovewr the Surface of the Earth", Proceedings of the IRE, 24, pp. 1367 – 1387, 1936; and 25, pp. 1203 – 1236, 1937.

[9] Sunde, E. D., Earth conduction effects in transmission systems, (D. Van Nostrand, Inc., New York, N.Y., 1949).

[10] Stratto n, J . A., Electromagnetic theory (McGraw-Hill Book Co., Inc., New York, N.Y., 1940).

[11] Sommerfeld, A., Partial differential equations in physics, Ch. VI (Academic Press, Inc. New York, N.Y., 1949).

[12] A. Sommerfeld, "The propagation of waves in wireless telegraphy," Ann. der Phys.; vol. 81, pp. 1135-1153, December 1926.

[13] Moor e, R. K., The theory of radio communication between submerged submarines, Ph. D. Thesis, Cornell University (1951).

[14] R. E. Collin, "Hertzian Dipole Radiating Over a Lossy Earth or Sea: Some Early and Late 20th-Century Controversies," IEEE Antennas and Propagation Magazine, 46, 2, April 2004, pp. 64-79.

[15] Banos, A. Jr., and J . P . Wesley, The horizontal dipole in a conducting half-space, Univ. of Calif. Marine Physical Laboratory, Reports No. 53- 33 and No. 54-33, 1954.

Background of Authors

Yahia Zakaria was born in June 18, 1982 in Cairo, Egypt. He is a permanent member of the research corporation at the Engineering Research Division, National Research Centre, Ministry of Scientific Research, Cairo, Egypt. He has been working at the National Research Centre, Ministry of Scientific Research since 2005. He is a member of the Society for Developing Computer Systems and Member of Egyptian Society of Engineering. He was one of the members of the Technical Office for follow-up and evaluation of performance at the National Research Centre since 2008 till 2010. He is a reviewer in two International Scientific Journals. He participated in many seminars and lectures at the German Academic Exchange Service (DAAD), Germany. His current research interests include Cellular Communication Systems, Channel propagation Models Of Mobile Communication, Electromagnetic wave propagation field and Wireless Network Engineering.

Burak Gönültaş was born in Ankara, Turkey. He is from Electrical and Electronics Engineering department, Nigde University, Turkey. He is a leader of Nigde University "Turkuaz" team for Tubitak Formula-G Solar Car Races and a member of Nigde University "Turkuaz" team for TubitakElectromobile Car Races by using RF module. He had a cooperation with Military Electronics Industries (ASELSAN) and Turkish Aerospace Industry Inc.(TAI - TUSAŞ) in 2014. He participated in many projects about line tracking and sumo robots with using programable integrated circuits. He is carrying out his Nigde University IEEE President of Supervisory Board duty.