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The Transient Electromagnetic Field above Atmospheric Surface Duct

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Abstract
The transient electromagnetic field generated by vertical electric dipole in evaluation duct is investigated theoretically. A vertical electric dipole in the surface layer is taken as the source of the electromagnetic field. We determine the electric field strength exactly at some fixed point in the duct layer expansion with time, the image of the primary source permits us to apply the method first for Cagnaird and later extended by De Hoop and Frankena to the cases .Hence, we can give a physically intuitive description of polarization dependence at the time of the electrical field strength. The distinction of different cases where the distances between the receiving and transmitting ends at greater or lesser than the total reflection distance is studied.
Keywords: Electromagnetic field, Magnetic dipole

1. Introduction

In the problem of electromagnetic radiation from a vertical dipole situated at a certain height above a plane earth, all field quantities are usually assumed to vary harmonically in time. Sommerfeld (1909), calculated the electromagnetic radiation from an electric vertical dipole, located above the plane interface of two media. Many writers, Wait (1970), Moore & Blair (1961) and Durrani (1964) have considered this problem; the aim of the present work is to extend the study-state to transient excitation when no restrictions on the distance between receiving and transmitting ends are made. Two integral transforms are applied to analyse the transient field of vertical electric dipole above a dielectric layer. The distinction of different cases where the distance between the receiving and transmitting ends is great and lesser than the total reflection distance studies by Abo-Seliem (1998). The problem has been studied by Arutaki & chiba (1980) and Abo-Seliem (2003) and Abo- Seliem (2004). Two integral transform are applied to analyze the transient field of a vertical electric dipole in a dielectric later. A laplace trancform in time and a two – dimensional Fourier transform in horizontal coordinates in space are used for the hertiz vector in the wave equation we use a Cagniard's method (Hewitt Dix 1963), and simplified by De Hoop (1960). In the present work, we confine our anther exclusively to the elementary vertical Hertizan dipoles. Embedded in air, we computed the z- component of the Hertz vector and showed the behaviour of the absolute value of the z- component of the hertz vector. The reflected waves and integrals Jones (1969), the component of the electric field strength is also arbitrary for the excitation function $\mathbf{F(t)=t}$ at some fixed but arbitrary position from the point of observation in the half-space.

2. Formulation of the problem

As show in Fig.1, the duct model of Kahan & Eckart (1950). A dielectric layer is assumed of relative permittivity ε_1 over laying an infinitely conducting plane earth which is confined by the plane $\mathbf{z=0}$ of a rectangular coordinate system

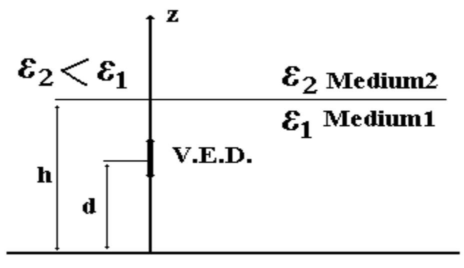

Fig.1: Geometric of the problem.

The source of the field is assumed to be a vertical electric dipole in the medium 1 at the point $\mathbf{x=y=0}$, $\mathbf{z=d>0}$ whose moment is given by $\tilde{\boldsymbol{\pi}}_e = (\mathbf{0,0,F(t)\delta(x,y,z-d)})$, t being the time variable and the three dimensional-distributions. Regarding, we make the assumptions $\mathbf{F(t)=0}$ for $\mathbf{t \le 0}$ and $\mathbf{dF(t)/dt=0}$ for

$\mathbf{t=0}$.

3. Method of solution

The starting point is the wave equation for the electrical field $\vec{\mathbf{E}} = (\mathbf{x,y,z;t})$ in the two media:

$$[\nabla^2 - \mathbf{v}_i^{-2}\partial_t^2]\vec{\mathbf{E}} = \begin{cases} \mathbf{0} \quad \textbf{for } \mathbf{i=2} \\ \mu_0 \mathbf{D}_t^2 \mathbf{F(t)}\delta(\mathbf{x,y,z-d})\vec{\mathbf{e}}_z - \dfrac{\mathbf{F(t)}}{\varepsilon_0\varepsilon_i}\nabla\partial_z\delta(\mathbf{x,y,z-d}) \quad \textbf{for } \mathbf{i=1} \end{cases} \tag{1}$$

Where $\mathbf{v}_i$ denotes the phase velocity of medium $\mathbf{i}$, $\vec{\mathbf{e}}_z$ is a unit vector in the z-direction. The application of a Laplace transform in time and two-dimensional. Fourier transform horizontal coordinates x, y leads under consideration of the initial boundary and transform of $\vec{\mathbf{E}} = (\mathbf{x,y,z;t})$ being the variable in the transform space, we get for $\mathbf{h < z < \infty}$

$$[\frac{\partial^2}{\partial \mathbf{z}^2} - \gamma_i^2 \mathbf{s}^2]\mathbf{F}^{(i)}(\alpha,\beta,\mathbf{z,s}) = \begin{cases} \mathbf{0} \quad \textbf{for } \mathbf{i=2} \\ \mathbf{f(s)}[\dfrac{-\mathbf{j}\mathbf{s}(\alpha\vec{\mathbf{e}}_x + \beta\vec{\mathbf{e}}_y)}{\varepsilon_0\varepsilon_i}\dfrac{\partial}{\partial \mathbf{z}}\delta(\mathbf{z-d}) + \\ (\Gamma_0 \mathbf{s}^2\delta(\mathbf{z-d}) - \dfrac{\partial^2}{\partial \mathbf{z}^2}\dfrac{\delta(\mathbf{z-d})}{\varepsilon_0\varepsilon_u})\vec{\mathbf{e}}_z] \quad \textbf{for } \mathbf{i=1} \end{cases} \tag{2}$$

Where $\mathbf{j}^2 = -\mathbf{1}$, $\gamma^2 = (\alpha^2 + \beta^2 + \mathbf{v}_i^{-2})$, $\mathbf{i = 1,2}$ with $\Re\mathbf{e}(\gamma_i) \geq \mathbf{0}$ in the medium 1. This an integral representation result of the Laplace transform of electric field in terms of two-dimensional inverse Fourier integral.

$$\mathbf{E}_z^{(i)}(\mathbf{x,y,z;s}) = \frac{\mathbf{s}^3\mathbf{f(s)}}{8\pi^2}\{\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}(\alpha^2+\beta^2)[\frac{\exp(-\mathbf{s}\gamma_i|\mathbf{z-d}|)}{\gamma_i} + \frac{(\mathbf{1}+\mathbf{c}_{12}\exp(-2\mathbf{s}\gamma_i(\mathbf{h-d})))\exp(-\mathbf{s}\gamma_i(\mathbf{z+d}))}{\gamma_i(\mathbf{1}+\mathbf{c}_{12}\exp(-2\mathbf{s}\gamma_i\mathbf{h}))} +$$
$$\mathbf{c}_{12}\frac{(\mathbf{1}+\mathbf{c}_{12}\exp(-2\mathbf{s}\gamma_i\mathbf{d}))\exp(-\mathbf{s}\gamma_i(2\mathbf{h-z-d}))}{\gamma_i(\mathbf{1}+\mathbf{c}_{12}\exp(-2\mathbf{s}\gamma_i\mathbf{h}))}\}\exp(\mathbf{j}\mathbf{s}(\alpha\mathbf{x}+\beta\mathbf{y}))\mathbf{d}\alpha\mathbf{d}\beta \tag{3}$$

With the reflection coefficient at the upper duct boundary: $\mathbf{c}_{12} = \dfrac{\gamma_1 - \gamma_2}{\gamma_1 + \gamma_2}$ here α and β are variables in the transform space of the two-dimensional Fourier transform $\mathbf{f(s)}$ is the Laplace transform $\mathbf{F(t)}$.

4.Application of Cagniard method

To come back the original space –time domain, the method of Cagniard which was modified by De Hoop (1960), can be used and extended to the present problem. The solution in the domain for the corresponding time – dependent function $E_x^{(1)}(x,y,z,t)$ is

$$E_x^{(1)}(x,y,z,t) = [^{E_z^{prim}}_{0\ for t \succ \tau_{\min}}(x,y,z,t) + \sum_{n=0}^{\infty}(-1)^n U_n^{(1)}(x,y,z,t) - \sum_{n=0}^{\infty} U_n^{(2)}(x,y,z,t)\ for t \prec \tau_{\min} \tag{4}$$

Where $\tau_{\min} = \min(\dfrac{R_0}{V_1}, \tau_n^{(1)})$ with $R_o^2 = (r^2 + (z-d)^2)$ where r denotes the horizontal transmitter – receiver distance and R_0 is the source – receiver distance.

$$E_z^{(prim)}(r,z,t) = \int_{R_o/V_1}^{\infty}[(\frac{4}{R_o}\int_0^{\pi/2}\text{Re}[u^2(\tau,\psi) + q^2(\tau,\psi)]d\psi)e^{-s\tau}]d\tau \tag{5}$$

Where

$$u = j\frac{\tau\sin\theta_0}{R_o} + (\frac{\tau^2}{R_o^2} - v_1^{-2})\left|\cos\theta_o\right|\cos\psi \quad \text{And} \quad q = (\frac{\tau^2}{R_o^2} - v_1^{-2})^{.5}\sin\psi \tag{6}$$

Then

$$E_z^{(prim)}(r,z,t) = \frac{1}{8\pi R_0\varepsilon_o\varepsilon_1}(2\cos^2\theta_o - \sin^2\theta_o)\frac{t^2}{t_o^2} - (\cos^2\theta_0 + 1) \tag{7}$$

With the arrive time of the primary field $t_o = \frac{R_o}{v_1}$ *and* $\sin\theta_o = \frac{r}{R_o}$

The image source maybe classical into six types, the function $U_n^{(1)}(x,y,z,t)$ is

$$U_n^{(1)}(x,y,z,t) = \begin{cases} \left.\begin{array}{l} 0 \text{ for } t < \frac{R_n^{(1)}}{v_1} \\ h_n^{(1)}(x,y,z,t) \text{ for } t > \frac{R_n^{(1)}}{v_1} \end{array}\right\} \text{for } \tau < \xi_n^{(1)}(\frac{\delta}{1-\delta})^{.5} \\ 0 \text{ for } t > \tau_n^{(1)}(q) \\ f_n^{(1)}(x,y,z,t) \text{for } \tau_n^{(1)}(q) < t < \frac{R_n^{(1)}}{v_1} \\ h_n^{(1)}(x,y,z,t) + g_n^{(1)}(x,y,z,t) \; for \frac{R_n^{(1)}}{v_1}, < t < \tau_n^{(1)}(q)\} \; \tau > \xi_n^{(1)}(\frac{\delta}{\delta-1})^{.5} \\ h_n^{(1)}(x,y,z,t) \text{ for } t > \tau_n^{(1)}(q) \end{cases} \tag{8}$$

Where

$$\tau_n^{(i)} = (v_2^{-2} - v_1^{-2})^{.5} R_n^{(i)}\left|\cos\theta^{(i)}{}_n\right| + (q^2 + v_1^{-2})^{-.5} R_n^{(i)}\sin\theta_n^{(i)} \tag{9}$$

$$\tau_n^{(i)}(\tau) = (v_2^{-2} - v_1^{-2})^{.5} R_n^{(i)} / \left|\cos\theta^{(i)}{}_n\right| \tag{10}$$

$\frac{\varepsilon_o}{\varepsilon_1} = \delta, R_n^{(i)}$ *and* $\theta_n^{(i)}$ Polar coordinates with respect in the image source Q_{ni}

$$\xi_n^{(i)} = 2(n+1)h + z - d$$
$$\xi_n^{(i)} = 2(n)h + z + d \tag{11}$$

The theory, in detail;

$$h_n^{(1)}(x,y,z,t) = \begin{cases} 0 \text{ for t} < \dfrac{\mathrm{R}_n^{(i)}}{\mathrm{V}_1} \\ \dfrac{1}{2\pi^2 \varepsilon_o \varepsilon_1 R_n^{(i)}} \int_0^{\frac{\pi}{2}} \mathrm{Re}[u^2(t,\psi)+q^2(t,\psi)] c_{12}^m(t,\psi)\, d\psi \end{cases} \tag{12}$$

With

$$c_{12} = \frac{\varepsilon_2(u^2+q^2+v_1^{-2})^{.5} - \varepsilon_1(u^2+q^2+v_2^{-2})^{.5}}{\varepsilon_2(u^2+q^2+v_1^{-2})^{.5} + \varepsilon_1(u^2+q^2+v_2^{-2})^{.5}} \tag{13}$$

$$u = j\frac{\tau \sin\theta_n^{(i)}}{R_n^{(i)}} + (\frac{t^2}{R_n^{(i)}} - v_1^{-2})\left|\cos\theta_n^{(i)}\right|\cos\psi \quad \text{and} \quad q = (\frac{t^2}{R_n^{(1)2}} - v_1^{-2})^{.5}\sin\psi \tag{14}$$

Furthermore

$$f_n^{(1)}(x,y,z,t) = \begin{cases} 0 \text{ for t} < \tau_n^{(1)},\, fort > R_n^{(1)} \\ \dfrac{-\mathrm{c}\,\mathrm{q}_1}{2\pi^2 \varepsilon_o \varepsilon_1 R_n^{(1)}} \int_0^{\frac{\pi}{2}} \mathrm{Re}[u^2(t,\psi)-q^2(t,\psi)] I_m c_{12}^m(t,\psi)\cos\psi\, d\psi fort > \tau_n^{(1)}, t < R_n^{(1)} \end{cases} \tag{15}$$

$$g_n^{(1)}(x,y,z,t) = \begin{cases} 0 \text{ for t} > \tau_n^{(1)},\, fort < \tau_n^{(1)}/v_1 \\ \dfrac{-\mathrm{c}\{\mathrm{q}_1^2(t) - q_{n_1}^2(t)\}^{.5}}{2\pi^2 \varepsilon_o \varepsilon_1 R_n^{(1)}} \int_0^{\frac{\pi}{2}} \dfrac{\mathrm{Re}[u^2(t,\psi)-q^2(t,\psi)]}{\{\mathrm{q}_1^2(t)\sin^2\psi - q_{n_1}^2(t)\}}] I_m c_{12}^m(t,\psi)\cos\psi\, d\psi fort < \tau_n^{(1)}, t > R_n^{(1)}/v_1 \end{cases} \tag{16}$$

where n=0,1,2,….i=1,2,m=n for i=2 and m=n+1 for i=1,with c=0 and i=2 and c=1 for all value of n and I in (15) !(16) we have

$$c_{12} = \frac{\delta(-u^2+q^2+v_1^{-2})^{.5} - j(u^2-q^2-v_2^{-2})^{.5}}{\delta(-u^2+q^2+v_1^{-2})^{.5} + j(u^2-q^2-v_2^{-2})^{.5}} \tag{17}$$

$$q_1 = \{\frac{1}{\sin\theta_n^{(1)}}[\frac{t}{R_n^{(1)}} - (v_2^{-2} - v_1^{-2})^{.5}\left|\cos\theta_n^{(1)}\right| - v_1^{-2}]\}^{.5} \quad \text{And} \quad q_n(t) = (\frac{t^2}{R_n^{(1)2}} - v_1^{-2})^{.5} \tag{18}$$

With

$$u = j\frac{\tau\sin\theta_n^{(1)}}{R_n^{(1)}} + (q^2 + \frac{t^2}{R_n^{(1)}} + v_1^{-2})^{.5}\left|\cos\theta_n^{(1)}\right|$$

In (15)

$$q^2 = q_1^2(t)\sin^2\psi$$

And in (16)

$$q^2 = q_1^2(t)\sin^2\psi + q_n^2(t)\cos^2\psi$$

5- Numerical results

We present some synthetic curves showing the horizontal normalization hertizian vector above the duct layer as function of normalization time when we take $\varepsilon_0 = 1$ and $\varepsilon_0 = 1{,}0004$ the height of the primary source and the point of observation has been taken to be z=d=20m and duct height h=15m . in such a manner that the corresponding potential of the primary source is independent of the horizontal distance r and takes on the value for $t > t_0 = \frac{R_0}{v_1}$ where R_0 denotes the spherical distance between the source and the point of observation.

If r=1000m is beyond that distance where the cotrribution of the image source Q_{0i} , to the total field undergoes total reflection at upper duct bondary , hence its shows the lateral wave fornt before time of the spherical wave fornt before Q_{0i} Fig.(2).

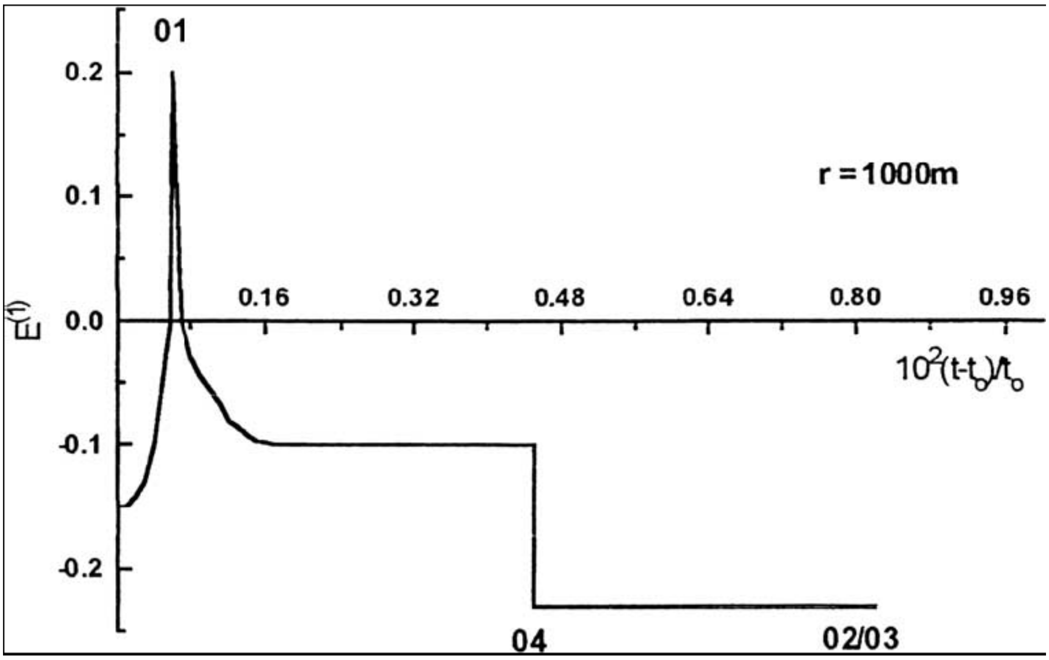

Fig. 2. Normalized potential within the duct layer as a function of normalized time (r= 1000 m).

Fig.(3) . If r=4000m the wave front due to the reflected first image source now arrives before the primary wave front and becomes greater and greater the case of r=5000m shows another detail; more and more reflected image source must be taken into account .

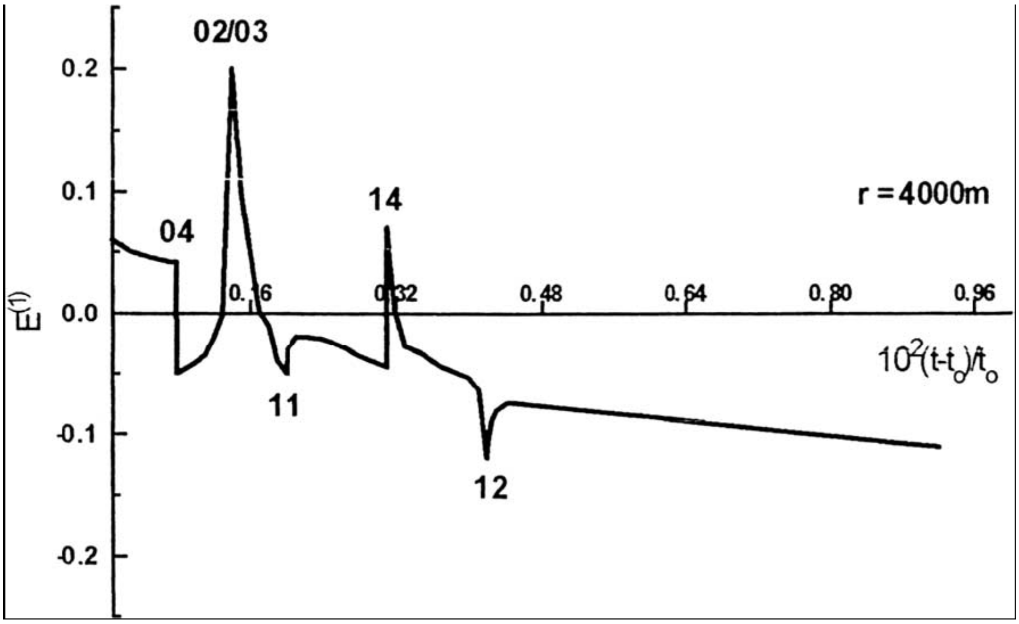

Fig. 3. Normalized potential within the duct layer as a function of normalized time (r =4000 m).

The case of r=5000m shows another interesting detail more and more reflected image source must be considered since with increasing distance more spherical wave front due to the reflected image source undergo total reflection and continuity to the receiving potential with their logarithmic singularities (fig.4).

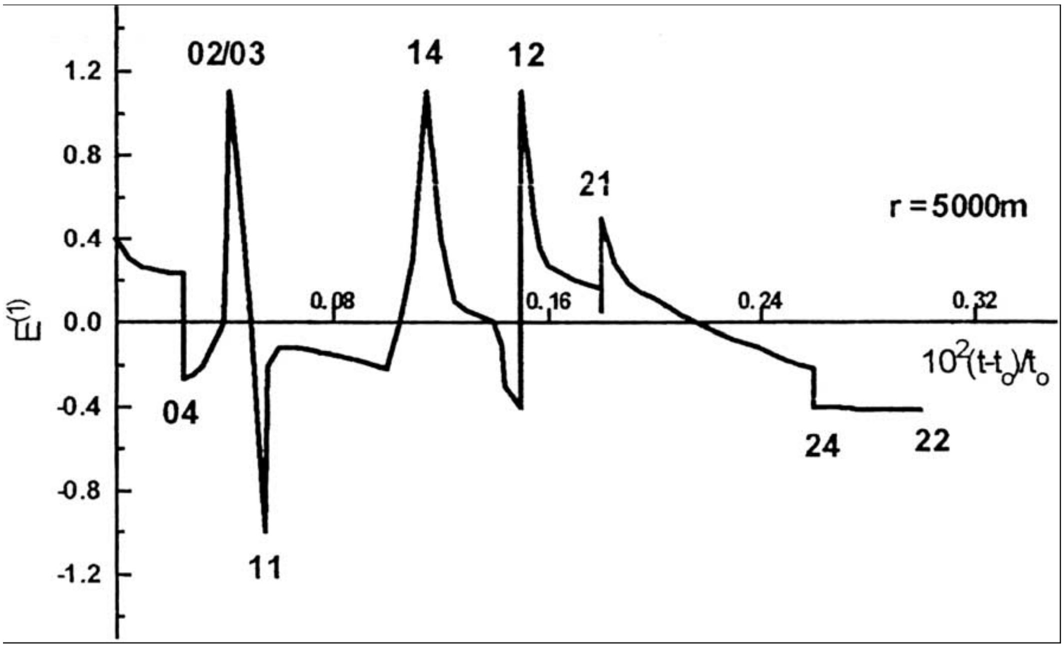

Fig. 4. Normalized potential within the duct layer as a function of normalized time (r =5000 m).

6. Conclusion

A theoretical study for computing the electromagnetic field from a Hertizan vector in the ionosphere is presented. The solution is valid for arbitrary distances between receiving and transmitting ends for a source position. The Saddle point method is used to compute the problem.

References

Abo-Seliem, A. A. (1998), “The transient response above an evaporation duct”, J. Phys. D. Appl. Phys. **31**, 3046-3050.

Abo-Seliem, A. A. (2003), “Propagation of the transient electromagnetic field above atmospheric surface duct”, Appl. Math. And Comb.**145**, 631-639.

Abo-Seliem, A. A. (2004), “Evaluation of the transient electromagnetic field in evaporation duct”, Appl. Math. And Comput. **151**, 411-421.

Arutaki A. and Chiba J. (1980), “Communication in a three-layered conducting media with a vertical magnetic dipole”, Trans. IEEE. Ap.**28**, 551-559.

Durrani, S. H. (1964), “Air to undersea communication with magnetic dipole”, Trans. IEEE Ap. **12**, 411-421.

De Hoop A. T. (1960), “A modification of cagniard’s method for solving seismic pulse problems”, Applied Scientific Research, Section B. **8**, 349-356.

Hewitt Dix C. (1963), “Cagniard's method and associated numerical techniques”, Journal of Geophysical Research. **68**, 1184–1185.

Jones D. S. (1969), “The theory of electromagnetism”, Pergamon Press, Oxford, 153.

Kahan T., and Eckart G. (1950), “Theorie de la propagation des ondes electromagnetiques dans le guide d’ondes atmospherique ”, Ann. Phys. **2**, 641-705.

Moore, R.K. and Blair, W.E. (1961), “Dipole radiation in a conducting half-space”, J. Res. Nat. Bar Standards. **65D**, 547-583.

Sommerfeld A. (1909), “Uber die Ausbreiting der welten in der drahtlosen telegraphic. Ann. D. phys,”, J. Res. Nat. Bar Standards. 28, 665-736.

Wait J. R. (1970), “Electromagnetic waves in stratified media”, Pergamon Press, Oxford, England, 608.