Radio Physics and Radio Astronomy, 2002, v. 7, No. 4, pp. 372-374

ABOUT RADIATION OF SHORT PULSES BY WIRE ANTENNA OF FINITE LENGTH

N.N. Gorobets, A.N. Dumin, O.A. Dumina

V.N. Karazin Kharkov National University
Svobody Sq., 4, Kharkov, Ukraine
E-mail: Alexander.N.Dumin@univer.kharkov.ua

The problem of short pulse radiation by the wire antenna of finite length is considered in time domain. Physical peculiarities of the change of a pulse form in all space of observation are investigated without any limitation on the antenna length and the form of pulse. The influences of the vibrator length and the spatial duration of pulse on a wave process are studied. The model of a slowly decaying pulse propagating in a long line is used as a base of the solution to the problem. The parameter of the decay is chosen from experimental data. The influence of the high order effects concerning with mismatch between antenna and fider line as well as fider line and ultrawideband pulse generator is studied.

1. Introduction

Vibrator antennas are widely used as a radiators of pulse signals in spite of distortion of signal form. The investigation of the problem in frequency domain was performed in work [1]. This paper is devoted to the solution of the radiation problem in time domain with vector potential method.

2. Statement of the Problem

The radiator of pulse signals is a conductor of length l which is disposed perpendicularly to an ideal metal screen. The geometry of the problem and co-ordinate system is described in Fig. 1.

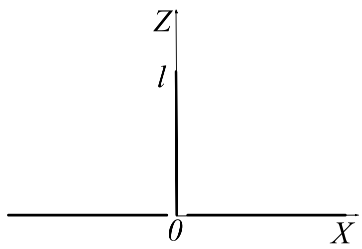

Fig. 1. *The problem geometry*

Current distribution on the conductor is presented as a travelling wave of current, which moves with velocity of light and has the time dependence in form of time derivative of gaussian

$$I\left(z,t\right) = -I_0 \frac{\left(t-\dfrac{z}{c}\right)}{\sigma} e^{-\frac{\left(t-\frac{z}{c}\right)^2}{2\sigma}-\alpha z}, \qquad (1)$$

where I_0 is the amplitude value of current, c is the velocity of light, σ defines the duration of the pulse, α determines the decay of current wave amplitude. We suppose that thickness of conductor is infinitely small, and α is a constant.

3. Solution to the Problem

The problem is solved with well-known method of electrical vector potential. The change of variables in Maxwell equations in the form

$$\operatorname{rot}\vec{E} = -\frac{\partial}{\partial t}\operatorname{rot}\vec{A}$$

yields the following equation in vector potential $\vec{A}$:

$$\nabla^2\vec{A} - \varepsilon_0\mu_0\frac{\partial^2\vec{A}}{\partial t^2} = -\mu_0\vec{I}\left(\vec{r},t\right),$$

where ε_0 and μ_0 are electrical and magnetic constants respectively, $\vec{I}$ is a given current of a source. Using the solution of this wave equation

$$\vec{A}\left(\vec{r},t\right) = \frac{\mu_0}{4\pi}\int\limits_V \frac{\vec{I}\left(\vec{r},t-\dfrac{R}{c}\right)}{R}dV$$

one can derive the following expression for radiated field in case of infinitely thin conductor:

$$\vec{E}\left(\vec{r},t\right) = \frac{1}{4\pi\varepsilon_0}\int\limits_l \left\{\frac{3\left(\vec{q},\vec{R}\right)\vec{R}-\vec{q}\left(\vec{R},\vec{R}\right)}{R^5} + \frac{3\left(\vec{I},\vec{R}\right)\vec{R}-\vec{I}\left(\vec{R},\vec{R}\right)}{cR^4} + \frac{\left(\vec{I}',\vec{R}\right)\vec{R}-\vec{I}'\left(\vec{R},\vec{R}\right)}{c^2R^3}\right\}dl'$$

where $\vec{R} = \vec{r} - \vec{r}'$, $\vec{r}$ is the radius-vector to the point of observation, $\vec{r}' = l'\vec{z}_0$ is the radius-vector to the current source, $\vec{I}'\left(\vec{r}', t - \frac{R}{c}\right)$ is time derivative of the current, $\vec{q}\left(\vec{r}', t - \frac{R}{c}\right) = \int_{-\infty}^{t-\frac{R}{c}} \vec{I}\left(\vec{r}', t'\right) dt'$.

The integration limits must be $-l$ and l because of influence of the screen.

The value of decay of current wave α is chosen from theoretical and experimental time dependencies of the received field for the radiator of the same type [2]. To take into account reflected current wave we suppose that it is described by the same expression (1) but with opposite sign of amplitude and coordinate z.

4. Numerical Simulation

The duration of the input bipolar signal for the numerical simulations (1) is 2 ns, the same as in [2]. Normalized time and angle dependencies of transversal electrical component amplitude for l =1,64 m are shown in Fig. 2 (R=2 m, near field) and in Fig. 3 (R=30 m, far field). The received signal consists of four parts radiated from the begin and the end of conductor by initial current wave and reflected one.

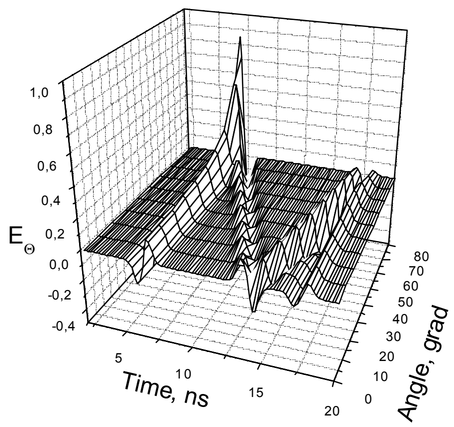

Fig. 2. *Time and angle dependencies of amplitude of transversal electrical component for R = 2 m*

Time dependence and spectrum of transversal field amplitude for different l are depicted in Fig. 4. It is shown, that the short vibrator radiates signal with the same form as a time derivative of initial current. In case of a long conductor we observe the influence of the current wave reflection that changes spectrum but does not increase total energy of received signal. We can take into account reflection from the source of current by the same way as for reflection from the end of the conductor. Time dependence and frequency spectrum of amplitude of transversal electrical component for the cases of absorption and total reflection of current wave from source are represented in Fig. 5. The case of two reflections from source is considered. Radiation losses cause the decay of amplitude of received field. So, real distortion of received signal must be smaller for partial reflections from source of current.

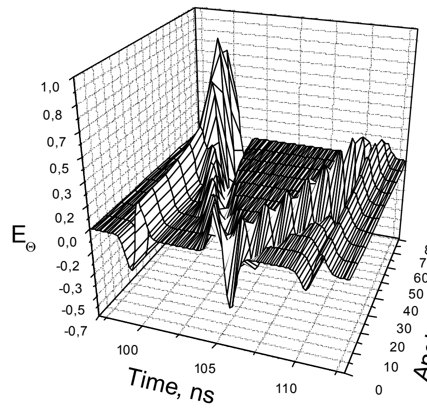

Fig. 3. *Time and angle dependencies of amplitude of transversal electrical component for R = 30 m*

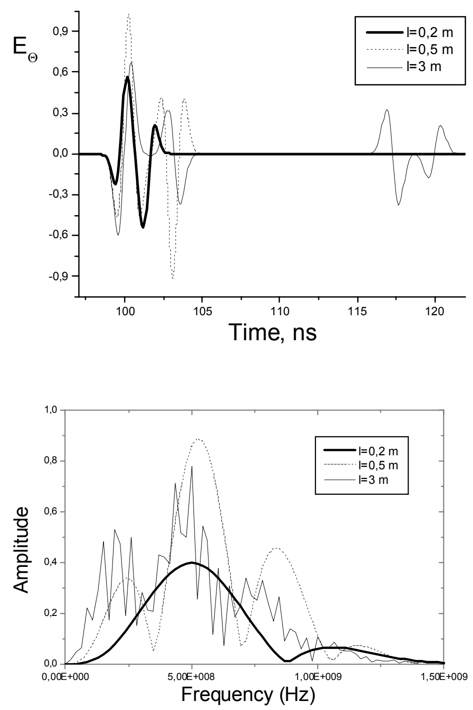

Fig. 4. *Time dependence and frequency spectrum of amplitude of transversal electrical component for R = 30 m and different l*

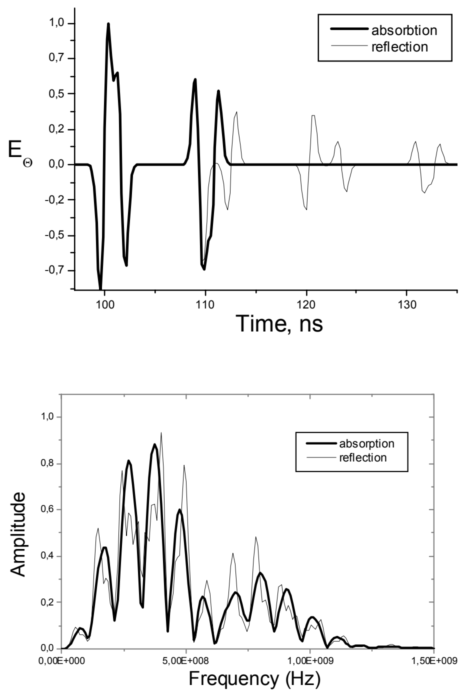

Fig. 5. *Time dependence and frequency spectrum of amplitude of transversal electrical component for the cases of absorption and total reflection of current wave from source (R = 30 m and l = 1,64 m)*

5. Conclusions

The problem of radiation of a vibrator have been solved using model of the travelling current wave excitation. The influences of conductor length and reflections from fider line are investigated.

References

1. N. Gorobets, A. Nechesa. Telecommunications and radio engineering. **53**, 36, (1999).
2. Yu.I. Buyanov, V.I. Koshelev, V.V. Plisko. Proc. Int. Conf. on Math. Meth. in Electromagnetic Theory, 312 (1998).

ОБ ИЗЛУЧЕНИИ КОРОТКИХ ИМПУЛЬСОВ ПРОВОЛОЧНОЙ АНТЕННОЙ КОНЕЧНОЙ ДЛИНЫ

Н.Н. Горобец, А.Н. Думин, О.А. Думина

Задача излучения коротких импульсов проволочной антенной конечной длины рассматривается во временной области. Физические закономерности изменения формы импульса во всем пространстве наблюдения исследуются без ограничений на длину антенны и на форму импульса. Изучается влияние длины вибратора и пространственной длительности импульса на волновой процесс. Как основа решения используется модель медленно затухающего импульса, распространяющегося вдоль длинной линии. Параметр затухания выбирается из экспериментальных данных. Изучается влияние эффектов высокого порядка, связанных с рассогласованием между антенной и фидерной линией, а также между фидерной линией и генератором.

ПРО ВИПРОМІНЮВАННЯ КОРОТКИХ ІМПУЛЬСІВ ДРОТЯНОЮ АНТЕНОЮ СКІНЧЕНОЇ ДОВЖИНИ

М.М. Горобець, О.М. Думін, О.О. Думіна

Задача випромінювання коротких імпульсів дротяною антеною скінченої довжини розглядається у часовій області. Фізичні закономірності зміни форми імпульсу в усьому просторі спостереження досліджуються без обмежень на довжину антени та на форму імпульсу. Вивчається вплив довжини вібратора та просторової тривалості імпульсу на хвильовий процес. Як основа розв'язку використовується модель повільно затухаючого імпульсу, що розповсюджується вздовж довгої лінії. Параметр затухання вибирається з експериментальних даних. Вивчається вплив ефектів високого порядку, пов'язаних з непогодженням між антеною та фідерною лінією, а також між фідерною лінією та генератором.