Научная статья
Original article
УДК 621.396

СРАВНЕНИЕ ДАЛЬНЕГО И БЛИЖНЕГО ПОЛЯ ЭЛЛИПТИЧЕСКОЙ СПИРАЛЬНОЙ АНТЕННЫ

COMPARISON OF THE FAR AND NEAR FIELD OF AN ELLIPTICAL SPIRAL ANTENNA

Фурер Ольга Вениаминовна, кандидат филологических наук, доцент, Поволжский государственный университет телекоммуникаций и информатики, г. Самара
Валиуллин Руслан Миндарович, аспирант, Поволжский государственный университет телекоммуникаций и информатики, г. Самара

Furer Olga Veniaminovna, Candidate of Philological Sciences, docent, Povolzhsky State University of Telecommunications and Informatics, Samara, e-mail: o.furer@psuti.ru
Valiullin Ruslan Mindarovich, graduate student, Povolzhsky State University of Telecommunications and Informatics, Russia, Samara, e-mail: koshki-tdr98@mail.ru

Аннотация. В статье рассматривается эллиптический спиральный излучатель, с заданными геометрическими параметрами. Для анализа электродинамических свойств излучателя в данной работе используются интегральные представления электромагнитного поля. При этом, используемый метод допускает тонкопроволчное приближение, что упрощает математическую модель (следует заметить, что использование подобных моделей весьма оправдано в большинстве практических случаях). Представлено распределение токов на структуре, сравнительные диаграммы направленности. В работе продемонстрировано, что диаграммы направленности дальнего и ближнего полей одной и той же структуры разительно отличаются, поля в ближней зоне имеют более сложное распределение.

Annotation. This article reviews an elliptical spiral radiator, with given geometric parameters. To analyze the electrodynamic properties of the emitter, integral representations of the electromagnetic field are used in this paper. In this case, the method used admits a thin-wave approximation, which simplifies the mathematical model (it should be noted that the use of such models is quite justified in most practical cases). The distribution of currents on the structure and comparative directional diagrams are presented. Calculation results show that the radiation patterns of the far and near fields of the same structure are strikingly different, with the fields in the near zone having a more complex distribution.

Ключевые слова: эллиптический спиральный излучатель, интегральные представления электромагнитного поля, тонкопроволочное приближение, математическая модель.

Keywords: elliptical spiral antenna, integral representations of the electromagnetic field, thin-wire approximation, mathematical model.

With the progress of telecommunications technology, the need for broadband antennas is constantly increasing. The class of spiral antennas is characterized by a wide bandwidth. The determining factor for this property of spiral antennas is that a traveling current wave is maintained throughout the entire operating bandwidth. There is no resonance phenomenon in this mode, unlike the standing wave mode used in narrowband antennas [1]. The class of narrowband antennas can include loop, vibrator antennas. To analyze the electrodynamic properties of antennas, integral equations are used, and the thin-wire approximation is used [2]. It should be noted that this approach simplifies the mathematical model, but in most cases the use of this method in practice is very effective and justified.

The mathematical model of an antenna is understood as a set of equations, both linear and differential, integral, which describe the physical processes occurring in the antenna. The vector potential method allows us to obtain the most accurate antenna models. In general terms, the vector electric $\mathbf{A}^{(e)}$ and magnetic $\mathbf{A}^{(m)}$ potentials are defined as follows [3]:

$$\mathbf{A}^{(i)} = \int_V \mathbf{j}^{(i)}(q)G(p,q)\,dV, \tag{1}$$

$\mathbf{j}^{(i)} \sim \mathbf{j}^{(e)}, \mathbf{j}^{(m)}$ – vectors of volume density of electric and magnetic currents;

$p = x, y, z$ – observation point coordinates;

$q = x', y', z'$ – source point coordinates;

G – Green's function, which is defined as:

$$G = \frac{1}{4\pi}\frac{\exp(-ikR)}{R}, \tag{2}$$

R – the distance between the source point and the observation point:

$$R = \sqrt{\left(x - x'\right)^2 + \left(y - y'\right)^2 + \left(z - z'\right)^2}. \tag{3}$$

Electric **E** and magnetic **H** field vectors are related to the corresponding vector potentials as follows:

$$\begin{cases} \mathbf{E} = -i\omega\mu_a\mathbf{A}^{(\mathbf{e})} + \dfrac{1}{i\omega\varepsilon_a}\nabla\left(\nabla \cdot \mathbf{A}^{(e)}\right) \\ \mathbf{H} = \nabla \times \mathbf{A}^{(e)} \end{cases}, \tag{4}$$

μ_a – absolute magnetic permeability of the medium;

ω – cyclic frequency.

Consider the geometry of the investigated structure, it is presented in Fig. 1.

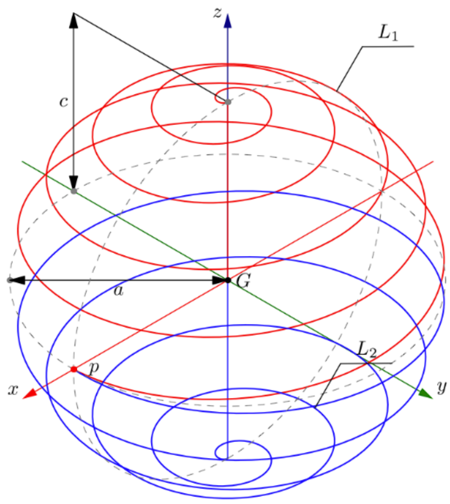

Fig.1 — Geometry of the investigated structure

The equation describing the spiral formation (L) has the following form [4]:

$$L: \mathbf{r}(\varphi) = a\cos(\varsigma\varphi)\cos\varphi\,\mathbf{x_0} + a\cos(\varsigma\varphi)\mathrm{S}(x)\sin\varphi\,\mathbf{y_0} + c\sin(\varsigma\varphi)\mathbf{z_0}, \quad (5)$$

S(x) – piecewise constant function, which is defined as [5]:

$$\mathrm{S}(x) = \begin{cases} 1, x > 0, \\ 0, x = 0, \\ -1, x < 0; \end{cases} \quad (6)$$

φ – the azimuth of the cylindrical coordinate system, is determined by the formula:

$$\varphi \in [-1;1] \cdot \pi N_l; \quad (7)$$

N_l – the number of spiral turns;

ς – parameter determined by formula (8):

$$\varsigma \in 1/(2N_l); \quad (8)$$

a, c – coefficients determining the semi-axis of the ellipsoid horizontally and vertically.

The structure under consideration (Fig. 1) has the following parameters:

$a=1$, $c=1$, $N_l=5$. When calculating the radius of the conductor r we take it to be $r=0.001$. The magnitude of the parameters *a*, *c*, *r* relative to the wavelength.

The results of the calculations are shown in Fig. 2–4. The directional diagrams were considered in the plane: $\varphi = 0, \theta = 0 \ldots 2\pi$.

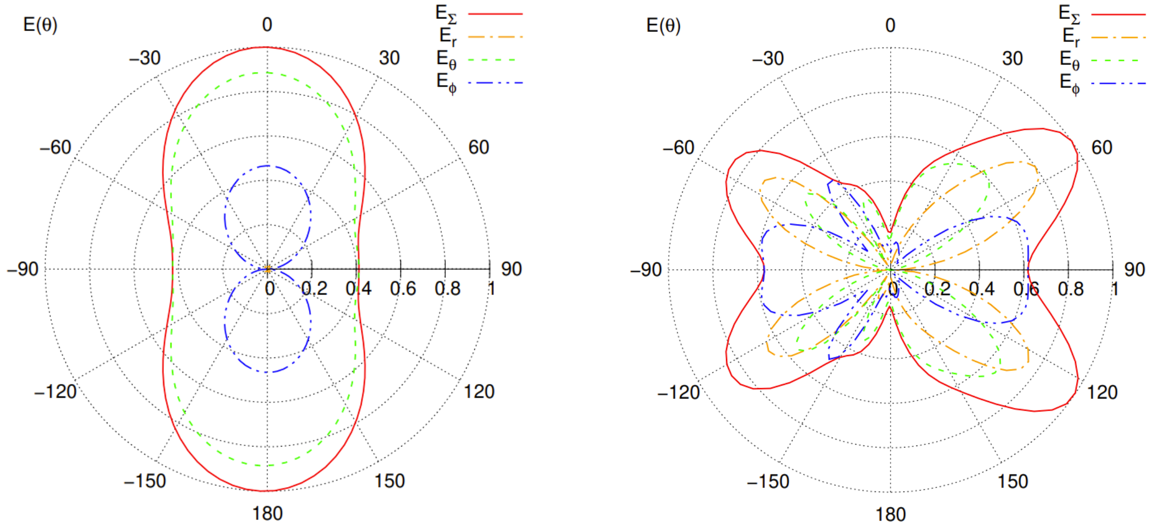

Fig. 2 Far–field (left) and near-field (right) directional diagram at $a/\lambda = 0.25$

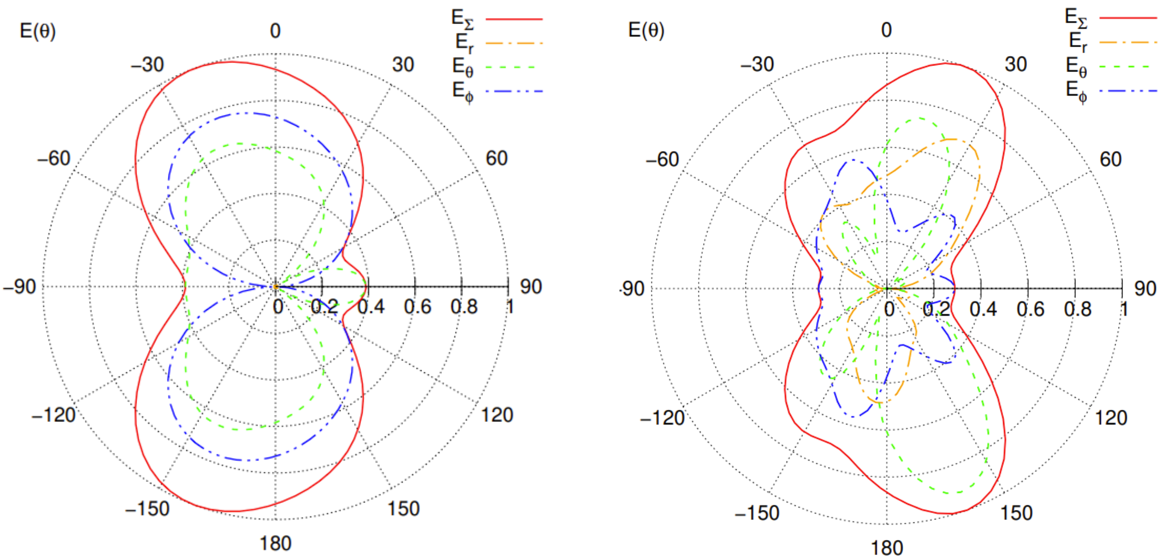

Fig. 3 Far–field (left) and near-field (right) directional diagram at $a/\lambda = 0.5$

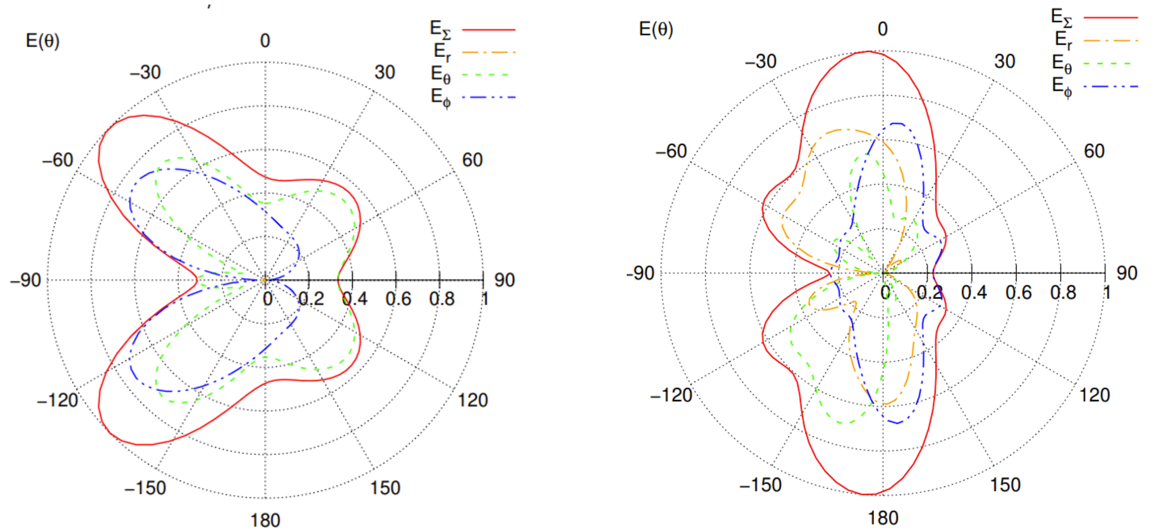

Fig. 4 Far–field (left) and near-field (right) directional diagram at $a/\lambda = 1$

From Fig. 2–4, we can conclude that the near field of the emitter has a more complex structure. It has a longitudinal $\mathbf{E}_r$ component since the field near the transmitter is short-circuited to the radiation source. In the far field, the $\mathbf{E}_r$ component is absent, so the far field can be considered transverse.

Литература

1. Рамсей, В. Частотно – независимые антенны [Текст] : В. Рамсей. – М.: Мир, 1968. – 176 с
2. Стрижков, В.А. Математическое моделирование электодинамических процессов в проволочных антенных системах [Текст] : В.А.Стрижков // Математическое моделирование — М.: изд. «Наука», 1989. – Т.1. — №8. – 127-138 с.
3. Электродинамика и распространение радиоволн [Текст] учеб. для вузов / ред. В. А. Неганов, С. Б. Раевский. Изд. 4-е, доп. и перераб. — М.: Радиотехника, 2009. – 744 с.
4. Валиуллин, Р.М. Построение математических моделей спиральных антенн на основе интегральных представлений электромагнитного поля [Текст]: магистерская диссертация / Р.М. Валиуллин. Поволжский государственный университет телекоммуникаций и информатики (ПГУТИ). Отдел аспирантуры и магистратуры. Кафедра радиоэлектронных средств (РЭС): науч. рук. Д.П. Табаков – Самара. 2022. - 74 с
5. Табаков, Д. П. Об описании излучения и дифракции электромагнитных волн методом собственных функций [Текст] / Д. П. Табаков // Известия высших учебных заведений. Радиофизика, 2021. – Т. 64. - №3. – С.179-191.

Literature

1. Ramsay, V. Frequency-independent antennas [Text] : V. Ramsay // Moscow: Mir, 1968. P. 176.

2. Strizhkov V.A. Mathematical modeling of electrodynamic processes in wire antenna systems [Text] : V.A. Strizhkov // Moscow: publ. Nauka. 1989. No. 8. P. 127-138.
3. Neganov V.A., Raevskiy S.B. Electrodynamics and Radio Wave Propagation [Text]: A. Neganov, S.B. Raevskiy. Ed. 4-th, updated and revised // Moscow: Radiotekhnika Publisher. 2009. P. 744.
4. Valiullin R.M. Construction of mathematical models of spiral antennas based on integral representations of the electromagnetic field [Text]: master's thesis / R.M. Valiullin. Volga Region State University of Telecommunications and Informatics (PSUTI). Department of postgraduate and master's studies. Department of radio-electronic means: supervisor. D.P. Tabakov - Samara. 2022. - 74 c
5. Tabakov D.P. On description of radiation and diffraction of electromagnetic waves by the method of eigenfunctions [Text] / D.P. Tabakov // Proceedings of higher educational institutions. Radiophysics, 2021. - T. 64. - №3. - C.179-191.

Для цитирования: *Фурер О.В., Валиуллин Р.М.* Учет косвенных расходов// Международный журнал прикладных наук и технологий "Integral" № 5/2022