ISSN: 2181-3906
2024

International scientific journal
«MODERN SCIENCE AND RESEARCH»
VOLUME 3 / ISSUE 2 / UIF:8.2 / MODERNSCIENCE.UZ

# PLANE ELECTROMAGNETIC WAVE PARAMETERS.

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https://doi.org/10.5281/zenodo.10629568

***Abstract.*** *Nowadays, in practice, when it is required to calculate electromagnetic fields, the use of some mathematical model is of great importance. Because, with the help of this model, it is possible to express the propagation of electromagnetic waves in real conditions. One of them is the plane electromagnetic wave model, which can be used to calculate many wave processes. Let's first understand a little bit about the plane electromagnetic wave. In this, first of all, it is necessary to learn the concept of wave front or wavy surface.*

***Keywords:*** *Signal, wave, electromagnetic field, plane waves, homogeneous medium, Plane electromagnetic wave, amplitude, Vacuum.*

# ПАРАМЕТРЫ ПЛОСКОЙ ЭЛЕКТРОМАГНИТНОЙ ВОЛНЫ.

***Аннотация.*** *В настоящее время на практике, когда требуется расчет электромагнитных полей, большое значение имеет использование той или иной математической модели. Потому что с помощью этой модели можно выразить распространение электромагнитных волн в реальных условиях. Одной из них является модель плоской электромагнитной волны, которую можно использовать для расчета многих волновых процессов. Давайте сначала немного разберемся с плоской электромагнитной волной. При этом, прежде всего, необходимо усвоить понятие волнового фронта или волнистой поверхности.*

***Ключевые слова:*** *Сигнал, волна, электромагнитное поле, плоские волны, однородная среда, Плоская электромагнитная волна, амплитуда, Вакуум.*

In practice, when the calculation of electromagnetic fields is required, the use of a mathematical model is of great importance. Because, with the help of this model, it is possible to express the propagation of electromagnetic waves in real conditions. One of them is the plane electromagnetic wave model, which can be used to calculate many wave processes. Let's first understand a little bit about the plane electromagnetic wave. In this, first of all, it is necessary to learn the concept of wave front or wavy surface. A wavefront is a surface where the phases of the field intensity vectors at each point have the same value.

Depending on the shape of the irradiator creating the field, the wavefront can be cylindrical, spherical, or have another shape. It should also be noted that the wavefront generated by the arbitrary irradiating system acquires a spherical shape at a very large distance from it. If we take a deeper look at this situation, we can understand the following. In radio communication lines, in almost all cases, the receiving antenna is located at a great distance. In this case, if the wavelength of the field is ten times smaller than this distance, this situation can be considered as long-range propagation. In practice, this condition is almost always fulfilled.

If we take into account the spherical distribution of the wave front, the receiving antenna receives a very small part of this front equal to its size. We can always consider a very small part of the sphere to be flat. For this reason, the plane electromagnetic wave model is important. The wave surface of the monochromatic field generated by the vectors is parallel to each other, or they call the wave lying in the same plane a plane wave. A plane wave in which the values of the field vectors are the same at all points of the wave front is called a uniform plane wave.

A plane harmonic electromagnetic wave propagating in an infinite homogeneous medium can be represented by the following equation

$$\vec{E}_m = (1\vec{x}\vec{E}_{xm} + 1\vec{y}\vec{E}_{ym} \cdot e^{-\alpha \cdot \psi}) \cdot e^{-j \cdot k \cdot z}$$

The expression for instantaneous values of the field vector has the following form

$$\vec{E}(t,z) = \vec{E}_{xm} \cdot e^{-\alpha z} \cdot \cos(\omega \cdot t - \beta \cdot z) + \vec{E}_{ym} \cdot e^{-\alpha z} \cdot \cos(\omega \cdot t - \beta \cdot z - \psi)$$

It is characterized by seven parameters of a plane electromagnetic wave in the state of propagation in free space. These parameters are written separately for the cases of wave propagation in mediums with conducting, semiconducting, and dielectric properties. As mentioned in the previous paragraphs, the classification of the environment according to the conductivity properties $tg\,\delta$ is done through the parameter

$$tg\delta = \frac{\sigma}{\omega * \varepsilon_a}.$$

1. The following formulas are the expressions of plane electromagnetic wave parameters.
2. γ – complex coefficient of wave propagation. This math parameter is used to simplify and transform expressions

$$\gamma = \alpha + j\beta$$

α – attenuation coefficient. This parameter shows the decay of the energy that occurs when the wave travels a distance of 1 m.

$$\alpha = \omega * \sqrt{\left(\frac{\varepsilon_a * \mu_a}{2}\right) * \sqrt{1 + tg^2\delta} - 1} \left[\frac{1}{м}\right]$$

β – phase coefficient. This quantity represents the angle by which the wave changes its phase when it travels a distance of 1 m.

$$\beta = \omega * \sqrt{\left(\frac{\varepsilon_a * \mu_a}{2}\right) * \sqrt{1 + tg^2\delta} + 1} \left[\frac{1}{м}\right]$$

$v_f$ – phase velocity. This parameter represents the speed of movement of the wavy surface, in other words, it shows the speed of oscillation of the field vector. $v_ф = \frac{\omega}{\beta} \left[\frac{м}{с}\right]$

$v_g$ – group speed. This parameter shows the speed of energy propagation

$$v_Г = \frac{d\omega}{d\beta}\Big|_{\beta=\beta_0} \left[\frac{м}{c}\right]$$

λ – wavelength. This parameter shows the distance traveled by the wave during one complete cycle

$$\lambda = \frac{2\pi}{\beta}\,[м]$$

$Z_c$ – characteristic resistance of the environment. This parameter is determined by the ratio of the complex amplitudes of the field vectors

$$Z_c = \frac{\dot{\vec{E}}}{\dot{\vec{H}}}\,[Ом]$$

In the vacuum state, the characteristic resistance of the medium is equal to 120p Ohm.

For real environments, it has a complex character and can be defined as follows

$$Z_c = |Z_c| \cdot e^{j\psi}\ [Ом]$$

$$|Z_c| = \sqrt{\frac{(\mu_a \cdot \cos\delta)}{\varepsilon_a}}\ [Ом]$$

From the above, it can be understood that a flat electromagnetic wave can be generated only in a limited part of space. However, in solving many practical problems, the external field is assumed to be completely flat at all points in space.

This facilitates the solution of electrodynamic problems.

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