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TEACHING PHYSICS WITH MATHEMATICAL ENVIRONMENT MathCAD

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Abstract: The paper describes the content and methods applied teaching the discipline "Physics. Field Theory".

Physics is one of the fundamental disciplines in the curriculum of bachelors' training in radio engineering. Its branch "Physics of electromagnetic fields" requires some specific teaching methods due to oversaturation with complex formulas and complicated mathematical apparatus of the theory of field.

Most students find this branch of physics quite confusing because of the difficulty of visualizing the interaction of electromagnetic fields in the space from multiple separate emitters.

To increase the effectiveness of teaching the subject, the authors combine the following teaching methods: method of education (reference method in the educational process) and methods of influence, including verbal methods (narrative, conversation, lecture), visual methods (demonstrations, illustrations), and practical methods (exercises and tasks).

The method of education is a key component in the overall process of educating students, which is the lever that drives its internal and external resources. The method of education is the most variable component of the educational process, which is closely associated with the relevant objectives of the process of education. Methods of influence are understood as ways and means of interlinked activities between a teacher and students aimed at developing tools and skills via math software.

The main purpose of such a "diverse system" is that it allows the most complete influence on the students. This creates an internal stimulus of interest and curiosity of students, increases their practical activity [1].

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The quality of the learning process can be significantly improved by using a training program for calculation of antenna arrays that enable to visualize the interaction of electromagnetic fields in the space from multiple separate emitters.

The quality of such an educational process manages to be raised considerably, applying the training programs of calculation of antenna arrays that allow you to visualize the most interaction in the space of electromagnetic fields from a variety of individual emitters. In practical classes the authors tested several programs in the mathematical environments MatLab, MathCAD, C++, Borland Delphi, HFSS, MMANA-GAL [2, 3].

These programs help students to speed up the development of the calculating algorithm and understand the physical nature of the mutual influence of design parameters of the aerial on each other and its radiation pattern (**RP**). The form of recording mathematical expressions in the program plays an important role, namely, its proximity to the usual mathematical symbols. Besides, the fast reference to graphs is essential to trace the influence on the ultimate result of calculations of any changes in the values of variables in mathematical expressions.

Mathematical environment MathCAD satisfies these requirements to the greatest extent. As an example of creating the training program in this environment, let's consider a program calculating linear equidistant antenna array (**AA**) [4]. According to the rules of writing programs in mathematical environment MathCAD, first it is necessary to make the description of the variables (Fig. 1), namely, the AA design parameters: the number of emitters, the distance between them, their mutual arrangement, the phase difference arising in the emitters of electromagnetic waves and their amplitude.

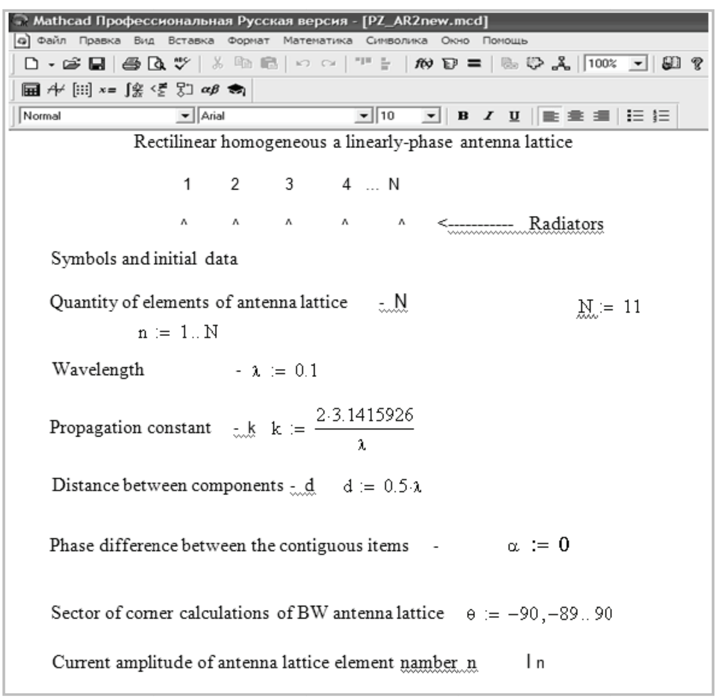

Fig. 1. Rectilinear equidistant linear phase array antenna

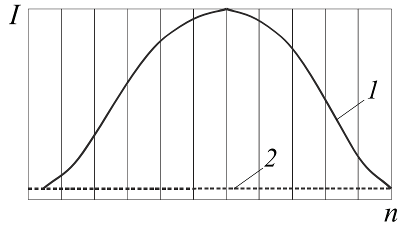

Fig. 2. Amplitude distribution "cosine square on a pedestal":
1 – cosine square on a pedestal;
2 – value of a pedestal

The figure shows that variables are written as common mathematical symbols or expressions that simplifies the comparison of the program code with the lecture material. The program can contain AA graphic representations, explaining its design features, and a text description of the set variables.

Further, in the form of usual mathematical expression, there is the program description of possible kinds of peak distributions of an electromagnetic field along axis AA, uniform and "cosine square on a pedestal" (Fig. 2).

To arouse students' interest in learning physics the authors use the method of visual analogies. This method enables to enhance personal and emotional state of students.

"Cosine square on a pedestal" has the form

$$\mathrm{I}_{\cos n} = \Delta + (1 + \Delta)\cos\left(\frac{\pi Z_n}{L}\right).$$

Each mathematical expression is followed by their graphic representation. Changes in the value of a pedestal Δ (Fig. 1) will lead to immediate changes in the form of the graph of amplitude distribution (Fig. 2). By using the ability to output the calculated values of the mathematical expression for the set of variables in the environment MathCAD, you can view the normalized amplitude of the electromagnetic field in each AA emitter.

Having set the number of AA emitters, their arrangement, the distance between them, the peak and phase distribution of the field along the array axis we can start RP calculation according to "the theorem of multiplication" which is formulated as follows: RP of AA is the product of RP single element on AA multiplier which represents the RP of the same AA, but consists of non-directed elements.

Apparently this formula is not very convenient for perception. Therefore the program has the graphic interpretation of "the theorem of multiplication". For this purpose, in the beginning, it is required to calculate the AA multiplier at various amplitude distributions in linear scale (Fig. 3).

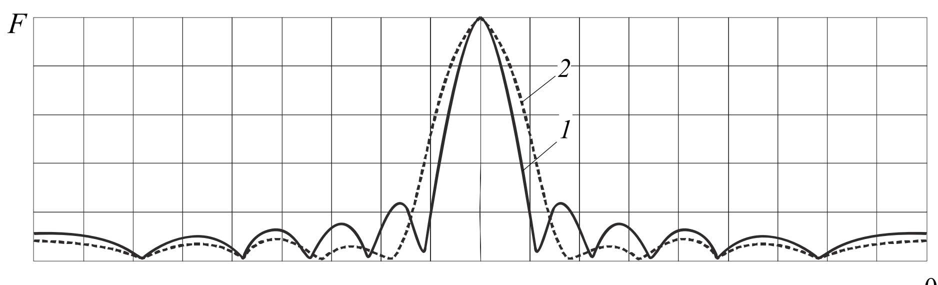

Fig. 3. Types of amplitude distribution:
1 – amplitude distribution "cosine square on a pedestal" $m(\theta)$;
2 – uniform amplitude distribution $x(\theta)$

Further, according to “the multiplication theorem” the calculation of RP of AA single element is made, which is accepted as a symmetric half-wave oscillator (Fig. 4).

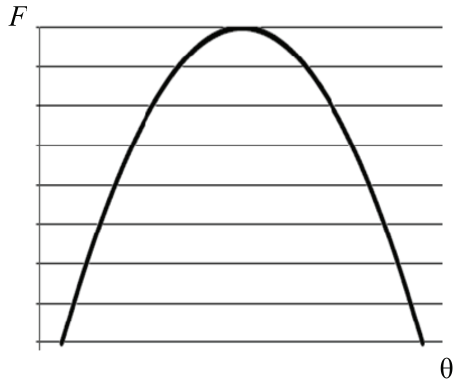

Fig. 4. Symmetric half-wave oscillator

After the calculation AA multiplier and RP of its single element, their multiplication is made.

For better mastering of physical essence of “the multiplication theorem” and understanding of the influence RP of single element AA on its RP, all the three components of “the multiplication theorem” are programmed and deduced on the separate graph simultaneously. In the program the graph is entitled “The illustration of the theorem of multiplication of radiation patterns” (Fig. 5):

$$t(\theta) = Fc\_\text{rawn}(\theta);\;\; y(\theta) = F\_AR\_\text{rawn}(\theta).$$

In accordance with the plan of practical training and using the described program, students complete practical tasks, such as to calculate and build on a personal computer using the training program the multiplier and the linear pattern of the AA under the following conditions.

1. Quantity of elements AA – N = 2; distance between elements AA – $d = 2\lambda$; a difference of phases of currents in next elements AA – $\alpha = 0$; $I_{m1} = I_{m2}$.

2. Quantity of elements AA – N = 2; distance between elements AA – $d = \lambda$; a difference of phases of currents in next elements AA – $\alpha = 180°$; $I_{m1} = I_{m2}$, etc.

Performance of these tasks allows the students to investigate the influence of all design data AA on the form of its RP.

The program described above and the methods applied in educational process, have been used by the authors in practical classes within several years. It reduces studying time of the difficult theory to 8 academic hours, including two lectures, one practical class and one lab lesson.

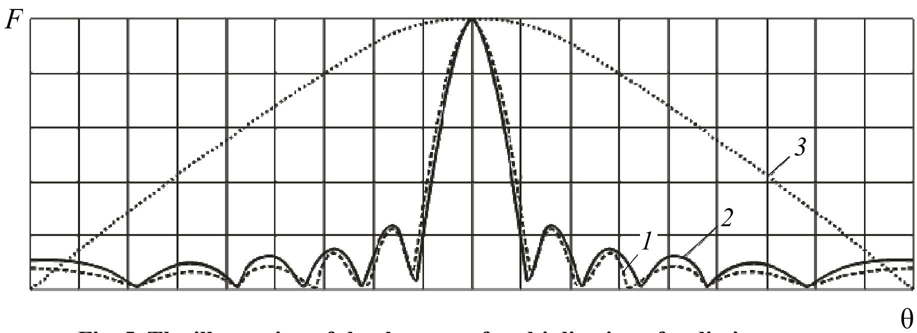

Fig. 5. The illustration of the theorem of multiplication of radiation patterns:
1 – RP of antenna aerial; *2* – antenna aerial multiplier;
3 – RP of single element

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Обучение физике с использованием математической среды MathCAD

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Ключевые слова и фразы: антенные решетки; диаграммы направленности; метод воздействия; метод обучения; теория поля.

Аннотация: Описывается содержание и методы, применяемые в учебном процессе, при проведении практических занятий по дисциплине «Физика. Теория поля».
