of the of the absorption coefficients are observed (+0.2 and greater) the permeability is significantly larger and R and T coefficients are less.

In the frequency ranges of negative D the EMI can be absorbed intensively. Such kind of materials could be perspective for the application of devices for information protection as well as for optical connections for integrated circuits. The latter could substitute copper conductors in the subterahertz frequency range and avoid parasitic losses and overheating.

IV. CONCLUSIONS

In summary, it has been established that at some certain parameters of a CNT-based nanocomposite consisting of ferromagnetic nanoparticles and transition shells and characterized by a resonant circuit in the subterahertz frequency range, the significant absorption could occur. At frequency change this absorption could be transformed to the amplification of EMI.

REFERENCES

[1] F. Qin, C. Brosseau. J. Appl.Phys. 111, 061301 (2012). 2. V.A. Labunov, A.L. Danilyuk, A.L. Prudnikava et al. J. Appl. Phys. 112, 024302 (2012).
[2] A. Atdaev, A.L. Danilyuk, V.A. Labunov et al. Semiconductors 50, 1702 (2016).
[3] A. Atdayev, A.L. Danilyuk, S.L. Prischepa. Beilstein J. Nanotechnol. 6, 1056 (2015).
[4] A. Davalos, A. Zanette, Fundamentals of Electromagnetism. Springer Verlag, Berlin, 1999.
[5] A.V. Avramchuk, M.M. Kasperovich, N.A. Pevneva et al. J. Appl. Spec. 83, 225 (2016).

METHOD OF ACCELERATED MODELING OF MICROSTRIP ANTENNA ARRAY CHARACTERISTICS USING CUDA TECHNOLOGY

V. Kizimenko
Belarusian State University of Informatics and Radioelectronics, Minsk, Belarus

I. INTRODUCTION

Currently, a large number of articles are devoted to modeling antennas with the use of Graphics Processing Units (GPU) and parallel computing architecture CUDA. At the same time, the main difficulty is the limited amount of video memory of video cards and its higher cost compared to conventional memory. The calculation is possible only for relatively small tasks and antenna arrays with a small number of radiating elements. One of the first papers on the use of video cards for solving electrodynamics problems was the article [1]. The implementation of the finite time difference method (FDTD) for the GPU in the Brook language was described. Modeling the process of electromagnetic wave propagation in free space on the GPU was 12 times faster than on the CPU. The paper [2] describes the implementation of the Method of Moments (MoM) on the GPU for 3D wire structures. Results of numerical modeling of a helical wire antenna with a cylindrical reflector are presented. The results obtained by the authors are in good agreement with the results obtained during the simulating a similar structure in the FEKO software. Compared with the option of the method for the CPU, an 8-fold reduction in the calculation time was achieved. Given the size of the video memory (896 MB) of the GTX 275 card used in the simulation, the maximum size of the input impedance matrix, available for calculation is 7500 × 7500 elements. In work [3] results of modeling of a single rectangular microstrip radiator by MoM method with reduction of the calculation time in 17 times are presented. The calculated characteristics of reflection coefficient are in good agreement with the results obtained using the software for electromagnetic modeling ADS-Momentum. Simulation with a sufficient degree of accuracy is possible for arrays with a number of elements less than ten. Article [4] is devoted to consideration of basic ideas on parallelization of the traditional finite element method (FEM). The main difficulty in this case is the intensive data exchange between blocks of code. To solve this problem, it is proposed to divide the original matrix into submatrices and group the elements within them in degrees of freedom. The results of comparison of the simulation time of the 7x7 monopole antenna array with 5,242,996 unknowns on a computer with a Xeon W3520 processor and Tesla C2050 accelerators are presented. Acceleration of simulation time using two accelerators was 5.37, using four – 5.5 times. It can be seen that due to the growth of data exchange, the increase in the number of video cards does not give a corresponding increase in computing performance: the low speed of copying data into video memory is an additional limiting factor. For example, for a GTX 670 graphics card, the data bandwidth from RAM to video memory is about 3.1 GB/s, and inside the video card is 192.2 GB/s.

To solve the problem of modeling the characteristics and parameters of multi-element microstrip antenna arrays, it was developed a special method that allows reducing the calculation time and the dimension of the matrices, which reduces the time required to transfer data to the video memory.

II. METHOD FOR CALCULATING THE CHARACTERISTICS OF MULTI-ELEMENT MICROSTRIP ANTENNA ARRAY, TAKING INTO ACCOUNT THE MUTUAL COUPLING BETWEEN ELEMENTS

To determine the initial dimensions of a single microstrip radiator, it is proposed to use a resonator model that allows to accurately determine the resonant frequency of the radiator. An analysis of various types of resonator models carried out in [6], showed, that the most accurate results are given by the F. Abboud, J.P. Damiano, A. Papiernik model [7] (the error in determining the resonance frequency is less than 1.8%).

After determining the initial dimensions of the microstrip radiator using the resonator model, a thin wire model is created on the basis of a modified Method of Integral Equations – MIE [8], which takes into account the effective dielectric permeability of the substrate. In Fig. 1 an example of a fine-wire approximation of a single rectangular microstrip element fed by a coaxial waveguide is shown.

Parameters of the radiator: plate dimensions a x b = 17×11 mm, dielectric constant of the substrate $\varepsilon = 2.33$; thickness h = 3.175 mm.

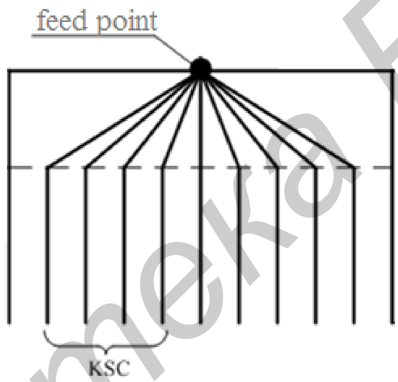

Figure 1 – Approximation of the microstrip radiator by a system of thin wires

In Fig. 2 the results of calculating the dependences of the input resistance on frequency using the modified Method of Integral Equations in comparison with the experimental data are shown.

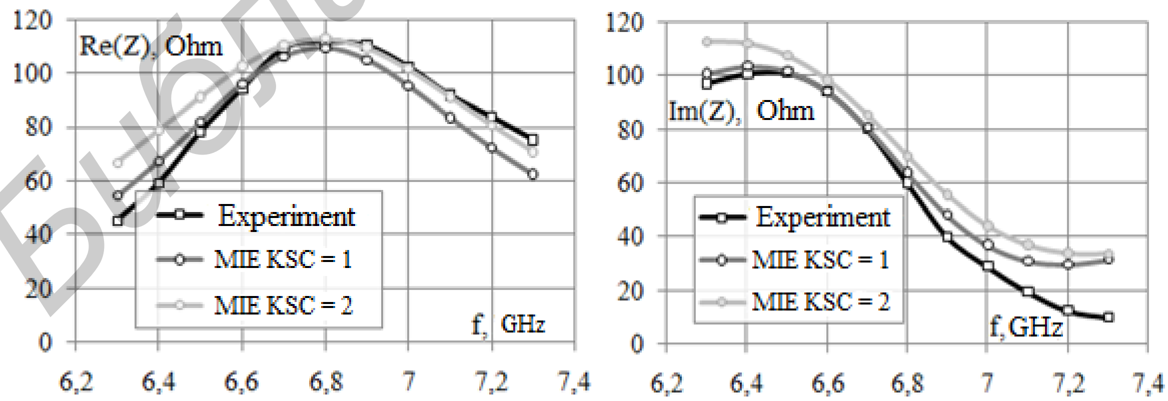

Figure 2 – Frequency dependences of the active and reactive part of the input impedance of a microstrip antenna

Based on the calculated model of a single microstrip radiator, an antenna array model is created from such radiators with a predetermined arrangement and spacing between the elements.

Fig. 3 shows the result of calculating the direction of the square antenna array (7×7 elements) with a step between elements along both axes $\Delta = 0.5\lambda$.

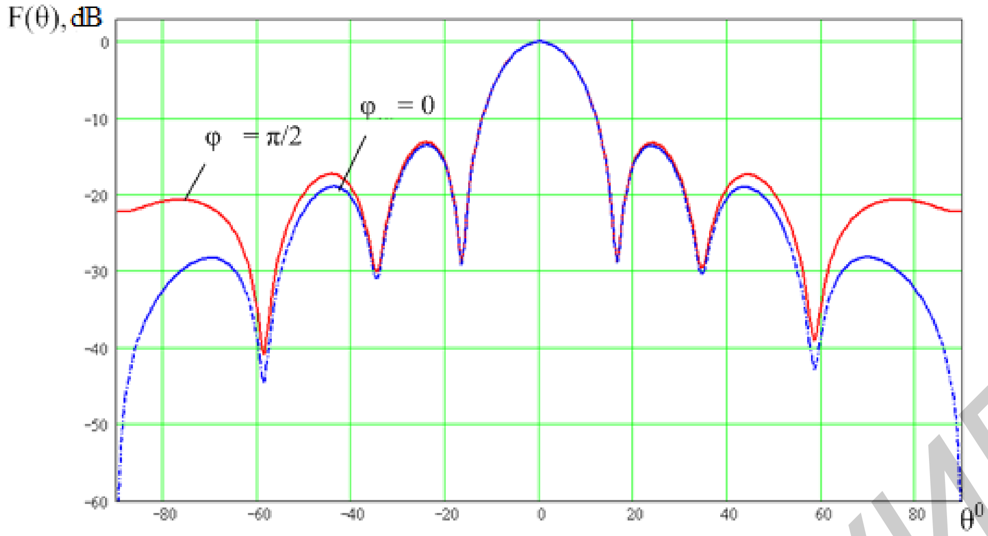

Figure 3 – Farfield of the microstrip antenna array (7x7 elements) at two planes

The presented results show that the developed thin-wire mathematical model basically corresponds to the real radiator with a solid plate and allows to simulate characteristics of both single microstrip radiators and arrays from them with rather high accuracy.

During the process of solving this problem at the final stage, the current distribution was determined by solving the System of linear equations (SLE) with the order of the matrix of mutual resistances 8428 (the total number of basis currents on the antenna array). To reduce simulation time, the source code was adapted to run on NVIDIA graphics accelerators using CUDA technology. Fig. 4 presents the printscreen of the window for monitoring the workload of the graphics accelerator, as well as a graph showing how many times the process of solving the SLE on the GPU is faster in comparison with the usual CPU.

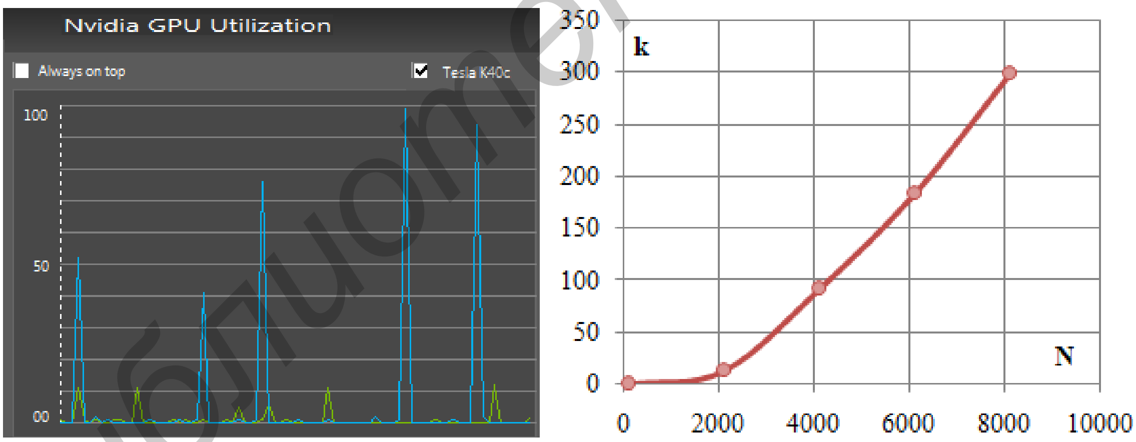

Figure 4 – Graph of the GPU workload and acceleration of the SLE solution process on the GPU in comparison with the CPU

The process of modeling was held on a computer with the Core i7-5820K (3.3 GHz), 16 GB of RAM, and the NVIDIA Tesla K40C graphics accelerator. As can be seen from the graph in Fig. 4, with the increase of the number of matrix elements up to 8100, the acceleration of the calculation process compared to the CPU is 297 times. During the process of modeling we should save matrixes of large sizes on a hard drive. To achieve additional speedup, we have tried new storage solution – Intel Optane DC P4800X [9]. The total time, which was necessary for recording and reading blocks of various sizes, was measured. In Fig. 5 you can see a graph, showing how much faster Intel Optane was in comparison with a conventional SSD.

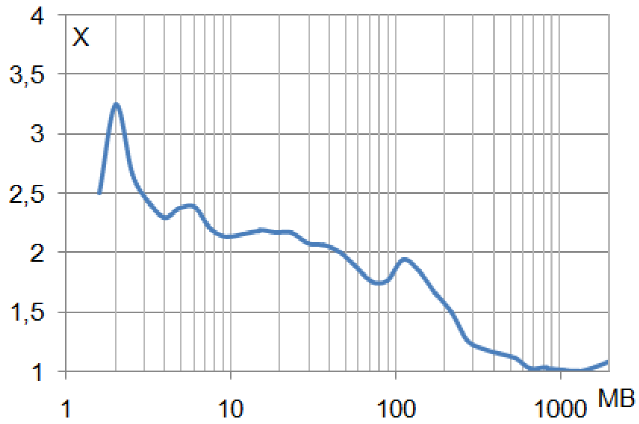

Figure 5 – The speedup (when saving data on Intel Optane DC P4800X compared to Intel SSD SC2BB48) vs. size of the stored block

III. CONCLUSIONS

A technique for fast calculating the characteristics and parameters of microstrip antennas and arrays using a resonator model and a modified Method of Integral Equations in a thin-wire approximation is developed. Significant acceleration of the calculation process is achieved through the use of CUDA technology and Intel Optane SSD.

REFERENCES

[1] Inman, M.J., Elsherbeni, A.Z. Programming video cards for computational electromagnetics applications // Antennas and Propagation Magazine, IEEE.–2005.– Vol. 47, Issue: 6.– P. 71 – 78.
[2] Noga, A.; Karwowski, A. Adapting MoM With RWG Basis Functions to GPU Technology Using CUDA //AWPL, IEEE. – 2011. – Vol. 10. – P. 480-483.
[3] De Donno D. GPU-based acceleration of MPIE/MoM matrix calculation for the analysis of microstrip circuits // Proceedings of the EUCAP-2011.– P. 3921 – 3924.
[4] Acceleration of the finite element method using hybrid OpenMP-CUDA // Proceedings of the APSURSI 2014.– Memphis, TN, USA, 2014.– P. 1379 – 1380.
[5] Cerjanic A. Method of Moments Modeling of Microstrip Patch Antennas with automatic GPU Acceleration // Microwave Symposium Digest (MTT), 2012. P.1-3
[6] Kizimenko V., Ulanovski A. Comparative Analysis of the Various Resonator Models in the Input Impedance Calculation of the Microstrip Antennas // 39th International Conference on Telecommunications and Signal Processing (TSP), June 27-29, 2016. Vienna, Austria. – P. 187-189.
[7] F. Abboud, J.P. Damiano, A. Papiernik "Simple model for the input impedance of coax-fed rectangular microstrip patch antenna for CAD", IEE Proceedings H of Microwaves, Antennas and Propagation.– Vol. 135, Iss. 5.– IET. – 1988.– P. 323-326.
[8] Kizimenko V.V., Ulanouski A.V. Fine-wire approximation of a microstrip radiator taking into account the effective permittivity of the substrate // Electronica-INFO, №6.– 2015.– Minsk, Belarus.– P. 45-50.
[9] Kizimenko V., 'First experience with Intel Optane P4800X', Linkedin, 2017. [Online]. Available: https://www.linkedin.com/pulse/first-experience-intel-optane-p4800x-viachaslau-kizimenko [Accessed: 30- Sept- 2017].

APPLICATION OF THE METHOD OF ELECTROTHERMAL ANALOGY FOR PREDICTION OF THE TEMPERATURE OF STRUCTURED SURFACES

V. Lobunov, A. Kuharenko
Belarusian State University of Informatics and Radioelectronics, Minsk, Belarus

I. INTRODUCTION

Investigation of heating peculiarities of surfaces of different materials, as well as revealing the laws of temperature variation of such surfaces, can be useful in developing both the materials and the structure of their coatings. Such coatings can be special paints, that absorb radiation, screens or masking mesh to hide objects, and protective ablative materials, used to protect the surface from heating. For example, promising