

Development of a new Efficient Numerical Method, creation of package of program and making experimental setup for recognition of latent objects

The **objectives** of the proposed project are creation of the program package for determination of the shape and position of metallic and dielectric bodies embedded within a dielectric media. Having recovered the shape, determination of dielectric parameters of the body. Construction of a high-speed detector, which must include a device, for the measurement and recording of phase and amplitude information over a two-dimensional surface, connected to the computer that by using of our program package will realize the detection process.

The **topicality** of the Project objectives is provoked by the problem of contactless determining of the latent bodies shape and position, which is important in numerous of application in different branches of science and technology. For example in Applied Electrodynamics, Tomography in Medicine for investigation of the internal organs, in Archeology for the study of fragile archeological samples, in Military Engineering for detection of explosive substances etc.

The Project participants in frame of the Laboratory of Applied Electrodynamics (LAE) of Tbilisi State University (The Head of LAE is doctor of phys.-math. sciences, prof. R. Zaridze) have a long (more than 30 years) and successful experience in research and development of various antenna and EMC problems. During 1970th-1980th, these works was performed in frame of military orders of Defense Ministry, Defense Industry Ministry, Radio Industry Ministry, Naval Ministry, Management Committee of Education Ministry and for others departmental Institutes of the Former Soviet Union (FSU). Specifically, Tbilisi group was involved in carrying out the top-secret researches on development of extremely narrow beam forming antenna arrays with extra-rapidly changing beam direction, antennas of flying objects with homing guidance, hidden (camouflage) antennas, *etc.*

Top-secret researches “Mina” (“Mine”), “Zhidkost” (“Liquid”), *etc.*). Even to the end of USSR, the group of LAE was involved in problems, which carried out under the resolutions of Central Committee of Communist Party and Council of Ministry of USSR from 1.05.85, N308-126, “Shakhta (“Pit”) KO4T”; from 2.08.84, N837-180 Complex-4; under the Decision of Commission of Council of Ministers on Military Industry Problems from 5.10.85, N328 “Shickotan –Phase2”. They were also the part of complex goal programs “Izluchenie” (“Radiation”) under the order of Education Ministry N53c from 27.02.86, “Complex” under the order of Management Committee N7 of Radio Industry Ministry, “UHF-2”- under the order of Education Ministry N64 from 11.03.84 and N797 from 03.12.86.

Partially in previous years, but especially starting with 1990, after destruction of Soviet Union, Tbilisi team turned to the research and development of important present-day civil electromagnetic (EM) problems both in antenna, field reconstruction and other topics of interest. Thus, together with scientists from Technical University of Berlin, Germany, Tbilisi team was involved in research and development of such problems, as electrostatic discharge. Also, the group find out tide scientific collaboration with Technical University of Athens on reconstruction of images of objects, which agree closely with stated project and we have a number of publications concerning this, patch and conformal antennas, design of microwave and optical devices as well as to investigate the complex media, and *etc.*

The cause for the successful work of the group was earlier and remains nowadays an original numerical method (MAS) for solution of complicated antenna and other diffraction problems.

Initially it was aimed to balance the lag of domestic computer resources from Western analogues by increasing efficiency of numerical means. The actual recognition of MAS as efficient numerical tool is due to the complication of the problems to be stated, and due to the permanent development of MAS to meet present-day needs. Thus, together with different knowledge and experience the use of MAS has allowed Tbilisi team to solve efficiently even complicated EM problems on the personal computers while, usually, high-capacity workstations are used for the same purpose. The main idea of the MAS during solution of diffraction and scattering problems was to find out the current distribution on some Auxiliary surface, shifted from real one, which creates the same scattered field everywhere we are interested in. Thus, in the area between real and shifted surfaces we are getting analytical continuation of the scattered field. A new idea, we are going to develop farther and apply in this project is to reconstruct the wave field, known on some surface, toward to the direction, which is opposite to propagations one. This idea based also on the uniqueness of wave field. This methodology was tasted in 1999 using numerical experiments, when we are using the values of scattered field in order to reconstruct the shape of the scatterers.

Sometimes when a direct contact to the body is undesirable, dangerous, or impossible at all such method is the only possible way to investigate it. Variety of methods exist of the immersed bodies shape reconstruction by means of irradiation by the field with the wave of significantly less length than the bodies sizes. The proposed method can be used even when the wavelength is commensurable with the body's sizes.

The **expected result** of this project is the development of a new efficient numerical method, creation of package of program and making experimental setup for recognition of latent objects.

The results of project can be immediately used for a safe search of buried metallic and dielectric bodies and for recognition of a latent objects in general. Otherwise (in addition), it may be used when a direct investigation of the body is not very informative or undesirable at all.

Potentially very versatile **methodology** will be implemented, namely, the Method of Auxiliary Sources (MAS).

Our **approach** is based on the concept of Auxiliary Absorbers.

The idea (method) of Auxiliary absorbers is closely related to the method of Auxiliary Sources. This approach has led to new insight into the investigation of diffraction problem. This method was further developed and intensively used by the Tbilisi State University research group. The Auxiliary Absorber gives rise to a time-harmonic incoming field instead of an outgoing one with the same time dependence, which is the case of Auxiliary Source. The field of Absorber in three-dimensional case is obtained by replacing $k \rightarrow -k$ in the field of Auxiliary Source, where k is a wave number. In two-dimensional case the field of Absorber is presented by the function $H_0^{(2)}(kr)$ -the second kind Hankel function of order zero. The method used by us for determination of the shape and position-(DSP) is just the holographic one. This method is based on the knowledge of the amplitude and phase distributions of scattered field on some open surface. In our approach, the incident field is taken to be a time-harmonic one, $e^{-i\omega t}$. The scattered field values are measured at the points uniformly distributed on some open surface at some distance from the body. The measured values of the field are used to satisfy the matching condition over this surface for the field constructed by using of the Auxiliary Absorbers. Making use of analytical continuation for the field constructed by the Auxiliary Absorbers from the measurement surface one recovers the scattered field. The recovered field is in good agreement with the original one in region between the body and a

measurement surface. The incident and the reflected waves have an opposite phases. Thus an absolute value of the total field (incident + reflected) has a local minimum at the scatterer surface.

For the metallic body the value of this minimum equals zero, because in such a case the incident and the reflected waves have the same amplitudes. Then we make a summation over absolute values of recovered fields corresponding to the different frequencies. This makes it possible to localize the minimum of that sum along the scatterer surface and allows one to use this method as the basis for a description of the DSP problem. Note that in the framework of this approach it is sufficient to use the electric field. Preliminary results in support of this approach are presented.

To carry out the objectives of the Project, the following Milestones will be realized:

1. Create the program package to find a perfectly conducting body enclosed in a dielectric media, which has a closed complicated form surface. Prepare the receiver mounted on a mechanical scanner and controlled via (by the) computer to gather the scattered field information at the points of surface as the scanner is moving about. This information must be digitized by the converter for a subsequent storage in computer.
2. Create the program package to find a dielectric body enclosed in a dielectric media, which has a closed complicated form surface. Prepare a wide band incident wave source to illuminate the target.
3. Create the program package to find a perfectly conducting body enclosed in a dielectric media, which has a half-space form. Prepare the samples of the metallic and dielectric bodies enclosed in a dielectric medium.
4. Create the program package to find a dielectric body enclosed in a dielectric media, which has a half-space form. Prepare an experimental device to test the efficacy of the proposed approach.