# Research and Development of Realistic Model of Health Safety Adaptive Antenna for Personal Communications Systems Using an Effective Numerical Method

**Summary:**

The **objective** of the Project is research and development of a new type of health safety antenna for Personal Communications Systems (PCS) with optimal geometric size and shape to provide desirable electric and radiation characteristics, and creation of user-friendly package of programs for computer simulation of dielectric coated antennas with required parameters.

The **topicality** of the Project objectives is provoked by the progress in Wireless Communications Systems (WCS), which has resulted recently in rising and fast developing area of Personal Communications Systems (PCS). In this regard, development of new PCS components and devices with improved characteristics is needed to meet ever-increasing demands. The most complicated and critical parts of these systems are antennas due to the up-to-date severe and, sometimes, contradictory claims to their geometrical, electrical, directional and compatibility characteristics. Specifically, the antennas should be well matched with feeder and with free space, and also to possess the wide-band characteristics. At the same time, they often desired to be minimized in size, to be as diminutive as it is possible. Moreover, the antennas should satisfy the present-day claims to ecological and health safety conditions, and minimization of electromagnetic energy radiation. These all is especially important in design of portable PCS.

It is well known that existing variants of omni-directional PCS antennas do not completely satisfy the present-day requirements of Electromagnetic Compatibility (EMC). The main reason of this is a non-optimal shape of radiation pattern of such antennas, when only a little part of radiated energy, directed to the receiver, is used for communication purposes. During the normal operation in close proximity of the user's head the main part (up to 60%) of RF energy is absorbed in the head tissues. This is because of high permittivity and conductivity of human's brain. As the majority of cellular phones operate at 1.6 GHz and 950 MHz the corresponding wavelength in the head's tissues varies from 2 cm up to 5 cm. The long-duration exposure to such radiation is highly undesirable. Also, because of circular pattern of the existing antennas in azimuth plane, the influence of user’s head on the antenna matching with open space is high and normally the radiated field even in opposite to the head direction sharply decreases because of absorbing EM energy. The radiated energy is inclosing on high conductivity, absorbed area.

A strong electromagnetic interaction between the antenna and the user’s body brings also to variability and instability of antenna characteristics. In order to get reliable communication using antennas with unsteady characteristics they are forced to radiate EM energy with excess, superfluous, unnecessary. And what is more, the existing PCS antennas are not ecological and health safety, because of thermal and other influence of radiated energy upon the user’s head tissues. The fact that the density of radiated energy decreases as $1/r^2$ at the distance from antenna worsens the situation. This means that the strength of the field near the antenna is very high, so the user’s head is located in the area of high strength of EM field. In spite of relatively low frequency and low energy of quantum ($h\nu$), which is unable to ionize molecules, the thermal influence of heating of the head tissues can causes a lot of undesirable effects (tiredness, headache and more severe consequences.). In addition, efficiency of such antennas is not high enough because of substantial absorption of emitted energy by user’s body. Since the energy emitted by batteries is not used in efficient way, this also reduces their living time.

That is why, research, development, manufacture of a new type of optimal parameter health safety antenna for PCS is an important technical, compatibility, ecological and health safety problem.

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.

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 and other topics of interest. 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. 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.

Research and development of antennas for PCS has become recently the key EM problem considered by Tbilisi team. During last few years, Tbilisi team was involved in development of a new portable antenna for cellular phones. A new 2D, rectangular, and later 3D, parallelepiped, models of such an antenna with back screen and dielectric coating were created, and then numerically simulated and optimized on characteristics. Also, a mutual interaction between antenna and human head was simulated. Moreover, a model of such an antenna with chiral coating was suggested and simulated. These researches have shown that a rectangular and parallelepiped PCS antenna models with dielectric coatings could be designed in such a manner, in order to display the desired radiation characteristics. They are compact, wide-band, and radiate into half space. However, these types of PCS antenna cannot be best matched with feeder and environment.

The supposed Project intends to be the further research and development of dielectric coated PCS antenna being lack of these defects.

Thus, LAE managed by Prof. Revaz S. Zaridze possesses all the necessary conditions to successfully fulfill the suggested Project, including the accumulative theoretical, experimental, methodical, technical and personal potential and the original works of the supposed Project participants on the examination of electromagnetic behavior of the combined structures made of various materials.

The **expected result of the Project is** creation of program package for computer simulation of dielectric coated PCS antennas. This program package should provide the following opportunities of:

- creation of the user-friendly interface program to build multi-layer complicate shape geometry of the antenna structure;
- entrance of desired input parameters for the size, shape and material filling of antenna components;
- 3D visualization of antenna model and of auxiliary geometry for its numerical simulation;
- computation of the desired electric and radiation characteristics of antenna in near and far regions;
- selection of the desired precision of calculations and evaluation of the obtained precision of calculations;
- creation of user-friendly interface for output characteristics in order to investigate detailed EM phenomena in antenna.

The **scientific significance** of the expected Project results consists in development of up-to-date approach to solve realistic antenna problems. It will also lead to the creation of competitive user-friendly program package for computer simulation of particular type of antennas being in widespread demand. The Project will result in discovering optimal shape and research of characteristics of novel variants of antennas for PCS to meet user desires and satisfy requirements of EMC, ecological and health safety. And, finally, the Project will give recommendations regarding optimal parameters of proposed antenna, which could have the potential commercial value in the marketplace.

Since the antenna problem to be considered in the Project is essentially voluminous (3D) and complicated, an efficient original numerical method, namely the Method of Auxiliary Sources (MAS), will be implemented and accommodated to solve this specific EM problem. According to the MAS, the unknown scattered field in each particular region is represented as a superposition of the fields of Auxiliary Sources (AS) specially distributed in non-physical regions. The reason for such representation is the linear independence of fundamental solutions of appropriate wave equations proved by well-known Georgian mathematicians: N.Muskhelishvili, I.Vekua, and V.Kupradze as early as in 1960$^{th}$. The correct choice of the type and distribution of auxiliary sources, which is the subject of theoretical and numerical analysis, provide the effective solution of the stated antenna problem as boundary electrodynamics problem and calculation of desired antenna characteristics with required accuracy.

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

1. Development of the physical model and mathematical statement of the desired antenna problem by adopting and developing the MAS to the specific boundary problem.
2. Theoretical solution of the stated problem with determining the required electrical and radiation characteristics.
3. Creation of program package with user-friendly interface for computer simulation of dielectric coated antennas.
4. Research and optimization of antenna characteristics to meet the claims to geometric size, electric and directional properties, EMC, ecological and health safety.