

G. Ghvedashvili, R. Zaridze, K. Tavzarashvili, A. Bijamov, I. Chelidze, D. Kakulia

Numerical Simulation of Metallic Antenna Covered with Dielectric Layer

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ABSTRACT. Structure of small metallic antenna for Personal Communications Systems covered with high permittivity dielectric layer is presented in this paper. This is a drop-shaped antenna which is supposed to have the wide band radiation characteristics due to its geometry and special structure. The dielectric layer helps to keep the size of antenna small. In order to avoid undesired increase of Q-factor due to this layer its thickness is kept as small as possible. The structure was numerically simulated using the method of auxiliary sources (MAS). The field distributions for particular frequencies are presented together with frequency response of investigated structure.

Key words: antenna, radiation, match, numerical methods.

The fast developing area of Personal Communications Systems (PCS) requires new components and devices with new and improved characteristics to meet ever-increasing demands. One of the critical parts of these systems is antenna. The geometrical, mechanical and electromagnetic characteristics of modern antennas should satisfy many important and in many cases contradictory requirements. Particularly the antennas are desired to be small in size, well matched from both feeding cable and free space sides and at the same time possess wideband characteristics.

This paper offers possible antenna structure that satisfies the above-mentioned criteria. The antenna is a drop-shaped metallic structure. This shape helps to match it with feeding cable and supports the wide range of operating frequencies. To reduce the size of antenna the metallic part is covered with dielectric layer made of high permittivity material (Fig.1). It is well known [1] that the reduction of antenna size using high permittivity materials makes its fractional band width smaller, that is why the thickness of introduced layer should be small enough to provide wide band operation.

The proposed antenna was investigated by numerical simulation using the MAS with its recent development [2]. The MAS is a general method for solving the diffraction problems of electromagnetics and provides a fast full wave analysis tool. Based on this method the program package with friendly user interface was developed to perform parametric study of antenna and to find and specify those of

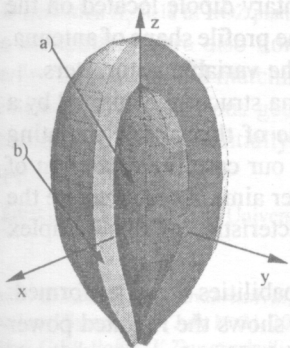


Fig. 1. Antenna Structure: a) metallic part; b) dielectric layer.

parameters that provide desired characteristics. This software provides the possibility to perform fast numerical experiments for optimization of parameters of the system. The frequency range in calculations is not limited by the numerical model and the method used. In this particular case the frequencies were chosen to be from 1 to 4 GHz, which are applicable to wireless devices.

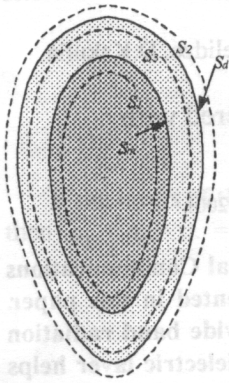


Fig. 2. The model of the structure and distribution of the auxiliary surfaces.

Model and MAS Algorithm. The scattering characteristics of investigated structure were calculated using the MAS. The model of the structure was a metallic body with boundary surface S_m and the dielectric layer with outside surface S_d (Fig. 2). According to the MAS algorithm the unknown field was represented by a number of auxiliary sources (AS) which are the fundamental solutions of the wave equation for every particular media or domain of interest. In this case the AS were the elementary dipoles distributed on the auxiliary surfaces S_1 , S_2 and S_3 . The AS distributed on S_1 , S_2 represent the field inside the dielectric layer and the sum of the field of AS on S_3 and incident field is the total field in free space outside the antenna. Also, the auxiliary surfaces S_1 and S_2 are shifted outside the dielectric layer and surface S_3 is shifted inside the domain covered by dielectric (Fig. 2). The unknown amplitudes of AS are found then by solving a system of linear algebraic equation, which is obtained by enforcing the boundary conditions in a number of points on S_m and S_d . The component of electric field tangential to the metallic surface S_m inside the dielectric layer must be zero on this surface and the tangential components of electric and magnetic fields on the dielectric surface S_d must be continuous.

$$E_{\tau}^m = 0 \Big|_{S_m}, \quad E_{in\tau}^d = E_{out\tau}^d + E_{\tau}^{inc} \Big|_{S_d}, \quad H_{in\tau}^d = H_{out\tau}^d + H_{\tau}^{inc} \Big|_{S_d},$$

where E_{τ}^m is tangential component of electric field on S_m surface, $E_{in\tau}^d$ and $E_{out\tau}^d$ are electric and magnetic field components tangential to S_d surface inside and outside dielectric respectively. E_{τ}^{inc} and H_{τ}^{inc} are incident electric and magnetic fields tangential to S_d surface. The excitation of the antenna was modeled by elementary dipole located on the symmetry axis at the bottom of antenna near its narrow part. The profile shape of antenna, thickness of dielectric layer and its permittivity were among the variable parameters.

The main goal of the investigation is creation of an antenna structure being fed by a coaxial cable and study of its radiating capabilities. In frame of this article radiating capabilities of the presented antenna structure are studied. In our case the excitation of the antenna was simulated by the elementary dipole. Our further aims are to simulate the antenna feeding by coaxial cables and investigate the characteristics of this complex radiating antenna structure.

For proposed antenna parametric investigation of its capabilities were performed. Some of the results are presented in the pictures below. Fig. 3 shows the radiated power of the structure versus frequency when the excitation was modeled by elementary dipole located on the symmetry axes along its orientation. The permittivity of the dielectric layer

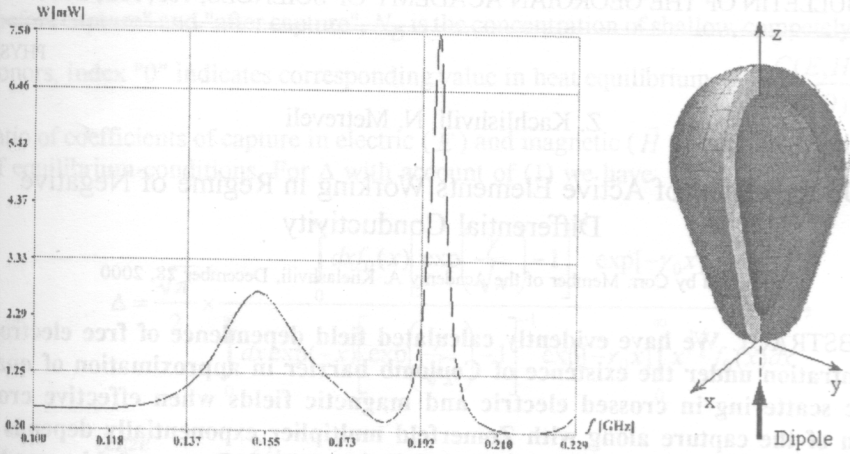


Fig. 3. Radiated power versus frequency when exciting dipole is parallel to the symmetry axes. Antenna height -1.2 sm , thick -0.8 sm , dielectric layer thick -0.12 sm ; Dipole position $(0.0\text{ sm}, 0.0\text{ sm}, -0.5\text{ sm})$.

located on the symmetry axes along its orientation. The permittivity of the dielectric layer equals to 10.0. The first resonance of the structure occurs at the frequency of 0.1536 GHz. The picture of the near field is shown in Fig. 4 together with radiation pattern.

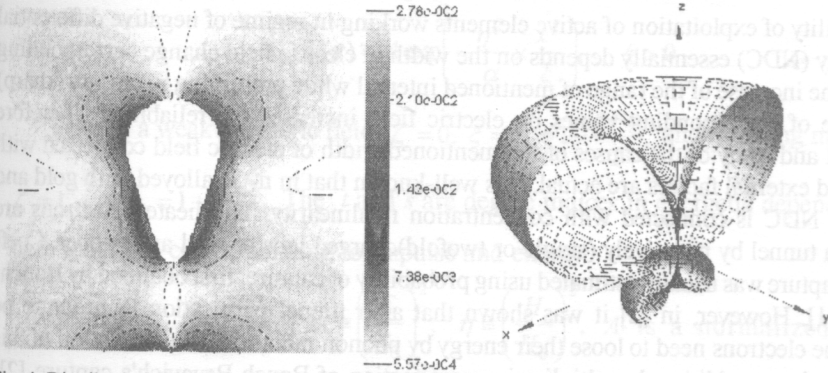


Fig. 4. Distribution H_y field in XOZ plane and radiated pattern frequency $f = 0.153\text{ GHz}$.

The computation are also done to study the behavior of resonance frequency, band width radiation pattern and matching of the antenna for different thickness and permittivity of dielectric layer and various geometrical parameters. The first studies have shown that the presented structure potentially is capable of working as wide band antenna useful in many applications.

I. Javakhishvili Tbilisi State University

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