Section 10

BIOLOGICAL EFFECTS OF EM FIELDS

APPLICATION OF THE MAS TO CAVITIES WITH APERTURES IN PROBLEMS OF EME

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Abstract. This article considers EM Ecology (EME) problems on cavities with apertures. Method of Auxiliary Sources (MAS) is used as a method of investigation [1]. Frequency range of research is resonant for object. Diffraction of Electromagnetic plan wave on the semi closed, perfectly conducted surface with some apertures is considered. Investigation is realized by numerical experiment.

Introduction

During the last decades, the increasing number of the powerful antennas with high frequency of communication or radar systems raises electromagnetic background. Usually, the measurement of the background has a place in outdoor environments - in the street, close to a building and on a roof of a building. One of the major aspects of EM Ecology is to understand EM field distribution inside the cavities with apertures, such as living or working places. Cavities with apertures composed with high conductivity surfaces can become a spatial resonators keeping up high EM field.

It is impossible to get authentic view about satisfaction of the sanitary standards without taking in account the resonant factor. The field's distribution inside these cavities depends on the frequency, shape of the cavities and position of the apertures. If in that area the dielectric object is placed, for example human body, the lossy object with high permittivity bends and attracts the near field. This property makes the problem more significant in order to find safe areas with minimal EM fields inside, when the limitation of EM sources is not allowed. There are lots of results of real measurement made indoors [2, 3, 4]. Presence of different outer factors makes unstable the measurement's results. For parallel analysis, the modeling of electro dynamical processes on electrically large objects by conventional numerical methods demands also huge computational resources. Research of effective approaches for numerical analysis of the resonant properties, eigen fields and eigen values of large cavities with apertures similar to the geometries of rooms and mobile objects has become necessary. This article considers the next and efficient development of MAS.

General MAS

Generally MAS is a method for solution boundary problems, more used in Applied Electrodynamic. Main idea is the representing of the scattered or the penetrative fields by fields of some auxiliary sources placed outside of the field's determination area. Main difference between MAS and the Method of Moments (MOM) or MAS and Integral Equation Method (IEM) is that MAS uses auxiliary non-real currents, shifted on so called auxiliary surface. Auxiliary currents create same scattered field as real currents. During of realization, the efficiency of the MAS greatly depends on selection of auxiliary surface. The more auxiliary surface is remote from real surface the better is satisfaction of boundary conditions. This property of MAS gives free play to find optimal auxiliary surfaces and presents special topic for investigation.

First significant advantage of the MAS is evident, when the Auxiliary Sources moves away from the physical boundary surface dividing two different mediums. Below there is considered an example for analyze how behaves satisfaction of the boundary conditions. In this case, just 3 collocation points come on every one wavelength square. In fig. 1 geometry of the problem is given. Flat, finite square area, with $l=6.67\lambda$ side sizes (surface area 42.25 λ^2), located in point of origin illuminated by dipole field axial Z on $h=6.67\lambda$ distance polarized along Y. Auxiliary surface is shifted on d distance along -Z. In the Fig.1 is shown typically dependence character of satisfaction of the boundary conditions ($E_{tau}=0$) on the shifting AS away from main surface for 4 different distances mentioned in the Fig.1.

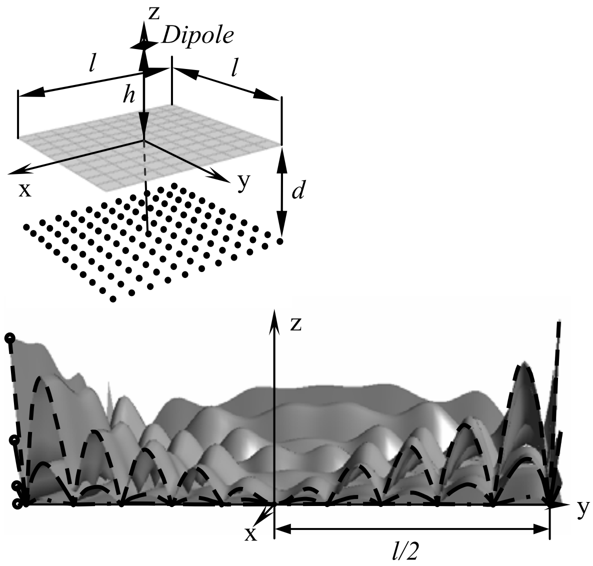

Fig. 1. Geometry of example and Typical distributions of the residual for different auxiliary distance *d*.

d/λ=3.33, Residual=2.00%
d/λ=4.00, Residual=0.60%
d/λ=6.67, Residual=0.00%
d/λ=13.3, Residual=0.08%

There is the tangent component of the total E field distribution. The satisfaction of the boundary conditions is demanded in 11x11 uniformly distributed collocation points; the deviation is distributed in area between them. Step by step moving AS away the deviation becomes less and less. For obviousness, in fig.1 just half of the plate is presented, cut in YOZ section. The total field is determined by same number (11x11=121 multiplied on 2, considering two orthogonal directions) of AS distributed with the same size plate.

In Fig.2 there is given character of convergence results of solution when increase the distance between collocation points and AS location. The accuracy of satisfaction of the boundary conditions for fixed number of AS increases sharply (See Fig. 2). This can be explained by the fact that shifting of AS inside the scatterer makes the sought scattered field function more smooth on the surface of the body and its identity with the incident field in the collocation points remains in other points of the surface, i.e. the fulfillment of the boundary conditions in the region between collocation points improved. For fixed number of collocation points on square wavelength there is the optimal shifted distance after which accuracy changes insignificantly. This peculiarity can be observed during realization of the method because, if the number of unknown and distance of shifting will be increase unnecessarily, the solution can fail.

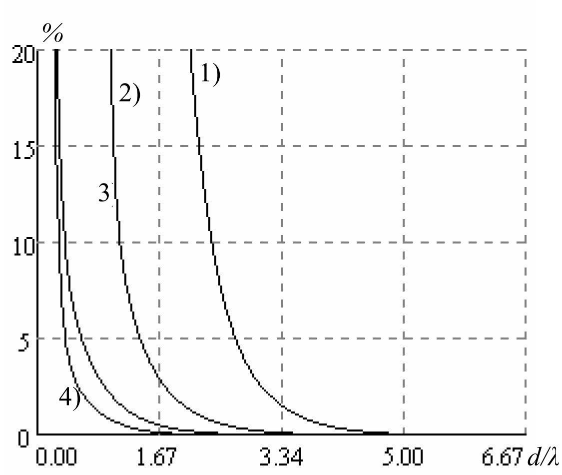

Fig. 2. Dependence of the boundary conditions satisfaction per relative auxiliary distance *d/λ* for different relative densities of collocation points

The reason is obvious, because every computer can distinguish the number's value with finite accuracy, significant digit and increasing number of unknowns the system of unknowns would become linearly dependent, which tends to the divergence and failure of solution. Particularly, this can has place when surface is the curved and moving away AS converge to the one point.

Fig. 3 shows dependences between the number of collocation points on λ square and the relative distance, when the values of residual are fixed.

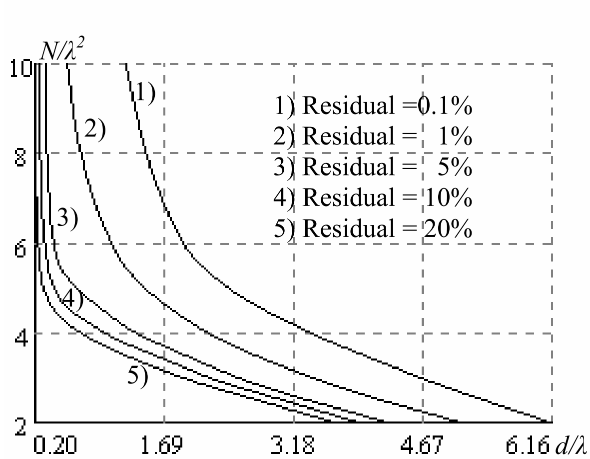

Fig. 3. Dependences N/λ^2 to d/λ for fixed values of boundary condition satisfaction

MAS Approach for Cavities with Apertures

Usually in MAS, auxiliary sources are fundamental solutions of wave equation. In three-dimensional case, the finding of an effective auxiliary surface for complicated shapes is often impossible. Contribution of electric charges dominates in near electrical field of Hertz's dipole. Describing of continuous current's field becomes complicated. In this case, the increase in density of auxiliary sources is necessary, which reduces efficiency of the MAS.

The Hertz's dipole has no geometrical dimensions and arisen problem with charge's field must be removed by the increasing of dipoles density on auxiliary surface. This circumstance guides to integration and integration means the using distributed currents.

Easiest and effective way of the representing of current on auxiliary surface is network, where segments of network are elements of current and corresponding charges are concentrated in junctions. This distribution provides continuous current on auxiliary surface and satisfaction of Kirchhoff rule. Auxiliary currents are continuous on auxiliary surface. At the same time this approach is effective from the points of view of convergence, calculation time and in case when auxiliary surface is closed to real surface. Furthermore, it allows hybridization with the Method of Moments [5].

For diffraction problems modeling on the cavities with apertures MAS proposes to supplement incomplete surface of cavities by imaginary surface. Now having the closed area inner and outer auxiliary surfaces can be set. Next, two sets of AS are placed on the auxiliary surfaces, l_{in} inside and l_{out} outside as shown in Fig. 4. The inner AS on surface l_{in} represents the field outside the cavity and on the boundary l, and the outer AS located on surface l_{out} represents the field inside the cavity and on the surface l. The Boundary conditions for the perfectly conducting bodies are used on the both sides of the cavity's surface and on the imaginary surface the continuity of the total tangential magnetic and electric fields is enforced, which leads to the system of linear equations relatively to unknown coefficients. The algorithm can be applied for solving problems where dielectrics are partially covered with conductive patches.

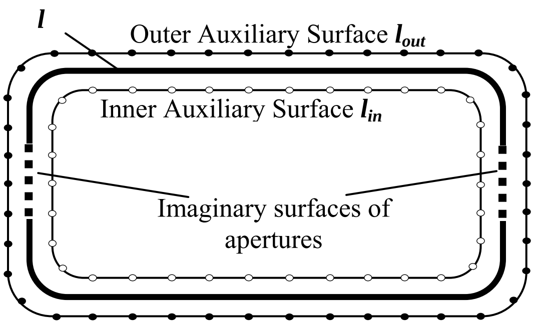

Fig. 4. MAS model of cavity with using auxiliary and imaginary surfaces

The shape of an imaginary surface cannot be set arbitrarily, as it influences the efficiency of the solution. It is good to avoid sharp corners in MAS. A smooth surface needs to be selected. Generally, the imaginary surface should have continuity of the second order of spatial derivative and with minimal value whenever possible, while usually only a continuity of the first order derivative is sufficient. It is advisable to select a large curvature radius, since the large curvature radius allows coverage of a large section of the surface with only a few AS. In practice, finding an appropriate rounded surface does not pose difficulties.

Results

For the numerical modeling the cavity like room with dimensions 5m^{x}3m^{x}2.5m is offered (see. Fig. 5). The cavity has two apertures on frontal and back side. Dimensions of apertures are 1.5m^{x}1.0m. For simplicity, the bounds of cavity are considered as PEC. Plane Electromagnetic wave propagates from x directions. E field has -y polarization and H field has z correspondingly. The magnitude of E is 1v/m. The frequency range is 10-400 MHz. The diffraction problem is solved on three numerical models with different numbers of unknowns: 1) n=4144, 2) n=6192, 3) n=7872. The Shielding Efficiency for middle point in cavity is calculated (see Fig.6). The Shielding Efficiency for electric field is obtained by formula $SE = -20 * \log_{10}(E_t / E_i)$, where E_t is total E field and where E_i is incident E field.

It is well known, that exposure to RF and microwave radiation can produce adverse biological effects in human beings. Below, some study of possible influence of the EM field, producing high localized RF energy deposition on the live organisms, located in external field.

In Fig.7 presents the results of calculation EM field distribution into 2 cases of the room: with two windows one along to another Fig.7a, and just one window (Fig. 7b). The incident field remains the same with amplitude 1, and directed to the open window. On the roller from the right side in the fig.7a there are the maximum values of the E field. In first case the E fields max possess the value is about 2v/m. In second case on the Fig. 7b roller points, that maximal value of E field is more then 5v/m. It is clear that the Q factor in

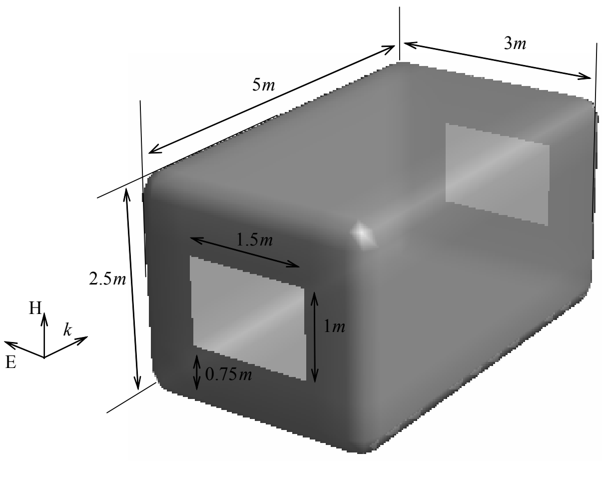

Fig. 5. Dimensions of room like cavity with apertures and problem statement

second case is more than Q factor of first cavity. The result underlines fact that the resonant factor plays very important role at the evaluation of EM fields in cavities.

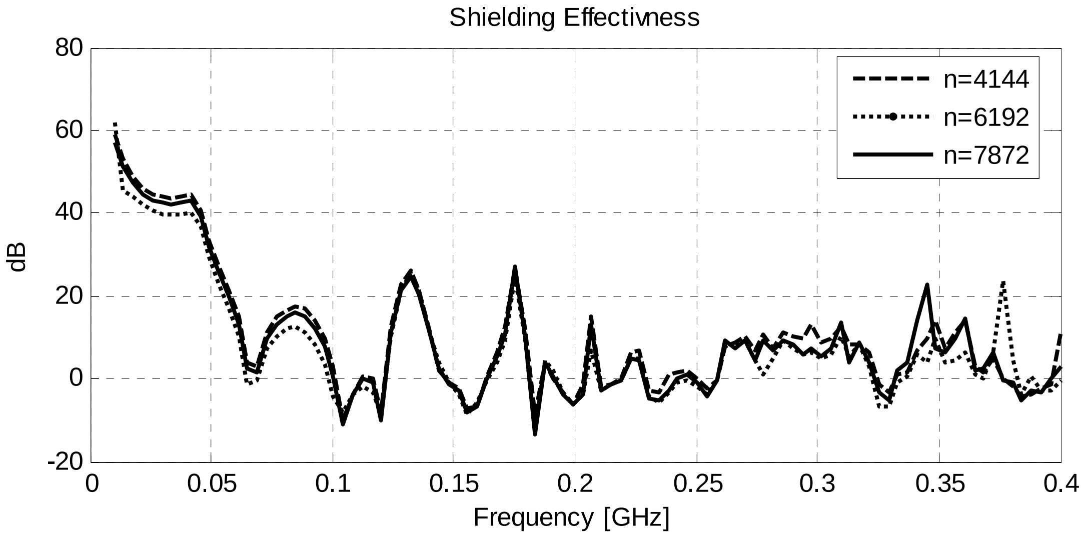

Fig. 6
The Frequency characteristic of shielding efficiency in middle point of the cavity computed for three numerical models with different numbers of unknowns.

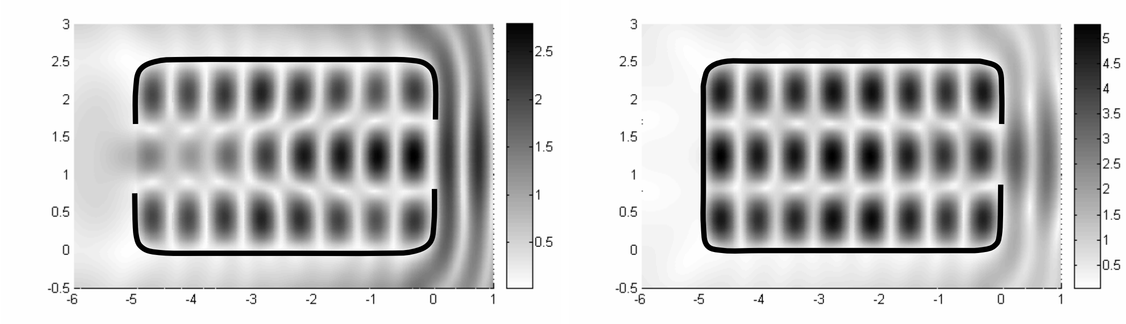

Fig. 7
a) b)
E_y field distributions in XOZ slice for two cases: the cavity with two apertures and the cavity without back aperture

Conclusion

The motivation of the article in big frame is to investigate electrodynamic, resonant properties of the semi open living place structures in miens of satisfaction of the safety and sanitary standards. Paper summarizes the acquisition of expert knowledge within the main principles and features of the MAS numerical technique in application to 3-D EMC problems. The limitations of the MAS, the area of applications, and the features which could be considered for efficient solution EM problems are presented. The MAS is extended to the simulation of the semi-open structures and problems.

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