Chapter 2: Propagation of electromagnetic waves

Introduction

When studying dynamic electromagnetic fields, we usually start with the propagation of waves in an infinite homogeneous medium, which is supposed being linear and isotropic. In this situation, a single wave is propagating, which can be attenuated only is lossy medium is assumed.

Electromagnetic waves, which propagate in infinite homogeneous medium, can be classified according to their equiphase surface as planar, cylindrical and spherical.

Plane waves can be observed in a long distance from the transmitting antenna. Plane wave propagation can be mathematically described by a scalar differential equation in the Cartesian coordinate system.

Cylindrical wave propagates from an infinitely long direct wire, which is flown by a high-frequency current. Cylindrical wave propagation is described by a scalar differential equation in the cylindrical coordinate system.

Spherical wave propagates from a point source. Spherical wave propagation is described by a vector differential equation in the spherical coordinate system.

Propagation of the above-described waves is relatively well-understandable and well-imaginable. Even the mathematical relations describing propagation of those waves are relatively simple, and moreover, the final equations are of a closed form (i.e., we get relatively simple formulae which can be easily used for practical calculations). Therefore, those topics are not discussed in our electronic textbook.

Theoretical description of wave propagation in homogeneous medium is given in **[1]** and **[2]**. Practical relations for the solution of given engineering tasks are in **[3]** at your disposal.

Examination of electromagnetic wave propagation complicates in the situation when some inhomogeneity appears in the medium. The inhomogeneity can cause wave reflection, wave scattering or wave diffraction. Reflected (scattered, diffracted) waves interfere with incident waves. In the surrounding of the inhomogeneity, regions with higher intensity (compared to the case without inhomogeneity) can appear (*primary wave* and *secondary one* are of the same phase). Next, regions with very low intensity can be found (*primary wave* and *secondary one* are of the opposite phase).

Therefore, computation of the wave propagation in an inhomogeneous medium is much more complicated than is a homogeneous one, and even understanding the mathematical description and building a proper notion is much harder. Therefore, we are going to study the related phenomena more in detail here.

In an inhomogeneous medium, its electric and magnetic parameters (permittivity, conductivity, permeability) change from a region to another region. Moreover, variations of parameters can be continuous or discontinuous.

The discontinuous variation of parameters is characteristic for the surface of objects, i.e. for an medium containing conductive or dielectric (or ferromagnetic) objects. In a real situation, buildings, trees, hills, cars, people or raindrops play the role of those objects. In our textbook, we start to examine those phenomena in an example of a thin planar sheet, which neither reflects nor transmits the incident wave. We are speaking about Fresnel diffraction and we describe it in chapter 2.1.

In the practical life, more realistic objects have to be considered. Including those considerations to our computations is enabled by the general theory of diffraction, which is described in chapter 2.2. In this chapter, the diffraction on an infinitely long perfectly conducting circular cylinder is discussed.

In chapter 2.3, geometric optics is introduced. Geometric optics is an efficient method for the computation of wave phenomena in more complicated media. This method adopted the conception of wave propagation along *beams*. Comparing to the classical geometric optics, we can compute the intensity variations and wave polarization for wave propagation in the medium with continuously changing parameters.

Chapter 2.4 deals with the geometric theory of diffraction (GTD). GDT extends the abilities of the geometric optics to the media with discontinuous inhomogeneities. GTD solves interaction of beams and objects, and laws of geometric optics are modified in order to eliminate obvious errors (intensity discontinuities on the border between the reflection and shade) on one hand, and to preserve advantages of the geometric optics on the other hand (conception of beams).

All the section is closed by the examination of *layered media* (media consisting of several layers of different permittivity and different thickness). Borders of layers are usually planar and parallel. Hence, the layered media consists of a certain number of plan-parallel layers. More information is given in chapter 2.5.