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C O N T E N T S

APPLIED ELECTROMAGNETICS

Wireless solution for traffic monitoring

Elena Chervakova, Marco Goetze, Tino Hutschenreuther, Hannes Toepfer, Bojana Nikolić, Bojan Dimitrijević

This work describes research aspects of the development of a sensor system to register traffic-related data, such as the number, type, and speed of vehicles on a "tactile road". This system aims to provide a cost-effective means of expanding upon existing traffic detection infrastructure in order to enable more accurate modeling and predictions and in turn contribute to the growth of electromobility by providing a basis for dedicated navigation solutions as well as for traffic control. Firstly, the overall system made up of several components will be described and aspects of the development of the embedded systems involved will be discussed. Secondly, the fact that the traffic sensors were to be realized as in-ground detectors brings about challenges concerning wireless communications considering the placement of sensors and the urban environment. Consequently, antenna configurations play a crucial role and have been both tested extensively and modeled theoretically. These research issues are described, results are explained and illustrated.

Introduction

Traffic monitoring is considered an essential means in realizing concepts of electromobility. Especially for electric vehicles with their shorter range compared to conventional vehicles, optimum navigation with respect to trip time and distance travelled is strongly dependent on up-to-date local information, such as link travel times or details on traffic congestions. This stimulates research towards solutions aimed at offering an adequate data basis for facilitating the growth of electromobility.

Application background

To support acquisition of data on road users, research activities are devoted to wireless sensor solutions that can be installed very easily at lower cost than the cable systems currently in widespread use for traffic detection. To this end, a sensor unit installed in the ground utilizes a magnetic field sensor. Passing vehicles cause a local change in the earth's magnetic field, enabling their detection. Furthermore, the vehicle's type can be classified, and using a pair of consecutive detectors, its speed can be determined.

In order to avoid having to wire detectors, these need not only be battery-powered but also communicate wirelessly. As the range of low-power wireless communications is limited, detectors at a given location (typically, an intersection or a cross-section of a road) communicate locally with a gateway. Gateways in turn employ mobile communications to deliver aggregated data to a central data concentrator which interfaces with a traffic computer system.

This way, a "tactile road" is formed which enables measuring the traffic flow. Fig. 1 shows the components resulting from the R&D discussed in this paper in context.

Fig. 1. Actual installation of a detector (electronics and housing shown separately) at an intersection in Erfurt. The position of the detector in the road can be recognized by the dark patch on the street. The gateway is attached to a traffic lights post at a height of 4 m.

In the project, the results were to be evaluated in the model city of Erfurt in central Germany. There, the new wireless sensor networks were to complement the detection solutions already in place, allowing traffic for data to be registered in finer detail than before.

Analysis of transient plane wave coupling to horizontal conductor in homogeneous lossy soil

Vesna Arnautovski-Toševa, Leonid Grčev, Marija Kacarska

Modeling of transient behavior of wire conductors in presence of lossy soil has been a subject of great amount of research. This problem has been dealt with in different ways, from application of rigorous full-wave approaches based on Sommerfeld formulation to simplified models more suitable for practical engineering studies. This paper presents comparison of two distinct approximate models for analysis of transient plane wave coupling to horizontal wire conductor buried in homogeneous lossy soil. The first approach uses quasi-static approximation of corresponding Green's functions that arise in rigorous Sommerfeld integral based on image and complex image theory. The second approach uses transmission line theory where two formulations are compared. The first one is based on Sunde's integral whereas the second is based on simplified logarithmic expression for per unit length impedance. The authors compare the range of applicability of the two forms of image models and the two forms of transmission line models in practical EMC studies. The results are verified by comparison with Sommerfeld model on the basis of rms error of the current distribution with respect to frequency range from 10 kHz to 10 MHz.

Introduction

The electromagnetic field coupling to buried wires has been analyzed in many electromagnetic compatibility (EMC) studies [1]–[2] due to great practical interest. The analysis is often done by using approximate transmission line (TL) modeling due to the simplicity in implementation and use in existing software for high frequency analysis. However, this approach does not represent complete solution for the given problem since it doesn't include the radiation effects. On the other hand, the antenna theory approach based on rigorous electromagnetic theory [3] with at least approximations is often computationally inefficient. For that reason approximate methods within antenna theory models have been studied intensively [4]–[5], which are based on quasi-static image approximation. The results given in [6] show that significant differences between different models arise especially when analyzing buried wire conductors.

In this paper we compare the accuracy of two approximate approaches. The first approach is based on quasi-static (QS) image theory, and the second one is based on transmission line (TL) theory. Next, a comparison with respect to exact full-wave model will be done on the basis of by rms error of the current distribution with respect to frequency range from 10 kHz to 10 MHz. The main objective is to analyze the applicability domain of the analyzed models in practical EMC studies. The results are also compared by Numerical Electromagnetic Code (NEC) reflection coefficient solution.

Mathematical model

Consider a single *x*–directed horizontal conductor of radius *a*, and length *L* buried at depth *d* in finite conductive homogeneous soil, shown in Fig. 1. Here we assume uniform plane wave of normal incidence $\boldsymbol{E}^i = \hat{i}_x E_0 \exp(jk_0 z)$. The homogeneous lossy soil is characterized by permittivity $\varepsilon = \varepsilon_0 \varepsilon_r$, permeability μ_0 and conductivity σ.

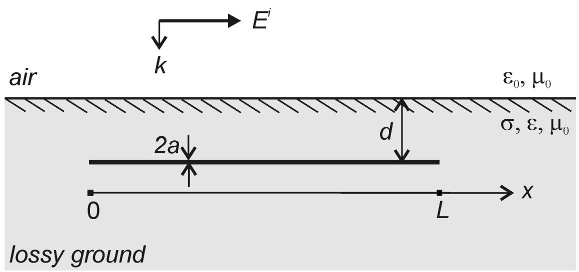

Fig.1. Horizontal wire conductor in lossy soil illuminated by a uniform plane wave of normal incidence.

To solve induced currents for a given problem we use moment method where the wire conductor is segmented in fictitious segments and the current

FEM – analysis of current displacement phenomena in slot embedded solid conductor

Marian Greconici, Gheorghe Madescu, Marius Biriescu, Martian Mot

In the paper the low-frequency eddy currents into solid conductors embedded in a slot are theoretically analyzed. The electromagnetic field in conductors has been calculated using numerical method with a program based on finite element method (FEM) in order to compute the eddy factors in some practical cases. One estimates the critical height of a single layer solid conductor embedded in a slot at different current frequency. Also, for multi-layer cases with solid conductors on top of the other or side by side one calculate the eddy factors using FEM. Because one found considerable differences between numerical results and similar analytical results obtained through classical approach it is evident that some coefficients and curves used in classical design stage must be reconsidered. For these purpose modern techniques like numerical computation of the electromagnetic field with FEM in order to assess accurately the copper losses of electrical machines.

The time-varying magnetic field within a conducting material causes eddy currents that flow within the conductor in addition to the main current and causes additional and unwanted losses. This phenomenon leads to an uneven distribution of current density in the cross section area of the conductor and it is known as the skin effect, [1]-[4], or current displacement effect.

The skin effect increases the effective resistance of the conductors and thus also can produce significant losses in the conductors, and is, therefore, of interest in electrical equipment and especially in electric machines. In most of cases, this is an undesired phenomenon.

The present paper analysis the current density distribution within solid conductor and present some numerical results for conductors of rectangular shape embedded in a slot. Both, the magnetic field and current density distributions, on the cross section of the conductor are computed using the FEM.

Conventional approach

The variable magnetic field induces eddy currents causing a non-uniform distribution of current density on the cross section of a solid conductor. This effect results in an increase of the resistive losses as compared with the direct current (DC) resistive losses. The AC to DC resistance ratio (or AC to DC resistive losses ratio) is defined as “eddy factor”:

(1) $$k_r = \frac{P_{ac}[\mathrm{W}]}{P_{dc}[\mathrm{W}]} = \frac{R_{ac}[\mathrm{Ohm}]}{R_{dc}[\mathrm{Ohm}]} \,.$$

The method for the eddy factor calculus has been proposed for the first time by the A.B.Field [5]. Further research on the skin effect in the slot has been developed by Emde, the research results being published between 1908-1922. According with this research, the eddy factor for the layer “*p*” of a solid conductor (Fig. 1) of rectangular shape embedded in a slot (open-slot, or semi-closed slot) could be calculated with [6]-[8]:

(2) $$k_{rp} = \varphi(\xi) + \frac{I_u\left(I_u + I_p\right)}{I_p^2} \cdot \psi(\xi)$$

where, k_{rp} is the eddy factor of the conductor in the layer “*p*”, I_p is the current through the conductor in layer “*p*” and I_u is the total current of the conductors placed under the layer “*p*”, i.e.:

(3) $$I_u = \sum_{k=1}^{p-1} I_k \,.$$

The auxiliary functions used in (2) are defined as:

(4) $$\varphi(\xi) = \xi \cdot \frac{sh2\xi + \sin 2\xi}{ch2\xi - \cos 2\xi}\,; \quad \psi(\xi) = 2\xi \cdot \frac{sh\xi - \sin\xi}{ch\xi + \cos\xi}\,,$$

with the dimensionless variable:

(5) $$\xi = h\sqrt{\frac{b}{b_c} \cdot \frac{\pi \mu_0 f}{\rho}} \,.$$

The eddy factor depends on the conductor height *h*, on the frequency *f* of the flowing current and on the resistivity of the conductor ρ.

Magnetoelectric energy source

Mirza I. Bichurin, Nikolay A. Kolesnikov, Roman V. Petrov, Slavoljub Aleksić

This article is devoted to the study of the magnetoelectric element based on magnetostrictive-piezoelectric laminate for use in energy harvesting devices. Magnetoelectric element works on the magnetoelectric effect which exhibits itself as inducing the electric field across the structure in an applied ac magnetic field and arises as a product property of magnetostriction in magnetic layer and piezoelectricity in piezoelectric layer. Possible applications of energy harvesting devices are in monitoring the human security, wireless sensor networks, telemetry, and others. Obtained results showed that one ME element can be used as an energy source.The layered ME structure based on the PZT plate had dimensions of 40x10x0.38 mm, and double-sided electrodes, which were fabricated from three layers Metglas and corresponded in size PZT plate. It was investigated element with dimensions 40x10x0.5mm, and the composition of the PZT-Metglas. Low frequency magnetoelectric coefficient was 1,24 V/(cm·Oe) at an output current of 2.6 microamp, on the resonant frequency of 41 kHz magnetoelectric coefficient was 1,32 V/(cm·Oe) at an output current 205 microamps.

Introduction

The rapid development of modern civilization accelerates the process of mastering the new not covered by the technical progress of spaces. Development of electric networks such the already familiar for us would not be well-founded for any place. In some places there is the inaccessibility of the energy system, in others there is the need for an independent power supply for devices, thirdly this is a definite economic benefit from application of energy harvesting system. On practice a variety of devices converting the energy of vibrations, wind, light, temperature gradient and heat into electrical one are used as independent power supply devices or devices collecting the energy. Construction of such devices can use piezoelectric, inductive, photovoltaic, thermoelectric, electrostatic, dielectric, and other elements. Possible applications of energy harvesting ideas are in the field of structural and industrial monitoring human health, the cells of wireless sensor networks, telemetry, and others. This will ensure the new developments in the field of energy storage (supercapacitors, batteries, fuel cells, microbial cells, and others.), new technologies in the collection of energy, energy-efficient electronics for the collection and distribution of energy, bioenergetics. New development of magnetoelectric (ME) materials allows to design the new energy sources, which will be effective enough for the energy product [1]. ME materials are an effective means to collect energy [2]-[5]. The layered magnetostrictive-piezoelectric materials are suitable for installation in a variety system of self-contained or mobile destination. Despite the insignificant level of power generated by one element, this may be enough to provide by power supply, for example, the sensor circuit or the microprocessor.

This paper is devoted to the study of the properties of one ME element of small size for the better understanding of how it can be used in more complex devices such as, for example, generators or energy harvesters, each of which can contain up to several thousand of simple ME elements. The study of the energy characteristics of ME elements will allow to predict the probable level of received energy, to develop the design of complex devices for collection of energy, to identify the most effective modes and to understand the ways of further improvement of ME elements for energy harvesting.

ME element

ME element can be manufactured for example of magnetostrictive and piezoelectric layers [6]. Layered structure based on piezoceramic PZT plate in this case had 0.38 mm of thickness, 40 mm of length and 10 mm of wide, Fig 1. Piezoelectric was polarized in the

FDTD simulation in wireless sensor antenna application

Bojan Dimitrijević, Bojana Nikolić, Slavoljub Aleksić, Nebojša Raičević, Hannes Toepfer, Elena Chervakova, Tino Hutschenreuther

In this paper an own developed FDTD simulation environment is employed for antenna analysis in a wireless sensor network for traffic monitoring. The analyzed antenna is part of a WSN node that is placed in the street. The node is protected by being placed in a plastic tube with a lid. Since this in-road implementation differs from the conventional use, properties of the applied commercially available antenna don't match the ones specified by the manufacturer. For this reason it is necessary to investigate how much this specific installation influences radiation properties of the applied antenna configuration and perform parameter analysis. It is shown that the influence of surrounding material and the change of weather conditions (which are represented through the change of relative electric permittivity and specific electric conductivity) doesn't affect significantly antenna operation in the applied design. Mounting of the antenna on PCB favorably affects matching properties of the antenna.

Introduction

A rapid advancement in computer technology today has made the computational electromagnetics (CEM) in general a powerful tool for antenna analysis and design, radar signature prediction, EMC/EMI analysis, design of electrical and medical devices and the prediction of radio propagation. One of the CEM methods that receive increasing attention in the literature is certainly the finite difference time domain (FDTD) method [1], [2]. Since this is a time-domain method, it is possible to obtain the system response in large frequency range with only one simulation run. It is particularly suitable for preliminary tests and parameter analysis in antenna design applications. However, one should be aware of its limitations. Namely, in the case of highly resonant structures the method suffers from lower accuracy and has long simulation times and a slow decay of the time-dependent electromagnetic (EM) fields [3]. Since wireless sensor application requires narrow band antenna, the modeling in FDTD was an additional challenge. Thus, it requires careful selection of parameters and cautious interpretation of the obtained results.

In this paper an own developed FDTD simulation environment is employed to analyze antenna and propagation properties of a specific wireless sensor network (WSN) for traffic monitoring that is developed at the Institut für Mikroelektronik- und Mechatronik-Systeme gemeinnützige GmbH (IMMS), Ilmenau, Germany [4]. In this application scenario, detectors utilizing magnetic field sensors are placed in the road surface to detect passing vehicles. The detectors function as WSN nodes communicating with a local gateway pole-mounted at a height of 4 metres. Besides line-of-sight obstructions due to traffic and the influence of seasons and weather, the typically low angle resulting from the communication between nodes and the gateway at intended distances of up to 100 metres poses issues which initiated the research discussed in this article. Additional details on the application context have been given in [5].

The commercially available antenna configuration, previously proven to be the most suitable solution for the particular application, was tested in the FDTD simulator and a parameter analysis is performed.

FDTD formulation

As a simulation tool, an own developed FDTD simulation environment is used. The exact update equations for H and E field components can be presented as (for the brevity only equations for H_x and E_x field components are presented)

Design of near perfect reconstruction IIR QMF banks

Nikola V. Stojanović, Dragana U. Živaljević, Negovan M. Stamenković

In this paper, we present a novel approach for the design of near-perfect-reconstruction two-band IIR quadrature-mirror filter banks. The proposed design method is carried out in the polyphase domain, where IIR filters are employed for non-linear phase compensation introduced by the allpass filters. In contrast to previous approaches in literature, IIR phase-compensation filters can be designed very efficiently using MATLAB software. Furthermore, starting from a generalized two-band structure, we introduce three special cases with different properties based on the same design principle. In all systems the remaining phase distortions are controllable and can be made arbitrarily small at the expense of the additional system delay. Simultaneously, aliasing can be minimized or completely canceled if further delay can be tolerated.

Introduction

Two-channel quadrature mirror filter (QMF) banks have received considerable attention and investigated for various signal processing applications, [1], [2], such as speech coding, communication systems, image compression and design of wavelet bases. In designing of QMF banks, three types of error that have to be eliminated or minimized exist: aliasing distortion, magnitude distortion and phase distortion. The conventional methods for QMF bank design, generally utilize the structure of finite impulse response (FIR) or infinite impulse response (IIR) to design a prototype low-pass analysis filter satisfying perfect or near perfect reconstruction conditions. However, the direct optimization of the prototype low-pass analysis filter yields both magnitude and phase distortions. Besides, the optimization procedure is complex and the computational requirements are burdensome.

Recently, the least-squares design of two-channel perfect reconstruction QMF banks can be constructed using a parallel combination of IIR all-pass filters. This approach allows more efficient implementation of the QMF bank in comparison to designing by the prototype filter. Much effort has been spent on designing IIR all-pass filters [3], [4] to simultaneously satisfy both magnitude and phase specifications. As compared to the prototype design of low-pass analysis filter, IIR all-pass-based methods have the advantages of focusing on the phase approximation without incurring both aliasing and magnitude distortions [3], and therefore posses lower computational complexity and accurate performance [5]. Therefore, the design of IIR all-pass-based QMF banks can be reduced to solving the all-pass filter optimization problem.

A number of IIR filter banks that have no aliasing and amplitude distortion have been reported [6]-[8]. The phase distortion is minimized by using a separate all-pass equalizer filter once the signal is reconstructed [9]. Perfect reconstruction two channel filter banks are presented in paper [10]. However, proposed IIR filter banks are not suitable for other applications where the constant group delay property of the analysis and synthesis banks are desired.

Several approaches have been developed for designing the IIR all-pass filters [11] based on reducing computational complexity or improving the design performance. In the literature [12], Kidambi formulated the IIR all-pass filter design problem as a linear phase optimization. The optimal all-pass filter coefficients are then obtained by solving a set of linear equations which involves a Toeplitz-plus-Hankel matrix. Consequently, the Cholesky decomposition or split Levinson algorithm can be used to efficiently solve the set of linear equations. The method proposed by Kidambi [12] is computationally efficient as compared to solving the general linear equations by directly computing a matrix inversion and multiplication. Furthermore, the computation of matrix inversion may cause numerical problems when the filter order is large. In previous work [13], the authors used trigonometric identities [14] and frequency sampling method to compute the Toeplitz-

Comparison of different models for determining the grounding rod resistance

Nenad N. Cvetković, Dejan B. Jovanović, Aleksa T. Ristić, Miodrag S. Stojanović, Dejan D. Krstić

Calculation methods, simulations and experimental measurement are carried out in the paper. The procedures include Method of Moments (MoM), empirical engineering equations for design of horizontal and vertical grounding rod electrodes, simulations and experimental validation. Calculation of grounding rod electrode resistance was performed with different empirical formulas. Obtained results by using these empirical equations that are used to estimate a grounding grid resistance in order to obtain required parameters such as touch and step voltage, maximum current, minimum conductor size and electrode size and maximum fault current level, are compared with simulation and experimental results. 3D simulation was performed in case of rod electrode with actual dimension and for this purpose FEM (Finite Element Method) - COMSOL software package is used and the potential distribution and resistances have been determined.

Introduction

The grounding rod electrode is one of the most commonly used earthing in the construction of grounding systems. As a very important part of each grounding system, it has a very wide intention. All grounding systems, regardless of the shape and design, have the same purpose and that is leading the fault current into the surrounding soil, safely and without consequences for the working environment. Grounding system of every power substation is performed by using rod electrodes connected together. Number of rod electrodes that constitute the grid, depends on the required value of the grounding system resistance. Because of that, internal meshes are performed in order to decrease grounding resistance. Rod electrode is of extremely significance for grounding system operation i.e. to provide proper function of electrical system, but to ensure the protection of people working in the vicinity of substation and equipment against danger of electric shock during the faults. Because of that it's very important to determine the grounding rod electrode resistance.

Procedure for determination of rod electrode resistance based on quasi-stationary approach, includes using the Method of Moments (MoM) [1], different empirical expressions for evaluation of rod electrode resistance, as well as Finite Element Method (FEM) based software package, COMSOL [2] and experimental validation.

The results obtained by using different empirical formulas are accurate within certain cases. Those formulas have some safety margins, due to usually long life time and aging effects.

Method of Moments

Applying quasistationary image theory and approach presented in [3], it is possible to analyze the rod ground electrode with length l and radius of cross-section a, ($a << l$), placed in homogenous soil of specific conductivity σ, Fig. 1. Specific conductivity of the air is labeled with σ_0 ($\sigma_0 \cong 0$).

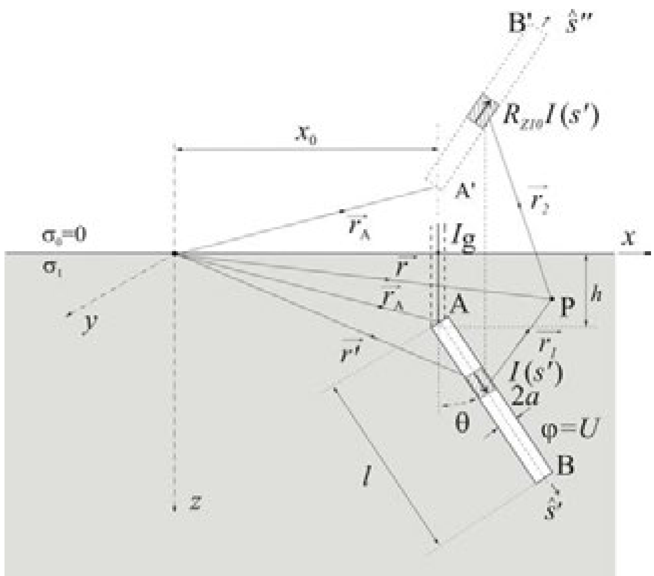

Fig.1. Rod ground electrode.

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