Proc. of the 2022 International Symposium on Electromagnetic Compatibility (EMC Europe 2022), Gothenburg, Sweden, September 5–8, 2022

Worst-Case Adaptive Model of Field Penetration into Shielding Enclosure

Eugene Sinkevich
EMC R&D Laboratory
Belarusian State University
of Informatics and Radioelectronics
Minsk, Belarus
esinkevich@bsuir.by

Yauheni Arlou
EMC R&D Laboratory
Belarusian State University
of Informatics and Radioelectronics
Minsk, Belarus
emc@bsuir.by

Natalia Sinyak
EMC R&D Laboratory
Belarusian State University
of Informatics and Radioelectronics
Minsk, Belarus
emc@bsuir.by

Ivan Shakinka
EMC R&D Laboratory
Belarusian State University
of Informatics and Radioelectronics
Minsk, Belarus
emc@bsuir.by

Xie Ma
China Electronics Technology
Cyber Security Co., Ltd.,
Chengdu, Taiyuan, China
18081045600@163.com

Wen-Qing Guo
China Electronics Technology
Cyber Security Co., Ltd.
Chengdu, Taiyuan, China
gigigigogogo@126.com

***Abstract*—A new approach to the description of the resonance properties of objects (vehicle compartments, cases of electronic equipment, connecting cables, etc.) in the problems of the analysis of electromagnetic compatibility and electromagnetic protection is proposed. The essence of the approach is to create worst-case adaptive models that adjust (adapt) a priori unknown resonance frequencies of the simulated objects for each input stimulus in such a way as to provide the worst value of the criterion of electromagnetic compatibility (or protection criterion). Within the framework of the proposed approach, a worst-case adaptive model of the penetration of electric and magnetic fields into a shielding enclosure (e.g., into a vehicle compartment) is developed; the model is based on the existing non-adaptive model using analytical expressions for the field inside a rectangular waveguide. The developed model is validated by the following example: the impact of external electromagnetic pulses (the radar pulse and E1 HEMP) on a vehicle (jeep) is analyzed; the results of the calculation by the developed model are compared with the results of the FDTD calculation.**

Keywords—electromagnetic interference, electromagnetic shielding, EMP radiation effects, time-domain analysis

I. INTRODUCTION

The wave dimensions of objects increase with increasing the frequency of electromagnetic disturbance. As a result of this, resonances are observed in many objects (compartments of vehicles, cases of electronic equipment, connecting cables, etc.). That is why the amplitude-frequency characteristics (AFCs) of such objects at high frequencies consist of many peaks observed at resonant frequencies and dips between these peaks [1], [2], [3].

When modeling parasitic electromagnetic couplings through such objects, the resonant frequencies are usually difficult to predict for the following reason: small errors and (or) simplifications in the mathematical description of object properties (geometry, structure) can lead to significant changes in the calculation results and to their deviation from the results of measurements [4], [5]. Incorrect prediction of the resonant frequencies by particular-case models (for example, by models of computational electromagnetics) can lead to erroneous prediction of absence of interference if the receptor or input disturbance is narrow-band (namely, if the bandwidth of the disturbance or the receptor is less than the frequency difference between two adjacent resonances of the object).

In order to avoid the erroneous prediction of absence of interference, frequency-domain worst-case envelope models are widely used for the analysis and design of electromagnetic compatibility (EMC) and electromagnetic protection. These models are formulated according to the following principle: it is conventionally considered that the resonance in the simulated object is observed at each frequency in the high-frequency region, therefore the worst-case model of AFC of the object is the upper envelope of the peaks mentioned above. The worst-case envelope model of AFC can be synthesized by the following methods: 1) analytically [6, p.227], [7], [8], [9]; 2) statistically, i.e., by processing the Monte Carlo simulation results [10], [4] or measurement results; 3) heuristically (for example, by connecting the maximums of one particular case of AFC with straight-line segments) [11], [12].

However, the worst-case envelope models are inapplicable in a situation where the input disturbance and the receptor are broadband: if the bandwidth of both the disturbance and the receptor is K times the peak width of the AFC of the object, then the use of the worst-case envelope model leads to an excessive overestimation of the response energy (or power for periodic disturbances) dissipated in the susceptible element of the receptor [13] approximately by a factor of K; the value of K may be so large that the worst-case envelope model is inadequate (useless in practice).

The purpose of this work is to develop a method for modeling an object whose resonant frequencies are a priori unknown; the method must make it possible to obtain adequate worst-case estimations of the critical parameters (energy, power, amplitude of time-domain realization) of the object response to an arbitrary electromagnetic disturbance in case of an arbitrary receptor bandwidth.

II. ADAPTATION OF RESONANT FREQUENCIES OF SIMULATED OBJECT TO INPUT DISTURBANCE

The most obvious way to achieve the formulated purpose is to combine the particular-case model and the worst-case envelope model. This can be done, for example, by the following algorithm: 1) estimate the frequency bandwidth of the input disturbance, the width of a peak in the AFC of the modeled object, and the bandwidth of the receptor; 2) based on these three values, decide whether to use the particular-case model or the worst-case envelope model. The limitation of such way is the high complexity of developing the