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Calculations and measurements of shielding effectiveness of slotted enclosure with built-in conductive stirrer

***Abstract**. Numerical analysis of shielding effectiveness (SE) of a slotted enclosure with built-in conductive stirrer has been presented. SE was calculated using two different methods: the Finite Element Method (FEM) and the Method of Moments (MoM). Results of calculations using two different electromagnetic simulators, COMSOL and FEKO, have been compared and experimentally validated using a GTEM cell test setup.*

***Streszczenie.** Przedstawione zostały wyniki obliczeń skuteczności ekranowania obudowy ze szczeliną i wprowadzonym do wnętrza metalowym mieszadłem. Obliczenia wykonane zostały przy użyciu dwóch różnych metod tj. Metody Elementów Skończonych (FEM) jak również Metody Momentów (MoM). Wyniki analizy numerycznej w programach COMSOL i FEKO zostały porównane z wynikiem pomiaru w komorze GTEM (**Obliczenia i pomiary skuteczności ekranowania obudowy ze szczeliną z zastosowaniem wbudowanego mieszadła przewodzącego**).*

Keywords: GTEM cell, shielding effectiveness, slotted enclosure, stirrer.
Słowa kluczowe: GTEM – komora, skuteczność ekranowania, obudowa z szczeliną, mieszadło.

Introduction

Theory behind shielding has been studied in detail long before numerical techniques for calculation of electromagnetic fields had been popularized. Analytical solutions for SE calculation exist rather for elementary problems [1]. Shielding is still important as one of methods for electromagnetic field reduction – both for emission and unwanted reception of electromagnetic disturbances although prediction of SE of real enclosures with their internal arrangement is still difficult.

In general, changes in slot sizes, their placement as well as enclosure internal arrangement will have a great impact on enclosure SE [2,3]. Using some simplification, numerical analysis can be performed for each enclosure internal setup. Unfortunately when it comes to SE measurement – tests have to be repeated for different setups. Because the need of changing orientation of the tested enclosure inside GTEM cell [4], measurement can be time consuming. This paper focuses on SE of slotted metallic enclosure with built-in conductive stirrer that is intended to represent several different internal enclosure setups. SE of the enclosure has been calculated with two different electromagnetic software suites Comsol and FEKO for several stirrer positions.

Enclosure model

Geometry of the slotted enclosure with placement of disturbance source shown on Fig. 1 is used widely in SE analysis [5-7].

FEM and MoM methods determine different construction of numerical model. MoM method requires meshing of introduced objects. In MoM, only introduced object have to be meshed so it leads to a conclusion that this method should be more efficient for Near Field calculations around the object of interest in comparison to FEM that require meshing of all volume inside and around the enclosure model.

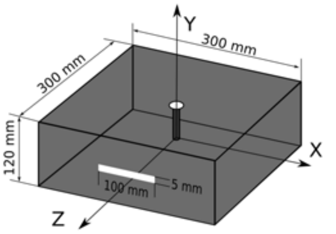

Fig.1. Enclosure model dimensions and source placement

Values of electric field in selected point in 10 cm distance in front of the slot aperture as well as total radiated power were considered.

Validation of numerical results for empty enclosure

SE of physical model made of 0,2 mm thin tin plated steel sheets has been measured using GTEM cell with network analyzer, amplifier and attenuators Fig. 2. S12 parameter was measured for both reference plane with monopole and tested enclosure. SE was calculated as difference in measured values of S12 parameter.

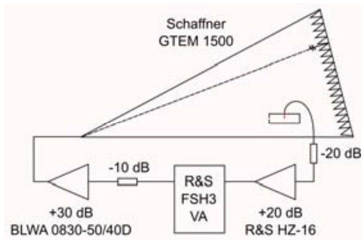

Fig.2. Measurement setup schematic

On Figs. 3 and 4 measurement results of SE and results of numerical simulations are compared. Analytical solution was calculated using algorithm described in [6].

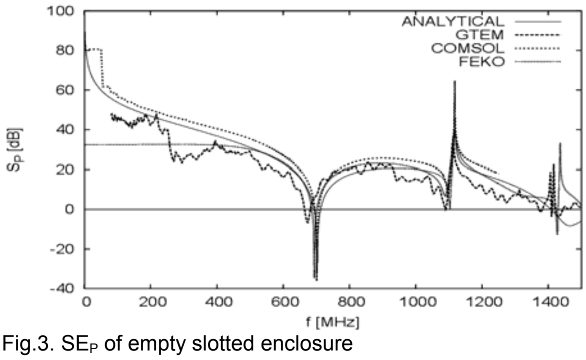

Fig.3. SE_P of empty slotted enclosure

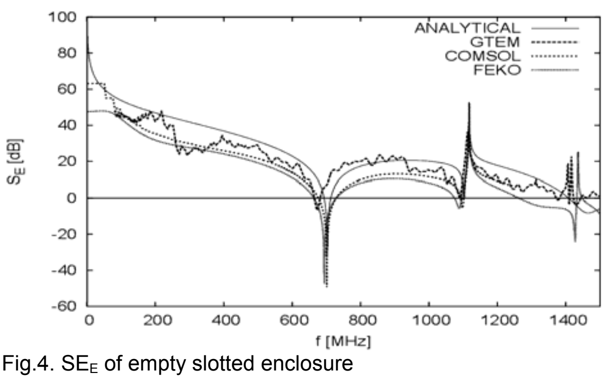

Fig.4. SE_E of empty slotted enclosure

SE characteristic calculated using total radiated power (Fig. 3) is different than the one calculated using field value in tested point in front of the aperture (Fig. 4). It is worth mentioning that for FEKO, power calculation in case of this specific model shows great deficiency for low (below 500 MHz) frequency range.

When using total electric field intensity, there is no such deficiency (Fig. 3 vs. Fig. 4). Calculations done with COMSOL had better consistency in this case.

Calculated results are in close agreement to the one presented in [3-5]. Numerical simulations show some inconsistency for frequencies below 100 MHz (FEKO) and 30 MHz (COMSOL). Increasing the number of elements in model, rises the frequency where the anomalies exists for both simulators. Because of those errors – results of SE for this model at these lower frequency ranges should not be considered reliable.

Model with internal stirrer

To simulate some changes in internal geometry, conductive stirrer was introduced inside the enclosure (Fig. 5). Numerical analysis was performed for several steps of rotation of the stirrer.

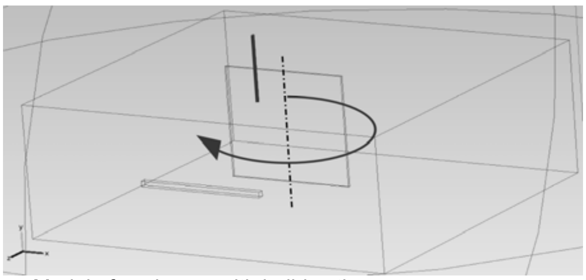

Fig.5. Model of enclosure with buil-in stirrer

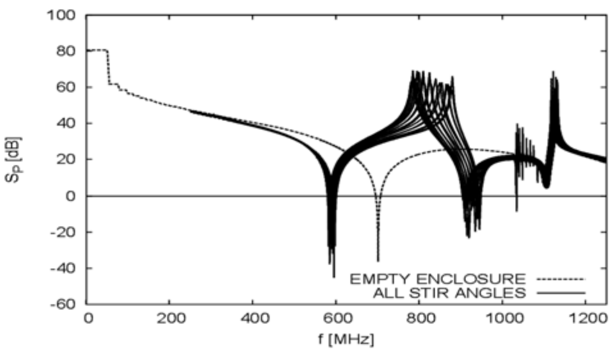

Fig.6. SE_P for all stirrer positions - COMSOL

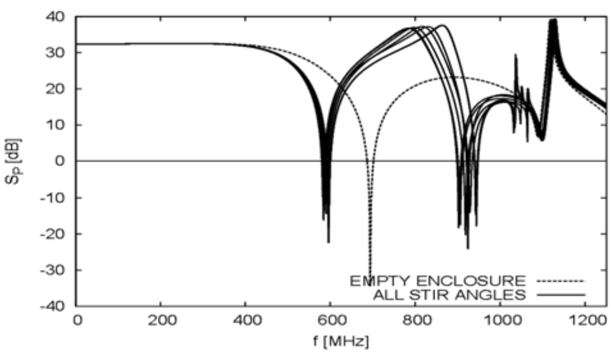

Fig.7. SE_P for all stirrer positions - FEKO

SE characteristics for all analyzed stirrer angles are compared with SE of empty enclosure on Figs. 6 and 7 for both electromagnetic simulators. FEM simulation was performed for 18 stirrer angles with the step of 10 degrees. MoM simulation was performed for 7 selected stirrer angles (of 0, 10, 20, 45, 60, 90, 135 degrees).

SE based on total radiated power calculated by FEKO (Fig. 7) is limited to its maximum value of 40 dB. For lower values of SE (below 20 dB), calculated results are similar to those obtained with COMSOL simulator.

Conclusions

Both method of calculation of electromagnetic field can be used for SE analysis of the enclosures. However some precautions should be considered when selecting model parameters as well as SE calculation method. Both numerical simulators show some weaknesses at low frequency range for presented model (below 30 MHz for COMSOL and 100 MHz for FEKO). Results for this range cannot be considered reliable. It is worth noticing that relying on total radiated power calculated when using FEKO can be misleading. Simulator notifies user about anomalies that could corrupt the output data, but discrepancy extends beyond the range of frequencies that trigger warning message. In such case, considering some near field based estimations could help to get the better view of the possible results. COMSOL proved to be more robust to obtain coherent results of the calculation for this particular model.

REFERENCES

[1] Schulz R. B., Plantz V. C., Brush D. R., "Shielding Theory and Practice," *IEEE Transactions on Electromagnetic Compatibility*, vol. 30, pp. 187-201, August 1988.

[2] Dehkhoda P., Tavakoli A., Moini R., "An Efficient and Reliable Shielding Effectiveness Evaluation of a Rectangular Enclosure With Numerous Apertures", *IEEE Transactions on Electromagnetic Compatibility*, vol. 50, pp. 208-212, February 2008.

[3] Wallyn W., Zutter D., Laermans E., "Fast Shielding Effectiveness Prediction for Realistic Rectangular Enclosures", *IEEE Transactions on Electromagnetic Compatibility*, vol. 45, pp. 639-643, May 2003.

[4] IEC 61000-4-20 Electromagnetic compatibility (EMC) – Part 4-20: Testing and measurement techniques – Emission and immunity testing in transverse electromagnetic (TEM) waveguides, 2007.

[5] Robinson M. P., Turner J. D., Thomas D. W. P., Dawson J. F., Ganley M. D., Marvin A.C., Porter S. J., Benson T. M., Christopoulos C., "Shielding Effectiveness of a rectangular enclosure with a rectangular aperture", *Electronics Letters*, vol. 32, pp. 1559-1590, August 1996.

[6] Robinson M. P., Benson T. M., Christopoulos C., Dawson J. F., Marvin A. C., Porter S. J., Thomas D. W., "Analytical Formulation for the Shielding Effectiveness of Enclosures with Apertures", *IEEE Transactions on Electromagnetic Compatibility*, vol. 40, pp. 240-248, August 1998.

[7] Thomas D. W. P., Denton A. C., Konefal T., Benson T., Christopoulos C., Dawson J. F., Marvin A., Porter S. J., Sewell P., "Model of the Electromagnetic Fields Inside a Cuboidal Enclosure Populated with Conducting Planes or Printed Circuit Boards", *IEEE Transactions on Electromagnetic Compatibility*, vol. 43, pp. 161-169, May 2001.

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