Investigations of Near-fields at Low and High Frequency using Numerical Approach

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Abstract — To design electromagnetic compatible products, it is one of the challenging task for EMC engineers as well as industries. To solve electromagnetic problems, computational electromagnetic techniques have been used for low and high frequency models at near-field before makings final products. For EMC modelling and simulation of a contactless fractal planar transformer at low frequency and dual die CPU at high frequency, electromagnetic field analysis and FEM techniques have used respectively. To validate results, near-field scanner has used to collect experimental data to compare with simulation.

I. INTRODUCTION

Electromagnetic Interference (EMI) is most significantly concerned and challenged in electronic products design because it could cause devices malfunction, subsequently unreliable and possible hazards. Electromagnetic Compatibility (EMC) holds a significant element during design and manufacture of electronics products. For ideal EMC, the system should satisfy criteria such as no interference generated to other systems as well as its self, not susceptible to the emissions from other systems. The traditional EMC engineers have mostly focused on the design of PCBs, enclosures and cabling to solve electromagnetic problems. Although, with higher frequency and integration density, stronger transient current generated due to switching activity of millions of transistors acting at same time. But at low frequency, EMC problems are immunity and radiations.

Since computational electromagnetic modeling techniques have moved from analysis to design in engineering practice. It can be used to solve real life EMC problems and help industry to provide better products and equipments. Furthermore, Computer modelling and simulation is used for the product design and problem prediction before making the products. This is the most cost effective way to design products.

Two numerical models, a dual die CPU and a contactless fractal planar transformer are discussed for high and low frequency respectively.The EMC modelling and simulation of a dual die CPU requires full-wave techniques, and for low frequency models such as power supply, contactless planar transformers require magnetic field analysis. Using FEM frequency domain approach for both low and high frequency, scan certain frequency ranges, for example several frequency-domain simulations can usually be run in the time and it would take for a single time-domain simulation. A further benefit to using frequency-domain codes is their capacity to use larger meshes for the lower frequencies, which in turn permits a shorter computation time. For low frequency, Near-field measurement is very difficult because any destruction can change the field distribution easily but it can be solved by simulation and calculated by analytical method [1]-[3].

II. NUMERICAL MODELS FOR NEAR-FIELDS

A. *Low frequency numerical model*

The contactless fractal planar transformer has the similar structure with others planar transformers. It consists of two pieces of flat ferrite and two fractal planar windings on the surface of PCB. It will be used to design contactless battery charger to charge small devices such as mobile phones. The contactless fractal planar transformer's structure is show in Fig .1.

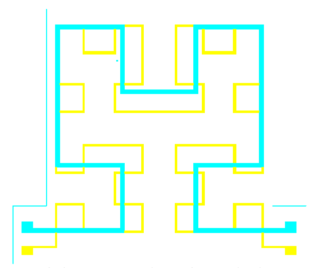

Fig. 1. Structure of the contactless fractal planar transformer.

The magnetic filed in the contactless fractal planar transformer can be determined by the following vector magnetic potential equation (1):

$$\nabla \times (\nu \nabla \times A) + \sigma(\partial A / \partial t) = J. \qquad (1)$$

where ν is the magnetic reluctivity , σ is the conductivity and A and J are magnetic vector potential and current density respectively. Galerkin's method is used to discretise the governing equation to solve the Low frequency problem. The FEM system matrix equation can be obtained as shown in equation (2):

$$G=[S]\ \{A\} + [M]\ \{A\}-\{K\} \qquad (2)$$

where the matrix [S] is global coefficient matrix, [M] is the time harmonic matrix, and {K} is driven source.

B. *High frequency numerical model*

The dual die CPU model was designed by applying microstrip patch antenna structure is show in Fig 2.

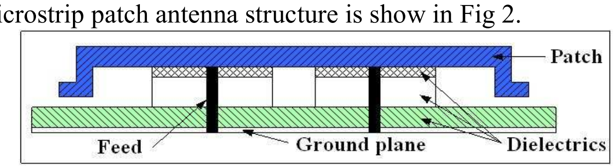

Fig. 2. Applied microstrip patch antenna structure for a dual die CPU model.

A complete solution to Maxwell's equations can derive from the full-wave computational technique within the computational domain for all conductors and materials. In this paper, frequency domain EM modeling was used. Frequency-domain codes are sufficient for antenna work and for examining specific issues because it can solve one frequency at a time. The frequency domain vector wave equation for ***E*** field can be written as (3):

$$\nabla \times \frac{1}{\mu} \nabla \times \mathbf{E} + \sigma_e \omega \mathbf{E} + \omega^2 \varepsilon \mathbf{E} = -j\omega \mathbf{J} \qquad (3)$$

where ω is angular frequency, **J** is the source current, and μ and ε are the permeability and permittivity of the problem space respectively. Perfectly matched layer (PML) and a finite conductivity boundary were applied in the simulation model. FEM matrix equation can also be obtained by Galerkin's method as shown in equation (4):

$$[S]\ \{E\} + [M]\ \{E\} - \{K\} = 0 \qquad (4)$$

where the matrix [S] is global coefficient matrix, [M] is the time harmonic matrix, and {K} is driven source.

III. Results and Discussions

A. High Frequency problem

For High frequency numerical model, the simulation and experimental results are shown in Fig. 3 and 4 respectively. The simulation based numerical technique has been used to measure E-field of the dual die CPU model without the heat sink. For experimental result, the E-field of a dual die CPU model has been calculated with help of near-filed probes and scanner to solve high frequency near field EMC problems.

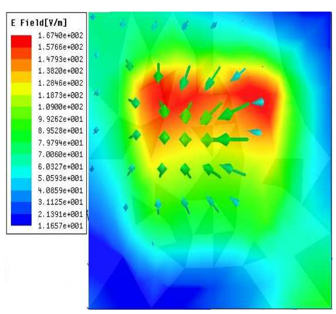

Fig. 3. E -field simulation plot of the dual die model without the heat sink.

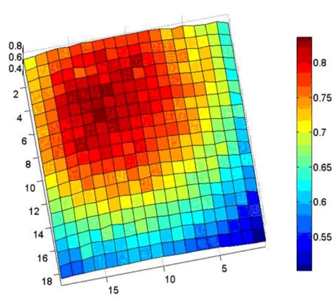

Fig. 4. Near-field measurement results of E field.

B. Low Frequency problem

For low frequency numerical model, 3D- magnetic field of basic fractal winding without ferrite at 1 MHz has been calculated by FEM based simulation method as shown in Fig. 5. In Fig. 5, peaks show the strongest magnetic field. At near-field, magnetic field distribution is so sensitive and difficult to measure because any destruction can change it easily. Therefore, the simulation method can easily solve EMC problems at low frequency. Furthermore, with the help of analytical technique, the simulation result can be verified.

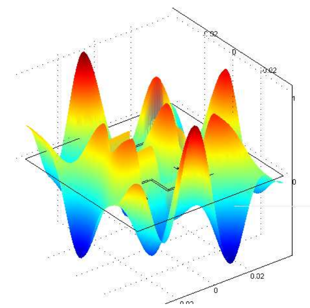

Fig. 5. 3D - magnetic field of basic fractal winding without ferrite at 1MHz.

IV. Conclusion

In conclusion, computational electromagnetic modeling techniques have been used to solve real life EMC problems. It can help industry to provide better products and equipments by computer modelling and simulation for the product design and problem prediction before making the products to meet current demand and supply. In this paper, the development of FEM approaches to EMC problems at low frequency such as contactless fractal planar transformer and at high frequency such as a dual die CPU comparatively magnetic field analysis and full-wave techniques. Experimental results were measured by near-field scanner for high frequency models and compared with the simulation. Numerical techniques are the best and cost effective ways to solve EMC problems.

V. References

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