Application Examples of Electromagnetic Wave Simulation Software "Poynting" in Manufacturing Industry

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It is becoming hard to produce designs when developing electronic equipment because of advances in packaging technology and strict regulations. It is specifically difficult to conform to electromagnetic compatibility (EMC) standards in the design phase. And this is a factor that causes development costs to increase. By implementing a simulation for virtual evaluation in the design phase of a printed circuit board (PCB), it becomes possible to significantly reduce the cost of measurement and evaluation. EMC measures in the design phase can be implemented by performing electromagnetic wave analysis of the whole model of a product comprised of a PCB, wiring and housing. To meet this need, Fujitsu has developed the electromagnetic wave simulation software "Poynting," that it markets and supports. Poynting is capable of rapidly carrying out calculations in a large-scale model with a high-performance computer system. It is suitable for analyzing noise in electronic equipment. This paper describes the features and advantages of Poynting. It also describes application examples of carrying out electromagnetic interference (EMI) analysis on power electronics equipment, near-field electromagnetic analysis of a PCB and electrostatic discharge (ESD) analysis of a cellular phone.

1. Introduction

In the field of design and development of electronic equipment, it is becoming hard to produce designs because of advances in packaging technology and strict regulations. In the technological background to this, efforts are being made to achieve high-density packaging, low-voltage driving and high-frequency clock to meet the product demand for improved processing speed, equipment downsizing and higher energy efficiency. In terms of regulations, there are requirements of standards on electromagnetic compatibility (EMC), which means resistance to electromagnetic waves radiated from itself or from the other equipment. In particular, it is difficult to conform to EMC standards in the design phase, which is a factor leading to increased development person-hours. In the past, developers often made a prototype for carrying out verification measurements and, if it failed to satisfy the EMC standards, they added countermeasure components while measuring the radiated electromagnetic noises and repeated trial and error to conform to standards. If applying countermeasure components was insufficient, then regulations, reworking including revision of the printed circuit board (PCB) design and LSI remaking was necessary, and this required re-prototyping and re-measurement. EMC relates to composite phenomena and is difficult to identify the source and mechanism. Accordingly, developers could not avoid taking measures dependent on their experience and intuition, often leading to application of excessive countermeasure components. For that reason, prolonged development periods and increased costs are posing a significant issue.

To address this issue, an approach is being taken in which virtual evaluation by a computer simulation is implemented in the PCB design phase, which is an upper process, thereby significantly reducing the person-hours required for prototyping as well as measurement and evaluation. As EMC measures, performing electromagnetic wave analysis of the whole model of a product comprised of a PCB, wiring and housing allows verification in the design phase.

This paper describes the features and advantages of the electromagnetic wave simulation software "Poynting,"[1] which is in use for EMC measures. It also describes examples of applying Poynting in scenes of product development to electromagnetic interference (EMI) analysis on power electronics equipment, near-field electromagnetic analysis of a PCB and electrostatic discharge (ESD) analysis of a cellular phone.

2. Advantages of electromagnetic wave analysis software Poynting

Poynting is general-purpose three-dimensional electromagnetic wave analysis software independently developed by Fujitsu. The following describes the advantages of Poynting.

2.1 Adoption of FDTD method

In the finite-difference time-domain (FDTD) method,[2] the object of analysis is divided by a orthogonal grid and Maxwell's equations, which are fundamental equations of electromagnetic waves, are calculated for both the time and space domains by calculus of finite differences. **Figure 1** outlines the FDTD method, which is characterized by the arrangement of coordinates of the electric and magnetic fields shifted with reference to the grid as shown in the upper right figure. In the time domain, the electric and magnetic fields are alternately calculated at every half-step. This method can be applied to wide-ranging fields from high-frequency microwave analysis to optical analysis. Calculation results of the FDTD method are obtained as temporal variations of the electromagnetic field in the same way as the real physical phenomena, which makes it suitable for analyzing transient phenomena such as impressed electro-static voltage. This allows the method to be linked with a circuit simulator, which will be described later. By applying the Fourier transform to the time-series data obtained, scattering parameters (S-parameters), which describe transmission characteristics of electronic circuits, EMI and other wideband frequency characteristics can be analyzed by carrying out electromagnetic analysis only once. The FDTD method allows easy 3D analysis of complicated shapes and facilitates simulation of product models imported from CAD data. The computational complexity of the FDTD method is in proportion to the number of grids that divide the model. Therefore, as compared with other analysis methods such as the moment method, in which the computational complexity exponentially increases with reference to the number of grids, the increase of the computational complexity of the FDTD method can be restrained even with large-scale analysis. This makes it suitable for analysis on scales used for industrial product development.

1) Boundary conformal function

Poynting is equipped with solver extension features for efficient implementation of analysis, one of which is the boundary conformal function. The conventional FDTD method uses a staircase approximation model even for an object with a curved surface, as

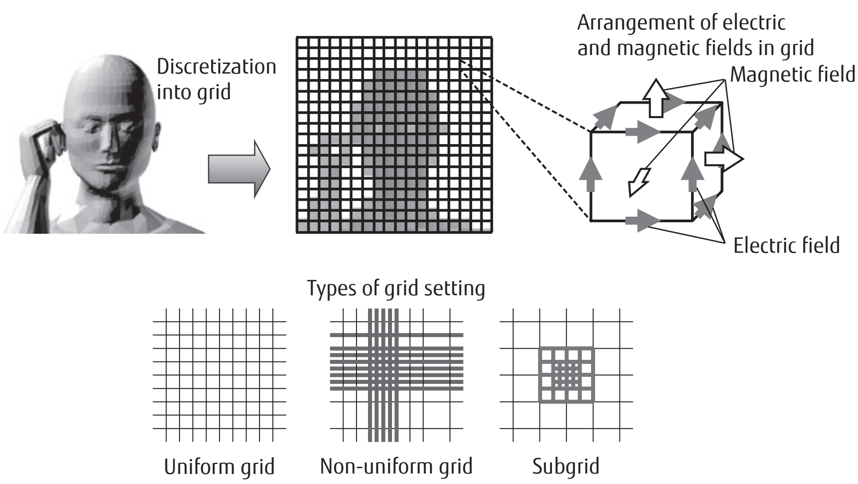


Figure 1
Outline of FDTD method.

shown in the left diagram in **Figure 2**, for calculation. The boundary conformal function takes into account a surface of the object that intersects the grid for calculation as shown in the right diagram in Figure 2, and this allows the characteristics of the shape to be maintained even with a large grid spacing and offers a high calculation accuracy. For verification of the accuracy, we have analyzed a model of a cylindrical cavity resonator of a perfectly electric conductor with a radius of 8.1 mm and height of 8.0 mm. The theoretical value of the resonance frequency of this resonator with accuracy is 14.166 GHz. The upper two graphs in **Figure 3** show the results of calculating resonance frequency using staircase approximation and boundary conformal function respectively. With the conventional staircase approximation, the divergence from the exact solution increases as the spacing of grids that divide the model becomes larger. Meanwhile, with the boundary conformal function used, the resonance frequency hardly varies even when changing the grid spacing. The lower graph in Figure 3 plots the grid spacing along the horizontal axis and the resonance frequency error along the vertical axis. It shows that use of boundary conformal function provides a higher accuracy than staircase approximation with the same grid spacing. Another point is that the computational cost required for achieving the same accuracy is significantly reduced by using this

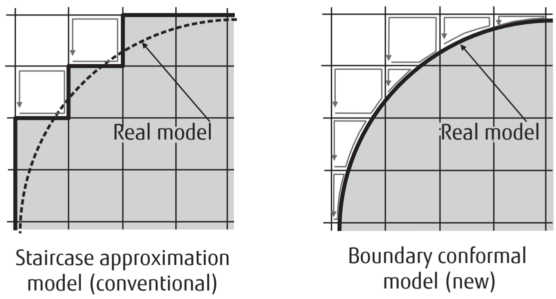


Figure 2
Staircase approximation and boundary conformal calculation techniques.

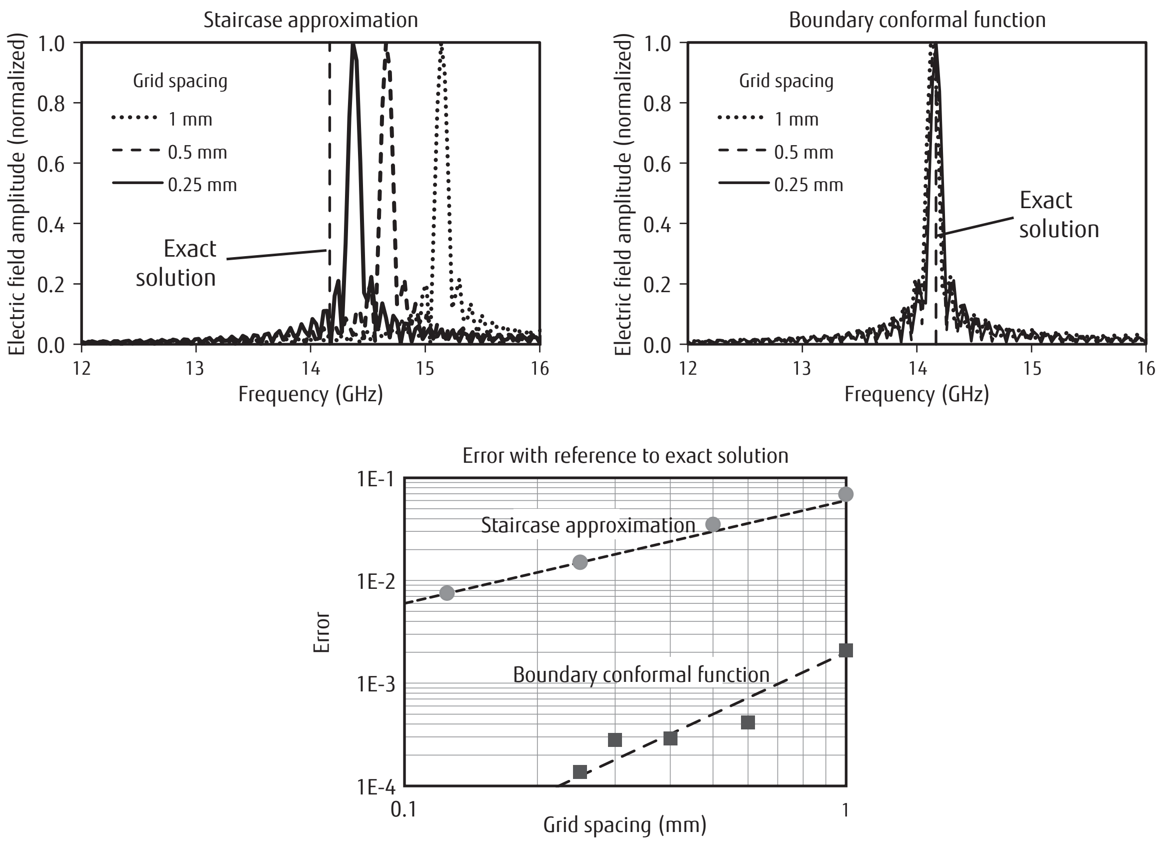


Figure 3
Comparison of calculation accuracy between staircase approximation and boundary conformal function.

function. The graph also indicates that, with boundary conformal function, the degree of accuracy improvement becomes higher than staircase approximation when the grid spacing is decreased.

2) Subgridding function

Poynting has the subgridding function, which locally provides a finer grid. Generally, software of the FDTD method allows the user to set non-uniform grid spacing in each of the three directions X, Y and Z, as shown in the lower center diagram in Figure 1. When non-uniform spacing is used to set grids for an analysis model that has a fine structure only in one location, the grid spacing is reduced not only in the fine-structured part but also in the areas along the three directions X, Y and Z centered on that part. This unnecessarily increases the number of grids and increases memory usage and computation time as well. Meanwhile, the subgridding function allows the user to specify 3D local area so as to reduce the grid spacing, and ensures that the minimum necessary number of grids is used for calculation. The upper diagram in **Figure 4** shows a model of a through-hole (hole for connecting between wiring of different layers) cut out from a PCB. We have applied a subgridding to this to set a finer grid only in the vicinity of the through-hole. The lower diagram in Figure 4 is a graph that compares the computation time and memory requirement between different grid settings. With the subgridding function used, the computation cost is decreased with the computation time reduced to approximately 1/2 and memory requirement to approximately 2/3 from those with a non-uniform grid.

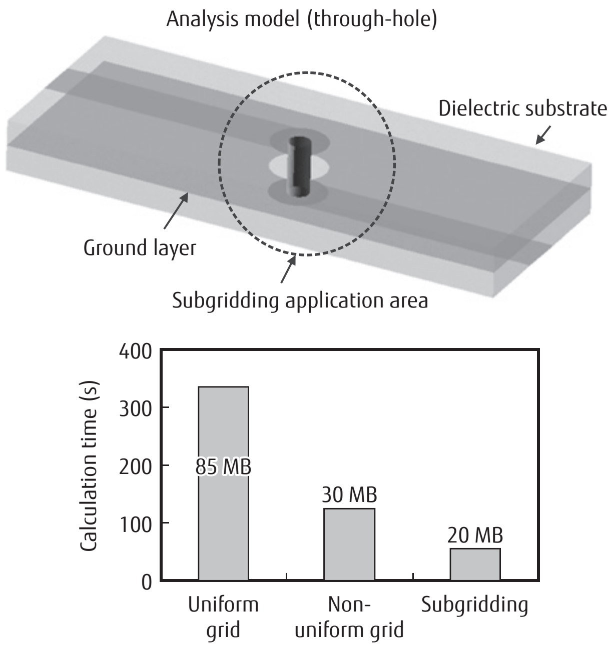


Figure 4
Calculation time and memory required for analysis with subgridding applied.

2.2 Parallel computation function

Parallel computing of the FDTD method is realized by dividing the computational domain and calculating the divided computational domain by each processor. The amount of communications between the divided domains is relatively small and the parallel performance is not much decreased by increasing the number of divisions, which makes it suitable for parallel computing. **Figure 5** shows the parallel computing performance of Poynting using Fujitsu's high-performance computer system FUJITSU Supercomputer PRIMEHPC FX10 (CPU: SPARC64 IXfx 1.65 GHz, 16 cores). The dotted line in the graph shows an ideal performance of the parallel computation. The analysis model is a PCB model with 2.05 billion grids, which is similar to the scale of analysis in practical product development, and a good computing performance of parallel computation is obtained up to about 1500 parallels. While performance with FX10 is presented here, good parallel performance has been achieved with PC cluster systems integrating Intel CPUs, such as Fujitsu's PC server FUJITSU Server PRIMERGY.

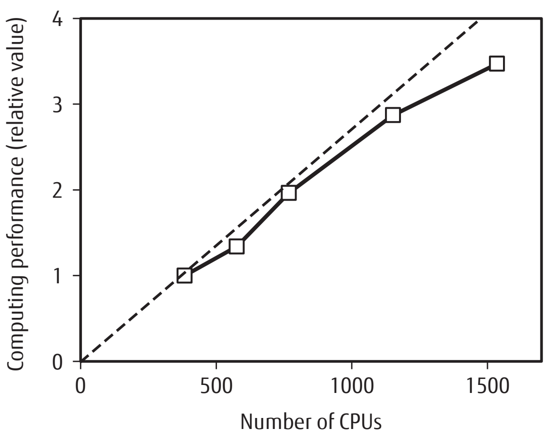


Figure 5
Parallel computing performance.

2.3 Circuit simulator linkage function

Poynting has the circuit simulator linkage function, which uses a circuit simulator to calculate the characteristics of circuit elements on a PCB for electromagnetic wave analysis. The upper diagram in **Figure 6** shows a conceptual image of operating the circuit simulator linkage. An IC, LSI, etc. on a PCB show nonlinear behavior. The conventional electromagnetic analysis dealt with these devices with simplified linear models, which posed the problem of insufficient accuracy when analyzing the PCB. Applying the circuit simulator to analysis of devices allows a user to reproduce nonlinear characteristics of power supply devices, LSIs and passive electronic components with parasitic elements taken into account. The circuit simulator uses analysis solver supporting Simulation Program with Integrated Circuit Emphasis (SPICE) for reproduction of the operation of an electronic circuit. The wiring portion of a PCB is analyzed by an electromagnetic wave simulator and linked analysis is executed by exchanging data with the circuit simulator through the linked analysis element. This allows higher-accuracy electromagnetic analysis of the entire PCB including reproduction signal waveforms and voltage fluctuation between the power supply layer and the ground layer that are closer to those of the actual equipment. Results of analysis using the circuit simulator linkage function and the partial element equivalent circuit (PEEC) method are compared in the lower diagrams in Figure 6. The result produced with this feature coincides well with a different computing method, which demonstrates its high accuracy.

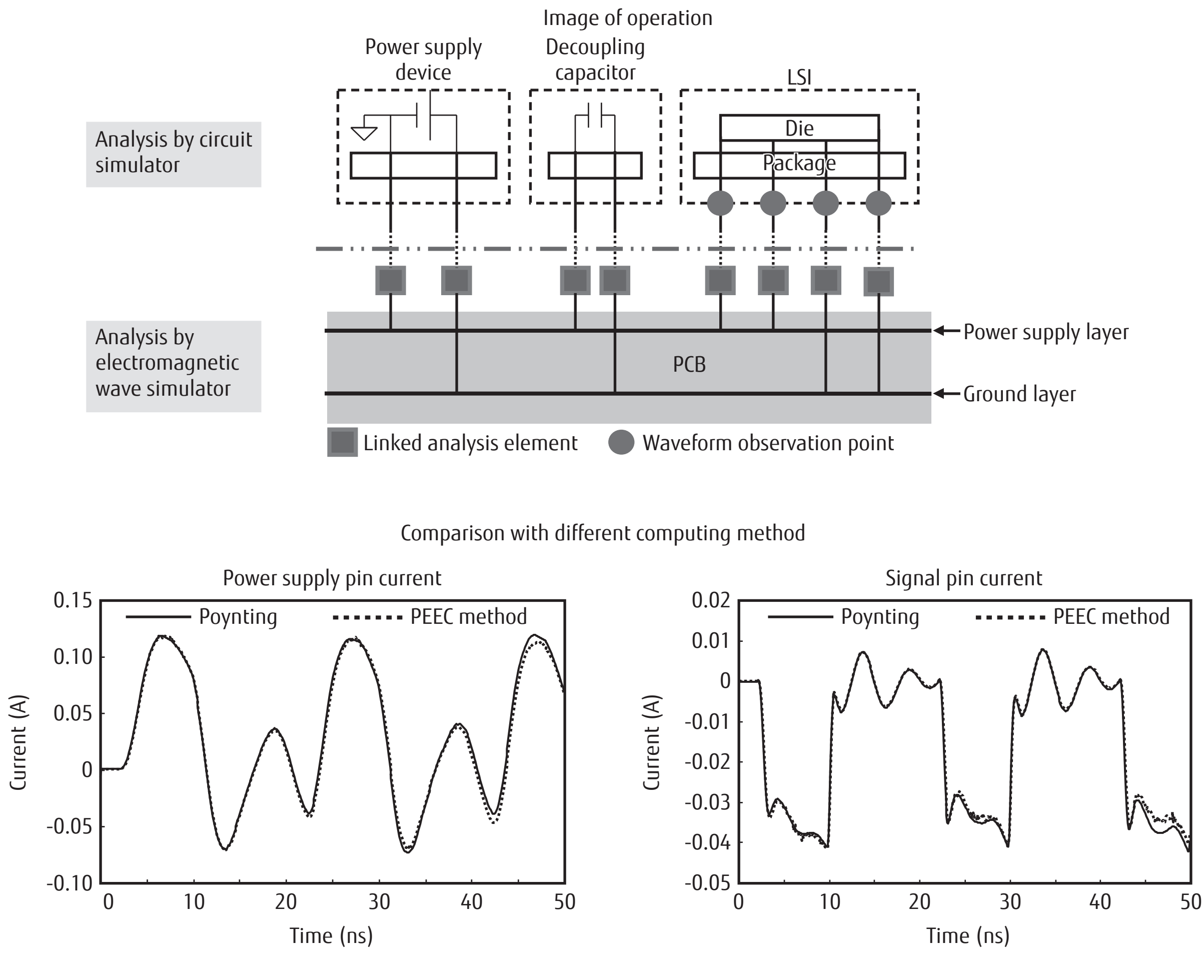


Figure 6
Circuit simulator linkage function.

3. Examples of analysis

3.1 EMI analysis on power electronics equipment

This subsection presents an example of analyzing the radiation noise of power electronics equipment of FUJI ELECTRIC CO., LTD., which uses Poynting.[3)]

Radiation noise generated from a piece of equipment is caused by PCBs, wire harnesses and metallic parts of housing. In addition, interference of these noise sources may increase radiated electromagnetic waves. For this reason, the entire structure of the equipment as well as the PCBs must be taken into account in simulation for its analysis as an integrated unit.

The left diagram in **Figure 7** shows the intensity distribution of an electric field radiated from power electronics equipment, which has been calculated by using this software. As the model, the power supply cable in addition to the main unit has been modeled. The result of analysis shows that radiated electromagnetic waves are generated not only from the main unit but also from the power supply cable. The right graph in Figure 7 is a comparison of the electric field intensity measured at a distance of 10 m from the equipment between the measurement and analysis values. The values coincide within the range of ±6 dB for the 30 to 100 MHz band. This band often causes problems in power electronics equipment, which demonstrates that electromagnetic wave analysis using Poynting is effective for suppressing the radiated noise of electronic equipment.

3.2 Development of cellular phone

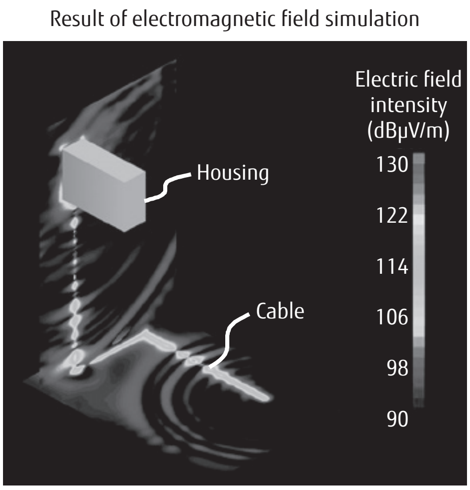
This subsection describes an example of applying Poynting to the development of Fujitsu's cellular phone.

1) Near-field electromagnetic analysis of PCB

As a common measure for reducing the noise generated from cellular phone PCBs, decoupling capacitors are provided for LSI terminals and other noise sources. In order to take effective measures by using the minimum number of decoupling capacitors, Poynting has been used to implement electromagnetic analysis. The upper diagram in **Figure 8** indicates the locations of six decoupling capacitors. The lower left diagram in Figure 8 shows the magnetic field intensity distribution with only two decoupling capacitors provided. There is a noise source where the magnetic field is strong. The right diagram in Figure 8 is the magnetic field distribution with all of the six decoupling capacitors provided. It shows that the intensity of magnetic field has become smaller and noise has been suppressed. The effectiveness of the noise suppression can also be confirmed by the higher magnetic field intensity near decoupling capacitors, which indicates a large current flowing into the decoupling capacitors. It demonstrates that electromagnetic simulation makes it possible to verify the effectiveness of noise suppression before prototyping.

2) ESD analysis

Cellular phones have had problems of increased sudden failures such as faulty operations, unintended



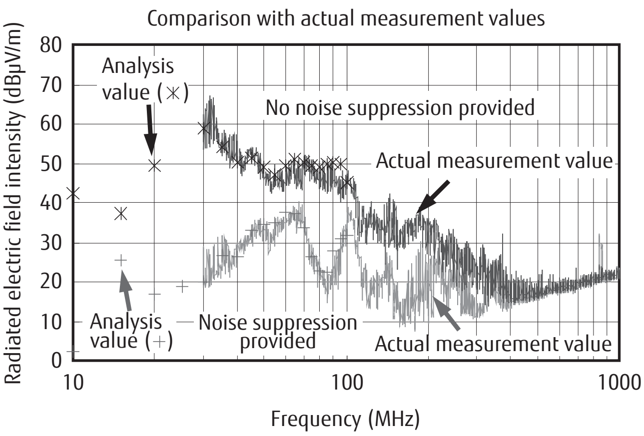


Figure 7
EMI analysis on power electronics equipment.

shutdowns and resets due to ESD, which is often generated in winter. To address these problems, Poynting has been used to verify the effectiveness of ESD noise suppression design before prototyping. An analysis model of internal components has been created from the CAD data of the product. The current pulse impressed on the component to simulate ESD. The right diagram in **Figure 9** shows the magnetic field distribution near the PCB with impressed current pulse, which is in proportion to the amount of current flowing in the PCB. While a current flows across the whole PCB before providing the noise suppression, it has been confirmed that, after providing the noise suppression, separating the ground of the PCB causes a current channel to be formed and the current flowing in the components on the PCB is decreased. This has reduced the number of failures caused by ESD and significantly cut the development costs.

4. Conclusion

This paper has presented the advantages of Poynting, electromagnetic wave analysis software developed by Fujitsu, and examples of its application.

In development and manufacturing of electronic

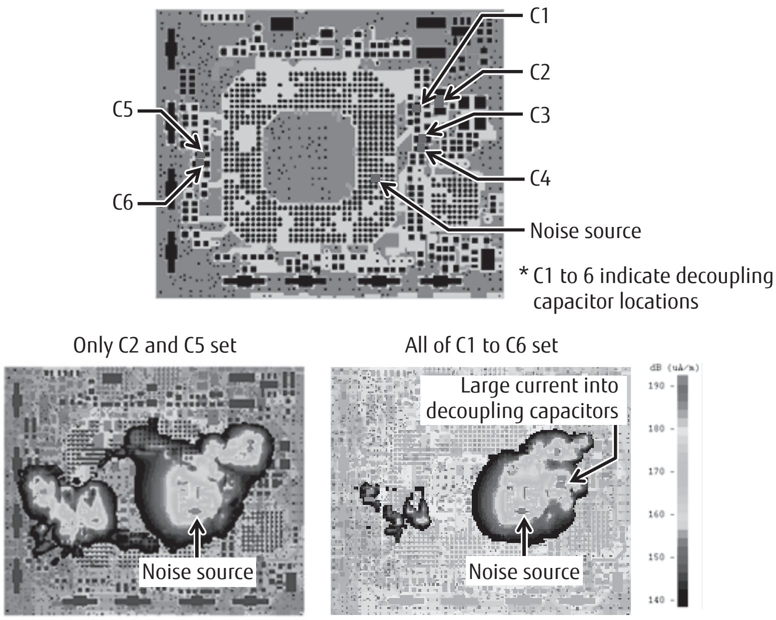


Figure 8
PCB analysis model and result.

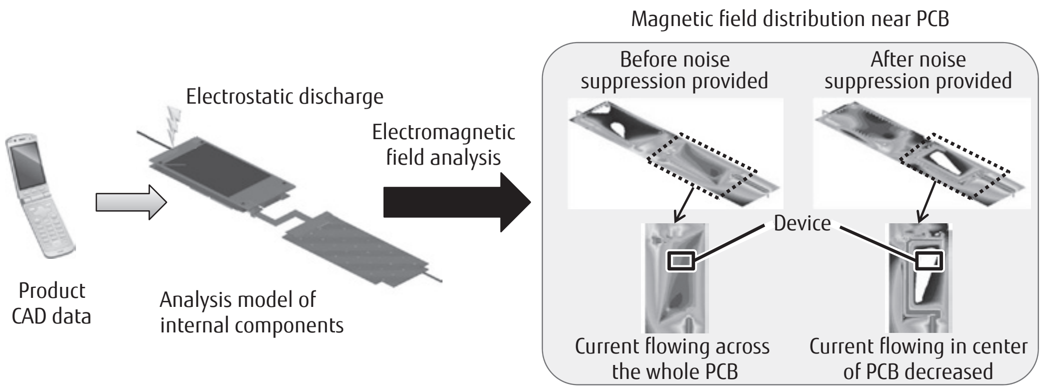


Figure 9
ESD analysis of cellular phone.

equipment, electromagnetic wave analysis is gaining importance due to the improved manufacturing technologies and standards. Poynting is highly versatile software developed to meet such needs. It is also suited for parallel computing and allows high-speed analysis of large-scale models using a high-performance computing system. By applying the circuit simulator linkage function, high-accuracy analysis reproducing the behavior of nonlinear devices such as LSIs and drivers is also possible.

In the future, we intend to work on technological development to extend features and expand frequency bands for the purpose of expanding the scope of application of electromagnetic analysis in the manufacturing industry.

Lastly, we would like to extend our deepest gratitude to Mr. Michio Tamate and Ms. Miwako Hayashi of FUJI ELECTRIC CO., LTD., who provided us with examples of analysis.

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