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POSITION PAPER

Data exchange and software integration: Interdisciplinary design challenges

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Abstract

Hewlett-Packard develops and markets a family of computer-aided engineering products used by high-frequency designers to model the signal path in contemporary communications systems. As design frequencies, clock speeds and packaging densities continue to increase, more designers are finding that system and circuit simulation products need to be complemented by electromagnetic simulation software to develop models for basic circuit functionality or to characterize and compensate undesired parasitic effects. The HP High-Frequency Structure Simulator (HP HFSS) is a frequency-domain, finite element-based simulator, which enables engineers to characterize high-frequency behavior in 2D (transmission lines) and arbitrary 3D structures. Links with mechanical computer aided design (CAD) software have also become more important as the 3D structures to be analyzed by HP HFSS can involve packaging parasitics when the housing in which the electrical circuitry is enclosed becomes an influence on the signal path. Depending upon the complexity of the structure to be analyzed, HP HFSS can require hundreds of Mbytes of RAM and disk during automated adaptive solution convergence processes which determine field and circuit parameter solution results to user-specified accuracies. Although computer resource requirements will always be an important consideration for users of this type of product, another important situation to address for the future involves the exchange of data between the different simulation and modelling tools required to take design from concept through simulation to manufacture. The introduction of physical simulation tools into the traditional circuit simulation arena changes the design process flow and increases the demand for improved integration and interoperability of circuit simulators, numerical EM simulators, and mechanical CAD software. This paper provides an overview of data exchange issues in high-frequency electrical–physical–mechanical design processes.

Keywords: HFSS; EM; Solid Modelling; Data Exchange

1. INTRODUCTION

Nowhere is it clearer than in the design of large complex systems that interdisciplinary issues addressed in an *a posteriori* fashion represent large adverse impacts on time-to-market and bottom-line profitability. The U.S. Government funding agencies (e.g., DARPA) also realize this and are expressing increasing concern that integration/link definition and implementation activities associated with electrical–physical–mechanical CAD data exchange have been slow to develop, may not encompass the full range of file format standards and will not provide complete portability of 3D geometry between the software tools used by designers within the different disciplines.

Although HP EEsof approaches the interoperability issues from a different perspective and with different motivations from U.S. Government funding agencies, there remains concern that no consensus objectives have been identified which are adequate motivators in which the various commercial software vendors are willing to invest or collaborate. HP EEsof is also concerned that the issues that surround robust geometry file portability between a wide range of mechanical CAD tools, multilayer layout products, and EM simulation engines are not sufficiently well understood by those who promote and recommend the funding of isolated integration/link events.

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HP EEsof believes that the implementation of a robust mechanism for 3D geometry portability, which will remain fully compatible with numerous and diverse mechanical CAD and multilayer layout product feature sets while simultaneously satisfying the geometry description requirements of the broad spectrum of downstream electrical and EM simulation products represents an extremely aggressive objective. That the development of the Standard for the Exchange of Product Model Data (STEP) standard has been under development for 10 years already, illustrates the difficulty in obtaining this type of objective even though it is recognized as a significant productivity obstacle by designers in many market segments.

2. MECHANICAL CAD GEOMETRY REPRESENTATION

Products within a given discipline often have different considerations and objectives that dictate which geometry representation they will use. Some common standards in place today include Initial Graphics Exchange Standard (IGES), stereolithography (STL), ACIS kernel (SAT) and STEP. Many successful commercial software tools elect to use different file formats from these thus opening business opportunities for third-party translation products. Some of the issues associated with the file format situation are identified below.

2.1. IGES (Initial Graphics Exchange Standard)

IGES supports wireframe and surface representations of geometries. Although difficult with only surface information, it is possible to rebuild some classes of solid models if supplemental information (e.g., topological face normals) is added to an IGES file and face connectivity can be reconstructed in the receiving tool. Not all systems that generate IGES surface representations provide this information and no surface information is contained in the IGES wireframe representation. Reconstruction of arbitrary 3D geometries using IGES translation formats is inadequate, will not satisfy EM simulation customer portability requirements, and cannot represent a viable commercial solution for HP EEsof simulation products (although IGES 2D can be used for portability of planar patterns for mask generation).

2.2. Stereolithography (STL)

This format is intended to drive rapid prototyping machines and has been provided as an export-only capability from most mechanical CAD products. The low precision solid model representation causes ambiguous geometry situations if used for communication of 3D model information to downstream simulation software products (e.g., HP HFSS). This translation format was originally available as an import-only capability with early versions of HFSS, but the inconsistent representation of triangular surface normals compromises its usefulness for numerical EM simulation and, consequently, cannot serve as a viable commercial solution for arbitrary geometry data exchange. Furthermore, because mechanical CAD products do not support an import capability for stereolithography, any possibility of developing bi-directional portability using this format is eliminated. Finally, because the stereolithography format is a faceted surface representation, it is unlikely that mechanical CAD vendors will be interested in developing an import capability given the industry move to analytic representations of solid models.

2.3. STEP (Standard for the Exchange of Product Model Data)

STEP is moving forward as a new international standard and is championed by a group of companies that include Hewlett-Packard, BMW, Boeing, Bosch, General Motors, General Electric, and Siemens. Some of the key short-term objectives of STEP are the standardization of complete 3D geometric solid model data (in the form of 3D boundary representation), surface model data and wireframe model data. SolidDesigner already supports bi-directional 3D geometry exchange using the STEP format. This path potentially offers the best opportunity to link the largest number of mechanical CAD systems and physical simulation products with the broadest range of capabilities at the lowest cost. This standard has been under development for about 10 years, but many more years of effort will be required before it is fully implemented.

2.4. ACIS kernel (SAT)

The ACIS solid modelling kernel commercialized by Spatial Technologies is being widely adopted within the mechanical CAD industry (e.g., Autodesk [AutoCAD], CoCreate-HP [SolidDesigner]). It is becoming a de facto standard. This kernel is also being adopted for EM simulation in products from HP EEsof (HP HFSS) and Ansoft (MacNeal-Schwendler/Aeries). The ACIS kernel supports many advanced solid modelling capabilities, including analytic geometry representation. A broad selection of third-party mechanical CAD translation products are being developed for the SAT format (e.g., the bi-directional ACIS Data Exchange Translators from International TechneGroup Incorporated [ITI], which support geometry transfer to and from SAT using IGES, VDAFS and STEP formats).

2.5. Other solid modelling kernels

Other solid modelling kernels that have been used in popular mechanical CAD systems include Romulus from Shape Data and Parasolid (an extension of Romulus). Parametric Technology Corporation's Pro/Engineer is finding exceptional acceptance in the growing mechanical CAD market.

Many HP EEsof customers are now using Pro/Engineer for their mechanical CAD applications and they have expressed general interest in translation capabilities between Pro/Engineer and the layout and simulation products used within the electrical engineering groups.

Numerous products with parametric geometry capabilities are now commercially available. Pro/Engineer and SolidDesigner are representative products, but many others are also being marketed today. Mechanical CAD products that provide a parametric geometry representation capability may require that special consideration be given to portability issues so that the parametric geometry benefits they provide are not compromised (e.g., geometry changes due to EM optimization of an imported solid model from a history-based mechanical CAD product may require that the entire solid model be rebuilt upon return of the now non-native solid model to the mechanical CAD tool).

Traditionally, EM simulation capabilities in 2D (transmission-lines), 2.5D (multilayer planar), or 3D (arbitrarily shaped structures) have required geometry representations to be faceted (e.g., a circular object that is easily described analytically has to be represented by a sequence of linear facets along the object boundary so that rectangular/triangular/tetrahedral meshes can be constructed for method-of-moment or finite element numerical analysis). It is highly likely that commercial EM simulation capabilities will be developed during the next several years, which can accommodate the full analytic geometry representations supported by contemporary mechanical CAD systems. However, the situation today remains that facetization of the analytic representation must take place before the geometry is suitable for numerical EM analysis. This implies that geometry filtering/modification must occur to ensure the appropriateness of the 3D geometry representation for simulation, but it also means that geometry translation is likely to remain predominantly unidirectional. Full and robust bi-directional portability is also dependent upon an ability to bring non-native and/or modified solid models into mechanical CAD systems, which support geometry parameterization without having to force the customer to rebuild manually the entire model.

Different mechanical CAD products often use different levels of precision and many allow users to set the level of precision for geometry representation (e.g., Pro/Engineer defaults to 1.12e-3 vs. 1e-6 for SolidDesigner, but both systems allow users to adjust this default accuracy as a trade-off for solid modelling speed). Variability in geometric precision is not only a problem for robust downstream automatic mesh generation algorithms, it is absolutely central to the issue of 3D model consistency in translation from the origination system into the receiver system. Data precision determines whether a consistent and unambiguous solid model can be rebuilt in the receiving system. When the receiving system uses a higher precision geometry representation than the originating system, it will often occur that the receiving system will detect geometry inconsistencies (e.g., multiple overlapping objects making material property assignment and solution results ambiguous). If the originating system is of higher accuracy than the receiver, small geometric detail may be lost causing the simulated model to be different from the model originally intended to be analyzed. Ambiguous object topologies may also result as the original model detail is altered to fit the lower precision of the receiving system.

3. MULTILAYER LAYOUT GEOMETRY REPRESENTATION

It is straightforward to generate simple 3D solid models for multilayer planar structures from commercial layout products from HP EEsof, Cadence, and Mentor using existing file formats provided by these vendors. However, when more 3D character is to be described in the originating layout tool (e.g., wirebonds and process-specific conductor cross-section shapes), the absence of native solid modelling capabilities imposes an insurmountable obstacle (short of developing internal solid modelling capabilities). A related issue associated with layout tools and the import of mechanical CAD data is the fundamental inability of layout tools to interpret and utilize general solid model data. Selected geometry information exchange has been demonstrated, but it has required tight collaboration between the layout and mechanical CAD vendors (e.g., Mentor and CoCreate-HP's SolidDesigner and also between Cadence and Parametric Technology Corporation).

4. EM SIMULATION TOOL GEOMETRY CAPABILITIES

The physical simulation tools used by the customer can impose severe restrictions on the nature of the geometry representation that can be imported for analysis.

Multilayer planar EM simulators mathematically reduce the 3D substrate structure through the use of Green functions to a planar pattern analysis problem (with some limited vertical conductor capability). These products are not able to take the general 3D solid model data generated by mechanical CAD systems, but they may be able to accept some 2D pattern geometry from products like AutoCAD.

Three-dimensional EM simulators based upon finite element methods require 3D solid model geometry representations. Today, these products are based upon tetrahedral meshes and analytic surface representations must be faceted prior to applying boundary conditions, assigning material properties and performing solution processes. In the near future, finite element-based EM simulators will be able to accommodate the full analytic geometry representations of contemporary mechanical CAD systems.

Three-dimensional finite difference time domain (FDTD) products are now becoming available in the commercial market place. These tools require a structured 3D-manhattan grid. They are not able to accept 3D solid model data representations today and this poses a difficult usability problem for customers. Vendors work around the difficulty of creating 3D geometries for FDTD analysis by providing limited geometry macro capabilities, but the geometry generality that can be simulated using the current products is severely limited with respect to what commercial finite element products can accommodate.

5. THE CURRENT SITUATION FOR HP HFSS

Although not without issues, HP HFSS is working to support the broadest range of geometry data import options as possible through the use of the ACIS (SAT) file format and third-party ACIS-STEP translators to other mechanical CAD formats. Given that most of the leading mechanical CAD products are able to generate STEP-formatted solid model data outputs, these third-party translator providers can be a bridge in this complex area of solid model data exchange. Even so, there remains a need based upon the geometry representation requirements associated with contemporary 3D EM simulation capabilities for geometry-healing algorithms and automatic facetization of analytic surfaces. Furthermore, geometry integrity issues associated with multistep format translation processes compound the difficulty of a cost-effective ability to support robust solid model data exchange between a product such as HP HFSS and the many mechanical CAD products in use today.

Dave Wilson has been with Hewlett-Packard since 1981. Prior to taking a 3-year leave of absence to study numerical electromagnetics in the Ph.D. program at University of Colorado, Boulder, in 1985, he was a millimeter-wave microcircuit designer for swept sources to 40 GHz. Mr. Wilson is currently responsible for setting the strategic direction for all of Hewlett-Packard's electromagnetic simulators. He has been the R&D Project Manager for the HP's *High-Frequency Structure Simulator* since 1989.