COMPUTER-AIDED EMC ANALYSIS OF ELECTRONIC *SYSTEMS*

EMC/IAP SUPPORT CENTER

The Electromagnetic Compatibility/Intrasystem Analysis Program (EMC/IAP) Support Center, a government funded facility operating under contract to IIT Research Institute, is in its fifth year of existence under the aegis of the Rome Air Development Center, Compatibility Techniques Section (RADC/RBCT). The Support Center, located at Griffiss AFB, interfaces with all government agencies and contractors, with emphasis placed on the promotion of information transfer between the research and development community and the EMC user community. The Support Center's charter is to update and maintain EMC/IAP software codes which have been developed by the government. Four primary codes currently maintained by the Support Center are discussed below.

The Intrasystem Electromagnetic Compatibility Analysis Program (IEMCAP) is a systems-level, computerized analysis program which may be used in analyzing electromagnetic compatibility for aircraft, spacecraft/missiles, or ground stations on both present and future systems. It acts as a link between equipment and subsystem EMC performance and total system EMC functionality and provides the means for tailoring EMC requirements to specific systems. This is accomplished in IEMCAP through detailed modeling of the system elements, i.e., identifying emitters and receptors of electromagnetic energy and their specific functional characteristics as well as the inclusion of various mechanisms of electromagnetic transfer.

The program incorporates state-of-the-art communications and frequency-domain EMC analysis mathematical models into routines which efficiently determine the spectra and evaluate the transfer modes of electromagnetic energy among generators and receptors within the system.

The system model for IEMCAP employs an approach of identifying all ports in the system having potential for undesired signal coupling. These ports are divided into arrays of emitter ports and receptor ports having identifiable coupling paths. Based on the defined conditions and overall analysis approach, an electromagnetic interference (EMI) margin is calculated. An incompatibility is said to exist when sufficient signal from an emitter port or emitter ports, is unintentionally coupled to a receptor port such that it exceeds its susceptibility threshold.

EMI margins which represent the ratio of received power to the susceptibility threshold and are of value greater than unity indicate interference; EMI margins less than unity indicate compatibility. Currently, IEMCAP spectrum models and transfer coupling models represent a "worst-case" approach to systems analysis and prediction of EMC/EMI.[1]

The General Electromagnetic Model for the Analysis of Complex Systems (GEMACS) code is the result of an effort to develop engineering tools to support the electromagnetic (EM) fields analysis required during the design, development, fabrication, installation, maintenance and modification of electrically complex systems.

GEMACS employs the Method of Moments (MOM) technique to solve Maxwell's equations for an arbitrary geometry of radiators and scatterers. It has two major advantages over other MOM codes. First, it enables the user to model a system using up to 2000 wire subsections. Out-of-core manipulation and banded matrix iteration (BMI) are the major features of this code which make the solution of such large systems of equations practical. Secondly, the input language for the code, and the architecture and structure of the code itself are designed to permit an organized growth of the capability of the code. It is the intent of the code design to allow the incorporation of other solution techniques, such as Bodies of Revolution (BOR) and the Geometrical Theory of Diffraction (GTD).

The program provides the short-term capability to model and characterize large systems in terms of near/far field radiation patterns, predict the coupling between large numbers of collocated antennas and the input impedance of antennas in large radiating systems. The long-term advantage is the inherent growth potential and Air Force wide commonality available to the users of this code.[2]

Nonlinear Circuit Analysis Program (NCAP) is a user-oriented computer code for determining the nonlinear transfer functions of weakly nonlinear electronic circuits. By utilizing a standard set of circuit elements, NCAP can analyze networks made up of interconnections of these elements. Structurally, NCAP solves the nonlinear network problem by forming both the nodal admittance matrix for the entire network and the first-order generator (current-source) excitation vector for each of the linear sources in the entire network. Applying Gaussian elimination to the admittance matrix and the current vector results in the first-order nodal voltage vector for the network, whose elements are the first-order transfer functions at all nodes in the network at the given excitation frequency. The higher-order transfer functions are solved in an iterative fashion using the weakly nonlinear Volterra Series approach.

NCAP is relatively simple to employ. The user enters a description of the circuit to be analyzed. NCAP performs the nonlinear analysis, and outputs the results. The input data define the topology of the circuit, circuit element values, linear and nonlinear devices used in the circuit, circuit excitation, and include provisions for specialized operations such as iterative data modification and frequency sweeping.[3]

The Wire Coupling Prediction Models enable the prediction of coupling between wires and their associated termination-networks in closely coupled, high-density cable bundles and flat pack (ribbon) cables on modern electronic systems.

The seemingly obvious approach to interference analysis is the use of uniform, multiconductor transmission line (MTL) theory to model the cable bundle. However, this model requires that the wires be parallel to each other along the entire cable length and their relative positions must be known and should not vary along the cable length.

The Wire Coupling Prediction Models are based on a complete and unified consideration of multiconductor transmission line theory as it applies to the prediction of wire-coupled interference. They attempt to avoid the limitations of general analysis and prediction techniques by including some numerically stable and efficient algorithms for solving the multi-conductor transmission line problem for large numbers of closely-coupled dielectric-insulated wires. Methods for computing the per-unit-length capacitance and inductance parameters are also taken into account.

The various coupling models appropriately place emphasis on the frequency response of the transmission lines rather than on the transient response, since nearly all EMC control documents refer to frequency domain phenomena. In addition, if one assumes linear termination networks and assumes no nonlinear effects associated with the transmission lines, then the equations describing the physical problem will be linear, and thus the frequency response will provide a completely general characterization. Matrix formulation of the equations and other results of matrix analysis are applied where necessary for a logical and concise development.

The Wire Coupling Prediction Model software tools consist of seven separate codes: XTALK, XTALK2, FLATPAK, FLATPAK2, GETCAP, WIRE and SHIELD. Although XTALK, XTALK2, FLATPAK, and FLATPAK2 implement the MTL model, each one considers or neglects certain factors, such as conductor losses, in order to provide an efficient computational program. XTALK neglects the presence of any wire dielectric, i.e., wires are considered to be bare; and also neglects the conductor losses, i.e., the conductors are considered to be perfect conductors. XTALK2 also neglects the presence of wire insulation but includes conductor losses. FLATPAK includes consideration of wire dielectrics as in ribbon cables but considers the conductor to be lossless. FLATPAK2 includes consideration of wire dielectrics and also includes the conductor losses.

The digital computer program GETCAP (which is an acronym for GEneralized and Transmission line CAPacitance matrices) is a Fortran code which calculates the per-unit-length generalized and transmission line capacitance matrices for ribbon cables for the analysis of crosstalk. Analysis and prediction of crosstalk may or may not involve the presence of dielectric isolation.

The problem of determining the currents induced in termination networks at the ends of a multiconductor transmission line by an incident electromagnetic field is quite important in determining the electromagnetic compatibility of electronic systems. The digital computer program WIRE is designed to calculate the sinusoidal steady-state terminal currents induced at the ends of a uniform, multiconductor transmission line which is illuminated by an arbitrarily incident electromagnetic (EM) field.

In order to assess the effectiveness of preventive measures involving cable shielding and twisted-pair wire configuration, the analysis and prediction tool SHIELD was established. SHIELD also predicts the coupling effects due to pigtails which can seriously degrade the effectiveness of braided-shielded cables. These programs form an initial library of specialized analysis capabilities for wire-coupled interference programs.[4]

Other codes maintained by the Support Center include Precipitation Static Electricity Analysis Program (PSTAT) which predicts noise fields and short circuit antenna currents caused by corona streamer discharges in airborne avionics systems; an antenna location plotting routine (ANTPLT) which helps verify the geometry of antenna positions using the input data for IEMCAP; a supplemental computer program (IMOD) which may be used by an EMC engineer to calculate possible intermodulation frequency situations within systems; and Advanced Composite Shielding Experiment Simulations (ACSESS) which employs transmission line analysis to compute the fields that penetrate a stratified system of advanced composite materials irradiated by a normally incident uniform plane wave.

Though primarily an arm of the Air Force, the user community which the Support Center services also spans the Army, Navy, NASA, and commercial and educational institutions. To better serve our users, the Support Center has initiated a three-tiered subscription service which provides a range of services to accommodate casual and comprehensive users. For further information about the Support Center please call 315/330-7168.

References

1 *Intrasystem Electromagnetic Compatibility Analysis Program (IEMCAP)*, Volume I, Users Manual Engineering Section, RADC-TR-74-342.

2 *An Introduction to the General Electromagnetic Model for the Analysis of Complex Systems (GEMACS)*, RADC-TR-78-181; and the General Electromagnetic Model for the Analysis of Complex Systems, RADC-TR-77-137, Volumes I-II.

3 *Nonlinear Circuit Analysis Program (NCAP) Documentation*, RADC-TR-79-245, Volumes I-III.

4 *Applications of Multiconductor Transmission Line Theory to the Prediction of Cable Coupling*, RADC-TR-76-101, Volumes I-VIII.

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