"EMC-Analyzer" – a specialized expert system for solving electromagnetic compatibility (EMC) problems of on-board and ground/water-based radio systems

General description

Application Area:

1. EMC analysis, design and maintenance at all stages of radio system development and application including preliminary research, detailed designing of system and subsystems, systems exploitation, support and modernization.

2. Types of systems supported by "EMC-Analyzer":

   – on-board systems (aircraft, helicopter, missile, satellite, ship, box-body, etc.),

   – ground/water-based systems (airport, seaport, building roof, antenna tower, local ground/water object, etc.),

   – complex local spatially distributed systems, groupings (several aircrafts, helicopters, ships, etc.).

3. Intrasystem EMC analysis, design and maintenance in on-board systems taking into consideration

   – various on-board radio-electronic equipment (different radio systems; computers and control systems, data-measuring systems, power supply equipment, etc.);

   – different on-board spurious electromagnetic couplings ("antenna to antenna", "field to antenna", "antenna to wire", "wire to wire", "field to wire", "case to case", "field to case", "ground loop");

   – taking into consideration external electromagnetic environment (EME).

4. Intrasystem EMC analysis, design and maintenance in spatially limited ground/water-based RF objects

   – with regard to various ground/water-based RF systems of different radio services (radio communication, radiolocation, radio navigation, radio monitoring, etc.);

   – taking into consideration external EME formed by spatially distributed radio frequency (RF) devices and systems.

Functionality

"EMC-Analyzer" provides the following opportunities:

1. Solving of on-board EMC problems in the assumption of presence of different equipment (different radio systems; computers and control systems, data-

measuring systems, power supply equipment, etc.) on the basis of system-level EMC criterion "Total integral interference margin".

2. The simultaneous consideration and danger estimation of spurious electromagnetic couplings of the various nature (through antennas and apertures, between cables, between cases, through grounding loops, etc.).

3. Creation of effective computer (mathematical) model of on-board radio electronic system or ground/water-based RF object which provides the EMC problems solving on all stages of on-board and area-based equipment development and application.

4. Opportunities of permanent improvement of elements of this model by measurements, more precise modeling of separate spurious electromagnetic couplings, allowing to raise considerably its usage efficiency from stage to stage of modeling on-board / ground/water-based system life cycle.

5. Substantiation of necessary adjustments of equipment characteristics for the intrasystem EMC problem solving, specification generation for system equipment by the use of the system-level EMC criterion.

6. Detailed nonlinear behavior simulation of on-board or area-based radio receivers in very complicated (severe) EME formed by thousands of modulated (narrowband and wideband) or noise external interferences.

    This simulation provides opportunities of full identification of the sources, reasons, places of occurrence and parameters of a linear and nonlinear radio interference (co-channel, adjacent-channel, spurious responses, intermodulation, desensitization, amplitude and phase cross modulation, reciprocal mixing, etc.) in radio receivers in severe EME.

    The "EMC-Analyzer" expert system is a unique software in the international software market, providing such totality of functionalities.

Advantages in comparison with analogues and competing offers

The "EMC-Analyzer" specialized expert system is a unique software proposal in the international software market, providing the analysis and solutions of the most complicated EMC problems at a system level, «as a whole», using the modernized resumptive platform of known research program IEMCAP (USA) in a combination with a number of original and effective EMC models and technologies developed in USSR and Belarus (discrete nonlinear EMC analysis and radio receiver behavior simulation technology, automated double frequency testing (DFT) technique for radio receivers, etc.).

Unique known analogue of the "EMC-Analyzer" would be the program E^3EXPERT, developed according to the contract F30602-98-C-0034 with the US Air Force Research Laboratory (see publication: A.Drozd, T.Blocher, A.Pesta, D.Weiner, P.Varshney, I.Demirkiran. Predicting EMI Rejection requirements using

expert system based modeling & simulating techniques, *Proc. XV Inter. Wroclaw Symp. on EMC*, Poland, Wroclaw, 2000)

In comparison with the E³EXPERT (later developed tool) the "EMC-Analyzer" has the following important advantages:

a) Development for expanded series of system formats (board system, box-body system, local ground system, local ground area).

b) Pinpoint accuracy of spectra representation (up to 32 000 000 frequency samples under a usual personal computer with Windows NT/2000/XP).

c) Possibilities of detailed nonlinear behavior simulation of on-board or area-based radio receivers in a very severe EME formed by thousands of modulated, non-modulated or noise external interferences with

  – high accuracy of radio receiver nonlinearity representation using high order polynomial models (up to 15-25-th order) coupled with high-accuracy simulation/modeling of nonlinear interference,

  – full identification of the sources, reasons, places of occurrence and parameters of a linear and nonlinear radio interferences (co-channel, adjacent, image and intermediate channels interferences, intermodulation, blocking, amplitude and phase cross modulation, local oscillator noise conversion, etc.) in radio receivers in complicated radio receiving conditions.

There are many well known and rather perfect software tools declared for use at the solving of EMC problems in local on-board and ground-based systems (groupings). As examples it is possible to note software of FEKO, ANSOFT, REMCOM, CST, Poynting Softwarer Ltd, etc.

All these tools provide the decision of concrete particular problems of detailed electrodynamics calculation of a relief of an electromagnetic field, characteristics of electromagnetic couplings between antennas or characteristics of particular spurious electromagnetic couplings in an on-board or ground-based radio system (grouping) (in frequency domain by method of moments (MoM) or in time domain using FDTD approach). These programs do not provide a several very important functions, such, as

  – analysis and solving of the most complicated EMC problems at a system level, «as a whole», taking into consideration an intensity of intrasystem interference defeat of the on-board or ground/water-based equipment;

  – a quantitative estimation of all number of available spurious electromagnetic couplings of the various physical nature being the reason of interference of various types - a radio interference, conducted interference, grounding interference, etc.;

- decision-making on EMC compliance or disparity in conditions of existence of numerous spurious electromagnetic couplings of the various nature (through antennas, between cables, between cases, induced in ground loops, inducted by external fields, etc.);

- detailed nonlinear behavior simulation of on-board or area-based radio receivers in very severe EME including the identification of sources, reasons, places of generating in receiver, and parameters of a linear and nonlinear radio interferences;

- substantiation (calculation) of necessary adjustments of equipment spectral or susceptibility characteristics for the intrasystem EMC problem solving, specification generation for system equipment using system-level EMC criterion.

Therefore all well known software tools for electrodynamics calculations with the use of MoM or FDTD (including the most advanced, perfect and expensive) do not replace, but only supplement "EMC-Analyzer" and provide the following opportunities:

- more precise characterization of separate most important spurious electromagnetic couplings in an on-board or ground/water-based system (grouping);

- improvement of the "EMC-Analyzer" system-level functions accuracy by putting these more precise characterization results into "EMC-Analyzer".

Application experience and peculiarities

Hundreds of original and well-known models and procedures are used in the "EMC-Analyzer". Approximately 80% of them are widely known and published in the scientific literature. Probably, a number of models and procedures are not the most exact of known and published in scientific literature. However the refusal of application of more exact models and procedures is dictated by the requirement of reception of useful practical result at reasonable spending of time and computational burden.

It is very important that just with the implemented models of spurious electromagnetic couplings "EMC-Analyzer" provides optimal for practice pessimistic character of EMC estimations the on-board or ground/water-based equipment.

According to the published data, there are following results of their application for the EMC analysis of on-board aircraft equipment:

- probability of a correct interference prediction of interference presence or absence: 0,82;

- probability of a false alarm (the interference is predicted, but in practice is absent): 0,17;

− probability of the interference omission (the interference is not predicted, but in practice is present): 0,01.

Similar results are observed in "EMC-Analyzer" application for EMC analysis of the other on-board or ground/water-based systems: the probability of the interference omission does not exceed 1-5 %.

Nevertheless, the opportunity of more accurate definition of characteristics of any spurious electromagnetic couplings available in on-board or ground/water-based system is provided in "EMC-Analyzer" if the user has results of more exact modeling or measurements. This feature allows to improve computer model of on-board or ground/water-based system created with the help of "EMC-Analyzer". This make extremely easier the solving of EMC problems at late stages of system life cycle, in particular, at exploitation and modernization phases, for example, if it is required to enter a new equipment into the structure of the system or to replace separate kinds of equipment.

<u>Application History</u>

− Since 1998 "EMC-Analyzer" has been delivered to more than 20 companies in 10 countries of four continents (Europe, Asia, North and South America, Africa).

− During these years, various versions of "EMC-Analyzer" software have been used by a number of customers for EMC analysis, design, and simulation on-board systems (aircrafts, helicopters, satellites, ships, box-bodies, etc.), for frequency planning of local ground systems and objects (building roofs, antenna towers, airports, etc.), for EMC education & training with reference to radio systems deployed at various sites.

− According to additional agreements, "EMC-Analyzer" developers update "EMC-Analyzer" versions to fit the requirements of customers – they enter new functions, develop additional mathematical models and algorithms, improve the user's interface, conjugate "EMC-Analyzer" with another software, etc.

− "EMC-Analyzer" developers contributed significant efforts to cater for high-grade testing of its new versions to achieve its high-quality functioning. Top quality of "EMC-Analyzer" software has recently been recognized and acknowledged, since 2000 there is no claims against its quality.

Examples of delivery (case studies on China market)

Customer	Customer's requirements	Work completed using EMCA
Customer 1 (China, electronics industry)	EMC analysis on the board of the aircraft or helicopter, calculation of necessary adjustments of equipment spectral or susceptibility characteristics for solving of intrasystem EMC problems, generation of specification for the equipment. The use of models and algorithms of IEMCAP (USA), compliance with the requirements of MIL STD 461/462 (USA), nonlinear EMC analysis by the use of the discrete nonlinear analysis (DNA) technology developed in BSUIR (USSR, Belarus)	Development of radio electronic systems located on board of a helicopter
Customer 2 (China, aerospace industry)	The requirements are analogous to the requirements of Customer 1 but the following are added: The use of models and algorithms of "EMC-Analyzer" for EMC analysis of the equipment located on board of a car The ability to define the spectrum of electromagnetic field existing inside the car body	Development of missile's and box-body on-board radio electronic systems
Customer 3 (China, aerospace industry)	The requirements are analogous to the requirements of Customers 1 and 2 but the following are added: The ability to calculate and visualize the distribution of intensity of electromagnetic field existing at a given height in a local ground area measuring up to 3x3 km	Development of local ground area complexes of radio electronic systems
Customer 4 (China, aerospace industry)	The requirements are analogous to the requirements of Customer 1.	Development of missile's on-board radio electronic systems
Customer 5 (China, university)	The requirements are analogous to the requirements of Customer 1.	Education, research projects for aerospace and ship industry

Concluding remarks

"EMC-Analyzer" specialized expert system is capable to provide essential simplification, acceleration and reduction in price of works in the field of EMC problems detecting and solving in local on-board and ground/water-based systems (groupings). "EMC-Analyzer" can be efficiently used at all stages of life cycle of these systems, but its application is especially effective at early stages of system life cycle (research, design, etc.). Pessimistic character of EMC estimation allows the users to decrease essentially the risk of losses caused by probable electromagnetic incompatibility of on-board or ground/water-based system equipment during designing of these systems.

And such important features of "EMC-Analyzer", as

‒ solving of EMC problems of on-board or ground/water-based system at a system level, «as a whole», on the basis of system-level EMC criterion "Total integral interference margin" taking into consideration available spurious electromagnetic couplings of the various physical nature,

‒ detailed nonlinear behavior simulation of on-board or area-based radio receivers in a very severe EME, which includes the identification of sources, reasons, places of generating in receiver, and parameters of a linear and nonlinear radio interference,

‒ substantiation (calculation) of necessary adjustments of equipment spectral or susceptibility characteristics for the intrasystem EMC problem solving, specification generation for system equipment by the use of system-level EMC criterion,

make "EMC-Analyzer" to be the indispensable assistant at

‒ the designing of complex on-board systems (aircraft, helicopter, ship, missile, satellite, box-body, etc.) and complex ground/water-based objects (airport, seaport, high-altitude tower with antennas, a local radio communication and radio control center, a roof of a high-altitude building with a plenty of antennas, etc.),

‒ the analysis of a possibility to allocate the additional equipment in an on-board or ground/water-based system in such a way that the new equipment do not create interference to the available equipment,

‒ the nonlinear behavior simulation/analysis of on-board or ground/water-based system radio equipment operating in a very complicated EME.