ANALYSIS OF ELECTROMAGNETIC COMPATIBILITY WITH INTERACTIVE GRAPHICS

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ABSTRACT

A graphics system has been implemented to provide a convenient, yet powerful interface between a modified version of the aircraft EMC analysis program ATACAP and the user unfamiliar with computer technology. This system communicates with the computational routines of AAPG (Advanced ATACAP Plus Graphics) via a set of standardized data files, thus allowing its straightforward incorporation with various other EMC computation packages.

The four graphics packages comprising the system are described, and the versatility of the system's interactive capability is examined. By its use, the time required for avionics EMC analysis is dramatically shortened, and the user's interest heightened, due to the flexibility and ease of use of interactive graphics as compared to a numerical printout.

ANALYSE DE LA COMPATIBILITE ÉLECTROMAGNETIQUE AVEC INFOGRAPHIE CONVERSATIONNELLE

RÉSUMÉ

On a mis en oeuvre un système d'infographie afin de réaliser une interface commode, mais néanmoins puissante, entre une version modifiée de ATACAP, programme d'analyse de la compatibilité électromagnétique dans un avion, et un utilisateur qui n'est pas familiarisé avec les techniques informatiques. Ce système est en mesure de communiquer avec les programmes de calcul de AAPG (ATACAP avancé plus organes d'infographie), au travers d'un ensemble de fichiers de données normalisés, ce qui permet son intégration immédiate à divers autres groupes de programmes de calcul de la CEM.

On décrit les quatre programmes-produits infographiques constituant ce système et on examine la souplesse de sa capacité conversationnelle. Grâce à ce système, le temps qu'il faut consacrer à une analyse CEM en avionique est réduit dans des proportions énormes; de plus, l'intérêt de l'utilisateur est plus grand du fait de la souplesse et de la simplicité d'emploi des organes d'infographie comparée aux feuilles de sortie chiffrées.

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by

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INTRODUCTION

The analysis of electromagnetic compatibility (EMC) between the multitude of avionic systems and their antennas on modern military and commercial aircraft, is essential for the adequate functional design of these systems for simultaneous operation. Computer codes such as AAPG[1] and IEMCAP[2] aid in this analysis, but the presence of typically fifty antennas on a single aircraft often results in hundreds of pages of numerical printout which, though comprehensive, can be both frustrating and formidable to analyze. Furthermore, these are batch oriented programs which do not readily lend themselves to interactive computer-aided design. The engineer must spend many hours in careful examination of the printouts before he can reformulate the input data and then execute the analysis once again.

Advanced ATACAP Plus Graphics (AAPG) has been developed to alleviate such shortcomings of EMC analysis and design. Emphasis has been placed on a reformulation of the man-machine interface to reduce the time required for such analyses, to heighten the user's interest and in particular to include the following requirements:

- the addition of graphical output whenever possible, while maintaining both an optional graphics hardcopy and an optional printout capability
- the segmentation of the EMC analysis and resulting output into discrete independent modules
- the division of all information in such a module into distinct pages, each displayable at any time, and all summarized on a single index page
- simplicity of use, even for those totally unfamiliar with computer technology, while retaining input data compatibility with ATACAP

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1 Antenna to Antenna Compatibility Analysis Program

2 Intravehicle Electromagnetic Compatibility Analysis Program

- the addition of an interactive capability, allowing the computer-aided design of functional avionics system by antenna relocations in a single terminal session.

Other requirements not directly related to man-machine communication include:

- AAPG's implementation on a 28K PDP-11 minicomputer system with a single disk drive and a Tektronix graphics terminal compatible with PLOT-10
- an improved electromagnetic interference (EMI) path computation algorithm
- the availability of more comprehensive output.

This paper examines AAPG in the context of its man-computer communications capabilities, thus postulating the successful implementation of the above requirements.

AAPG INPUT REQUIREMENTS AND INTERACTIVE CAPABILITY

Input Requirements

The input data format of AAPG is compatible with that of its parent program, ATACAP. The information required by the program consists of a description of the aircraft geometry in terms of its simplified mathematical model which assumes a flat or round bottomed cylinder for its fuselage, a matching cone for its nose and a flat planar surface for each wing. A description of every aircraft avionics subsystem is necessary, including receiver and transmitter frequency ranges, as well as all antenna specifications and each antenna's position. The name of the file containing this data is specified during AAPG's initial dialogue with the user, who may then also request a conveniently formulated and organized list of this data to be printed.

The geometry of a specified aircraft and the characteristics of all necessary avionics subsystems usually must remain unchanged. Thus the problem faced by the EMC engineer is the proper placement of all antennas so that they do not interfere with each other. At times, the structure of the aircraft can be used to attenuate unwanted electromagnetic signals coupling into systems, while allowing the antennas to transmit and receive unhindered in the required directions. Otherwise filtering must be used to overcome undesired coupling.

The older EMC programs analyze this entire system using the specified antenna positions, printout the amount of EMI for each interfering receiver/transmitter antenna pair, and then terminate execution. The single most important difference of AAPG is that it uses the specified antenna positions as initial values, computes the same results as ATACAP, but then allows the user to graphically reposition any antennas he wishes in an attempt to lower the EMI margins, followed by a recomputation of these margins without terminating the analysis. This interactive procedure can continue indefinitely until all aircraft antennas are suitably placed so that interference is reduced to acceptable levels. Alternatively, a file containing the current analysis status can be established and saved on disk, and the analysis continued at any later time. When such a confirmation is desired, the re-start option is specified by the user during AAPG's initial dialogue.

Antenna Repositioning

This interactive capability is supported by one of the four AAPG graphics packages: the Antenna Position Input package. The current antenna location in relation to the aircraft model is shown on two orthogonal views (Figure 1). The user simply manipulates a joystick

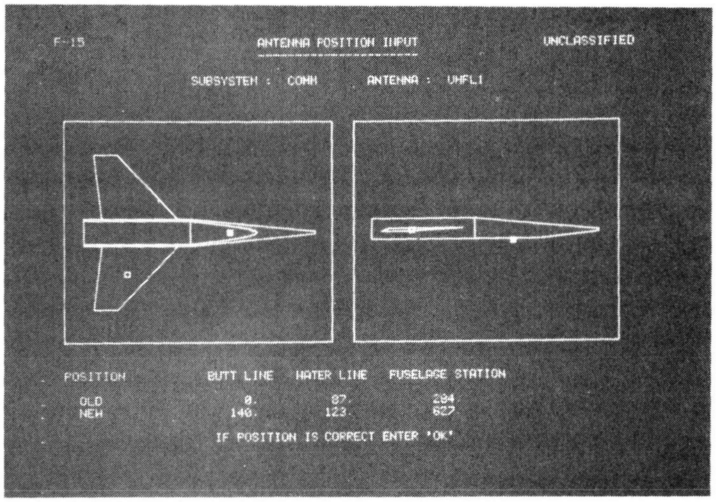

Figure 1

Antenna Position Input Template

or a set of crosshairs to specify the new antenna position, first on the top view, and then on the side view. The coordinates of the new antenna position are printed on the bottom of the screen, and if satisfied, the user types "OK" to proceed. He is then prompted to re-specify the four antenna orientation angles and the antenna location code, typing a carriage return if the old values are to be retained. If satisfied, the program prompts him to type the one character confirm command, thus effecting the antenna repositioning. Such a command forces the user to take positive action to produce the change, thus minimizing the specification of an ill-considered antenna position.

AAPG GRAPHICS OUTPUT

The graphical output produced by AAPG is generated by three distinct display modules, which complete the list of the AAPG graphics packages:

(1) Input: Antenna Position

(2) Display: Frequency Coincidence

(3) Display: Antenna Position

(4) Display: Propagation Path and EMI Margin

Frequency Coincidence Display Package

In order for a transmitting antenna to interfere with a receiving antenna, the corresponding receiver and transmitter operating or spurious frequency ranges must overlap. The transmitter power and receiver sensitivity over these ranges are rarely constant. The receiver usually has 'skirts,' while the transmitter usually has several harmonics of differing power levels, each of which also has a set of skirts in which its power level decreases.

The frequency coincidence display package provides an index of every receiver operating on the aircraft, and all transmitters having frequency coincidence with each of these receivers (Figure 2).

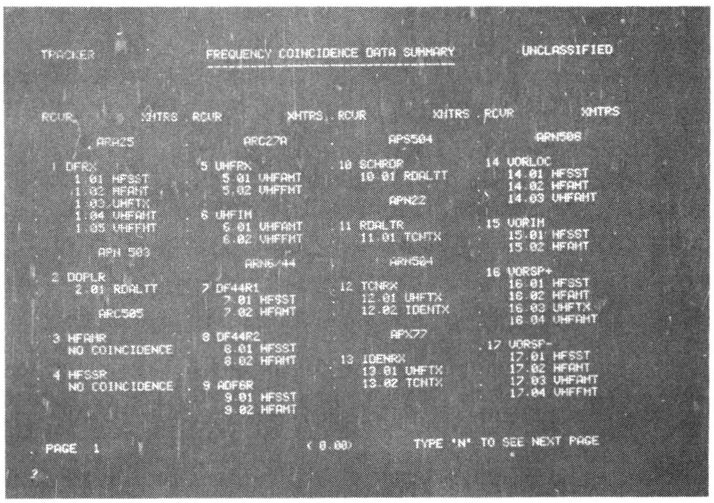

Figure 2

Frequency Coincidence Index

Each receiver is referenced by a two digit number (e.g. 06), and each coincident receiver/transmitter pair is thus referenced by two such numbers (e.g. 06.01 refers to the first transmitter that is coincident with receiver 06). The convenient index codes are used in all coincidence and interference specifications in any of the AAPG graphics packages.

The magnitude of the potential interference, and the interfering frequency range can be either plotted or numerically displayed by the frequency coincidence display package. In response to simple one or two character commands with the appropriate index numbers, this package can plot

(1) magnitude versus frequency for a single coincident receiver/transmitter pair (Figure 3)

(2) operational frequency ranges for a single receiver and all interfering transmitters, with or without skirts.

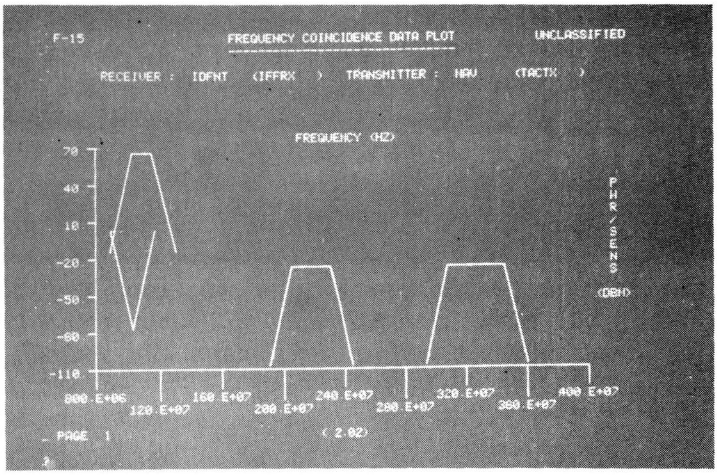

Figure 3

Frequency Coincidence Spectrum Level Display

Both displays are available with either a logarithmic or a linear frequency axis. The numerical displays available specify

(1) all the coincident harmonic numbers of every transmitter coincident with a particular receiver

(2) the minimum and maximum values of the frequency range of coincidence of all harmonics of one of the transmitters coincident with a particular receiver.

In this manner, comprehensive, descriptive frequency coincidence information can be conveniently obtained with a minimum amount of user effort.

Antenna Position Display Package

This package is used as a documentation aid, showing the positions of the antennas in a particular subsystem plotted on the aircraft model (Figure 4). The antennas in the subsystem can be labeled, and the azimuth and elevation angles with which the aircraft and antennas are viewed may be set to any values the user wishes.

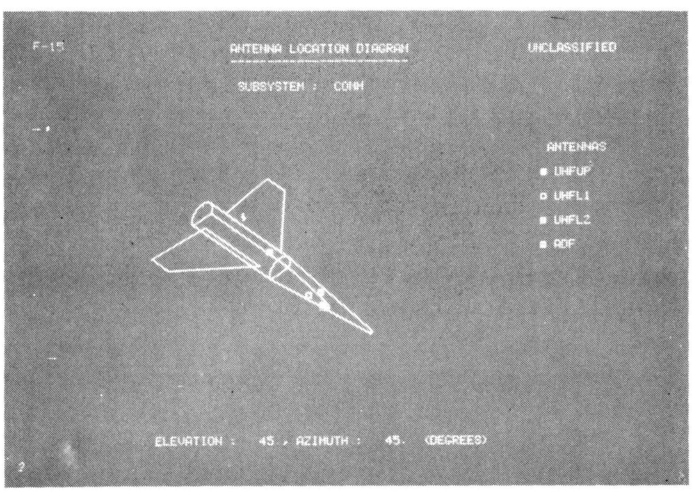

Figure 4

Antenna Position Display

Propagation Path and EMI Margin Display Package

The ratio of the unwanted power received from a transmitter to the receiver threshold power level for coincident frequencies between receiving/transmitting antenna pairs is called the EMI margin. It is computed as

$$EM = \underbrace{(P - CL_X + G_X)}_{\text{effective transmitted power}} + \underbrace{(TL + SS + ES)}_{\text{path power attenuation}} + \underbrace{(GR - CL_R - SR)}_{\text{effective receiver sensitivity}} \quad (dB)$$

where

P = the transmitter power at the coincident frequency, dB_m

CL_X = the transmitter cable loss, dB

R_X = the transmitter antenna gain, dB

TL = the free space transmission loss (Friis formula), dB

SS = the surface shading loss (creeping wave diffraction), dB

ES = the edge shading loss (wedge diffraction), dB

G_R = the receiver antenna gain, dB

CL_R = the receiver cable loss, dB

SR = the sensitivity threshold of the receiver, dB_m

The numerical value of each of these parameters for every frequency coincident harmonic of an interfering receiver/transmitter antenna pair is displayed by this package (Figure 5).

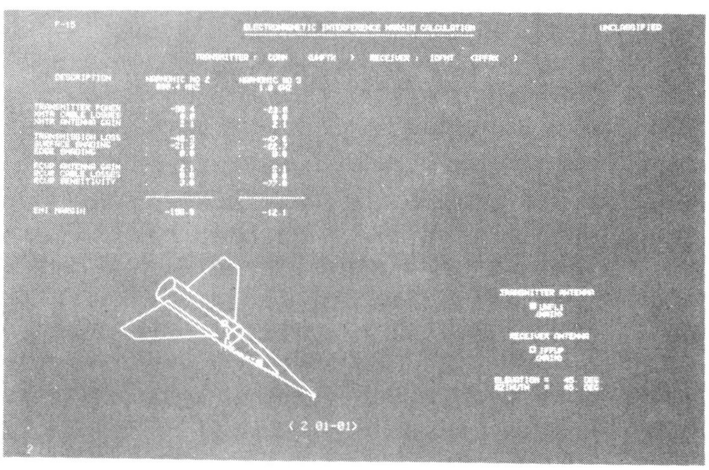

Figure 5

EMI Margin & Propagation Path Display

The resulting EMI margin is underlined if positive, warning the user of potential interference so that he may use the antenna position input package to try to increase the absolute values of the losses TL, SS, and ES by altering the position of one or both interfering antennas.

The EMI propagation path is also drawn on the aircraft model display. This display can have orientation angles best suited for viewing a particular path (Figure 5). Furthermore, all numerical data can be suppressed to accommodate an enlarged view of the propagation path.

To obtain these displays, the user may either specify the index number of a coincident receiver/transmitter pair resulting in a directory of all antennas used by this pair, and then specify any two of these antennas; or he may sequence through all available EMI displays by simply typing N when he wishes to proceed to the next one.

THE STRUCTURE OF AAPG

The Program

When AAPG passes control to its graphics system, all the necessary computations have already been performed and stored in various disk data files (Figure 6). The graphics system merely reads this information and displays it appropriately, thus providing an almost instantaneous response to the user's commands.

The graphics system can either maintain control, pass control to the EMI computation routines at the user's request to recompute for altered antenna positions, or terminate execution saving the current status of the analysis for future continuation.

The Display Manager

Control, when in possession of the graphics system, is routed by the display manager. If the graphics system maintains control, it can be passed to any of the four graphics packages (Figure 7). When all EMI computations are complete, AAPG passes control to the graphics system, whose display manager lists the options available to the user on the CRT screen.

SUMMARY AND STATUS

Interactive graphics, when added to modern EMC Analysis as in the AAPG code, provides a number of vital new elements in a complex task. It gives a meaningful overview of all key elements of each possible interaction between coupled systems. Each of these can be called up at will for visual examination while hardcopies provide a comprehensive report useful in the selection of frequencies for test programs or for analyzing test results. The ability to relocate antennas, recalculate the coupling paths and to quickly view the results provides a design tool and perception for the analyst which heretofore has been denied him.

The code is currently in use by the Canadian Department of National Defence in Version 01. A number of electromagnetic modelling improvements, such as better diffraction coefficients and tail structure representation are expected to be implemented in 1979.

ACKNOWLEDGEMENT

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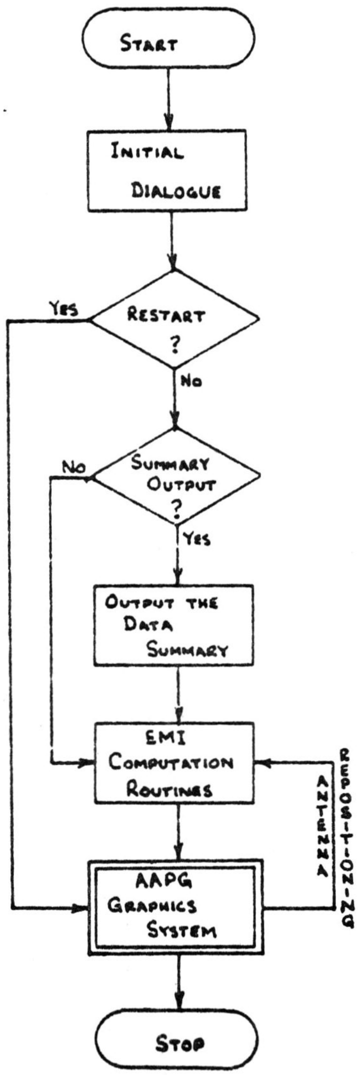

Figure 6

Flow Chart
AAPG Structure

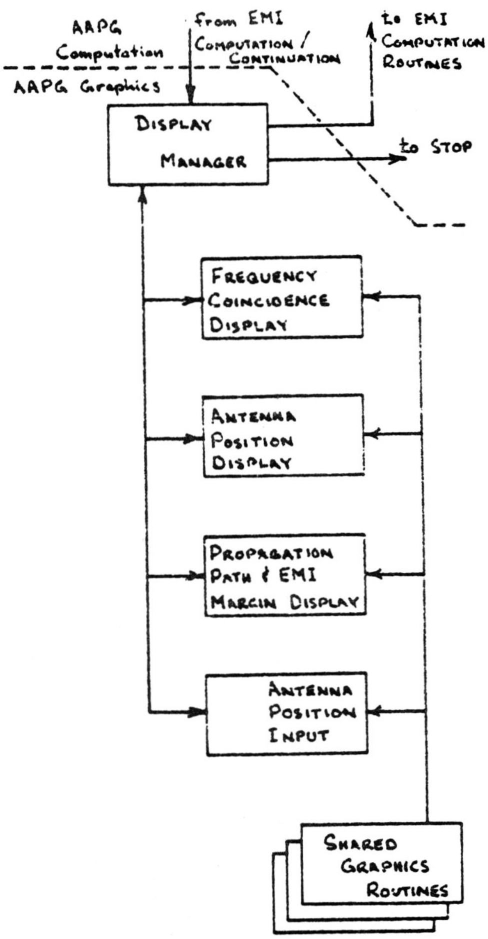

Figure 7

AAPG Graphics
Structure