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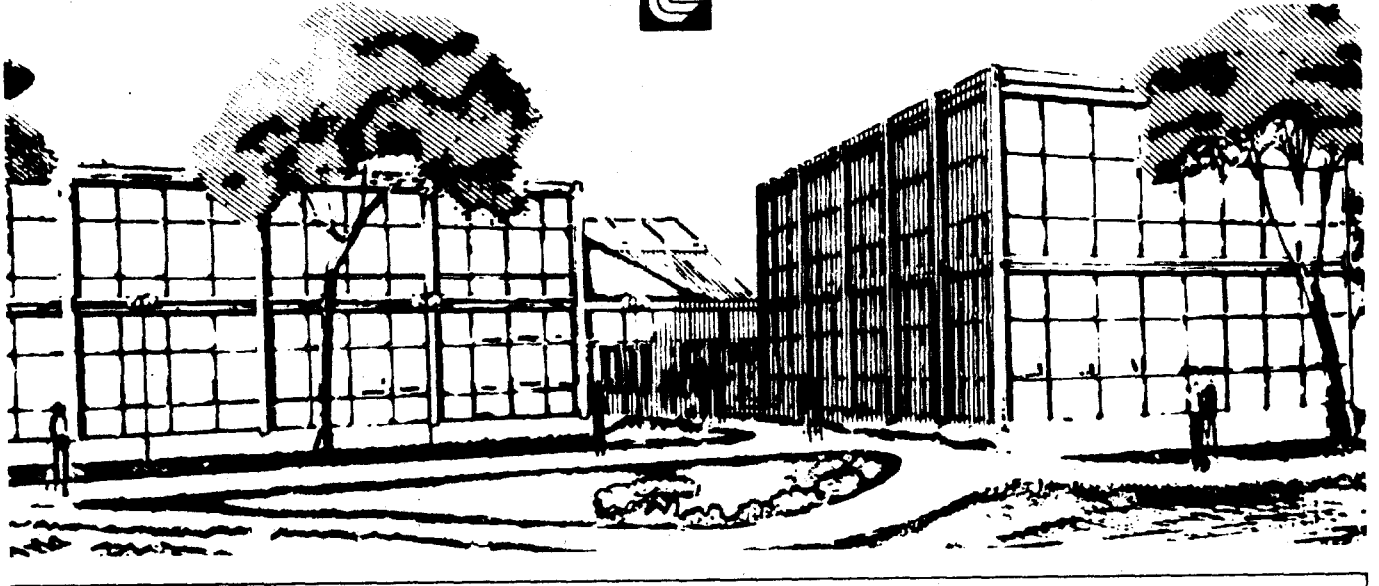

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EMP PROTECTION TECHNOLOGY INTERCHANGE

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Summary

Investigation and assessment of the potential degrading and destructive effects associated with the nuclear electromagnetic (EMP) phenomena has created a large technological base. This base is indeed quite broad owing to the unique and system-pervasive character of the EMP. One of the aims of an emerging discipline, such as that associated with EMP, is to provide for adequate transfer and integration of the developing technology into the overall engineering community. This paper reviews briefly the needs of the community and discusses how EMP hardening and protection information can be transferred or exchanged. Many of the current and generally available sources of information are listed, examples of interchange methods are provided, and problems of developing specifications, standards, and suitable guidelines for design and incorporation of protection are also discussed.

Introduction

Extensive effort has been devoted to the investigation and assessment of the potentially degrading and destructive effects associated with nuclear electromagnetic pulse (EMP). This electromagnetic pulse phenomena is created by a nuclear detonation and can cover large areas if the nuclear device is detonated at high altitudes above the surface of the earth. This paper attempts to review some of the technology associated with the EMP with emphasis on the needs of the technical community and how the exchange or transfer of EMP hardening and protection information. The approach here is to describe briefly the EMP environment, indicate some of the predominate and potentially destructive effects, identify some of the needs of engineers, and provide references to available sources.

Environment Description

EMP is a complex electromagnetic radiation phenomena with a wide range of spectral components. Another expression used for this phenomena is radioflash, but EMP is more like a radiated video pulse than a pulse of radio frequency. The precise characteristics of an EMP vary as the location of the nuclear source detonation is changed from near to or on the surface of the earth to a high altitude above the surface of the earth. At very high altitudes the EMP can cover large sections of the earth, perhaps one-half or more of the area of the United States, with large amplitude of field strength. There are many different types of EMP environments and many different situations which may arise for equipment. The references[1-3] provide much more detailed discussion of the phenomena than is possible here. A large portion of Protection concern, however, is associated with the high altitude EMP (sometimes referred to as HEMP) because of its widespread coverage, and the fact that it may be the only environment of immediate concern to some equipment otherwise not effected by this type of nuclear event.

EMP Effects

The EMP environment produces a variety of effects near or in a system. Here the

effects are ordered according to approximate sequence of occurrence.

1. The primary effect of an EMP is to illuminate a system or a portion of it with an electromagnetic field. Representative pulses for a free field HEMP environment are given as having E-field amplitudes of approximately 5×10^4 v/m and a time characteristic of the type $e^{-at} - e^{-bt}$, with a = 4.0 and b = 476, (t expressed in microseconds).[3]

2. Secondary effects of EMP are the time-varying induced currents and voltages on cables, wires, antennae, lines, airframes, and in general, any metallic or good conducting element in the path of the pulse or an aperture through which it penetrates. These always occur; at the minimum they represent additional noise in the system. Such induced signals usually appear as damped oscillatory waveforms as characteristic resonances are excited.

3. Possible succeeding effects then are usually the physical source of difficulty. These are thermal heating effects, sparking, insulation breakdown, and other nonlinear saturation or overloading effects such as in filter elements or limiting devices.

4. Permanent damage or burnout of circuit components can occur as a result of the above physical processes. Certain semiconductors, capacitors, and metal film resistors are particularly susceptible to damage. Operational upset of the system can also occur, caused by the presence of an interfering signal which obviously might do many things to operating electronic units. The determination of which components are critical and likely to be damaged, and which critical circuits or subsystems are prone to upset is a key ingredient of the protection process.

Clearly, the above effects are not necessarily sequential in the order given as the burnout of a component in one part of a system could occur before the electromagnetic pulse has reached another part of the system. However, protection measures have been surveyed[4] according to effects as above.

Protection Information and Needs

The protection or hardening of a system involves knowing something in a definitive sense about the inherent susceptibility to the various effects, being able to provide adequate estimates of the coupling levels into susceptible areas, having the necessary protection engineering techniques, and of course, having a methodology for carrying out the entire process of hardening.

There are many ways to review this. If one looks at the overall problem in a broad sense, there can be seen the need for general methodology, susceptibility, interaction and coupling, and protection information. This has been discussed previously both in an EMP[5] and EMV[6] context. Protection alone may involve several specialities such as those involved in

- systems engineering and design integration
- layout and grounding practices
- shielding and bonding techniques
- cabling and connection methods
- filters, limiters, and other protective devices
- implementation and production methods
- field maintenance procedures
- protection validation
- product assurance

In this paper, only brief attention is provided to general methodology, susceptibility, and interaction and coupling, as the emphasis is in protection technology. There is considerable technology in susceptibility and in interaction and coupling. The EMP notes published by the Air Force Weapons Laboratory at Kirtland AFB contain a large amount of the theoretical base associated with the interaction and coupling problem area of EMP. A computer code newsletter from Lawrence Livermore Laboratory has also been circulated

and some codes distributed.

Protection of a system could involve, from a hardware standpoint, everything from an extreme of a totally-enveloping shield concept to a complete new replacement of whatever might be destroyed by the EMP. In practice, it is not always simple to decide to which extreme direction a protection approach should be oriented. Some or all of the following could be used:

- intentional envelope shield concept
- partial shielding convenienced by structure of system
- shielded cables, subsystems
- interface protection
- limiting and filtering
- circumvention of disturbing effects

Without the presence of contribution to shielding afforded by the inherent structure of many systems (aircraft skin, ship hull, building rebar structure, equipment boxes, etc.) the penalty for EMP protection could be quite high. However, the analysis of such contribution may be difficult because of the many penetrations ordinarily necessary to provide proper operation for the system. The treatment of many such penetrations involves a technology of its own[7] since it involves non-electrical elements, openings such as windows, and various system-unique features.

Examples of protection hardware information thus include fundamental application data on such items as

- filters
- shields
- cables
- connectors
- transient suppression devices
- fiber optics

Protection design or application information should be oriented toward performance in the expected EMP environment that the particular element is subjected to. Unfortunately, there appears to be no universal set of specifications yet available. Thus, a manufacturer is forced to provide either a broad line of devices, covering a range of environments, or to design to special order. Specification development and its integration with other EM effects is one of the significant tasks that the protection engineer or system designer is faced with.

The above discussion of protection engineering has attempted to provide an overview of the types of technology involved. Each individual topic is quite important in itself, and no attempt is made to justify what is included or not.

Sources of Information

As discussed above, there is considerable need for many different types of information by the engineer engaged in the hardening or protection of systems. It can be quite frustrating to attempt to locate conveniently available sources of useful EMP engineering information. There is considerable publication in the field, but much of this is either unavailable generally, or discusses only segments of the problem of hardening. Below are listed different types of publications, many of which are identified in the references.

Handbook-Oriented[8-18]

Most of the unclassified comprehensive works published and generally available through the usual government distribution channels are listed in the above references. These involve hundreds of pages of material, but the user usually will not find adequate coverage of his particular problem in any of them. They do provide a basis for determining what approach to take, or what data appears to be available.

Special Notes

The Defense Nuclear Agency (DNA) EMP Awareness Course Notes[1] have done much to alert the community to the EMP problems and provide awareness of the general types of

technology. Unfortunately, these notes are not being updated continually. There is also the engineering notes series published by Lawrence Livermore Laboratory for DNA which deals with protection engineering and management technology. These are widely circulated and copies are available through the National Technical Information Service (NTIS). Summaries of these notes are available.[19] The special AFWL Note series has been mentioned previously in connection with interaction and coupling.

Other Books

In the protection area, apparently only two books have been published which have a significant amount of information dealing with EMP specifically.[3,20] Of course, there are many engineering reference books dealing with shielding, semiconductor applications, etc. However, most of these do not deal specifically with transient phenomena such as the EMP produces.

Journals and Proceedings

The IEEE Transactions on EMC are beginning to include more and more papers on EMP. Also, nearly every EMC or lightning-oriented conference in recent years has had papers or sessions dealing with various aspects of EMP. The IEEE Transactions on Nuclear Science also include material on components. As the technical problem becomes less specifically connected to an EMP effect, its identity in the literature may not be apparent from the title alone. Other publications deal more externally with other EMC problems as well.[21]

A special conference provided the first large exposition (six volumes) of technology across a broad range of scientific and engineering disciplines bearing on the EMP problem. The cross section included environment, instrumentations, interaction and coupling, simulation technology, hardening technology, and system level considerations. Hart's paper[22] contained a good review of the status of EMP documentation at that time.

Special Reports and Seminars

There are literally hundreds of special reports dealing with some aspect of EMP. Consultation of the references of any of the recent books published will identify large numbers of these. Special seminars are sponsored frequently by DNA, and occasionally there is an IEEE seminar dealing with the general subject, also.[23]

Computer Codes

Computer codes form the basis for a large amount of the analysis which leads to protection designs. It appears that in the protection design itself, that use of conventional circuit and system analysis codes are frequently employed to provide a response calculation. General purpose computer codes are continually being surveyed and compared.[24]

Conclusions

It is apparent that some specialized EMP topics are appearing more frequently in the open literature. Sometimes these are not recognizable as pertaining to the EMP protection problem. There still appears to be a recognizable need for more information on general system hardening approaches as well as on specific protection examples. Detailed engineering data in the form of drawings, specifications, test summaries, and evaluations of protection (even if very limited) would be quite helpful in concept formulation and in advanced development for future systems. From the standpoint of transfer of EMP protection information, it would also be quite helpful if each system program office could arrange to provide for a technical record of the engineering developments in a program. These should be detailed and accurate, but presented in sufficiently nonspecific system terms so that the information is clear and easy to obtain.

From the overall viewpoint, there still appears to be the need for quite general

hardening guidelines, specialized information for training personnel, data banks for reference for preliminary design and for assessment of existing systems, optimization of protection designs, and studies on integration of EMP with other EM effects. The transfer and integration of EMP protection technology can be accomplished with a concerted cooperative effort.

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