Protect Against EMP

— field techniques that mitigate effects

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You congratulate yourself on a job well done. As a communications officer stationed near Fulda Gap in West Germany, you have just finished monitoring the message flow for the latest week of field exercises. Now, this beautiful summer day—with routine traffic, clear communication, and business as usual—you relax.

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From a remote site over 1,000 kilometers away a single missile rockets into an almost vertical trajectory. Though detected immediately, the missile has no apparent target and appears not to violate any western European air space. (No alarm is raised as the missile rises to a height of 400 kilometers and its single, high yield nuclear payload detonates.)

Throughout the entire theater no one hears the explosion, no one sees a flash in the sky. But almost instantaneously, all electronic communication nets and all computers go down. Commercial power fails as well.

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You face the task of establishing communication with higher, lower, and adjacent headquarters without even the use of telephones. Command, control, communications, and intelligence (C^3I) capabilities seemingly plummet to zero. What's happening? Is this a prelude to a Warsaw Pact attack? What can be done?

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The culprit in this hypothetical (but possible) scenario? You call it EMP (electromagnetic pulse), one of the effects of a nuclear explosion that can create theater-wide chaos. Though not harmful to people, EMP damages or upsets all kinds of unprotected electronic equipment, especially those employing semiconductor devices.

Field protection techniques exist that minimize EMP vulnerability of Army electronic equipment. EMP vitally concerns not only field commanders and their staffs (who must fight the battle), but also the personnel who must operate and maintain such equipment in a hostile environment. More commonly known nuclear effects—nuclear radiation, thermal flash, and blast—occur at the tactical level.

Less well known EMP, which has no known effects on personnel, essentially is an enormously powerful radio signal of short duration which resembles lightning. Significant differences distinguish the two, however. EMP lasts only billionths of a second versus millionths of a second. EMP's field strength measures in the tens of thousands of volts/meter versus thousands of volts/meter. A significant portion of EMP's energy occurs in the VHF and UHF range, whereas lightning's energy distributes itself more in the HF range (see figure 1).

If the burst point of the nuclear missile is above 30 kilometers altitude, EMP covers thousands of square kilometers on the earth's surface.

In this case the EMP will be the

Figure 1. Pulse energy distribution over frequency.

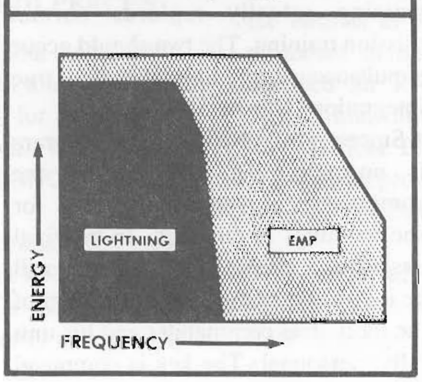
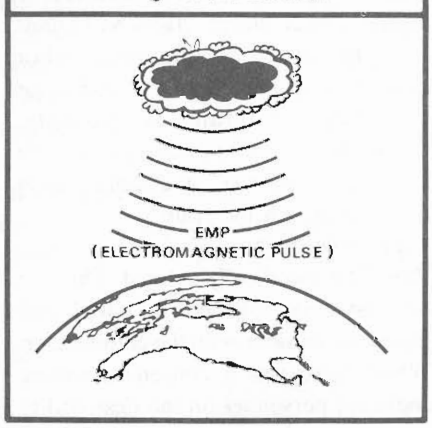


Figure 2a. Dominant nuclear effect, high altitude burst.



dominant nuclear effect since other effects will not be of any significance by the time they reach the surface of the earth. On the other hand, the effects of EMP from a surface or low altitude nuclear burst will extend about as far as other weapon effects for impact on military equipment. In this case, the commander must consider all effects to determine safety zones for men and equipment. A comparison between high altitude and surface burst EMP is shown in figures 2a and 2b.

EMP Effects

EMP primarily affects electrical and electronic systems by entering through antennas, external cable connections and openings in cabinets, shields, and circuit enclosures. The effect can be either operational upset of the system (for example, improper countdown sequencing of a launcher) or burnout of a component (for example, a transistor in a timing circuit).

The seriousness of the effect depends on the circuit design, on how effectively EMP energy is picked up by energy collectors such as antennas, cables, and holes, and on how well equipment protection is maintained. Most vulnerable to EMP are modern computers and microprocessors designed with integrated circuits, computer power sources, life support controls, modern transistorized telephone equipment, communication transmitters/receivers, and frequency converters.

Less vulnerable to EMP are electronic controls that use vacuum tubes, low-current switches, relays, and metering instruments. Hazardous equipment containing detonators, explosive squibs, and pyrotechnic devices also fall into the less vulnerable category while ordinary power equipment not containing semiconductors are least vulnerable to EMP.

Small common use items like digital wrist watches, compasses, and hand calculators are also insensitive to EMP because of their small size. Typical vulnerability levels for commonly used electronic parts are shown in figure 3.

What You Can Do

You can protect equipment against EMP by using protective devices where signals can enter (antennas and cable terminals) to divert the undesired energy to ground, and by properly shielding circuits from outside electromagnetic fields.

In addition, you can achieve considerable protection by simply following sound engineering practices in circuit paths, system connections, and equipment grounding. If a system was not designed with EMP hardening in mind, as is the case with older, fielded equipment, protection can still be achieved. Just follow mitigation techniques in operating and maintaining the equipment to minimize exposure to EMP, thereby reducing the amount of EMP energy going into the circuits from outside sources.

Mitigation Management

EMP mitigation rests with each unit and soldier that uses electronic equipment. The first step lies in developing a realistic attitude toward EMP. Here are some helpful

Figure 2b. EMP, surface burst.

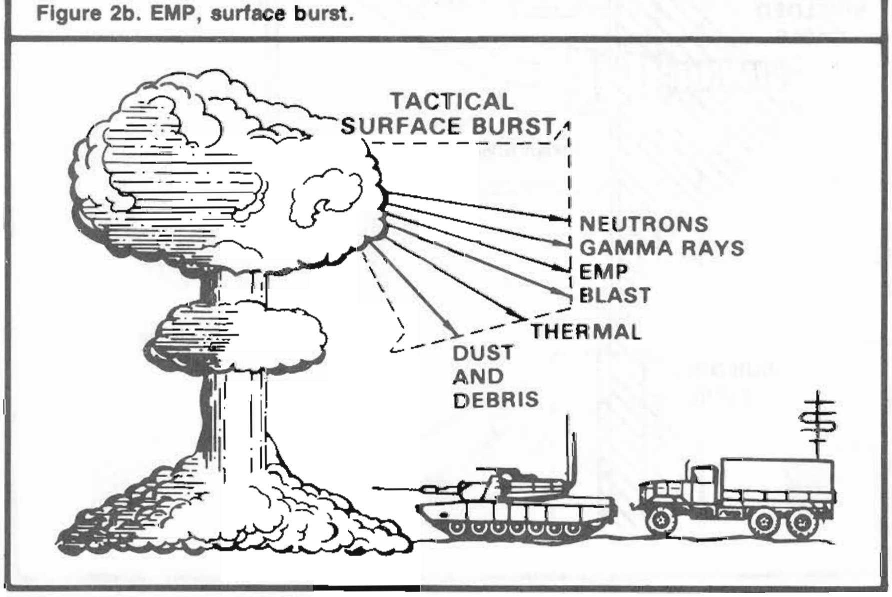
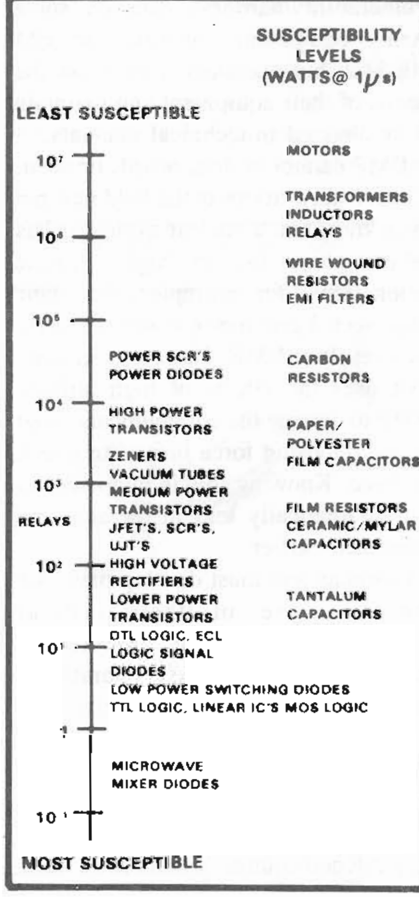


Figure 3. Spectrum of upset and damage of thresholds of electronic parts.



suggestions that soldiers can follow.

• Many soldiers underestimate EMP. But, EMP was one of the earliest nuclear effects correctly predicted and actually observed during atmospheric nuclear tests. Since then, it has been studied and shown in many scientific experiments for over 30 years. The effects are well known.

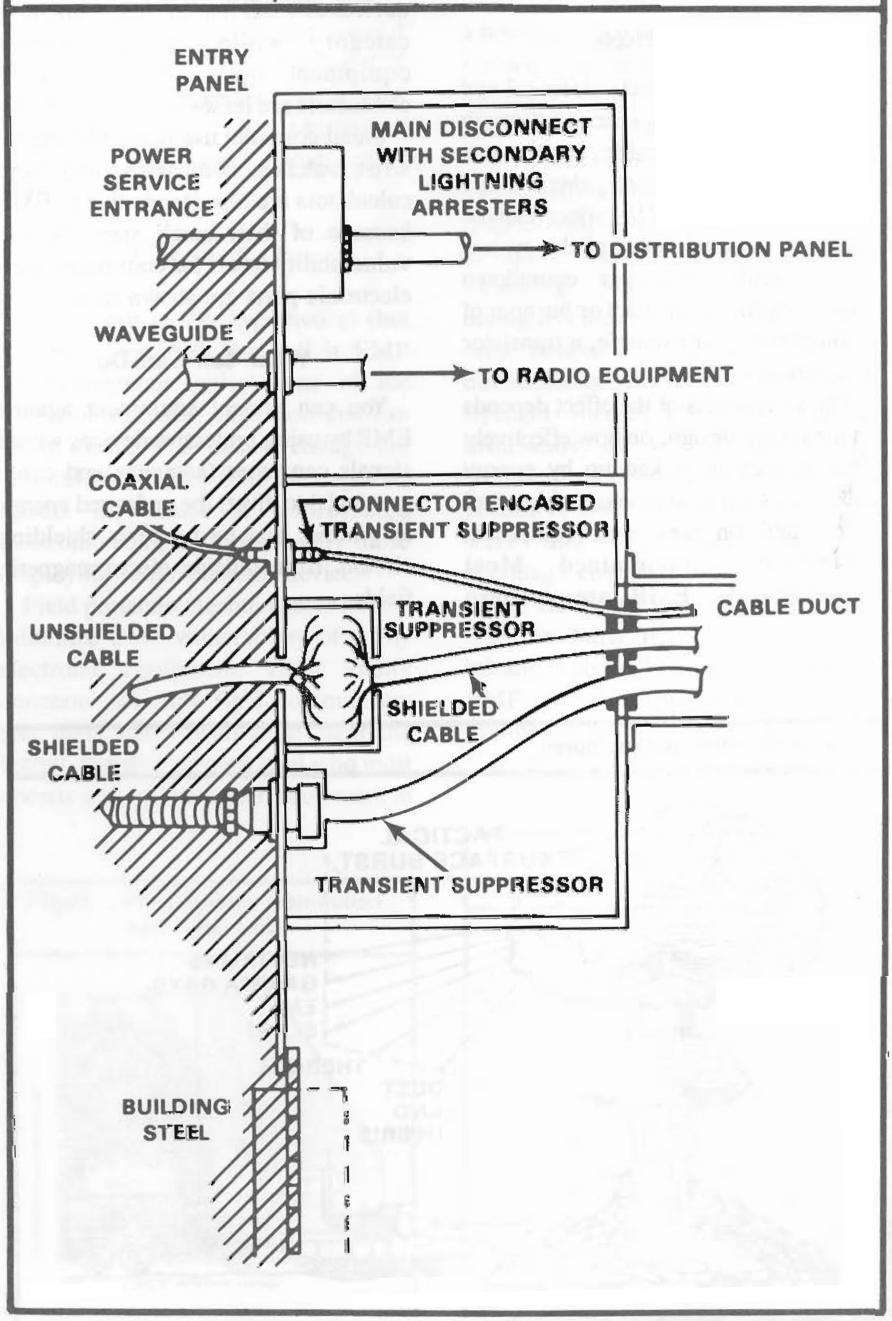
• Combat units should include correct information about EMP and its effects in their training. Hearsay statements describing EMP as a blinding flash of lightning that instantly kills or injures everyone in a unit or automatically destroys all tactical materiel is science fiction, not fact. Unit training must concentrate on information in field manuals (FMs), technical manuals (TMs), field circulars (FCs), and other Army publications to provide the correct picture of EMP and its effects. The fact that EMP has no effect on personnel should be emphasized in training, as should the fact that much of our equipment is being hardened to EMP during development. Relative vulnerability/hardness data on some Army equipment are listed in FM 101-31-2, but operators must know the status of their equipment and maintain it as directed in technical manuals.

• EMP cannot be felt, heard, or seen. Conceivably, troops in the field may not even know that a nuclear explosion has taken place (as in high altitude detonations, for example), but their unprotected gear may not work properly as a result of EMP. There is a strategy that uses the effects of high altitude EMP to destroy the communication net of the opposing force before an attack in force. Knowing this is important as was dramatically told in the scenario presented earlier.

• Commanders must develop plans for the best use of their critical communication and electronic equipment which satisfy operational requirements but also recognize that essential electronic equipment can be severely damaged by EMP. Hardened equipment should be placed in support of the most critical mission. Unhardened equipment should be used in other, less sensitive and routine applications to preserve the readiness of hardened equipment as much as possible. Decisions involving EMP mitigation will require trade-offs between use of hardened and unhardened electronic equipment.

• EMP hardness built into a system, as shown in figure 4, can easily be wasted by improper maintenance of the equipment or improper modification of its components just for the sake of convenience. Any addition of new connectors (for example, adding new telephone wire into a shelter that does not go through an approved surge arrestor), extra power cable runs to air conditioning units or connections to ventilation units, and so forth, can seriously impact the hardness of the

Figure 4. Typical cable entry points of hardened systems with terminal protection.



protected area. A more serious offender of hardness maintenance, however, is simply neglecting the equipment for a prolonged period of time. Equipment deteriorates even when not used. For this reason a well-defined maintenance schedule coupled with periodic inspection is of utmost importance for all fielded equipment. Commanders must ensure that a maintenance program exists and is rigorously followed, and that maintenance problems are properly identified and deficiencies corrected without delay, in accordance with approved procedures.

While it's impractical to list all of the possible EMP mitigation procedures that could be followed in tactical situations, some general guidelines can serve as examples of the proper use of equipment to minimize exposure and damage.

Equipment Installation

When you have a choice, avoid use of antennas designed for frequencies found in EMP (10K Hz-100 MHz). These include long wires or rods, wide angle doublets, and omni-directional antennas. Small directional antennas and those designed to pick up frequencies above 100 MHz are recommended. If practical, extend antennas the minimum amount that is consistent with operational requirements; this also will reduce the potential for EMP damage.

Avoid the creation of wire loops which are very efficient energy pickups, much like magnetic dipole antennas. Learn to recognize unintentional loops created in the process of installation. For example, a phone line may run from a van through a switchboard to a command post which normally has a power line to a generator. If the same generator has a connection to the van also, the result would be an effective loop antenna as shown in figure 5a.

You may find a similar situation in field installations where unintentional loops are created by the interconnecting communication cables between shelters as shown in figure 5b. To avoid cable loops, run interconnecting cables in parallel groups and in as close proximity to one another as cable length and available space will permit, as shown in figure 5c.

Some large antennas use guy wires as braces to provide stability. These wires can also function as EMP pickups unless the line connections are well insulated, as shown in figure 6.

Keep cable runs as short and straight as possible, as shown in figure 7. The length of a cable is a major factor in determining the amount of EMP energy

Figure 5a. Equipment interconnection showing cable loop.

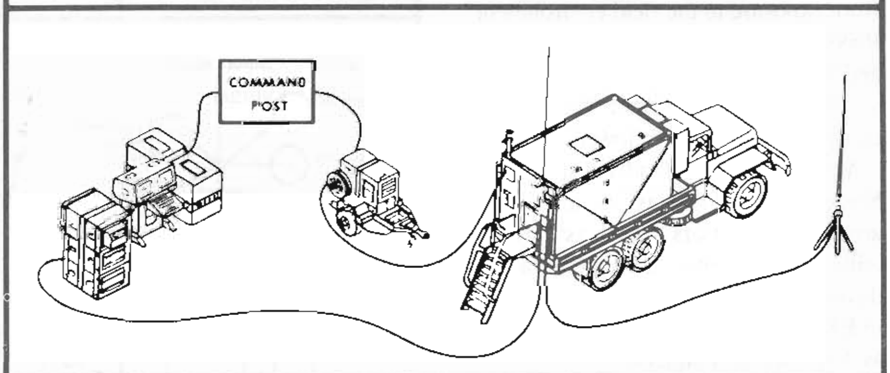


Figure 5b. Typical C³ system configuration showing interconnecting cables.

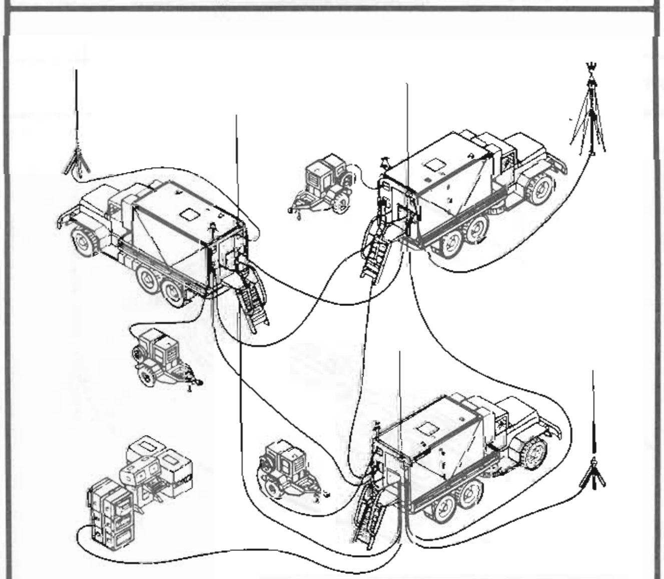
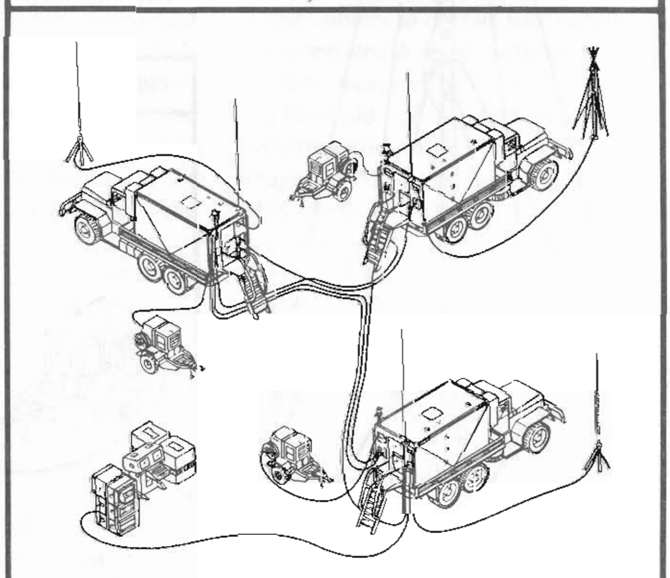


Figure 5c. Preferred routing of interconnecting cables to eliminate loops.



picked up and transmitted to the equipment. Cables should be run on the ground and clustered, wherever possible. Cables strung on poles can pick up more EMP than those on the ground.

Burying cables underground is not worth the effort, since deep burial (10 feet or deeper) is needed to have reasonable EMP protection. Shallow burial will not provide significant protection to EMP although protection against other combat hazards may be enhanced (for example, vehicles, shrapnel, and so forth). Balanced shielded, twisted pair cable should be used whenever practical instead of a coaxial cable.

Proper grounding of equipment, shelters, and cable shields is very important. The best grounding method in field installations is the single point "star" (or "crow's foot") and the "tree" configuration. The "tree" is likely to be the most practical grounding scheme for many systems, as shown in figures 8a and 8b. Furthermore, a good electrical grounding system must be maintained. In dry areas the ground around the anchor point must be kept moist.

Equipment Maintenance

You can defeat the EMP hardness that has been built into a system by improper maintenance. Equipment deteriorates in the course of its normal use and also from exposure to the field environment. Recommended maintenance procedures and schedules for the equipment as well as for the shelter that houses the equipment must be followed.

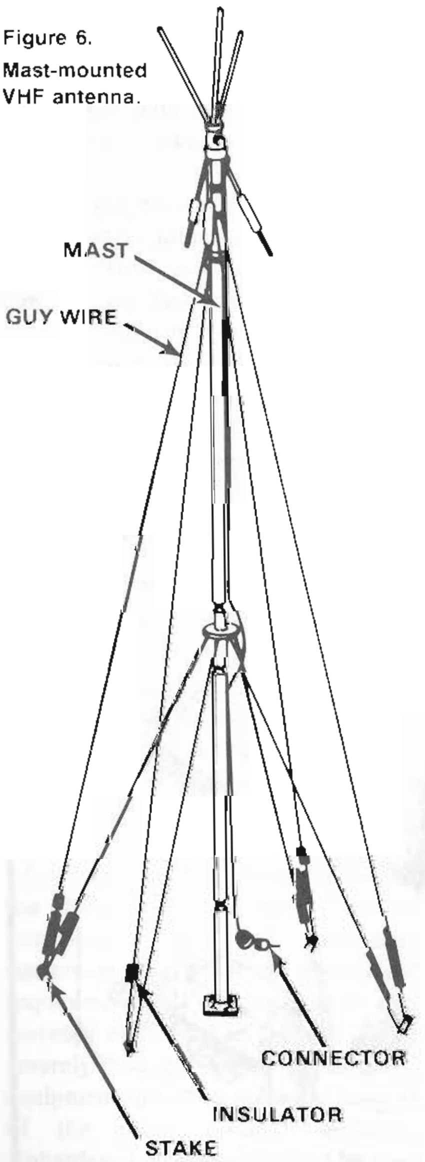
You should periodically inspect such hardening features as metal gaskets around the doors, gaskets around windows and vents, cable penetrations through the walls to maintain the built-in EMP protection. It is also important to keep metal connections clean and provide a good metal-to-metal contact without gaps or breaks in the connectors.

Repair damage to walls, shields, and enclosures without delay to ensure that a clean metal-to-metal contact is restored. Worn or damaged cable shields must be repaired or replaced even if the damage does not impair the operation of the equipment. Any break in a protective shield can result in a total loss of EMP protection.

The accumulation of rust and dirt on connecting metallic surfaces must be prevented by periodic cleaning. Field units must be discouraged from adding "home-made" connections of any kind to hardened equipment. Even a small break in the shielding designed to provide EMP protection can result in the loss of the protection.

In general, the maintenance required

Figure 6.
Mast-mounted VHF antenna.



Figures 8a and 8b.

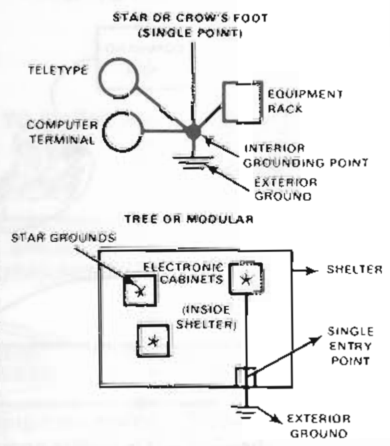
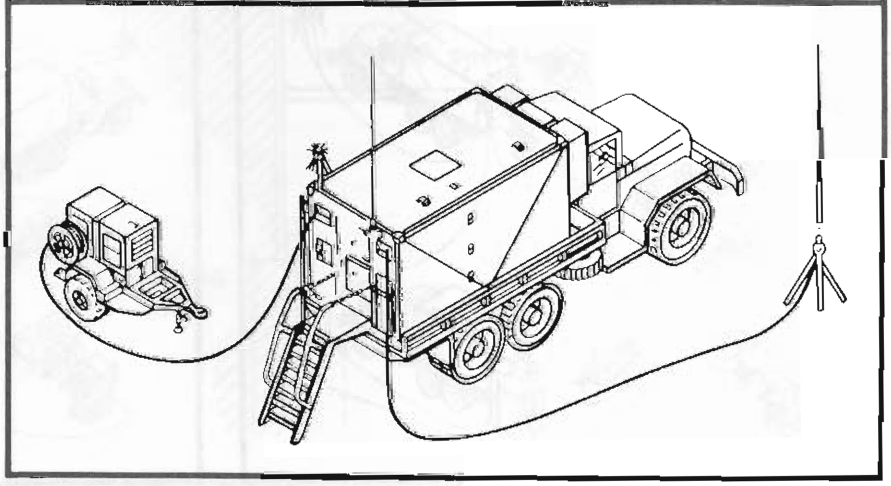


Figure 7. Typical power and communication cable field installation.



to meet chemical warfare requirements will also be advantageous for EMP protection. Vans and cases which are designed to survive in a chemical warfare environment are often airtight with clean contact between edges of the outer surface of the container. This is the same clean contact required to maintain EMP shielding and hardness.

Operational Considerations

In addition to the installation and maintenance procedures previously mentioned, there are also operational considerations that mitigate EMP effects. If mission conditions permit it, for example, electronic equipment can be shut down during off-time periods and all antennas and interconnecting external cables disconnected from the equipment. Simply turning the equipment off does not provide the same protection since damaging EMP can still enter through the external connections.

In dispersed operations multiple mode communications should be established. Units generally can access alternate modes of communication such as field telephones, messengers, aircraft and vehicle radios, flares, and other signal devices.

Most EMP energy is contained in the frequency spectrum below 100 MHz. While many tactical radios operate in this frequency range, others, like microwave systems, don't. Consequently, a microwave grid could survive when other radios fail and could, therefore, be a very effective alternative communication mode. The possible loss of radio communication from the impact of EMP and also from battle damage, reinforces the need to develop and practice alternate communication schemes for backup.

Because of the very high sensitivity of computer equipment to EMP, you need to take special steps to provide protection. Unless hardened, store and operate computers in shelters, vans, or vehicles which are well shielded. You can store extra calculators and other small electronic devices in used metal ammunition cans in sheltered areas, but away from the sides and corners of the shelter.

Computer tapes, discs, and drums tend to be relatively resistant to EMP. However, a copy of all stored data and information must be kept and maintained separately from the system to serve as back-up in the event that the original tape, disc, or drum is damaged due to EMP-induced operational upsets. For mission-essential information, two copies are recommended and they should be stored separately. It is also important to disconnect computer equipment from power lines and from other external cables when not in use.

Support Equipment Interface

Most of the EMP-sensitive electronic equipment needs some type of external support for operation. Radio transmitters, for example, need external antennas, computers need an external power source, and so forth.

Proper connections at interfaces are extremely important. When linking shelters to antennas, to other shelters, or to power sources, all connecting cables should be grouped as much as practical and placed in metal conduits. If the group of cables must penetrate into the shelter, the point of penetration should be concentrated at one location as much as possible.

Cable shields, ground buses, and other connectors should be terminated on the exterior of the shelter without penetration through the wall. Lines running into the shelter should be insulated just prior to entry into the shelter to afford a discontinuity in the metallic conduction path into the system.

Examples include air conditioning lines, water pipes, ventilating ducts, exhaust pipes, and so forth. If terminal protection is provided for cables at the interface, extreme care should be taken that the protective devices are not damaged or disconnected (see figure 4).

Commercial power sources are not protected against EMP and must be considered as effective transmitters of EMP. The long lines used in all civilian power systems can pick up significant amounts of EMP energy that will cause damage to military equipment connected to it.

Therefore, on the integrated battlefield, military power generating equipment should be used and commercial power should be considered only as an emergency backup.

Summary

Techniques exist to mitigate the interaction of EMP on fielded communications and electronics equipment. The implementation of the procedures given should start with correct information on EMP and its effects. Without a realistic attitude toward EMP by commanders as well as operating units and personnel, even the best hardened equipment will prove ineffective if nuclear weapons are used on the battlefield. If you follow approved operating and maintenance procedures, the effects of EMP on military equipment can be reduced even in the absence of elaborate protective devices.

The importance of the interconnections between equipment and support elements which present a barrier to EMP coupling must be stressed. Integration of these mitigation and maintenance procedures into mission planning and their employment in troop training significantly increases a unit's ability to operate successfully on the integrated Airland battlefield should nuclear weapons be used.

[Two field circulars provide additional information—FC 50-16, Electromagnetic Pulse Mitigation Techniques, (US Army Combined Arms Combat Development Activity (USA CACDA), 1 February 1984) thoroughly discusses EMP mitigation techniques, and FC 50-17, A Technical Overview of Electromagnetic Pulse (USA CACDA, 1 June 1986) discusses just what its title says. You may obtain additional assistance through the US Army Nuclear and Chemical Agency (USANCA) point of contact, Mr. Adam F. Renner, Commercial (703) 664-6287.—[EDITOR]