

Appendix C

Nuclear Burst Effects on Electronics

Electromagnetic pulse is a nuclear weapons effect that can have significant impact on electrical and electronic equipment. EMP, although it represents only one percent of the total energy produced by a nuclear burst, can destroy or cause serious damage to electronic equipment through current surges.

Transient-radiation effects on electronics has similar effects to EMP, except TREE is caused by gamma and neutron (initial) radiation. Although gamma radiation causes only temporary ionization of electronic components, this can lead to permanent damage in other parts of the

equipment. Fast neutrons cause permanent damage by displacing (or dislodging) atoms in crystals. Shielding that reduces gamma and neutron radiation will reduce the effects of TREE. The cause of the damage may be short in duration but permanent. Damage amount depends on the dose rate. The effects on electronic equipment may or may not be shielded out.

Unlike lightning, EMP does not produce a flash in the sky or a loud noise. Also, devices that protect equipment against lightning do not necessarily provide protection against EMP (see Figure C-1).

Types of EMP

Nuclear explosions occurring at heights of roughly 2 kilometers to 30 kilometers are, for complex technical reasons, less likely to produce EMP effects of concern to forces in the field. There are two types of EMP of particular importance for tactical forces:

- Surface-burst EMP (SBEMP)
- High-altitude EMP (HEMP).

Surface-Burst EMP

Surface-burst EMP is produced whenever a nuclear device is set off on the ground or at a low altitude above the earth. A tactical nuclear weapon could produce SBEMP.

SBEMP from surface bursts at altitudes of about 200 meters or less can be even more powerful than HEMP—HEMP energy levels may be in the range of 50,000 volts per meter. Values for SBEMP may be in the region of one million volts per meter. Furthermore, these high levels of SBEMP may couple (weld together) buried or above-ground cables outside the immediate vicinity of the nuclear detonation. If this happens, these cables may remain intact and transmit tremendous surges of energy to connected systems down the line.

Because of the physics involved, SBEMP fields extend only to ranges on the order of 10 to 20 kilometers from the point of detonation. These fields are significant for tactical units that might be far enough away from a nuclear

detonation to avoid damage due to blast, thermal and other effects, but they still may be subject to damage from SBEMP. At the same time, however, a range denoted in tens of kilometers is considerably below the ranges associated with HEMP; its effects can cover areas on the order of thousands of kilometers.

Furthermore, depending on a unit's location within the area affected by SBEMP, other effects (blast, thermal, radiation) may be of greater tactical significance. For

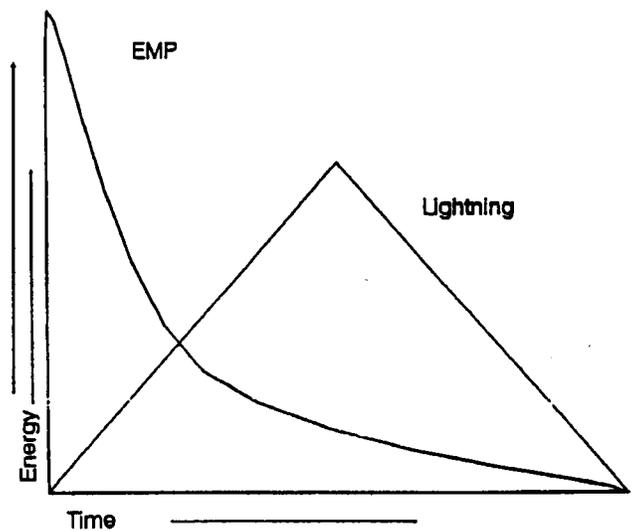


Figure C-1. Comparison of EMP and lightning en-

high-altitude nuclear detonations, in contrast, EMP is the only militarily significant nuclear weapons effect.

A unit not affected by the other effects of a near surface burst of a nuclear weapon can still be affected by SBEMP, which is the most far-reaching of the prompt effects produced by a nuclear weapon detonated on the ground or at low altitude.

When units are threatened by SBEMP, commanders are aware that a threat exists because of the thermal, blast, and other effects of the nuclear detonation. However, commanders may not be aware of the effective ranges at which the SBEMP energy can damage critical electronic equipment. For example, if a 10-kiloton nuclear weapon were detonated on the ground, the safety (standoff) distance for troops in the open is about 2,400 meters. At this range, troops could withstand the thermal effects, which would extend farther than blast and other immediate effects. In this same example, however, EMP damage to some types of critical electronic equipment could occur at ranges of 5,000 meters.

High-Altitude EMP

High-altitude EMP (HEMP) is produced when a nuclear explosion occurs 30 kilometers or more above the earth's surface. Because of the physical processes that generate HEMP, which differ from those that produce SBEMP, HEMP effects can have considerable strength at great distances. Units throughout a theater might be affected without ever being aware that a nuclear explosion had taken place. An example of HEMP's effects is provided by a test conducted by the United States in 1962 in which a nuclear device was detonated above Johnston Island in the Pacific. EMP effects were evident in electronic devices in Hawaii, 800 miles away from the test site.

Furthermore, a nuclear detonation 400 kilometers above Moscow would produce an EMP field that would cover all of Germany. US forces in Germany would not see a flash nor feel a shockwave, yet the HEMP field could damage or destroy critical electronic components in communications systems and other materiel. While the strengths of HEMP fields vary, it could be as much as 50,000 volts per meter. Since field forces have no way to anticipate the levels of EMP to which they will be subjected, tactical units must be capable of withstanding the worst case, 50,000 volts per meter. Figure C-2 illustrates HEMP ground coverages of at least 25,000 volts per meter for heights of burst of at least 100 kilometers (inner ring) and 500 kilometers (outer ring).

While 99 percent of HEMP energy is at frequencies below 100 megahertz, most HEMP occurs in the frequency ranges between 100 kilohertz and 10 megahertz. Communication systems operating in these frequency ranges are most likely to pick up EMP energy and suffer damage. Correspondingly, microwave and other systems that operate at higher frequencies are less likely to be

impaired because their antennas are not designed to pick up energy in the frequency ranges in which EMP energy is most likely to occur. Because of the extremely high altitudes of the explosions that produce HEMP, forces in the field will not be affected by the blast, thermal, radiation and other effects of the nuclear weapon. Indeed, field units may not have any indication that a nuclear explosion has occurred except for the arrival of HEMP and the resultant effects on electronic equipment.

In some respects, EMP energy is similar to radio waves produced by nearby lightning strikes. Both involve a sudden pulse of energy, and both are attracted to intentional and unintentional collectors or antennas. EMP and lightning differ in the following crucial respects:

- EMP pulses rise much more rapidly. The pulse rise time for EMP may be a few billionths of a second; the comparable interval for a lightning pulse involves millionths of a second.
- Each field strength can differ radically. Lightning may be in the range of a few thousand volts per meter; EMP can involve 50,000 volts per meter. In some circumstances, a nearby lightning strike (50 to 100 meters distant) may be similar to some manifestations of EMP energy.
- HEMP pulses are shorter in duration—usually less than a thousandth of a second as compared to lightning pulses that last hundreds of milliseconds.
- Lightning occurs at much lower frequencies and in bands well below the frequencies used by tactical communications systems. Unfortunately, EMP concentrates in some of the bands most frequently used by tactical communications systems.

Because of these differences, devices that provide protection against lightning strikes may not necessarily protect against EMP effects.

The HEMP Threat

High-altitude EMP (HEMP) can present unique threats to tactical forces. Because of the extremely high altitudes at which these nuclear detonations occur, forces on the



Figure C-2. EMP ground coverage over US map.

ground may be unaware of the explosion until after EMP has struck, causing damage to unhardened equipment.

Such a high-altitude nuclear burst could disable US forces' communications, sensors, and other electronic equipment. By employing hardened equipment and using mitigation techniques, the aggressor might use HEMP to create confusion and surprise in US forces.

This type of preliminary attack would have an added advantage, aside from its effects on electronic systems: the high altitude nuclear burst would not cause collateral damage.

In this unclassified publication, a detailed assessment of enemy threats cannot be provided. Note, however, that such exploitations of HEMP effects would be consistent with the emphasis Threat military doctrine places on surprise attack, the potential use of nuclear weapons at the outset of a conflict, and Threat operational procedures in which units are trained to operate for sustained periods

with minimal communications (and hence less reliance on communications equipment). Furthermore, some unclassified assessments suggest that many items of Threat military equipment may be capable of withstanding EMP effects.

Because of the possibility of nuclear proliferation, the unique threats posed by HEMP may be encountered in conflicts with other aggressor nations as well. A nation that has only recently acquired nuclear weapons may have only a small number of them available for use. In a conflict with the United States, such a nation might use one or more nuclear weapons to produce HEMP effects to disrupt operations of US forces and make them more vulnerable to follow-on conventional, chemical, and nuclear attacks.

These threats posed by HEMP reinforce the requirement to integrate EMP mitigation techniques into tactical unit standing operating procedures to ensure that mission-essential capabilities are not upset or destroyed.

Tactical Equipment

Tactical units use many types of electronic equipment and electrical components, such as radios, radars, power generators, calculators, fire-control systems, computers, and computer chips. Also, units use civilian sources for electrical power. The primary threat of EMP is damage to electronic equipment and components.

Both HEMP and surface burst EMP (SBEMP) can damage electronic equipment by causing current surges, burning out or melting components, and upsetting computer memories. Modern microprocessor computer chips, increasingly used in tactical equipment, are particularly vulnerable since they are designed to operate at very low power levels.

EMP can cause functional damage or operational upset. Functional damage is physical damage to equipment that requires replacement or repair of components. It should not be assumed that equipment suffering from functional damage is destroyed forever. By using postattack mitigation procedures, it may be possible to quickly return the item to use (such as, by replacing fuses and resetting circuit breakers).

No physical damage is evident with operational upset. This may appear to be less important than functional damage. However, it can be just as damaging, because EMP interferes with the operation of the equipment by erasing data from a computer memory or by causing a computer device to send an erroneous signal to the piece of equipment it controls. In addition, operational upset is of concern because it can occur at EMP energy levels that are 1/10th to 1/100th of those required to inflict functional damage. EMP does not directly affect internal electronic components. It can only cause damage if it gets into a piece of equipment through collectors or antennas, or if it

penetrates an equipment case and couples to internal wiring. Examples of damage caused by operational upset are-

- Operators of intelligence gathering and target acquisition equipment may lose track of hostile forces.
- Essential information such as crypto identification codes may be lost.
- Pilots of helicopters and fixed-wing aircraft may be given erroneous information on their instrument panel readouts.
- Weapon guidance systems may malfunction.

Unhardened equipment varies in its vulnerability to EMP. While the hardness or vulnerability levels of specific items of equipment are classified, the most vulnerable categories of equipment are shown in Figure C-3 (next page).

As emphasized in Figure C-3, vulnerability to EMP can vary significantly within each category of equipment. Several rules of thumb can be employed to make rough estimates of the vulnerability of electronic equipment (None of these rules apply to EMP-hardened equipment. Hardened material should withstand EMP effects.):

- Any system that employs a digital computer is susceptible, particularly to upset. EMP can destroy or distort the information contained in the computer's memory.
- Pieces of equipment with state-of-the-art, low-power transistors and semiconductors are more susceptible to EMP damage than similar equipment using older technologies with vacuum tubes.
- The more powerful the signal a piece of equipment (such as a radio receiver) is designed to receive, the less susceptible it is to EMP-induced damage.
- Equipment with large collectors is more susceptible to EMP damage than equipment with small collectors.

- Unhardened radios operating at frequencies of 100 megahertz or below, (such as, high frequency systems) are susceptible. Communications systems operating at frequencies above 100

megahertz (such as, super high frequency and microwave equipment) may be less susceptible.

Personnel

Personnel can be directly injured by EMP only if they are physically touching metallic collectors (cables, railroad lines, etc.) at the moment of the tremendous EMP surge. However, troops are unlikely to be in this situation and can be instructed to avoid physical contact with such collectors.

EMP hazards may exist from indirect or secondary EMP effects. For example, damaged electronic equipment may

catch fire if relays are switched to the wrong positions. Also, pilots may receive incorrect information from digital instruments that have been upset by EMP. These secondary effects can be mitigated using appropriate standing operating procedures.

Collectors and Antennas

Unlike some other nuclear weapon effects, the damage caused by EMP depends in large part on the configuration of the equipment subjected to it. For example, equipment that has been developed in EMP hardening programs can resist high levels of EMP. The key to these hardening programs is shielding—creating barriers between the EMP energy and critical components of the equipment. Recall that EMP is a powerful radio wave, and like other radio waves, it is picked up by collectors and antennas. Shielding eliminates unintentional antennas or creates protective barriers around critical electronic components.

While there is no substitute for the use of equipment that has been hardened against EMP, some of the principles of EMP hardening and shielding can be employed by units in the field to minimize EMP effects. Collectors and antennas have a major impact on the amount of EMP energy that can get into a piece of equipment and cause damage.

In developing EMP mitigation plans, commanders need to know about the two types of antennas that absorb EMP

- Intentional antennas are those normally used with tactical communications equipment.

- Unintentional antennas are any metal conducting materials, to include rail lines, pipes, power lines, vehicle bodies, and concertina wire used to protect positions.

Commanders' EMP mitigation plans will be effective only if they deal with both types of collectors and antennas. Usually, there are a number of unintended EMP collectors in or near a tactical unit.

Commanders can identify the unintended antennas in their units and areas of operations to which EMP mitigation procedures must be applied. If there is a metal object in the unit area that you would not want to touch during a lightning storm (particularly if you were to take the object and place it vertically in the air), it is probably an unintended antenna, such as, a long wire, grounding rod, spool of metal cable, or rail line.

However, this rule of thumb only applies to the identification of potential unintended antennas through which EMP energy might couple to electronic/electrical systems. EMP is not the same as lightning, and devices that provide protection against lightning generally do not automatically provide protection against EMP.

Basic Planning

EMP mitigation is not something that can be handled by a higher headquarters. Each unit employing communications and other electronic equipment must develop and implement an EMP mitigation plan consistent with its assigned mission(s). The following paragraphs contain planning considerations that should be used when developing mitigation plans.

Take EMP effects seriously.

If no mitigation procedures are used, both HEMP and surface-burst EMP (SBEMP) can damage mission-essential electronic equipment that is not hardened.

Don't exaggerate the effects of EMP.

EMP is not a blinding flash of energy that instantly kills or injures everyone or automatically destroys tactical material. Primarily, it affects electronic equipment and the use of mitigation techniques can reduce or eliminate damage caused by EMP. Hardened items may not be affected at all.

Don't regard EMP as a hard to understand newly discovered effect. EMP was one of the nuclear weapon effects predicted during the first nuclear tests, and it has been studied for over 30 years. You don't have to be a nuclear physicist to understand how EMP can affect

tactical equipment or to develop and implement effective mitigation procedures.

Use hardened equipment.

Through command channels, commanders can obtain information concerning the EMP hardness of their equipment, including the identification of equipment that has been hardened in EMP shielding programs.

Make maximum use of and place primary reliance on hardened equipment.

Keep hardened equipment hardened. Improper use or maintenance can reduce the hardness or shielding of equipment. Use EMP mitigation procedures to maintain the hardness of shielding equipment; and ensure that troops follow maintenance procedures specified in technical manuals.

Know your equipment. Ensure all personnel in the unit know their equipment and understand the factors that make these items more or less vulnerable to EMP damage. Some characteristics, such as the use of microprocessor computer chips in a system or the presence of an intended or unintended antenna, can have a major impact on a piece of equipment's vulnerability.

Avoid myths and misconceptions. EMP has been the subject of a number of popular science articles that are not necessarily accurate. Some false rumors about EMP and EMP mitigation have been circulating. Here are the facts—

Don't rely on lightning suppressors and arrestors. While EMP is similar to lightning in some ways, EMP is more powerful and differs in other characteristics. Hence, military and commercial devices that provide adequate protection against lightning strikes generally do not provide protection against EMP.

Don't plan on wrapping everything in aluminum foil or putting every item of equipment in metal boxes. Taking these steps may make sense when dealing with small, redundant items, such as an extra hand-held calculator might be kept in a sealed ammunition can. As a general rule, it doesn't make sense to try to put all of your equipment away in these types of expedient shielded containers. In reality, your equipment may not be protected and more importantly, you need your equipment to accomplish the mission.

Don't rely on nonmilitary standard commercial equipment. During peacetime

training, it is tempting to use commercial radios and other nonmilitary-issue equipment which are nonstandard and not

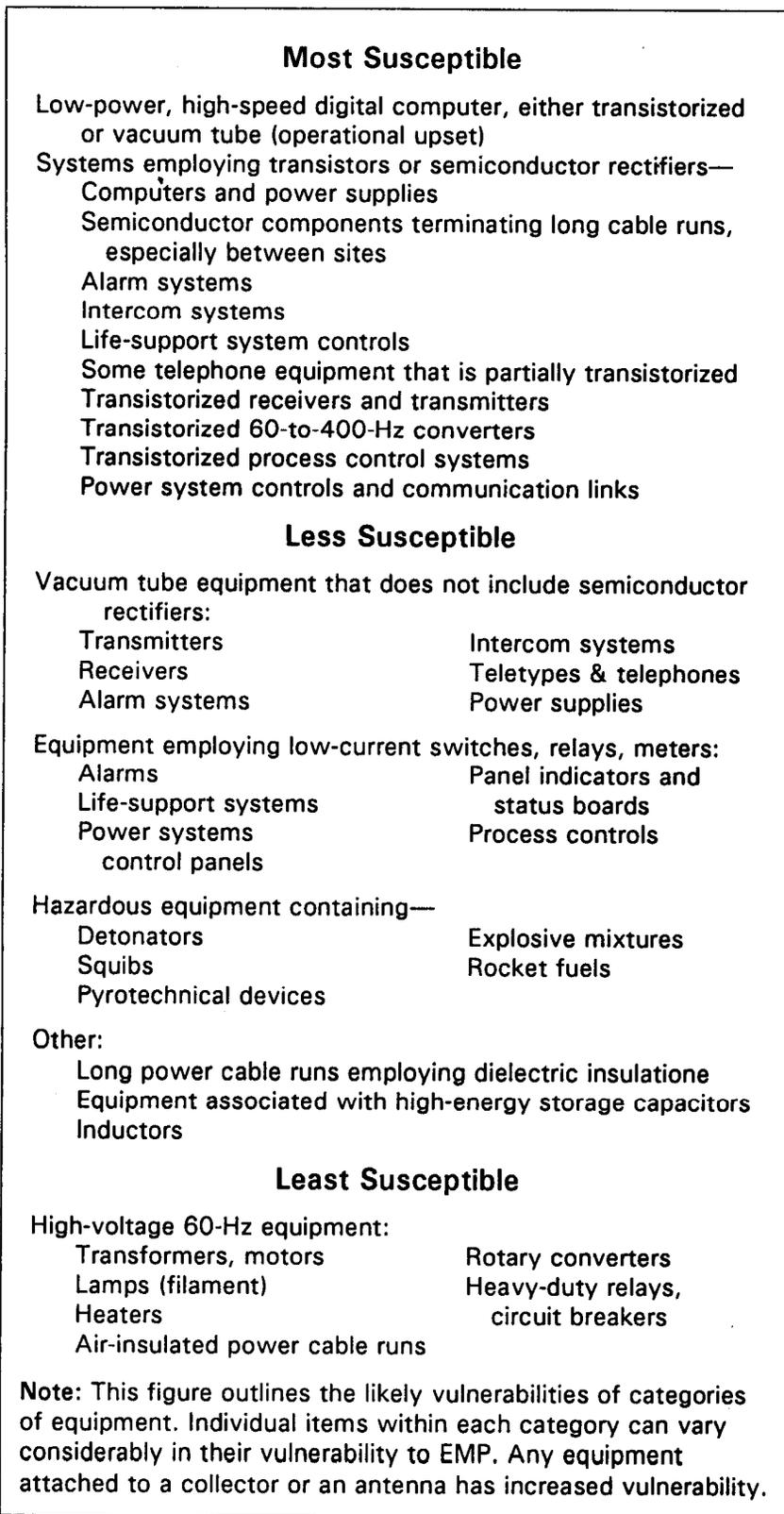


Figure C-3. Degrees of susceptibility to EMP for equipment.

EMP hardened. In many situations, quick reconstitution and recovery of standard-issue equipment will be possible because the needed parts are in the supply system. This will not be true for nonstandard items.

Avoid the single-event fallacy. In assessments of potential tactical situations, don't assume that EMP will occur once and then be over. The contrary may be the case. An aggressor may initiate a precursor attack with high altitude EMP to initially damage unprotected equipment, and then follow-up with additional high altitude or surface-burst explosions to exploit the tactical situation. The only valid countermeasure is to adopt and sustain EMP mitigation postures consistent with tactical missions.

Anticipate EMP. Effective EMP mitigation techniques must be integrated into a unit's standard operating procedures. Units should normally operate in a protective posture. Additional protective measures to be undertaken if

warning of an attack is provided should take no more than 15 minutes to implement.

Integrate EMP mitigation into battle plans.

AirLand Battle doctrine requires the synchronization of all elements of the force in integrated plans. Commanders must understand their superiors' overall operational concepts and plans, and must take the initiative to exploit opportunities to implement these plans as the opportunities occur.

Effective EMP protection procedures are not confidential nor impractical. In most cases, effective EMP procedures are simply extensions of approved tactical doctrine.

Place priority on EMP mitigation procedures that are consistent with the unit's assigned missions and aligned with the basic operational concept—AirLand Battle doctrine. Place emphasis on mitigation techniques that are integrated into unit standing operating procedures, with particular emphasis on warning or short warning conditions.

Mitigation Techniques

EMP mitigation techniques apply in the following three environments in which tactical units operate:

1. Administrative and training situations.
2. Preattack and during attack operations.
3. Postattack recovery and continued operations.

This appendix presents EMP mitigation techniques appropriate for each of these environments. The distinctions made between these three environments are not hard and fast. For example, tactical operations will be conducted concurrent with the implementation of postattack recovery measures. Furthermore, the presentation of these techniques is cumulative, and the techniques suggested for administrative and training situations also should be carried forward to the preattack, during attack, and postattack environments.

Administrative and Training Situations

Some of the most important EMP mitigation procedures can be initiated under peacetime administrative and training conditions. These include—

- Adhering to maintenance procedures.
- Training with back-up systems.

Under all conditions, the most important EMP mitigation procedures are to use hardened equipment and to maintain equipment hardness by using correct maintenance and operational procedures. Improper maintenance can readily reduce or eliminate a piece of equipment's built-in EMP hardening.

Extreme caution must be exercised when adding components to already hardened equipment, such as, placing new systems in a hardened van or mobile shelter.

As a general rule, making an addition to stand-alone equipment that does not have wires or connectors running outside the protected enclosure does not interfere with the EMP hardening of the shelter. However, any addition of new connectors (such as, running a telephone wire or extra air conditioning or ventilation hoses into a shelter) that do not go through an approved surge arrestor and penetration shield or connector, can seriously impact on the hardness of the protected area.

Rules of Thumb

Many EMP-hardening schemes create shields between the electronic equipment and external EMP environments. Therefore, any cable or other penetration that creates a hole or gap in the shield can seriously degrade the system's survivability. Field units should never add connectors to hardened equipment unless directed to do so. Even the small break in the shielding required "to allow a heater power cord or a ventilation hose to enter can be damaging. A number of rules of thumb can be kept in mind when performing maintenance on both EMP-hardened and nonhardened systems, from backpack radios to communications vans:

- Make every effort to ensure that metal-to-metal connections are clean and provide good metal-to-metal contact. Ensure that no gaps exist in the shield. Don't allow dust or dirt to accumulate. Make sure that sloppy paint jobs don't allow globs or paint to build up along the edges of hatches, doors, or other openings.
- Check for, and repair holes and cracks, ensuring that clean metal-to-metal contact is restored.

- Ensure that operating and maintenance personnel can identify all cable shields used for the system.
- Have maintenance personnel check, repair, and, if necessary, replace shields that become worn or damaged. Ensure that shields make good contact with connector shells.
- Replace loose or damaged connections, such as, gaskets and finger stocks.
- Keep access panel doors and other openings shut whenever possible. Such openings provide breaks in shielding and allow EMP energy to enter and damage components.
- Minimize the length of cable runs and avoid cable loops, if possible. Long runs and loops can create unintentional antennas that attract EMP energy.
- Ensure power systems and other cable layouts are in an approved “tree” configuration. This configuration is outlined in the discussion of cables and grounding.
- If the system uses filters, ensure they are maintained according to appropriate technical manuals.
- DO not add grounding points within an enclosure or shelter. Multiple grounds can create loops, which can have damaging currents induced into them by EMP.
- Ensure copies of all required technical manuals and other pertinent documents are available.
- Train and cross train personnel in prescribed maintenance procedures and evaluate their performance in field conditions. Take advantage of the maintenance required to meet chemical warfare requirements. Vans and cases 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.

Training With Back-Up Systems

Tactical forces use electronic equipment, which can be operationally upset or seriously damaged by EMP, for a variety of purposes, including—

- Position finding and reporting.
- Communications.
- Computation and calculation (such as, targeting solutions).
- Storage of tactical and logistical information.

For each of these functions, there are approved nonelectronic or alternative electronic procedures and systems. Maps and compasses can provide location information. With adequate preplanning, a backup signal system, employing messengers, flares, sound-making devices, and other nonelectronic means, can be employed. Also, multiple electronic systems, such as, wire and SHF radios, can be used to supplement potentially vulnerable HF and UHF radios.

Nomograms and slide rules can be used to solve tactical problems. Also, extra calculators can be stored in empty, sealed ammunition cans within vehicles or vans. Manual systems exist that can be used to sort and retrieve tactical and logistical information.

In a combat environment where forces might be subjected to EMP, a firm grasp of these approved procedures can make the difference between defeat and victory. Commanders can be confident in the ability of their units to employ these approved backup procedures only if they train and test their forces prior to combat.

Preattack and During-Attack Operations

While it is impossible to list a single set of EMP mitigation procedures to be used in all tactical situations, some general guidelines likely to be valid in most circumstances are discussed in this section.

Learn to recognize EMP effects.

Under demanding field conditions, individual items of electronic equipment may fail for a number of reasons other than EMP. For instance, combat units may be subjected to radio electronic combat (REC) that may interfere with radio communications by jamming and emitting false signals. It is important not to confuse these events with the effects of EMP. In addition, it is important to recognize that the effects of EMP may not be immediately evident, particularly if a unit has many items of equipment that have been hardened to resist EMP effects. Nevertheless, EMP effects could be present, with potentially disastrous consequences, such as, upsetting computer memories so they no longer provide an accurate portrayal of the tactical situation.

Several rules of thumb can be used to identify the possible presence of EMP effects.

- Failures in electronic systems that are confined to nonhardened items of equipment.
- Failures in multiple types and numbers of nonhardened electronic systems.
- The simultaneous failure of electronic equipment in multiple units. This can be ascertained by establishing contact with adjacent units and higher headquarters.
- The inability to establish electronic communications and/or the sudden occurrence of static. REC can also interfere with radio transmissions; but REC does not cause physical damage to the radio itself. Hence, if nonhardened radios continue to function, but encounter static or jamming, REC, rather than EMP, may be the cause.
- The results of arcing—burnt or melted spots—can indicate the impact of EMP on a nonhardened system.
- If sufficiently close to a surface burst to observe blast and thermal signatures, presume that EMP effects may be present. Use the other rules of thumb to identify the potential effects of high-altitude EMP.

Ensure subordinate leaders understand the commander’s operational concept. If EMP degrades or eliminates communications, mission accomplishment hinges on the ability of subordinate leaders to implement

the intent of their commander's operational concept until communications are reestablished.

Keep subordinate commanders apprised of critical intelligence information. The electronic systems used to gather, process, and disseminate information concerning hostile forces may be upset or damaged by EMP effects. Subordinate leaders will be able to respond to the loss of this information only if they have a clear picture of the most critical facets of the battlefield situation before the intelligence information was interrupted or lost.

Make maximum use of the least vulnerable equipment:

- If only some of the equipment in a unit has been hardened against EMP effects, commanders must place these items where they can have maximum impact (like contributing to the main effort).
- Maximum use also should be made of unhardened, but less vulnerable, equipment. For example, radios operating at frequencies of 100 megahertz and above tend to be less vulnerable to EMP than radios operating at lower frequencies.

Provide for redundant, multiple mode communication links between positions. It has always been sound tactical doctrine to provide for alternative modes of communication between positions, such as, backing up a radio link with wire or messengers. The need to reduce EMP effects on radios and other electronic equipment gives even greater priority to this requirement.

Preplanning and training in the use of backup and alternate communications nets are essential. Wherever and whenever consistent with the mission, establish two or more communications paths and have a contingency plan to reestablish communications. For example, SHF radios might be used as an alternative link because they are less vulnerable to EMP. Area microwave nets might be another option, as well as fiber optics systems, if available, since they couple very little (if any) EMP energy. Other alternatives include air, messengers, motor vehicles, and wire.

Note: If fiber optics are wrapped in metal, the metal can function as an antenna and the devices attached to fiber optics cables may be vulnerable. Also, fiber optics may be susceptible to damage from radiation.

Try to **maintain a stock of critical spare parts.** In some cases, EMP damage may affect only one part of a system, which, if replaced, will allow the device to function as before. Fuses are particularly important; therefore, troops need to know the locations of all fuses in their equipment and maintain and keep spares on hand.

Emphasize crosstraining. After equipment has been subjected to EMP, reconstitution and recovery will be maximized if personnel know what to look for and what to do to restore essential equipment.

Prepare safety plans and practice safety drills. In some mitigation postures, troops will be operating in closed equipment vans and other shelters. Under these

conditions, fires that may start after EMP damages relays and other electronic components could be a hazard. Troops need to practice the skills needed to extinguish electrical fires inside shelters and enclosures, and must have appropriate life-support and fire-fighting equipment at hand.

Remember that **EMP may not be the most significant effect.** While both types of EMP cause similar types of damage, it is useful to recall the basic differences between them:

- While surface-burst EMP is the most far-reaching of the effects produced by a near-surface-burst nuclear weapon, it may or may not be the most important effect for tactical unit operations. In some situations, depending on METT-T, emphasis may be given to blast and thermal effects.
- In case of a high-altitude nuclear detonation, the only effect of the weapon that can affect troops in the field is HEMP.

Recognize that **indications and warning** of enemy use of surface and air burst nuclear weapons **may not be present for HEMP threats.** Current doctrine highlights a number of indicators that may provide warning of enemy use of surface and air burst nuclear weapons. These include the withdrawal of hostile forces from contact, increased air reconnaissance, heightened activity on the part of enemy NBC units, and steps taken by hostile forces to increase their mission-oriented protective posture status. Such indicators, however, are unlikely to provide warning of a high altitude EMP threat.

Collectors and Antennas

For EMP to damage electronic and electrical equipment, the EMP energy must establish contact with these devices. Army hardening programs protect equipment by establishing shields between the harmful EMP fields and critical components.

The form that damaging EMP energy takes depends on the type of antenna or other receiver that picks up the energy. Long lines tend to pick up electrical energy; loops tend to gather magnetic energy. Both can be extremely damaging, especially on sensitive computer memories.

Because they are not commonly regarded as collectors or antennas, unintended pickups may be overlooked. Potential unintended antennas include such objects as gun tubes, heating and ventilation ducts, water pipes, fuel pipelines, conduits, grounding rods and wires, commercial phone and power lines, missiles, guy wires, fences, railroad tracks, and power lines from generators, etc. Remember, if you wouldn't touch the object if it were standing upright in a lightning storm, assume it is an unintentional collector or antenna.

A number of EMP mitigation techniques that can be employed with these collectors or antennas follow:

- Identify all collectors or antennas in your area. Even a quick survey can reveal surprising vulnerabilities to EMP.

- Where possible, avoid contact of equipment with unintentional collectors or antennas:
 - Each physical contact is an opportunity for EMP to enter and damage tactical equipment. For example, signal and power equipment attached to commercial lines can pick up damaging surges of power.
 - While contact with unintentional antennas, such as civilian and military power lines, should be avoided, don't cause any unnecessary damage to these facilities. They may be of value for recovery and reconstitution.
- When possible, disconnect and collapse collectors or antennas. If the mission permits, shut down electronic equipment and disconnect all antennas. Simply turning the equipment off is not sufficient; damaging energy can still enter through the antennas.
- Where possible, avoid use of the most vulnerable antennas. The most vulnerable types of antennas include long wires or rods, wide angle doublets, and omnidirectional antennas. Less vulnerable antennas include—
 - Those with smaller radiating elements, such as small directional antennas, that pick up relatively less EMP energy.
 - Antennas designed to pickup frequencies above 100 megahertz.
- Extend antennas to the minimum amount possible. The amount of potentially damaging EMP energy that gets into a radio depends, in large part, on the length of the antenna.
- Avoid loops.
 - Avoid the creation of loops in wire and other antennas or collectors. Loops act as magnetic dipole antennas, allowing magnetic EMP energy to affect the systems connected to them. Exercise caution in using equipment with internal loops, which can also function as antennas.
 - Recognize different types of systems that might be linked in nonobvious loops. For example, a phone line may run from a van to a switchboard; the switchboard may be linked by wire to a command post; the command post may have a power line connection to a generator; and the same generator may have a power line to the van, thus resulting in an effective loop antenna or collector.
- Ensure antenna guy lines are properly insulated from the antenna. Some large antennas use guy lines as braces to provide stability, and these lines can function as antennas, coupling EMP. This energy will flow into the antenna (and through it into electronic equipment) unless the antenna or guy line connections are well insulated.

Cables and Grounds

Normally, ground cables and rods provide protection from lightning. From the standpoint of EMP mitigation, however, grounds and other forms of cables are unintentional antennas. The following points must be considered for grounding and other forms of cables.

First, avoid loops that function as magnetic dipole antennas. Loops may not be obvious immediately; different types of equipment and connectors may be involved. Secondly, whenever possible, rely on short, straight cable runs. The length of a cable has a major impact on the amount of EMP energy that it picks up and transmits to equipment. For example, a 5-foot cable run might pick up an electrical current of 5 amps, which is enough to operationally upset some electronic equipment, but not enough to cause functional damage. A 1-mile cable run in the same EMP field could pick up as much as 50,000 amps. Try to use short straight cable runs with low impedance grounds; and if possible, cluster cable runs.

If cables are strung in the air, they can pickup more EMP energy. Shallow underground burial does not provide significant protection; and deep burial (10 feet or more) is not worth the construction effort.

Use balanced, shielded, twisted-pair cable in preference to coaxial; and use coaxial in preference to unshielded cable. Imagine three 250-foot cables in the same EMP environment. An unshielded cable could pick up as much as 100,000 volts. A coaxial cable could pick up only about 1/30th of this energy—roughly 2,000 to 3,000 volts. A balanced, shielded twisted-pair cable would do even better, only picking up about 500 to 1,000 volts.

If grounds are required for troop safety, provide them according to the specifications in technical manuals. Also use grounds that offer the best protection against EMP. If available, make use of insulating material, such as rubber mats, in communication vans, shelters, etc.

Whenever possible use common grounds. In multiple cabinet systems (communications vans), ground each cabinet within the shelter and have only one common ground reaching outside the vehicle to the earth. Employ grounding schemes that provide the best protection against EMP. Figure C-4 outlines the preferred grounding schemes for EMP mitigation—the single-point star or crow's foot ground and the "tree." The tree grounding scheme is likely to be the most practical for many configurations of equipment. Since loops are to be avoided, use the tree configuration whenever equipment needs to be linked by connectors that might couple EMP energy.

Command, Control, Communications, and Intelligence

C³I equipment poses some of the most challenging tactical decisions for commanders developing EMP mitigation plans and procedures.

Dispersed operations, to include the use of remotes, increase survivability by reducing the unit's single-point signatures and increasing the number of targets an enemy must find and engage. At the same time, when operating in this mode, units depend more on electronic devices to maintain command and control through communications.

FM 3-3-1

For example, long lines between positions that can function as unintended antennas, can increase the unit's vulnerability to EMP. Furthermore, if electronic communications are interrupted or destroyed by EMP, the unit may not be able to accomplish its missions.

There are realistic tactical trade-offs for which no pat answers can be offered. However, some guidelines can be applied to specific METT-T situations. Remember the following:

- Use redundant, multiple-mode communications. Units generally do not have extra radio equipment, but do have access to other modes of communication, such as field telephones, messengers, flares, and other signal devices, and aircraft and vehicles.
- Make maximum use of the least vulnerable equipment:
 - Most EMP energy occurs in the frequency range below 100 megahertz. While many tactical radios operate in this frequency range, some, like microwave systems, do not. Figure C-5 shows the correlation between megahertz and commonly used abbreviations for radio frequencies.
 - Microwave grids may be very effective alternative communications nets.
 - Broadband radios pose major problems in that EMP energy is broadband. Hence, broadband radios can couple more energy than narrow-band radios.
- Plan for the potential loss of communications equipment. Everyone in the unit should know the standing operating procedures to be adopted if, for any reason, one or more modes of communication are lost. Units should practice using backup and alternative systems.
- Consider disconnecting some communications equipment. This extreme measure may need to be considered; however, mission factors must be examined carefully before using this tactical option. If this mitigation technique is employed, the best procedure is to disconnect the radios from antennas and/or store them inside sealed vans, vehicles, or shelters.
- Other effects, in addition to EMP, may interfere with radio communication. A high-altitude nuclear detonation can affect the earth's ionosphere and thereby interfere with radios that use the ionosphere to move signals. By the same token, radios may be lost due to battle damage. These possibilities reinforce the need to develop and practice backup and alternate communications schemes. Take special steps to protect computers. These steps may include—
 - To the extent practical, operate and store computers in shielded shelters, vans, or vehicles. Consider placing extra calculators and other small devices in ammunition cans, and storing those cans in sheltered areas away from the sides and comers.
 - Computer tapes, discs, and drums tend to be relatively resistant to

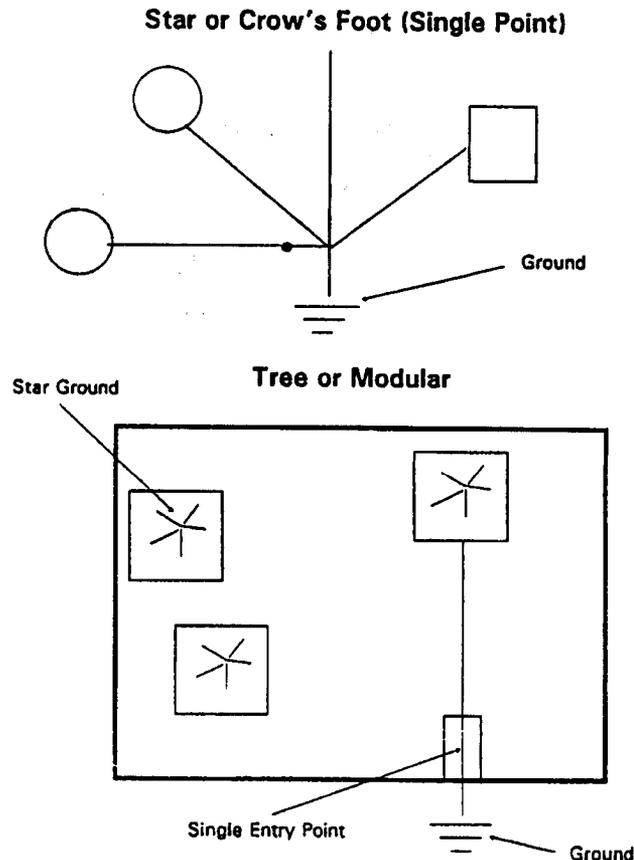
EMP effects. Make regular backups of computer memories to ensure that essential data is not lost in case of EMP-induced operational upset or damage, and store them in a separate place, ideally an EMP-shielded van, shelter, or vehicle.

Shelters and Shielding

Even if EMP fields are very powerful, damage to equipment can be limited or eliminated if devices are kept in shielded shelters that prevent the EMP energy from entering. The key principles to remember when dealing with shields and shelters are the requirements for a continuous shield made of metal.

Shields are continuous when they have no breaks or openings. Once the shielding metal is at least a few millimeters thick, having a continuous shield with no breaks is more important than adding more layers of shielding metal. However, most shields and shelters used by tactical forces will have openings (van doors, access panels in radio cases, etc.). If these apertures are left open, the integrity of the shield is compromised, and damaging EMP energy can enter to damage equipment.

EMP is composed of both electrical and magnetic energy, and any conducting metal can shield against



C-4. Good grounding schemes for EMP mitigation.

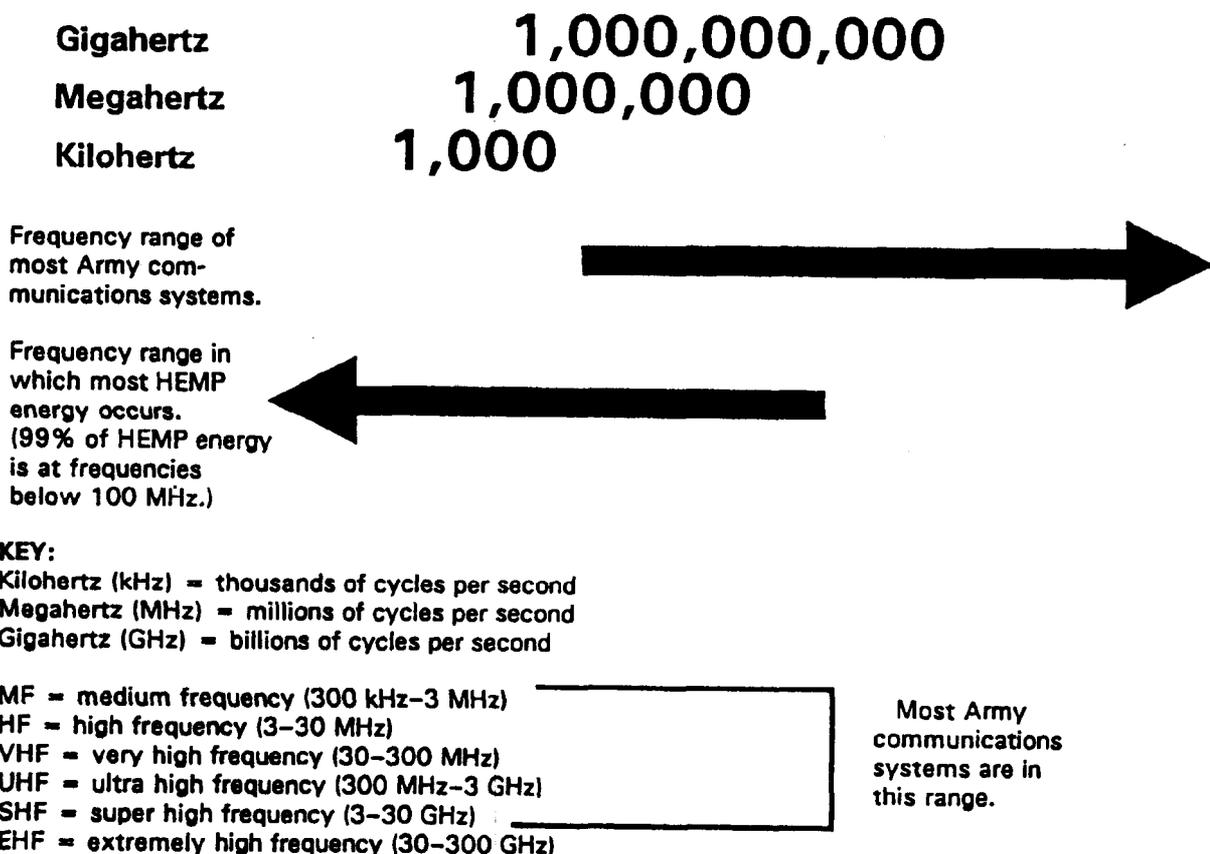


Figure C-5. Radio and EMP frequencies.

electrical effects. Iron and steel provide good protection against magnetic EMP energy. Other kinds of shielding are unlikely to be effective and/or practical for field use.

Shielded shelters can take many forms. A communications van or an armored fighting vehicle is what many people think of when shelters are discussed. However, an ammunition can (with the lid tightly closed) is an expedient shelter for small items such as calculators or backup computer diskettes, and the metal case of a radio can be an effective shelter if antennas have been removed and all access panels are closed.

It is possible to have cables, antennas, and other connectors attached to, or running into, a shielded shelter and still maintain the EMP protection. One should not have complete confidence unless these connections have been evaluated in an Army EMP shielding program.

Nevertheless, there are good layout procedures that can limit the possible damage from running (intended or unintended) antennas through shields into shelters. Proper procedures must be used when linking shelters to antennas and other connectors. These procedures include—

- If possible, group cables and other intended or unintended antennas.
- Place groups of cables in metal conduit.

- If the group of cables must enter the shelter, place them near the phone or power penetrations.
- Try to terminate cable shields, ground buses, and other connectors on the exterior of the shelter without a penetration.
- If possible, insulate penetrating lines just before entry into the shelter, for instance, air conditioning lines, water pipes, ventilation ducts. Exhaust pipes are penetrations that can serve as unintended antennas, and they should be insulated if possible.

As is true for all EMP mitigation procedures, commanders need to consider shielding and shelters in the context of their overall tactical situation. Employment of proper maintenance and operating procedures is of particular importance.

Power Sources

Electronic equipment needs power. In some situations, power sources may be more vulnerable to EMP effects than the devices being driven. While generating equipment may be fairly resistant to EMP, devices within the generating equipment that control power generation can be vulnerable. Therefore, the following procedures can be used to lessen power source vulnerability. If EMP occurs, commercial power equipment and sources may be taken off

line. Therefore, plan to rely on military power-generating equipment. The long lines used in civilian power systems can pick up significant amounts of EMP energy, which can cause damage to military equipment connected to the civilian grid.

Automatic control systems and other components may be vulnerable to EMP effects. If consistent with the mission, the best posture is to have this equipment shut off and physically disconnected. Keep commercial power grids in mind as a potential source of energy after an initial attack.

Commercial power sources may be able to stay on line or come back up after EMP energy hits.

Use of commercial power sources after an attack requires an evaluation of trade-offs. On the one hand, this may be the most readily available alternative or backup source, particularly for combat support and combat service support units. On the other hand, the next EMP attack may damage critical connected equipment. Selective use may be the best option with some systems (but not all) interconnected on a mission-specific basis.

Postattack Recovery and Continued Operations

For either HEMP or SBEMP, the first priorities of commanders should be to continue to engage in tactical operations and to carry out high-priority, mission-essential, recovery and reconstitution operations that integrate EMP mitigation with other tactical considerations.

Use standing operating procedures to establish and implement priorities. Postattack and transattack environments will be confusing. Hence, commanders need to establish recovery and reconstitution priorities prior to the attack, and exercise oversight to ensure these priorities are followed.

Avoid the single-event fallacy.

There is no reason to presume that an attacker will stop after the initial use of nuclear weapons, particularly if high-altitude EMP is being used to create surprise. Indeed, hostile forces may plan to use a series of EMP attacks to disrupt and destroy US forces' combat capabilities. If a unit abandons its EMP mitigation posture as soon as it begins recovery and reconstitution operations, it will be highly vulnerable to a follow-on attack.

Unit standing operating procedures and plans must strike a balance between recovery and reestablishment of mission-essential capabilities and maintenance of mitigation postures against EMP and other nuclear weapon effects.

Place a high priority on the reestablishment of command functions. Since EMP predominantly affects electronic equipment, and since the maintenance of command is the prerequisite for effective operations, mitigation techniques that advance this objective should be given high priority.

Start with a rapid assessment of damage. In a unit that has been subjected to EMP effects, electronic equipment may be functionally damaged, operationally upset, or unaffected, depending on shielding, effectiveness of EMP mitigation posture, etc. Therefore, initial postattack operations should include a rapid assessment of the overall damage inflicted on predesignated high-priority equipment.

Implement quick-fix repairs on critical equipment. Even though electronic equipment has suffered functional damage from EMP, repairs may be straight-forward, such as, resetting circuit breakers or replacing fuses. Troops

should be taught the procedures needed to attempt quick fixes, and should have necessary tools and parts (such as fuses) on hand.

Presume that upset has occurred to computers.

Mission-critical computer memories can suffer upset at levels of EMP that are far lower than the intensities required to inflict functional damage. At first glance, the results of upset may be invisible and may only be revealed when it becomes evident that critical information is incorrect or unavailable. It is a good practice to assume that memories have been upset and automatically reload backups.

After this has been done, create a duplicate and save it as the backup and return it to its EMP protected location to be used if additional attacks occur.

Test all equipment. Consistent with command priorities, all electronic equipment should be inspected for operational upset and/or functional damage. This includes items that have been shielded or hardened against EMP effects in Army shielding programs. In some cases, both upset and functional damage may not be immediately evident.

When inspecting equipment for damage, focus on the most obvious areas for problems. In assessing damage and attempting expedient recoveries, begin with the obvious fixes (fuses and circuit breakers) at the obvious places-points at which EMP energy may have entered the system via components near the antenna.

Army targeting doctrine does not call for the deliberate use of EMP effects to inflict damage on targets. Any damage that does result is a bonus. It is, however, highly consistent with AirLand Battle doctrine to exploit the possibilities for surprise that enemy use of EMP may present. An enemy employing EMP effects to disrupt mission-critical electronic equipment may be subject to tactical surprise if the commanders of US forces, who survived the attack with essential combat capabilities intact, seize and exploit the initiative. In addition, recognize that EMP can function as a valuable supplement to the nuclear attack warning and reporting system. In many tactical situations, EMP effects may be the first indication that nuclear weapons have been employed.