UNITED STATES MARINE CORPS
Senior Courses Training Section
Company B
Marine Corps Communications-Electronics School
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ANNEX A
HS-3.8

STUDENT HANDOUT

ELECTROMAGNETIC INTERFERENCE

LESSON PURPOSE. The purpose of this lesson is to provide a ready reference for personnel concerned with the site layout and with the operation and maintenance of Marine Corps electronics equipment, systems, or platforms and to make them aware of the causes and effects of EMI problems and how to control them. Specifically, the student will be able to identify and characterize EMI-related problems, accurately report EMI problems experienced within a command, and develop a programmatic approach to EMI control within a command. Furthermore, by knowing how to recognize, take action against, and subsequently report the potential hazards of Electromagnetic Interference the communicator will not only provide for reliable, secure, expeditious, and flexible communications but also the protection from the loss of human life will be greatly enhanced.

OUTLINE

1. Electromagnetic Environment. Recently the term Electromagnetic Environmental Effects (E3) has come into use within the Department of Defense (DOD) to better describe the total dimensions of the electromagnetic environment as it effects Command, Control, Communications, Computers, and Intelligence (C4I) systems. EMI is one part of this total picture. Other related components of E3 are listed below and shown in Figure 1. To assist in comprehending the objectives of EMI control, an explanation of these other components follows.

LIGHTNING

EMI **ES**

HERO **EA** **EP**

E3

EMC **EMP**

EMV **RADHAZ**

P-STATIC **EMCN**

Figure 1 -- Electromagnetic Environment

a. Electromagnetic Compatibility (EMC). EMC is the ability of a system or equipment to operate within design tolerances in its intended environment, with adjacent systems and equipment, and with itself.

b. Electromagnetic Vulnerability (EMV). EMV is the undesired response of a system or equipment to the electromagnetic environment or the threshold above which a system or equipment may be undesirably influenced by other electromagnetic energy.

c. Emission Control (EMCON). EMCON is the selected control of emitted electromagnetic or acoustic energy to minimize its detection by enemy sensors or to improve the performance of installed friendly sensors.

d. Precipitation Static (P-STATIC). Precipitation static consists of charged precipitation particles that strike antennas and gradually charge the antenna, which ultimately discharges across the insulator, causing a burst of static.

e. Radiation Hazard (RADHAZ). RADHAZs are radio frequency electromagnetic fields of sufficient intensity to produce harmful biological effects in humans.

f. Electromagnetic Pulse (EMP). EMP is an intense single-phase transient electromagnetic wave that may be generated when a nuclear weapon is detonated or may be generated by nonnuclear means. This intense wave may damage semiconductor components that are found in receiver front-end or signal processing circuitry.

g. Electronic Support (ES), Electronic Attack (EA), Electronic Protection (EP). ES, EA, and EP are the divisions of Electronic Warfare (EW) involving actions taken to ensure friendly, effective use for the electromagnetic spectrum.

h. Lighting. High amplitude electrostatic discharges causing irregular bursts of static in Amplitude Modulation (AM) type receivers.

i. Hazards of Electromagnetic Radiation to Ordnance (HERO). Under some circumstances, certain ordnance components are susceptible to malfunction, burnout, dudding, or ignition when subjected to high-intensity Radio Frequency (RF) fields.

2. Definition of Electromagnetic Interference. Electromagnetic interference is any electromagnetic disturbance that interrupts, obstructs, or otherwise degrades or limits the effective performance of electronics/electrical equipment. It can be induced intentionally, as in some forms of electronics warfare, or unintentionally as a result of spurious emissions and responses, intermdulation products, and the like.

3. Electromagnetic Interference Overview. EMI occurs when electromagnetic energy affects a system or piece of equipment in an unintended or undesirable manner. For EMI to occur, there must be a source, a victim, and a coupling path. Figure 2 shows the relationship of these three elements of EMI.

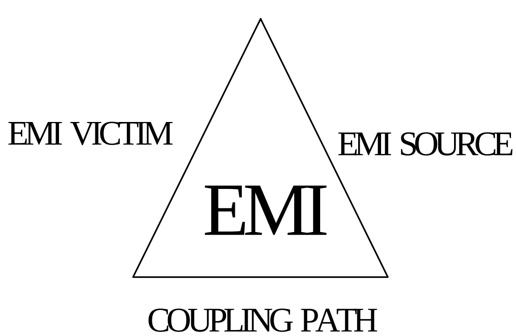


Figure 2 -- Electromagnetic Interference Triangle

The victim can be any component, equipment, or system affected by radiation from the source. The coupling path is the means or mechanism through which the energy is transferred from the source to the victim. Of course, the source is the actual emitter of the EMI. Figure 1 shows the relationship of these three elements of EMI.

a. Sources of EMI. Interference can come from either natural or man-made sources. Figure 3 illustrates these possible EMI sources.

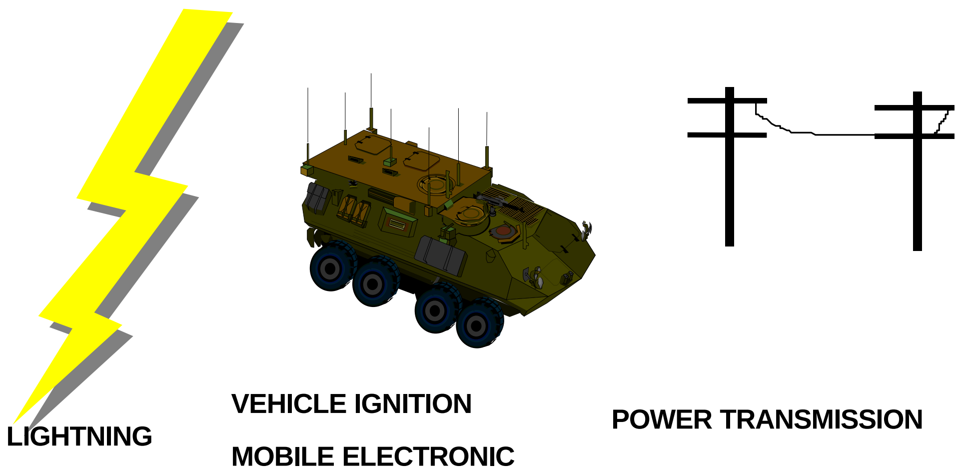


Figure 3 -- Natural and Man-made Sources of EMI

(1) Natural interference is broadband in nature; that is, it is spread across a large range of the frequency spectrum. Natural interference originates in and beyond the earth's atmosphere. Most atmospheric emission usually occurs below 50 MHz, and is most noticeable in its affects to Amplitude Modulation (AM) communications, especially those below 30 MHz. Atmospheric emissions depend on such things as frequency, time of day, season, location, and weather conditions. The most prevalent types of natural interference are electrical storms, precipitation static, and cosmic interference. Reception of natural interference can best be minimized by the use of directional antennas, proper equipment grounds, and effective frequency management.

(2) Man-made interference is the most significant source of Electromagnetic Interference. It may be either narrowband or broadband in nature. Narrowband interference is sharply tunable and exists only at specific frequencies. Broadband interference is continuous and distributed over a number of channels or receiver passbands. The most prevalent sources of man-made interference are functional Radio Frequency (RF) energy, self-generated signals, and incidental interference; hence, communications, radar, weapons control, and navigation systems all present the potential for causing man-made interference. Other common sources of man-made Electromagnetic Interference include the operation of unshielded small appliances, operating near high power lines, interference from other communications equipment, and improper cable routing (especially bad when cables carrying sensitive digital information, like computer cables, are routed parallel to power cables or the mixing of HF and VHF circuits in one 26 pair cable).

(a) Narrowband noise is sharply tunable and exists only at specific frequencies. It is usually caused by other transmitters which are tuned to the same or almost the same frequency, or by siting antennas too close together. On some equipment, such as the LVTC-7, which has many radios of various types, we may have to compromise. Because there is just so much space to put antennas on a vehicle such as the LVTC-7, we will get a certain amount of narrowband noise most of the time. Additionally, radar, because of its high power output, can also cause considerable narrowband noise interference.

(b) Functional Radio Frequency (RF) energy is unintentionally transmitted frequencies which can be either narrowband spurious emissions and harmonics or broadband (arcing) noise throughout the frequency band. When coupled into improperly shielded or filtered systems, these functional transmissions may cause interference to internal equipment components. Figure 4 shows how transmitters may generate energy at frequencies other than the one desired.

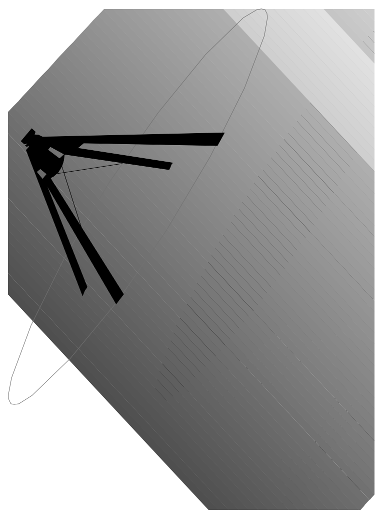


Figure 4 -- Transmitters May Generate Energy at Other Frequencies

(c) Self-generated interference signals are one of the most common forms of Electromagnetic Interference; that is interference caused by the interaction of radio frequency signals with elements of a system's own frame or with the vehicle that transports it. Hence, the system's own frame or the vehicle itself are intercepting significant levels of radio frequency energy. Figure 5 illustrates examples of self-generated EMI.

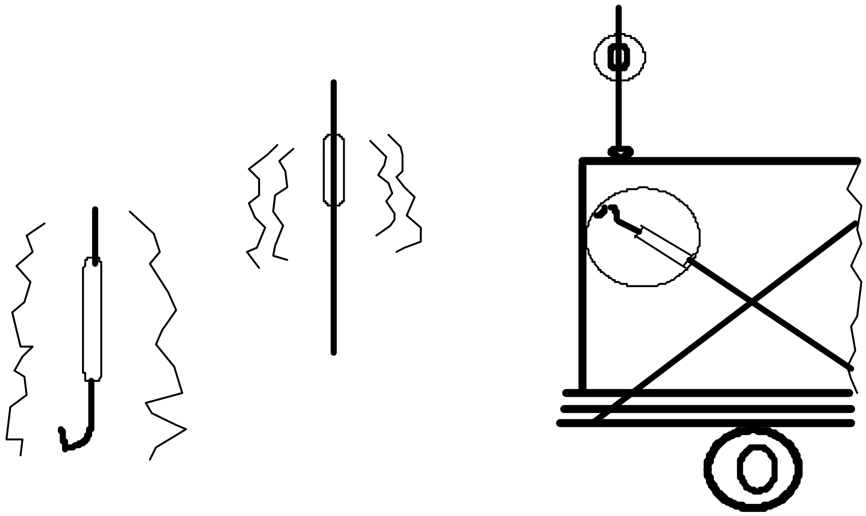


Figure 5 -- Examples of Self-Generated EMI

Self-generated interference, as we said, is the most commonly occurring, and likewise, the most preventable. Self-generated interference falls into two categories: Broadband Noise (BBN) and narrowband Intermodulation Interference (IMI) signals.

1. Broadband Noise (BBN) is characterized by intermittent noise bursts (much like those generated by electrical storms) that affect large portions of the frequency spectrum. Broadband interference is generated by loose or intermittent points of contact at metallic junctions which receive RF signals from nearby transmitting antennas. When conditions are right, these received signals cause electric current flow across the metallic junction. Such arcing may occur between loose or broken elements of an antenna. The sudden change in current produced by the contact between these objects produces broadband noise. It should be noted that if these same junctions are corroded as well, they can also produce IMI. Some good examples of broadband noise include: loose antenna connections, improper grounding, corroded antenna parts, and for vehicular mounted equipment (especially vans) improper common grounds.

a. To correct this BBN problem, the arcing junction points must be eliminated. All metallic items in the antenna field must be carefully installed, properly preserved, and thoughtfully stowed. All metal-to-metal junctions must be properly bonded to achieve good, clean, zero-impedance electrical contact or must be insulated to prevent contact and arc-over. The appropriate method to be used depends on each junction, its purpose, its portability/disassembly requirements, and the materials on hand. Welded junctions achieve excellent electrical continuity but cannot be disassembled. Also, welding is not practical for dissimilar metals. Bolted junctions can be used so long as mating surfaces are properly cleaned to bright, shiny metal; preserved with conductive, noncorrosive compound to exclude contaminants; and sealed to prevent deterioration, rust, or corrosion.

b. Stainless steel bolts, nuts, and washers should be used in all installations exposed to weather to inhibit rust formation. It is preferable that this hardware be nonmagnetic because ferromagnetic hardware in the RF signal path of an antenna system might become an Intermodulation Interference (IMI) source. When neither welding nor bolting is practical, a bondstrap might be required to bridge the junction. When the metal-to-metal contact point does not require bonding, such as when it is not part of the system ground plane, insulation to prevent electrical contact may be practical. Also, nonmetallic replacements such as portable ladders, guy wires, slings, and antenna masts can be used when they are not part of the communications system's antenna-radiating elements or ground plane.

2. Intermodulation Interference (IMI) is a form of EMI that occurs as a result of mixing two or more RF signals in a nonlinear element. IMI products are narrowband EMI signals that appear as harmonics or as sum-and-difference frequencies when two or more transmitters are keyed simultaneously. A nonlinear element is simply one in which the current through the element is not at all times proportional to the voltage across the element, as in a linear element. Figure 6 shows the relationship between linear and nonlinear elements.

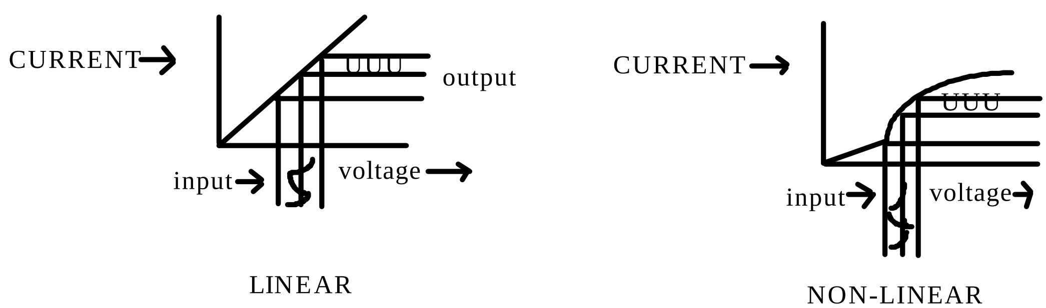
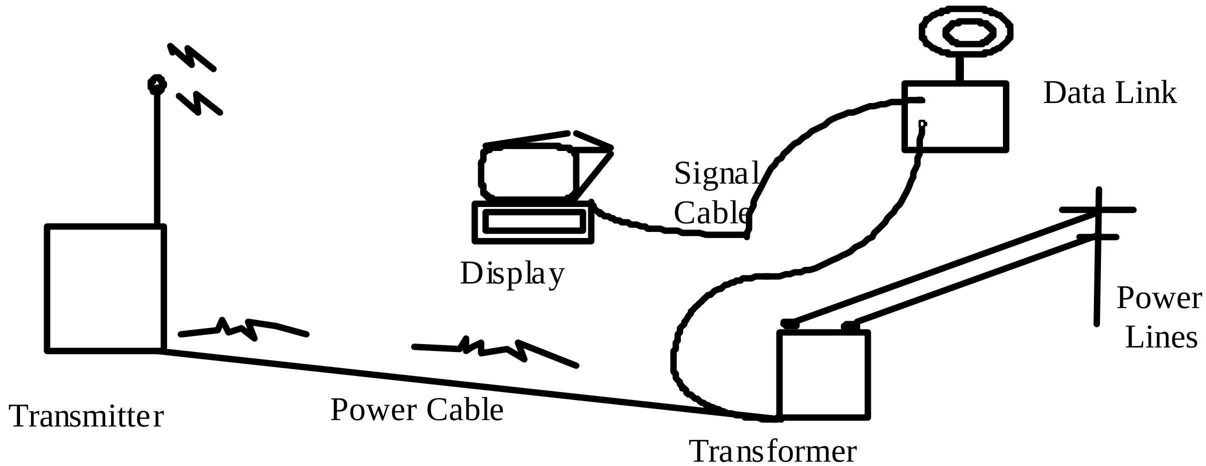


Figure 6 -- Linear and Nonlinear Elements

Nonlinearity results in distortion of incoming signals, mixing them, and thus producing new, undesired signals. Any corroded metallic junction will have nonlinear conduction characteristics. The nonlinearities that cause the most IMI problems, however, are those metallic junctions exposed to weather. Such items include antenna mounts, cables, shackles, and corroded nuts, bolts, and turnbuckles. Additionally, concertina wire laid too close to a transmitting antenna, water cans placed on vehicles, or simply a helmet placed near a radiating source may produce IMI. Harmonics of the primary frequency may also be generated due to the conduction characteristics of the junction. For example, if f1 is the first frequency and f2 is the second frequency, additional frequencies, known as intermodulation products, or harmonics, will be generated. Hence, consider your operating frequency of 35 MHz (f1) added to your operating frequency of 33 MHz (f2). These two frequencies added together equal 68 MHz (f3). If 68 MHz is being used at the same site, or in the same location, there could, and most likely would be, a problem. Ferromagnetic metals are also of technical importance to Electromagnetic Interference, especially iron, cobalt, nickel, and their alloys. These metals are subject to the Barkhausen Effect: When the internal domains are aligning magnetically with the external field, the alignment is not a smooth process, but proceeds in a series of small, jerky steps. These jerky steps produce Intermodulation Interference (IMI), and, hence, EMI. Because of the possible generation of broadband noise when ferromagnetic materials are used, it is important that ferromagnetic nuts, bolts, washers, and lugs be avoided in the RF path, such as fastening the antenna lead to the coupler. Nonferromagnetic hardware should be used whenever possible. Nonferromagnetic hardware has the added advantage of being corrosion resistant, thus providing longer operation, free from EMI.

(d) Incidental interference is associated with equipment or devices that do not generate a useful signal as their prime function. Switching devices, ignition systems, electrical equipment, powerlines, and fluorescent lamps are the major sources of this type of interference. Automotive ignition systems generate RF interference, although communications vehicles <u>normally</u> include shielded cables and spark wires. Power transmission lines carry interference caused by multiple sources such as power generators, air conditioner compressors, or other like interference sources. It is easy to understand how and why these items can be a source of very intense, continuous broadband interference.



b. Coupling Paths. The means by which an interference source is coupled to the victim equipment is significant in interference problems. There are three common modes of coupling: direct radiation, indirect coupling, and conduction. Figure 7 illustrates examples of coupling paths.

Figure 7 -- Coupling Paths

(1) Direct radiation includes the coupling of functional signals between transmitting and receiving antennas and between transmitting antennas and equipment.

Direct radiation is illustrated in Figure 8. Radiated signals may gain direct entry into equipment through ventilation holes, meter and other panel openings, and inadequately shielded cabinets or cables.

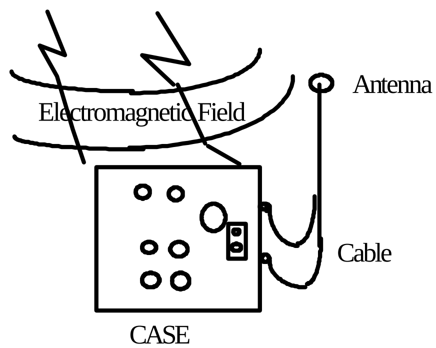
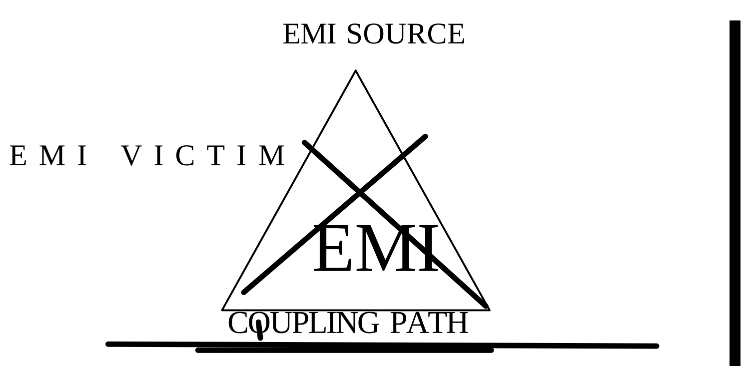


Figure 8 -- Direct Radiation

(2) Indirect coupling occurs in most instances when cables with high-power levels run parallel to cables that control sensitive electronics systems. Energy coupled in this manner can disrupt the signal on the sensitive line and interfere with the function of the subsequent electronic circuits. Some examples of indirect coupling are:



(a) Power cables coupling to audio circuits, which causes an excessive hum in the system.

(b) Tracking radar servo cable coupling to computer circuits, in which case transients cause reset of digital logic circuits.

(c) Power cable coupling to Closed-Circuit Television (CCTV) camera cables, which adds lines to video display, thus causing picture break up.

(d) Radar modulation cables coupling to Identification, Friend or Foe (IFF) control cables, which causes inadvertent mode enabling.

(e) Radar antenna power cables coupling to navigation system antenna cables, thus preventing reception of navigation signals.

(3) Conduction occurs because interference can be coupled directly from one piece of equipment to another by hard wire conduction. When two items of equipment share a common power source or generator, coupling interference frequently occurs between them on the powerline. A complete circuit path is necessary for this process to occur. There must be a direct connection between two circuits, and, in addition, a return path. Figure 9 shows a source coupling to a receiving device by conduction through common power-supply wiring.

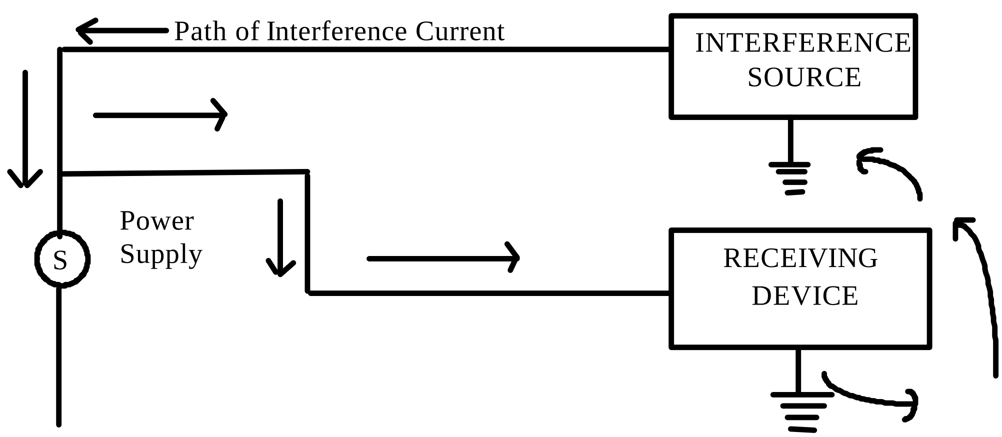


Figure 9 -- Conducted Emission

If the means of coupling is removed, the interference source can no longer affect the victim equipment and the interference will cease, as shown in **Figure 10**.

Figure 10 -- Without Coupling, Interference Ceases

c. System Susceptibility. As previously stated, equipment becomes a victim of EMI for many reasons. We discussed that automotive ignition systems generate RF interference extending into the GHz frequency range if not properly shielded and the fact that communications jeep installations normally include shielded cables and spark wires. Likewise, power transmission lines carry interference caused by multiple sources such as power generators, air conditioner compressors, or other like interference sources. (See Figure 11)

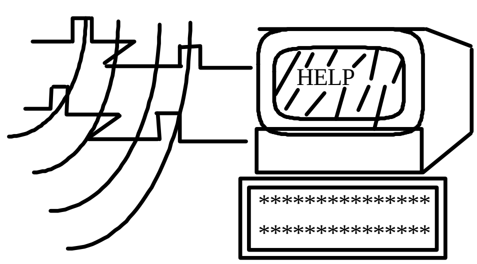


Figure 11 -- Computers are Susceptible to Radar Pulse

There are three levels of Electromagnetic Interference we in the communications environment should be concerned with. The severity of the levels constitutes the degree of required action to be taken by the equipment operator. We shall note, however, that the less severe the interference, the less is the action normally taken by the operator. Doctrinally, as soon as an operator realizes interference is occurring, he should begin to take action.

(1) Mild interference does not contribute significantly to system degradation or operator fatigue and is normally tolerated by equipment operators. Although mild interference may be detected visually or audibly, operators report no inability to operate the system within its design parameters.

(2) Moderate levels of interference requires corrective action because it reduces operator and equipment effectiveness. IT SHOULD NOT BE TOLERATED. Unfortunately, some forms of moderate interference go undetected because the operator believes it is simply natural interference or some interference inherent within the system over which he has no control. Due to a lack of EMI awareness, he believes that the problem will always exist and he must find ways to work around the problem, which usually causes more problems. Moderate interference is the most insidious form of EMI because it usually goes unresolved.

(3) Severe interference renders the victim equipment useless or nearly useless. The interference may affect an entire system or only a portion of the system, such as an operating frequency band or a single mode of operation. Severe interference is normally reported because it causes a drastic loss of system capability or possibly an aborted mission. By now, the communications system is severely degraded and corrective action needs to occur in order to bring the system back on line.

In order to prevent our communications systems from being victimized by EMI, we must perform three measures. First, we must recognize when our systems are being disrupted by EMI; second, we must take action to correct any EMI problems that are affecting our communications systems; and finally, we must report any and all problems that are encountered.

4. Take Action. Once EMI problems have been recognized, actions can be taken to eliminate or control them. These actions can be either preventive or corrective in nature, or a combination of the two. Marine Corps equipment is designed to perform specific functions in support of Marine Corps missions. Besides the primary operational functions, however, reliability, ease and cost of repair and maintenance, compatibility with other equipment, and level of operational skills required are other important aspects that have been considered in Marine Corps equipment. Maintenance and preventive maintenance routines have been developed to keep the equipment operating at the required performance levels. Electromagnetic Interference (EMI) control is an especially important consideration in preventive maintenance programs. The following paragraphs describe general EMI control maintenance and preventive maintenance concepts for Marine Corps equipment.

a. Preventive Actions. Every Marine Corps unit that operates communications equipment should have an EMI inspection program. This program can be concurrent with normal maintenance programs, and is used to check for potential EMI problems. An inspection checklist which identifies common potential EMI problem areas should be available to personnel making the inspection. A sample EMI checklist is provided at the end of this handout as a general guidance for the construction of a checklist tailored to fit most units. Therefore, when a problem gets discovered during an inspection it can be subsequently corrected.

b. Preventive Techniques. Techniques which can be used to prevent EMI hazards include coupling, shielding, grounding, bonding, utilizing filters, and corrosion control.

(1) Indirect coupling should be avoided between cables carrying high power levels or electrically noisy signals and cables connecting to sensitive electronic circuits.

(2) Shielding is the most common form of interference suppression. Shielding comes in many forms and is used to protect cables, equipment, and, under certain specialized conditions, antennas.

(3) Grounding is directed at the reduction of EMI by minimizing the coupling of interference into electronic systems. Grounding also provides other benefits. For communications, effective grounding improves antenna performance. This helps in the EMI arena because the increased signal levels are less susceptible to interference. Safety, of course, is another aspect of grounding.

(4) Bonding is the process of providing low impedance union between two metallic conductors. Bonding techniques recommended for EMI suppression include:

(a) Class A - A bond achieved through the process of welding or brazing.

(b) Class B - A bond achieved by mounted hardware and other areas of metal-to-metal contact inherent in normal installation of an item or equipment.

(c) Class C - A bond achieved by bridging two metallic surfaces with a metallic bond strap.

(5) Filters are extremely effective in reducing and suppressing EMI. Filters attenuate undesired EM signals while passing the desired ones. The application of a filter, however, in a subsystem requires careful consideration of a variety of trade-off factors such as insertion loss, impedance, power-handling capability, distortion, tunability, cost, weight, size, and rejection of undesired signals.

(6) Corrosion control is the process of eliminating the elements of corrosion. Corrosion has been defined as the process by which material returns to its natural state. The

metals found in construction are not used in their original state, but have been refined to give them a more useful form which is generally not stable. As the refined metals are exposed to the atmosphere and water, they slowly revert to their original state by forming stable chemical compounds. This process occurs in all metals, including those used with communications equipment.

c. Corrective Actions. Let's take a look at some basic fixes for controlling EMI that have been proven effective. These fixes can be simple operator techniques such as adjusting receiver controls or changing frequencies. An example of a more permanent fix would be the rerouting of a transmission line. Other techniques include managing or time-sharing frequencies so that only one signal is transmitted at a time, inserting filters or video blankers, and, if necessary, removing or shutting down the EMI source. Strict adherence to the frequency plan and your units Electromagnetic Compatibility (EMC) SOP will also help reduce or prevent EMI.

d. Electromagnetic Compatibility (EMC) SOP. Promulgated in order to more effectively promote EMI awareness and the importance of electromagnetic compatibility; that is, our ability to take full and effective use of the electromagnetic spectrum, without causing EMI to friendly equipment because of that use. An EMC SOP should be used by any unit which operates electronic/electrical equipment. This SOP should reinforce the vital importance of maintaining EMC in Marine Corps systems. All personnel play an important role in achieving this goal.

e. Report Your EMI Problems. EMI problems should be reported as soon as possible. Remember, other units may be, or may have experienced, the same problem you are now encountering. A fix for your problem may even exist, ready to be implemented.

(1) EMI HOTLINE. One of the major elements of the corrective action program is the EMI hotline. Marine Corps Order (MCO) 2400.1 provides details on this program.

(a) The hotline is available to all Marine Corps activities seeking informal, expert EMI technical assistance. It is manned by a commercial firm and the telephone number is (703) 425-9666. Collect calls will be accepted 24 hours a day, 7 days a week; however, the line is manned by technical personnel only during working hours (0800-1700, Eastern Standard Time/Eastern Daylight Time, Monday through Friday). At all other times, the line will be answered by a recording service which will take the caller's name and telephone number. Contact will be made with the caller no later that the next working day.

(b) When a problem is reported on the hotline, basic data are required by engineering personnel to research a problem and get back to the caller with appropriate assistance or recommendations. When making a hotline report, it is desirable that the caller be prepared to answer the following questions:

1. What type of system is affected?

2. What equipment or procedure(s) are affected?

3. What equipment or procedure(s) appear to be causing or aggravating the problem?

4. When did the problem or incident occur (date/time)?

5. Summarize briefly the problem or incident. Is this the first time the problem has occurred or has it been encountered before? Occasionally? Consistently?

6. Do you know if the problem has been reported previously by official traffic, message, letter, or telephone? Can you provide the message originator and date-time-group, or, if by letter, the originator, serial number, and date? Was Headquarters Marine Corps an action or information addressee on the letter or message traffic?

(c) The above information is useful in resolving the problem, but it is not mandatory for reporting a problem via the hotline. The purpose of the hotline is to provide technical response rapidly for emergency problems. Its use is encouraged. If the answers to any of the above questions are not available, the problem should still be reported. The missing answers will be developed as part of the problem resolution.

(2) Hard Copy Reports. The EMI hotline does not replace other current reporting requirements. These hard copy reports are part of the Marine Corps Maintenance Management System; specifically, the Quality Deficiency Report (QDR) and the Equipment Repair Order (ERO). Should the equipment have design deficiencies that cause EMI, a QDR must be completed. An ERO is used to request performance of equipment maintenance, such as; modifications, calibration, Limited Technical Inspections (LTIs), and corrective maintenance. Ensuring these reports are completed will allow for timely action to be taken Marine Corps-wide.

(3) Marine Corps Electromagnetic Environmental Effects (E3 Control Team. Headquarters Marine Corps has established an Electromagnetic Environmental Effects (E3) Control program specifically designed to deal with EMI problems. The objectives of the program are to: identify and assess E3 problems throughout the Fleet Marine Force (FMF); assist the FMF in correcting E3 problems; and assist the acquisition manager in controlling E3 in newly purchased equipment.

(a) Investigative Electromagnetic Environmental Effects (E3) Control Teams. Once a problem has been brought to the attention of HQMC, investigative control teams may be assigned to identify and assess the situation. These teams are supported by contractors specializing in E3 control and often participate in field exercises in order to determine the nature of current problems.

(b) These control teams will also make recommendations for prevention of future EMI problems.

REFERENCES

1. OH 3-3F, *Guide to Electromagnetic Interference Control*

2. MCO 2400.1_, *Establishment of Marine Corps Electromagnetic Interference Control Hotline*

3. MCO 2410.2_, *Electromagnetic Environmental Effects Control Program*

NOTES

ATTACHMENT.

A - *Electromagnetic Interference Checklist*