Electromagnetic Pulse and the Radio Amateur - Part 1

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Electromagnetic Pulse and the Radio Amateur

Part 1: Will your station survive the effects of lightning strikes or electromagnetic pulse (EMP) generated by nuclear explosions? The information in this series will help you harden your radio system.

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Radio amateurs have long been concerned with protecting their radio installations against lightning. Many have applied lightning protection where required by local electrical codes. Traditionally, the installed protection is designed to combat "slow" lightning strikes (having rise times on the order of tens of microseconds) with protection from direct overhead strokes obtained by sheltering important conductors with a grounding system.

To address the transient threat, including lightning-voltage surges and electromagnetic pulse (EMP), it is necessary to protect installations against electromagnetic fields rising to a peak intensity of 50 kV/m in several nanoseconds. While some modern lightning-protection devices are effective against a lightning transient threat, the majority of them will not act in time to prevent the faster EMP from entering the radio equipment.

Protection of Amateur Radio installations is becoming more difficult as circuit components become more sensitive to transients. ICs are susceptible to damage at transient levels smaller than those of discrete transistors, which are more susceptible than vacuum tubes. New protection devices such as metal-oxide varistors (MOVs) offer protection within one nanosecond of the arrival of a transient pulse such. When properly selected and installed, such devices show promise of providing protection against the universal transient threat.

Background

One of the primary reasons for the existence of Amateur Radio is to provide a public service. Over many years, this service has proven to be most valuable during emergencies. At first, the amateur public emergency service existed spontaneously on an individual basis. Today, it has evolved into a well-established system that includes the Amateur Radio Emergency Service (ARES), the National Traffic System (NTS), the Radio Amateur Civil Emergency Service (RACES) and the Military Affiliate Radio System (MARS).[1]

Radio amateurs have provided communications during natural disasters such as tornadoes, hurricanes, floods and blizzards when other forms of communication have been inadequate. The amateur uses portable, mobile and fixed-station radio equipment that is not necessarily dependent on commercial power. In almost every community large and small, there is a cadre of experienced radio amateurs willing to respond to the need for emergency communications.

In addition to the role amateurs fill during natural disasters, the National Communications System (NCS) has long recognized that the Amateur Radio community provides a great national resource. It is of value not only to the public, but also to augment civil and military agencies. To enhance the nationwide posture of telecommunications readiness for national emergencies, the NCS and the ARRL have a written memorandum of understanding. Its purpose is to establish a broad framework of cooperation and a close working relationship with volunteer radio amateurs for national emergency-communications functions. Therefore, it is in the national interest to find ways to enhance the survivability of the Amateur Radio system in a nuclear environment.

EMP Defined

Electromagnetic Pulse (EMP) is defined as a large, impulsive type of electromagnetic wave generated by a nuclear explosion. EMP commonly refers to a nuclear electromagnetic pulse (NEMP). In this usage, it is a plane-wave, line-of-sight electromagnetic phenomenon that occurs as a result of an above-ground nuclear detonation. NEMP has an electric field strength of 50 kV/m horizontally and 20 kV/m vertically, with a pulse rise time to peak of 5 to 10 nanoseconds.

There are several different types of EMP resulting from a nuclear explosion. One of the more significant types is the High-altitude EMP (HEMP) that results from a nuclear explosion above 30 miles in altitude. The HEMP is created by the interaction of high-energy photons (gamma rays) with atmospheric molecules, producing Compton electrons. These electrons decay in the Earth's magnetic fields, emitting photons in the process.

System-Generated EMP (SGEMP) is produced by the direct interaction of high-energy photons with systems (equipment), rather than through their interaction with atmospheric molecules. SGEMP is important because of its effects on satellite systems and in-flight missiles.

The third type, Magnetohydrodynamic EMP (MHD-EMP) is different because of its distinct physical generation mechanism, later occurrence, smaller amplitude and longer duration. It is sometimes referred to as late-time EMP. MHD-EMP poses a threat for very long landlines (including telephone cables and power-distribution lines) or submarine cables.

EMP Description

Of the three types of EMP, HEMP poses the greatest threat to the Amateur Radio operator's equipment. Therefore, this report deals primarily with HEMP and lightning.

Generation Process

A major threat exists to every Amateur Radio installation in the US from the possibility of high-altitude nuclear explosions over the central part of the country. One such detonation at a height of 250 to 300 miles could produce an EMP/transient effect over the contiguous US. Significant

[1]Notes appear on page 36.

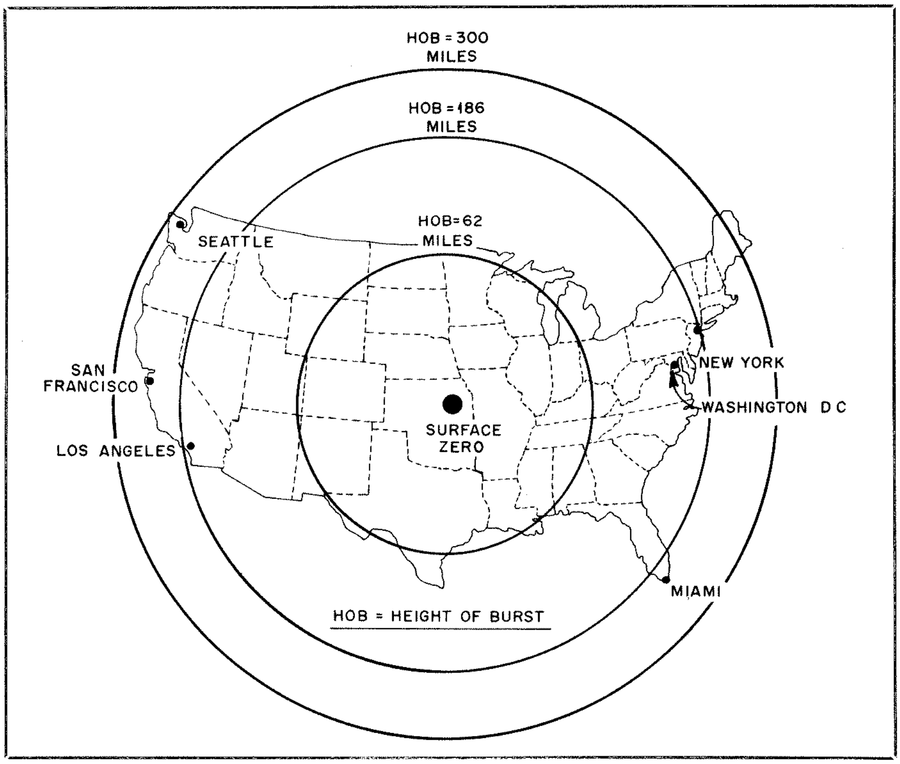

Fig 1—EMP ground coverage for high-altitude, 10-megaton nuclear explosions at altitudes of 62, 186 and 300 miles.

EMP levels can occur on the Earth's surface at all points within line-of-sight from the explosion. If high-yield weapons are used, the EMP field strength felt on the earth will not vary significantly with the height of the explosion. Therefore, a high-altitude explosion, which can cover a large geographic area, will produce essentially the same peak field strength as a low-altitude explosion, which covers a small geographic area. Fig 1 illustrates the areas that EMP would affect based on height of burst (HOB) above the US.

The Compton Effect

During a nuclear explosion, gamma rays (high-energy photons) are radiated in all directions from the source. These gamma rays react with the atmosphere to produce large electrical charges and currents, which are the sources of the electric and magnetic fields that comprise the EMP. The basic physical process that converts the gamma-ray energy into EMP energy is known as the Compton Effect.

When a gamma ray strikes an atom in the atmosphere, it knocks an electron free and drives it outward from the detonation. Since the electrons (Compton electrons) are smaller, they are moved outward more rapidly than the remaining large positively charged portion of the atom. The results are a charge separation in the atmosphere, and creation of a huge electric current. This charged region in the atmosphere is called the "deposition region." An additional current is generated when the Compton electrons are deflected from their original path by the Earth's magnetic field and spiral around the geomagnetic field lines. They complete about one-third of a revolution before they decay and are reabsorbed by the atmosphere. The current generated by this magnetic deflection is a major component of the deposition region in a high-altitude nuclear blast.

Deposition Region

In a high-altitude nuclear blast (30 miles or more above the Earth's atmosphere) the gamma rays radiated in a downward direction travel through the near vacuum of space until encountering a region where the atmospheric density is sufficient to produce the Compton Effect and the resulting deposition region. The deposition region is generally circular and is approximately 50 miles thick in the center and tapers toward the outer edge, with a mean altitude of 25 to 30 miles (Fig 2). The radius of the deposition region is determined by the height of the burst, the yield of the nuclear device, and is limited by the curvature of the earth. The deposition region is formed quickly since the gamma rays and the Compton electrons both travel at nearly the speed of light (186,000 mi/s) in a vacuum. The rapid generation of the deposition

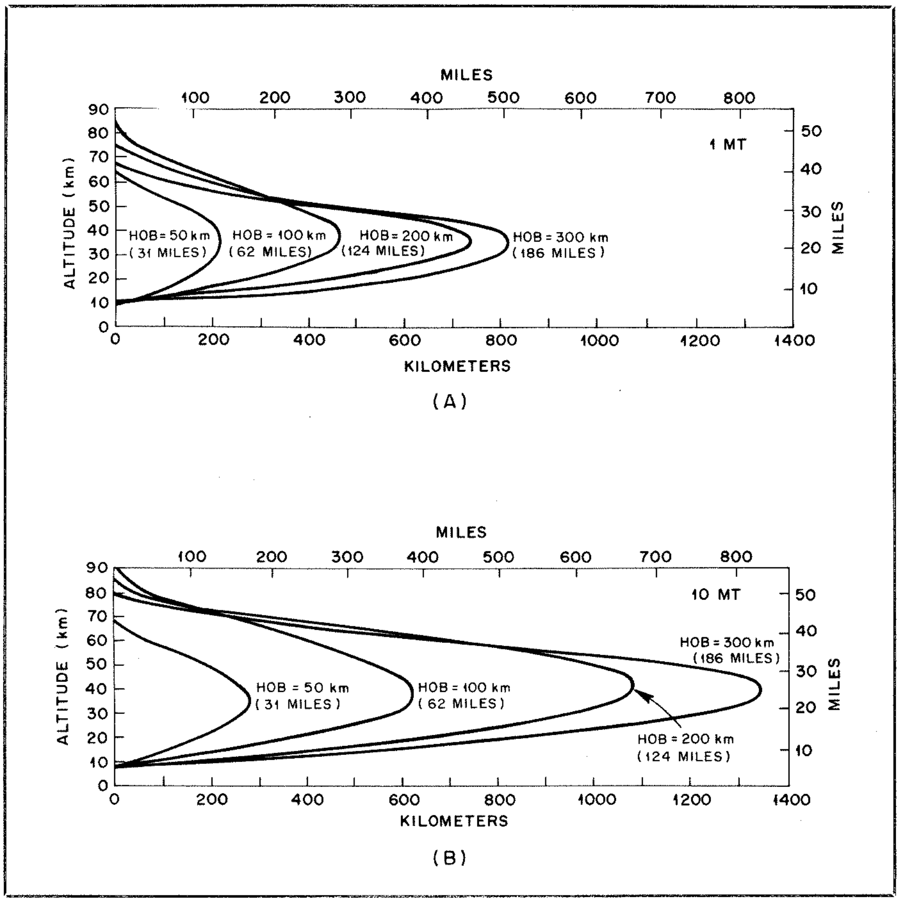

Fig 2—At A, deposition regions for a 1-megaton nuclear explosion at altitudes of 31, 62, 124 and 186 miles. Deposition regions for a 10-megaton nuclear explosion at the same heights are shown at B.

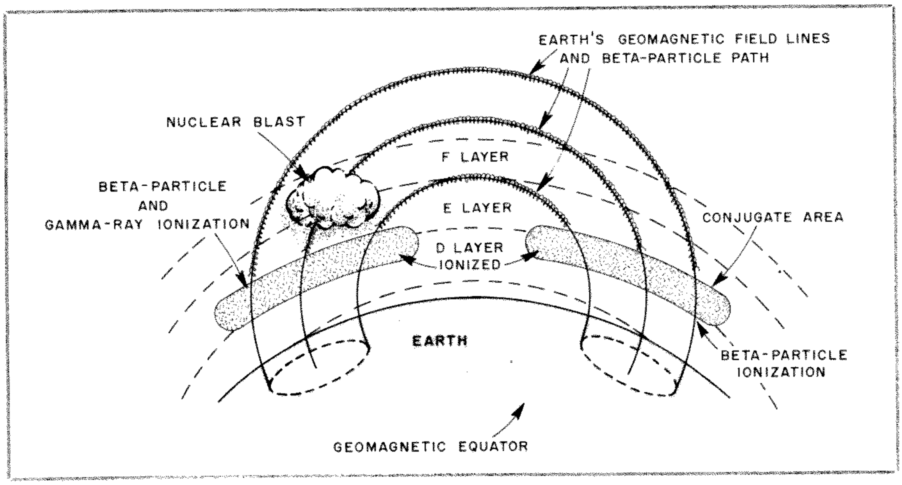

Fig 3—Depiction of the magnetic conjugate.

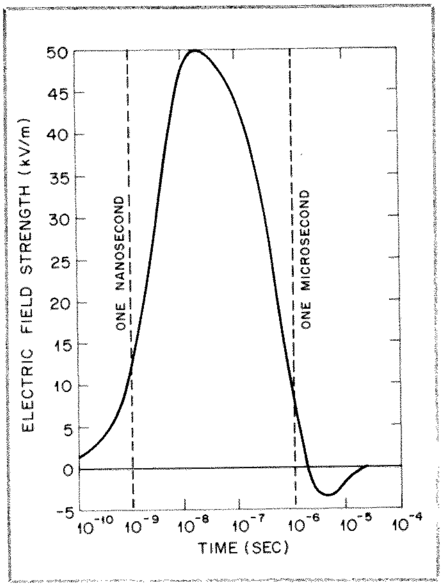

Fig 4—Electric field strength of a typical EMP wave.

region results in a pulse with a very fast rise time, covering a broad frequency range.

Magnetic Conjugate

A high-altitude detonation also generates beta particles, or free electrons, that spiral along the Earth's magnetic field lines. This creates an increase in the ionization of the D layer of the atmosphere not only at the local area, but also in the area known as the magnetic conjugate—in the opposite hemisphere! Fig 3 graphically depicts the immensity of EMP's widespread effects. Amateurs in both the local and opposite hemisphere may find a sudden loss in their ability to communicate.

Electromagnetic Spectrum Effects

Amplitude (Waveform)

An EMP has a fast rise time and a short duration when compared to lightning surges. A high-altitude EMP rises to peak voltage in approximately 10 nanoseconds (ten billionths of a second) and has a duration of approximately 1 microsecond (1 millionth of a second); see Fig 4. A lightning stroke, on the other hand, rises to peak voltage in about 2 microseconds and lasts 100 times longer (1 thousandth of a second) than an EMP.

A significant difference between EMP and lightning is that EMP effects are felt over a much larger area simultaneously, not just locally. Any conductor within the area of an EMP will act as an antenna and could pick up the electromagnetic energy. The voltages and currents induced in these conductors are comparable to those produced by the largest lightning bolts. However, the total energy of the EMP current is not as large as a nearby lightning-current pulse because of the short duration of the EMP.

Lightning can be viewed almost as a steady current when compared with EMP. The instantaneous peak-power density for an EMP is typically 6 MW/m^2. However, since the pulse is of such short duration, the total energy received on the ground is only about 0.6 J/m^2.[2]

Radio Frequencies

The energy of a high-altitude EMP is spread over a major part of the RF spectrum. Since the pulse has such a fast rise time and short duration, it covers a broad frequency range extending from 10 kilohertz to 100 megahertz. The electric field strength remains fairly constant in the 10-kHz to 1-MHz band; it decreases by a factor of 100 in the 1- to 100-MHz band and continues to decrease at a faster rate for frequencies greater than 100 MHz. Most high-altitude EMP energy is at frequencies between 100 kHz and 10 MHz, and 99% lies in the frequency spectrum below 100 MHz (Fig 5).

Coupling

Electromagnetic energy is radiated downward from the deposition region to the earth. Any conductor beneath or near the deposition region will act as an antenna and pick up the electromagnetic energy. Long power-transmission lines are effective in picking up the low-frequency components of the EMP. Short metallic conductors, including internal parts of electronic equipment, pick up the high-frequency components of the EMP. A list of collectors is shown in Fig 6. The energy on the conductor is in the form of a strong current and voltage surge that is transmitted to the attached electronic equipment. Table 1 illustrates EMP-induced surges on conductors.

Equipment does not have to be attached directly to a collector (conductor) to be damaged; EMP/transient-pulse energy can be coupled to the equipment in other ways. For example, an electric current can be induced, or a spark can jump, from a primary conductor that collects the EMP energy to a nearby secondary conductor

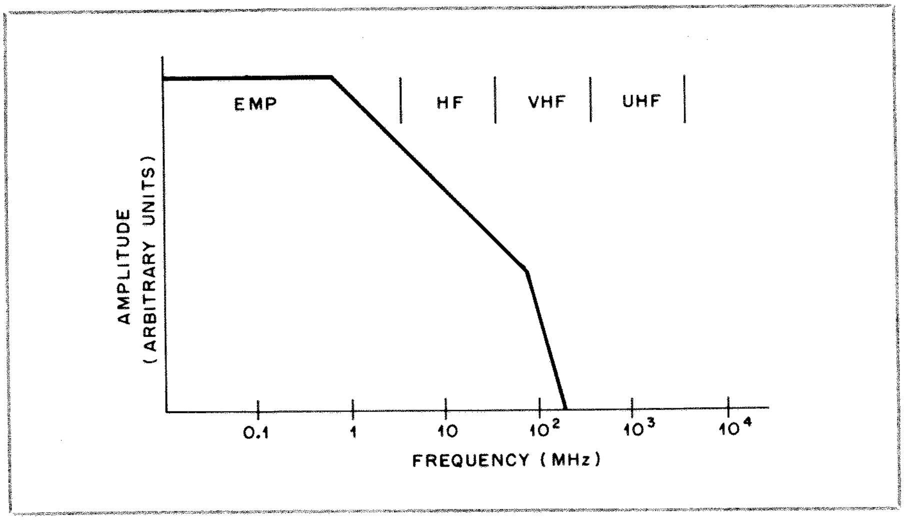

Fig 5—The frequency spectrum of EMP.

Typical Collectors of EMP Energy

- Long runs of cable, piping or conduit
- Large antennas, antenna feed lines, guy wires, antenna supports (towers)
- Overhead power and telephone lines and supporting towers
- Long runs of electrical wiring, conduit, and so forth in buildings
- Metallic structural components, girders, reinforcing bars, corrugated roofs, expanded metal lath, metal fences
- Railroad tracks
- Aluminum aircraft bodies

Fig 6

Table 1

EMP-Induced Surges on Conductors

Conductor Type	*EMP Rise Time (Microseconds)*	*Peak Voltage (Volts)*	*Peak Current (Amperes)*
Long, unshielded wires (power lines, large antennas)	0.01-0.1	100 k-5 M	1 k-10 k
Unshielded telephone wires at wall outlet	0.01-1	100-10 k	1-100
Ac power lines at wall outlet	0.1-10	1 k-50 k	10-100
HF antennas	0.01-0.1	10 k-1 M	500-100 k
VHF antennas	0.001-0.01	1 k-100 k	100-1 k
UHF antennas	0.001-0.01	100-10 k	10-100
Shielded cable	1-100	1-100	0.1-50

Table 2

Effects of Nuclear Detonations on Radio Systems

Frequency Range	*Degradation Mechanism*	*Spatial Extent and Duration of Effects*	*Comments*
VLF	Phase and amplitude changes	Hundreds to thousands of miles; minutes to hours.	Ground wave not affected, lowering of sky-wave reflection height causes rapid phase change with slow recovery. Significant amplitude degradation of sky-wave modes possible.
LF	Absorption of sky waves, defocusing.	Hundreds to thousands of miles; minutes to hours.	Ground wave not affected; effects sensitive to relative geometry of burst and propagation path
MF	Absorption of sky waves.	Hundreds to thousands of miles; minutes to hours.	Ground wave not affected
HF	Absorption of sky waves, loss of support for F-region reflection and/or multipath interference.	Hundreds to thousands of miles, burst region and conjugate; minutes to hours.	Daytime absorption greater than night-time, F-region disturbances may result in new modes, multipath interference
VHF	Absorption, multipath interference, or false targets resulting from resolved multipath radar signals.	A few miles to hunreds of miles; minutes to tens of minutes.	Fireball and D-region absorption, circuits may experience attenuation or multipath interference
UHF	Absorption.	A few miles to tens of miles; seconds to a few minutes.	Only important for line-of-sight propagation through highly ionized regions

that is connected to the equipment, but not to the primary conductor.

There are three basic ways to couple the EMP energy from a high-altitude nuclear explosion to a conductor on the earth: electric induction, magnetic induction and resistive coupling (direct-charge deposition). Electric induction occurs when a current is induced in a conducting element by the electric-field component that is in the same direction as the conductor's length. Magnetic induction takes place in conductors that are in the form of a closed loop. The magnetic-field component moving perpendicular to the plane of the closed loop causes a current to flow in the conducting loop. Resistive coupling occurs when a conductor is located in another conducting medium, ie, the earth, water or the air. When a current is flowing in the conducting medium, the conductor provides an alternative current path and shares the current with the medium. Resistive coupling can be generated as a by-product of electric or magnetic induction.

Nuclear Weapons Effects on Radio Signals

Nuclear weapons can degrade and black out radio signals far from the immediate blast zone. Degradation of radio signals by nuclear weapons varies with the explosion yield, distance and altitude. Signal degradation may include high noise levels, absorption, attenuation, ionization and partial or complete blackout. The effects may extend hundreds to thousands of miles and last from minutes to hours. Normal HF ionospheric propagation paths (below the Maximum Usable Frequency—MUF) may be disrupted at the same time that new paths that were not previously available are created in the upper HF or low VHF bands. It is by no means certain, however, that HF communications will be completely disrupted under all circumstances (Table 2).

Lightning

Lightning and EMP have similar characteristics. Both take the form of a fast-rising electromagnetic pulse that can generate large currents in conductors. Earlier studies generally stated that the effects of EMP exceeded those of lightning, but more recent reports indicate that lightning effects can be equal to or exceed those of EMP in the lower-frequency spectrum, while EMP effects are more severe in the higher-frequency spectrum.

Lightning Description

Lightning is a natural, transient, high-current electrical discharge occurring in the atmosphere. Lightning occurs when a region of the atmosphere attains a huge electric charge with the associated electric fields large enough to cause electrical breakdown of the air, creating a discharge path for the charge.

The most common lightning path is the intracloud discharge path. From an electrical equipment standpoint, however, the cloud-to-ground lightning discharge path has the highest potential for causing power disruption and equipment damage. Typically, the upper portion of the thunder cloud carries a greater positive charge while the lower part of the cloud carries a large negative charge. In a cloud-to-ground lightning discharge, the negative charge in the cloud is lowered by the dissipation of the electrons into the earth. A typical cloud-to-ground lightning discharge can last from 1/5 to 1/2 of a second and is composed of several discharge components. The total discharge occurrence is called a *flash.* The typical lightning flash is composed of three to four high-current pulses called *strokes.* Each stroke lasts about 1 millisecond with a delay between strokes of 40 to 80 ms. The first stroke is initiated by a preliminary breakdown in the cloud, which channels a negative charge toward the ground in a series of short luminous steps called the *step* *leader*. As the step-leader tip approaches the ground, the electric field beneath it becomes large and causes one or more upward-moving discharges to be initiated from the ground. When the downward-moving leader contacts one of the upward-moving discharges, the leader tip is connected to ground potential. The leader path ionizes the air making it a conductive plasma that is luminous. The return stroke, a ground potential wave, propagates up the ionized leader path discharging the leader channel. The return stroke produces a peak current of typically 30 kA in its lower portion, with a rise time of from zero to peak in about 2 µs. The return-stroke energy heats the leader channel to temperatures approaching 60,000 °F and produces a high-pressure channel that expands to generate a shock wave that is heard as thunder. If a residual charge is available at the top of the channel, a charge called a *dart leader* may propagate down the first stroke channel. The dart leader initiates the second, third and fourth return strokes, if any.

Lightning Energy

The normal peak current in a single return stroke will range from 10 to 40 kA with 175 kA for a severe stroke and with a charge transfer of 2.5 C (coulombs).[3] The total lightning discharge, when composed of several strokes, can transfer a charge of 25 C. The energy associated with a typical lightning stroke will vary depending on the dynamic resistance of the conducting channel, with values estimated to range from 250 J to 10 MJ.

Lightning and EMP Compared

A direct or nearby lightning strike can equal or exceed the electromagnetic field strength of EMP. To compare a direct lightning strike with EMP, 35 kA will be used as an average value of the peak current of the first return stroke and 175 kA as the value of the peak current of a severe first return stroke. At 1 meter from a direct lightning ground strike, the magnetic-field energy for the average return stroke is equal to the EMP at a frequency near 10 MHz and exceeds the EMP at frequencies below 10 MHz. At 1 meter from a direct lightning ground hit, the energy of a severe lightning return stroke exceeds the EMP to frequencies above 10 MHz. At 50 meters from a severe lightning stroke, the energy of the total electric field exceeds that of EMP at frequencies below about 1 MHz; and for the average first return stroke, the total lightning electric-field energy exceeds that of EMP below about 300 kHz.

The major difference between lightning and EMP is the area affected. EMP can affect an area of thousands of square miles, while lightning can affect an area of only a few square miles, with severe effects normally within a few hundred feet from the lightning discharge path. EMP can damage small electronic components and transmission lines, while a direct lightning strike can cause major structural damage to antennas and towers, as well as electronic equipment.

Physical Effects on Equipment

The primary effects of EMP that are of interest to the Radio Amateur are those that would produce direct damage to the sensitive electronic components of the station. The amateur is also interested in the temporary blackout caused by disruption to the ionosphere. A nuclear detonation causes intense changes in the ionosphere that increase or decrease the amount of ionization within a particular layer of the atmosphere. This change can result in the absorption of the radio signal or change the signal path (refraction) to the extent that communication is not possible. The fireball itself can disrupt communications because it generates an opaque area that radio signals cannot penetrate.

More widely known disturbances such as blackout (the complete disruption of electromagnetic signals for a short period) and scintillation (the scattering of signal energy caused by fast-changing ionization irregularity) should not be confused with EMP. Neither of the foregoing can damage equipment like EMP can. Radio propagation degradation, through refraction and absorption, usually lasts for a few minutes to a few hours, depending on the frequency. It is important only where continuous communications are of vital importance, because blackout and scintillation are only temporary and produce no permanent damage to primary or ancillary radio equipment. EMP, however, produces almost instantaneous and possibly permanent damage to sensitive electronic components. Fig 7 shows how signal propagation may be affected.

The components of the amateur's radio system that can be most affected are those directly attached to a primary collector (conductor) of EMP energy. The amateur's transceiver is most sensitive where it is connected to the commercial power lines and the antenna transmission line. Other sensitive connection points include the microphone, telephone lines and any remote-control lines.

There is a large number of electronic and electrical components that can be permanently damaged by the voltage and current surges induced by EMP/transients. As a general rule, smaller components are more susceptible to damage than larger ones. The most susceptible components are ICs, then discrete transistors. Somewhat less susceptible components are capacitors, resistors and inductors. Least susceptible are the large components such as solenoids, relays, circuit breakers, motors and transformers.

Transceivers

The typical amateur transceiver is subject to EMP/transient damage and temporary effects from a number of sources. The primary sources are EMP energy collected by antennas, transmission lines and electrical-power lines; to a lesser extent by remote-control, telephone, microphone and speaker lines, and so on. The transceiver would be damaged primarily where these lines enter it at the antenna matching network, internal power supply, telephone-patching equipment, microphone and speaker connections, and so on. If the transceiver case is metallic, it may provide enough shielding to prevent damage from EMP energy collected directly by the transceiver's internal wiring and circuits.

Where EMP energy does enter the transceiver, it may burn out ICs and FETs. More hardy components, when not destroyed completely, may have degraded performance because of changes in their electrical properties. All solid-state components may experience a change in state that causes temporary signal errors or that requires resetting. Vacuum tube equipment has shown little vulnerability to EMP.

Small VHF radios contained in metal cases are not vulnerable if the external microphone and antenna are disconnected. Also, the radio must be physically removed from other external conductors such as power cords and telephone lines.

Antennas

Antennas are designed to be efficient collectors of electromagnetic energy at their design frequency. An antenna designed to operate in that part of the RF spectrum where EMP energy is high will exhibit a high coupling efficiency for EMP. It is possible for high voltages and currents to be coupled into these efficient EMP antennas. Equipment attached to these antennas will likely be damaged by the resulting energy. Antennas designed to operate at frequencies outside the EMP energy spectrum will be less likely to act as efficient couplers and may not collect high voltages and currents.

Since most high-altitude EMP energy is concentrated between 100 kHz and 10 MHz, antennas in this frequency range will be subject to the strongest EMP-induced voltages and currents. All antennas designed to operate between 10 and 100 MHz will also be subject to high EMP-induced voltages and currents; however, the EMP energy decreases steadily as the frequencies increase. In general, all antennas designed to operate at frequencies below 100 MHz will be subject to strong EMP coupling, since 99% of the EMP energy is found below 100 MHz. Unfortunately for the radio amateur, the HF bands fall within that part of the spectrum that contains a great amount of EMP energy and a high coupling efficiency. On the other hand, amateur VHF antennas are less efficient collectors of EMP energy since they operate above 100 MHz.

When exposed to a high-altitude EMP event, the amateur's HF antenna could collect a potential of several thousand volts. These high voltages could physically damage the antenna line, balun and any at-

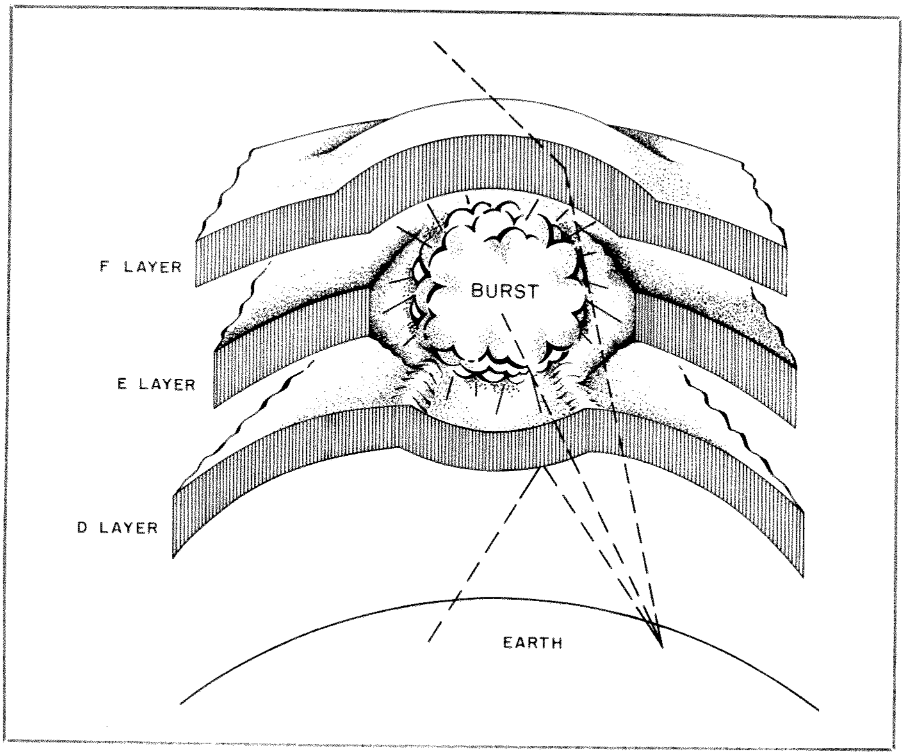

Fig 7—Atmospheric disruption and warping of the Earth's atmosphere caused by a nuclear explosion. Dashed lines show hypothetical signal propagation

tached electronic equipment. Other conductors associated with the antenna system can act as collectors of EMP energy. They are the control cables to the antenna rotator, the antenna mast, guy wires and even the ground system. These all can collect high levels of energy and conduct it directly or indirectly to sensitive electronic equipment. These unintentional collectors are, in many instances, more efficient EMP antennas than the RF antenna they support. Their coupling efficiency is determined primarily by their length, which may be long enough to allow them to operate as an EMP antenna in the strongest part of the EMP energy spectrum. Energy from these collectors, when not directly connected to sensitive radio equipment, can jump or arc to conductors (even short ones) that are connected to radio equipment.

Commercial Power Equipment

Transmission Lines

Power-transmission lines are extremely efficient collectors of EMP energy. The long runs of open, exposed wire can couple large voltage and current transients. Long, unshielded power lines can experience peak EMP-induced surge voltages of between 100 kV and 5 MV, and peak currents of between 1 kA and 10 kA.

Power-transmission lines act as long current conductors with the earth acting as a return conductor. The EMP-induced current flows down the line through the load (equipment) to ground. The amount of energy dissipated in the load depends on the impedance of the load path to ground. Equipment that presents a large impedance will experience larger peak voltages than equipment exhibiting a smaller impedance and therefore may experience more damage.

Power-Line Transformers

Normal power-line transformers will pass a part of EMP-generated currents through capacitive coupling across the windings. Commercial power transformers reduce the severity of the EMP by decreasing the peak voltage and extending the rise time of the pulse. In addition, the internal inductive and capacitive reactances of the transformer make the transformer act like a band-pass filter that attenuates frequencies below 1 and above 10 MHz.

Power-Phase Differences

EMP currents that are generated in the three phases of a power line are similar, and voltages in all three phases are nearly equal with respect to ground. The greatest danger exists to equipment connected from one phase to neutral or ground. Less danger exists to equipment connected between phases. The typical household wall outlet supplies 117 V, single phase. Therefore, amateur equipment using this 117-V power source is susceptible to receiving damage from EMP.

Household Circuit Breakers

Household circuit breakers will not offer EMP protection to the amateur's radio equipment because the damaging pulse will pass through the circuit breaker before it has time to react. However, internal arcing in the breaker box and in normal household wiring may limit the peak pulse to about 6 kV.

The amateur should expect the local commercial power system to be damaged and experience outages from the EMP transient. These outages could last for several hours to several days. The power-line EMP transients can cause component damage.

Telephone Equipment

The commercial telephone system consists, in large part, of unshielded telephone switches and cable systems. Although a considerable amount of lightning protection has been built in, there is little protection provided for EMP voltage and current surges. An unshielded telephone line may experience a peak voltage between 100 and 10 kV and a peak current of between 1 and 100 A. In recent years, the telephone companies have started using solid-state switching systems that could be highly sensitive to EMP. The older, existing transient over-voltage protection for telephone circuits is robust and can withstand repeated EMP transients without damage. Even the typical telephone handset is likely to withstand EMP without damage. Amateur telephone-patching equipment, however, is subject to EMP damage and should be protected.

Computers

One price that modern users pay for the convenience of microelectronics is a greater susceptibility to electrical transients. In computers, particularly when used with Amateur Radio equipment, the same kinds of vulnerability exist as with regular ham gear, only more so. In a typical amateur setup, the program and data are input through a keyboard, cassette recorder or disk drive, and a video display terminal (VDT), printer, cassette recorder and disk drive serve as output devices.

Microprocessors are especially susceptible to EMP and transient-voltage surges. Damage to an amateur's computer can run from simple logic upset or temporary memory loss to fused components and permanent memory loss. Increased voltage may destroy the cathode-ray tube (CRT) and disrupt or otherwise impair disk drives and other ancillary equipment.

Repeaters

Microcomputers are having a large impact on FM repeater design and on an increasing number of automated systems under program control. Repeaters are subject to the same threats as any amateur

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Electromagnetic Pulse

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piece of equipment. Often, repeaters are collocated with other communications equipment on a joint-use antenna tower. This makes them quite susceptible to receiving an EMP.

Antenna Rotators

Heavy-duty motors are less susceptible to EMP than smaller, less-rugged electronic components. Antenna rotators, although fairly immune to EMP effects because of their normally heavy metal cases and large components, may be rendered useless if there is a line-voltage surge to the rotator remote-control box. The line surge need not be caused by an electromagnetic pulse.

Satellite Transceivers and Antennas

Because of the sophisticated nature of satellite transmitters and receivers, and especially of their antenna systems, EMP and line-voltage transients remain serious problems. As noted earlier, the satellite itself is susceptible to SGEMP.

Satellite antenna systems require azimuth and elevation rotators. These rotators are fairly resistant to EMP. However, the antenna tower or mast and the remote-control lines are very likely to pick up large surge currents from EMP and lightning. The ac power supply for the rotators may fail, leaving the antenna array useless or extremely difficult to aim. Marrying a computer and satellite transceiver increases the station vulnerability. Virtually all stations, regardless of the type of equipment used, will be hostage to the commercial power supply unless served by a separate, emergency back-up power source.

Part 2 will discuss the testing of EMP/transient protection devices.

[Editors Note: This series of articles is condensed from the National Communications System report (NCS TIB 85-10) "Electromagnetic Pulse/Transient Threat Testing of Protection Devices for Amateur/Military Affiliate Radio System Equipment." A copy of the unabridged report is available from the NCS. Write (no SASE required) to Dennis Bodson, Acting Assistant Manager, Office of Technology and Standards, National Communications System, Washington, DC 20305-2010, or call 202-692-2124 between 8:30 AM and 5 PM Eastern Time.]

Notes

[1] When the term "radio amateur" is used in this report, it includes the MARS amateur volunteer.

[2] One joule (J) is the energy expended during one second by an electric current of 1 ampere flowing through a 1-ohm resistance. One joule is equal to 1 watt-second. A 60-W light bulb burning for 1 second expends 60 J of energy.

[3] The coulomb is defined as the ampere-second. One ampere is the current intensity when 1 coulomb flows in a circuit for 1 second.