Appendix B

Electro-Optical Systems

Smoke and obscurants influence the visual portion of the electromagnetic spectrum. They also provide protection for our forces by influencing frequency ranges we do not normally perceive with our senses.

All sensory equipment (to include the human eye, viewers, vision enhancement devices, trackers, and seekers) requires a certain amount of energy (a minimum threshold) before they can perform their functions. A sensor will also fail to function if the level of energy, in the frequency range the device is designed to work within, is too great (a maximum threshold). Smoke and obscurants provide us a means to render sensors ineffective, by decreasing or increasing the amount of energy available to the device or sensor (Figure 15).

There are three categories of obscurants: natural, by-product, and artificial. We can use natural obscurants advantageously if we correctly forecast the weather. Darkness, fog, sandstorms, and precipitation are examples of natural obscurants. By-product obscurants on the battlefield result from combat actions. Examples include the smoke caused by the burning of buildings and equipment, dust raised by maneuvering units, and the airborne dust and particles thrown by exploding artillery and mortar fire.

We produce artificial obscurants with smoke production equipment or munitions as described in Chapter 1 and Appendixes D and E. We use these specifically to attack enemy electro-optical (EO) systems.

Figure 16, on the next page, shows the effect obscurants have on target acquisition and guidance systems from the visible through the millimeter wavelengths of the electromagnetic spectrum.

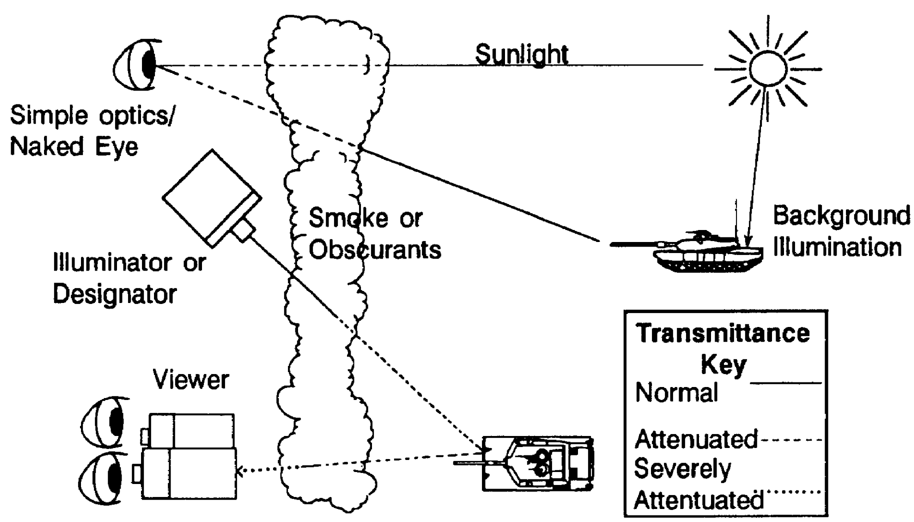

Figure 15. Obscurant effects on vision and viewers.

Sensors and Effects

On the AirLand battlefield, what is seen can be hit and killed. Precision-guided munitions and sophisticated sensors that provide new means of observation and detection have appeared on the battlefield. Smoke and other obscurants can degrade the effectiveness of sophisticated precision-guided weapon systems.

Target Visibility

When you conceal an object by smoke, a number of factors determine the degree of obscuration. Physical properties of the object, such as size, shape, color, brightness, and reflecting properties of various parts of the surface, determine the density of the smoke required for effective obscuration. The degree of illumination of the area, the background setting, and angle of observation have an important effect.

The overriding factor in smoke screen effectiveness is the total concentration of smoke and the path and length of the smoke cloud between the observer and the target. Thus, one observer may detect the target, while a second observer may not, because of extended line of sight through the smoke to the target.

When considering target visibility, it is important to distinguish between the sighting of an object and identifying that object as an enemy target. The prevention of detection is the severest test of a smoke cloud. Although most detection efforts in the past were in the visible spectrum, modern technology has extended the useful spectrum beyond the visible wavelengths.

Infrared (IR) **rays** have properties similar to those of visible light. However, IR rays may readily pass through materials that lessen visible light (for example, IR rays pass more readily through the atmosphere than visible light, even through light rain, snow, and fog). Night vision devices use the IR rays produced by or reflected from an **object.** Active IR is radiation produced by an illumination source and then reflected from an object; heat radiates from an object. IR radiation depends on the type of radiating material and its temperature. With an increase in temperature there is an increase in radiation. In hazy weather, IR devices can give a two- to four-fold increase in range over visible spectrum devices. In foggy weather, IR devices suffer a marked decrease in range, but are still superior to visual devices. Many of the restrictions noted for IR also apply to military laser range finders and seekers.

Sensors and Viewers

As a result of the development of IR and radar devices during World War II and subsequent technical advances, electronic sensors have supplemented conventional visual methods of target acquisition and aiming. The introduction of electronic techniques has also enhanced our ability to detect and attack targets at night and in adverse weather.

We can degrade the performance of electronic sensors by using obscurants (smoke and dust). Some of these devices can be rendered ineffective; others can be degraded significantly; still others will not be affected at all. However, to effect sensors we must use the right kind of obscurant at the right place, at

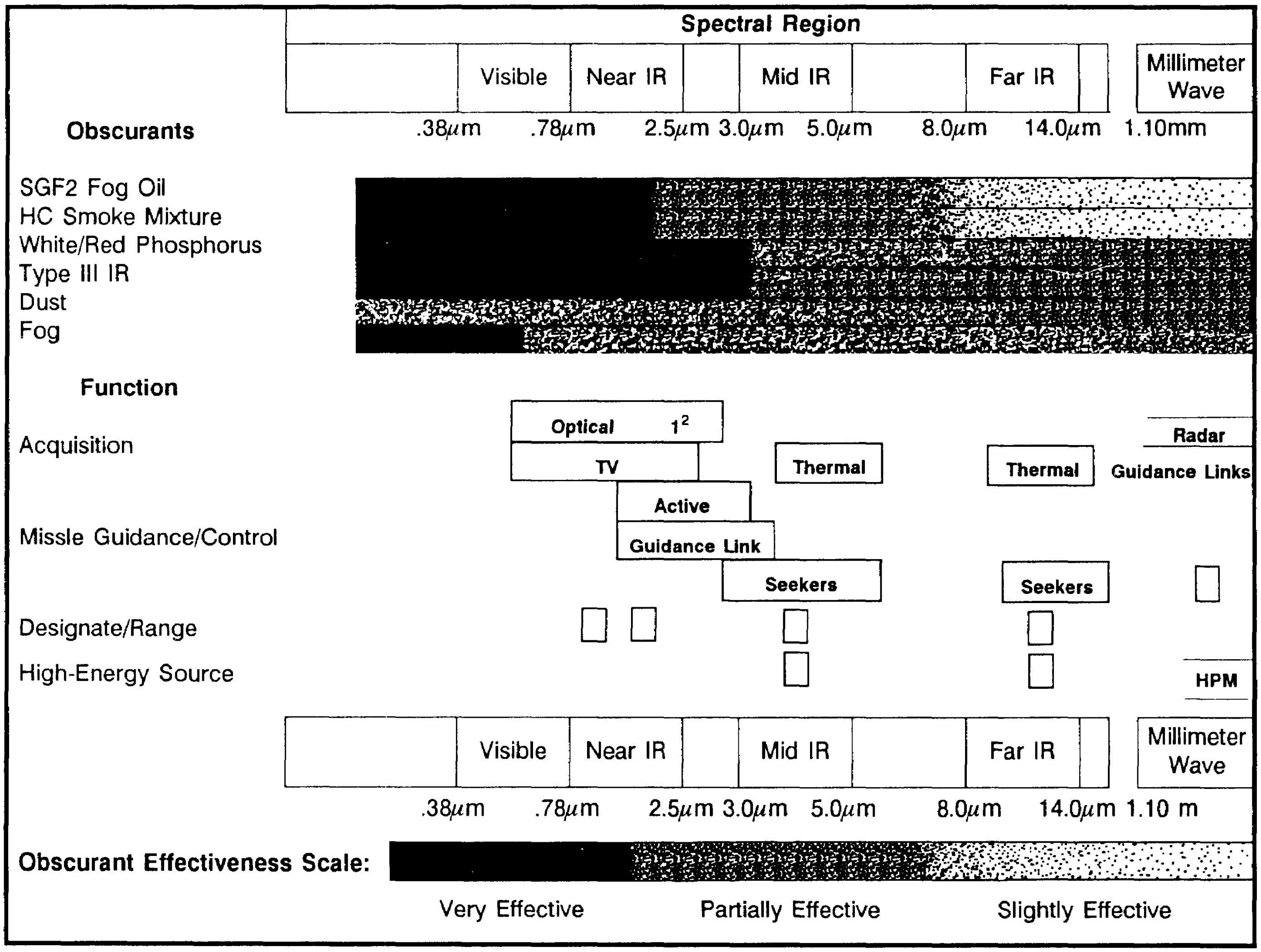

Figure 16. Obscurant effects on battlefield electro-optical devices.

the right time, and in sufficient quantity.

The eye is the basic receiver for several types of EO sensors. Four sensors that rely on the eye are the naked eye itself, the telescope, the television viewer, and the image intensifier. Sensors can be active or passive depending on the mechanism they use to detect and intensify the images.

Operational Considerations

The eye, the telescope, the television viewer, and the image intensifier all require illumination of the target and its background. The sun, moon, stars, or illumination rounds may provide this illumination. The eye detects reflected light and is dependent upon the contrast between the brightness of the target and its background. The telescope improves the capability of the eye by enlarging the target image. Television viewers are used to provide viewpoints from distant, hostile, or awkward positions. Television viewers can also function as image intensifiers or to enhance contrast. Image intensifiers electronically magnify the light received, increasing it to a level the eye can see. Contrast enhancement electronically increases the brightness of the target, making it easier to see.

Passive sensors use available natural light. We use passive systems when the available light is sufficient to illuminate the target. An active viewer system consists of a viewer and an illuminator, which floods the target with light. Illuminators for different active viewing sensors include lasers, searchlights, or flares. We use active sensors when there is not enough light to illuminate the target.

Effects of Obscurants

Placing obscurants between the target and the viewer will degrade the performance of these sensors. Target acquisition and identification depend on the contrast between the target and its background and the brightness of the target. Smoke and dust will decrease this contrast and brightness by attenuating light reflected from the target. Rain, snow, fog, and haze will also degrade the performance of these systems. To use an obscurant against these sensors, place the obscurant in the line of sight between the target and the observer. Obscuration use in moonlight can also degrade the contrast of target and background. We can further degrade the contrast of a target with its background by the light from the sun that fails directly onto the obscurant and is then scattered into the line of sight. The amount of degradation depends on the position of the sun and the depth of the obscurant cloud. Degradation is greatest when both sun and target have about the same line of sight to the observer or viewer. Considerable degradation can also occur when the sun is directly behind the observer or viewer.

Thermal Viewers

Passive thermal viewers use the natural thermal radiation differences between target and background to form an image – hence the name thermal viewer. Another name for a thermal viewer is forward looking infrared (FLIR). These thermal viewer systems require no external source of radiation and can successfully operate on a dark night if the targets are sufficiently warmer or cooler than the background. The thermal viewer is used in fire control systems, in some thermal homing missiles, and for surveillance purposes.

Reducing the apparent contrast between the target and its background may degrade the effectiveness of the thermal viewer. Obscurants degrade sensor performance by attenuating the target radiation signature reaching the viewer. The thermal radiation produced by the cloud may also degrade performance of the sensor. The initial burst of a munition will also produce a hot spot of thermal radiation, possibly saturating or blinding the viewer for a few seconds. Such hot spots may also divert or decoy thermal-tracking missiles.

Most smoke attenuates thermal radiation less effectively than visual radiation, so more smoke is required to degrade thermal viewers; the relative amount depends on the agent employed. However, some smoke (for example, HC and fog oil) is not very effective against thermal viewers. High concentrations of WP and RP and black smoke are more effective against thermal viewers.

Command-Guided Missiles

Most command-guided missiles are command to line of sight (CLOS) missiles, which operate in one or more spectral regions. The oldest of CLOS missiles are visually and manually controlled, requiring the operator to track both the missile and its target, while simultaneously guiding the missile to the target (for example, the Soviet Sagger). Tracking the missile can be aided by putting a beacon on the missile. This guidance scheme has been relatively easy to defeat, since either the target or the missile can be obscured, and a miss results. In addition, the flash from an exploding HE or smoke munition could serve to distract the gunner, again resulting in a miss.

The next type of missile control is semiautomatic CLOS (for example, the Dragon). In this case, the operator or gunner only tracks the target; the missile is automatically guided. This reduces the burden on the gunner and increases the accuracy. However, to cause a miss it is only necessary to obscure either the missile beacon or the target; further, the sensor tracking the missile may be blinded for a short period of time by the flash of an exploding munition. Many systems using this type of guidance use a beacon and tracking sensor that operate in the near IR. With visual target tracking this presents no difficulty. However, with the advent of thermal imagers a situation known as spectral mismatch can occur. In this case, and under obscured condition, it may be possible to see a target with the thermal imager but not to hit the target because of obscuration of the missile beacon.

A third type of guidance is automatic CLOS. Both target and missile are tracked automatically, usually by different sensors. This type of CLOS guidance is the most sensitive to obscuration, especially with sensors operating in the shorter wavelengths.

A more recent type of guidance command for CLOS missiles is beamrider guidance. Here, a gunner tracks the target either manually or automatically while illuminating the target with a beam of light. Usually this beam is provided by a laser, and most beamriders operate in the near and far IR spectrums. Most do not use the visible portion to prevent exposing the firing position. Sensors on the rear of the missile look back at the beam projector. These sensors track the beam, and the missile guides itself to the target. Beamrider guidance suffers from the same obscuration limitations as conventional CLOS missiles with a beacon. As a rule, the lasers used in beam projectors have more power than the equivalent beacon on a CLOS missile. As a result, the laser beam is harder to obscure.

Beamrider missiles are built so that the spectral mismatch is not the weak link in terms of susceptibility to obscuration. If you track a target using the visible portion of the spectrum, guidance is performed using either the IR or millimeter wavelengths. Similarly, if target track is carried out with a thermal imager, the missile is guided using a far IR or millimeter wavelength. In effect, the target-tracking element of the beamrider system is usually the most vulnerable to obscuration.

Most CLOS missiles receive guidance commands by a wire connecting the launcher and the missile. The wire is not susceptible to obscuration; however, severing the wire (for example, by shell fragments) will result in a miss. Some CLOS missiles receive guidance commands by a radio link in the radar or millimeter portions of the spectrum. These commands are difficult to degrade using conventional obscurants. Of more importance is the effect of the electromagnetic radiation emitted during an HE detonation. This radiation may cause the missile to miss its target. As a rule, it is easier to obscure the target tracker of a beamrider system than the laser beam that guides the missile. This target tracker is usually a viewer or a thermal viewer.

Obscuring the target tracker (viewer or thermal viewer) usually causes a miss and may even prevent the gunner from launching the missile if the target cannot be seen. The flash of an exploding munition behind the missile may blind the tracking sensors on the rear of the missiles, causing the missiles to miss the target.

Terminal Homing Missiles

This guidance is characterized by a missile with a seeker at the front that tracks the target and guides the missile to the target. There are two categories of terminal homing missiles: those that lock on the target before launch and those that lock on the target after launch. Missiles that lock on after launch are generally more susceptible to obscuration effects than missiles acquiring lock before launch. Terminal homing seekers operate in one or more of three modes: active, passive, or semiactive.

Most active seekers operate in the radar and millimeter wavelength regions. These seekers are not, as a rule, adversely affected by obscuration, although they may be blinded momentarily by the detonation of an HE or smoke munition. Passive seekers may operate in any spectral region. The most common seekers operate in the IR. Passive seekers operating in the visible or IR regions may be either imaging or nonimaging.

Passive imaging seekers have essentially the same susceptibility to obscuration as any imaging sensor, although far IR imaging seekers may look on a WP cloud that is hotter than the target and track the cloud as the target. This type of seeker may also be blinded by the flash from a detonating munition and therefore miss its target.

Nonimaging IR seekers often use two spectral bands. These two bands are used to discriminate between real and false targets (such as fires or hot rocks). These seekers can be decoyed by the difference in obscuration effects upon the two spectral regions. This difference may cause the seeker to think the target is a rock (and ignore the target) or to think a fire is the target (and attack the fire). Semiactive seekers use energy reflected from the target for tracking. Usually, the target is illuminated by a laser operating in the IR. Target illumination does not have to come from the launch point or site. This type of seeker may be defeated by obscuring the beam, either before or after it is reflected from the target. If obscuration is placed closer to the laser than to the target, sufficient laser energy may be scattered by the cloud to cause the missile to track the obscurant cloud rather than the real target.

Radar and Millimeter Wave Sensors

We can use radar and millimeter wave sensors to determine the position and/or velocity of the target. Since these form only poor images of the target, we do not get recognition and identification in the usual manner.

Dust and conventional smokes do not effectively degrade radar and millimeter wavelength sensors. However, other highly effective countermeasures exist. A munition dust cloud does produce obscuration for a few seconds when the burst is in, or very near, the line of sight. In the far term, we will use millimeter wave obscurants, projected onto enemy positions, to degrade radar and millimeter wave sensors.

Directed-Energy Weapons

Directed-energy weapons differ in operation and effect from all other weapons. They include lasers; high-power microwaves; particle beams; and non-nuclear, directed electromagnetic pulse (EMP). Except for lasers and high-power microwaves, directed-energy weapons are in the early stages of development.

Directed-energy weapons transmit energy at or near the speed of light in the form of subatomic particles or electromagnetic waves. This energy impacts on the target as heat or shock. Directed-energy weapons can damage soft targets and soft components of hard targets, such as lenses, electrical and electronic components, and eyes. New equipment will have built-in defenses against known directed-energy weapons. We will fit older equipment with protective devices. In the near term, we will use smoke and obscurants to reduce the impact of attack by directed-energy weapons.

Lasers

As of 1990, no army is known to have laser devices fielded for use specifically as weapons. However, laser target designators and range finders are in the inventories of all major armies, and their numbers are increasing. Any of these laser devices can be used as a weapon. Laser weapons are effective against optical and EO systems: specifically, eyes and fire-control sights.

Laser range finders are used on the M60A2, M60A3, and Ml series tanks and our artillery units. Artillery fire support teams for airborne, ranger, and special forces units use the lightweight target designator; fire support teams for mechanized, infantry, and air-assault units use the ground-locating laser designator in either the ground-mounted or vehicle-mounted mode; and all fire support team members use the GVS-5, binocular-type, laser range finder.

Additionally, artillery survey parties use laser devices for surveying gun positions. Scout platoons are equipped with GVS-5 laser range finders. USAF and Navy aircraft (F4, A7, F111, F105, F16, and A6 aircraft) may also carry laser target designators. Although these are not intended as weapons, accidental eye damage can occur if someone moves into a laser beam path and looks directly at the beam, or a laser beam reflects off a shiny surface into someone’s eyes. A high-power laser beam striking in front of an EO device such as night vision devices or thermal imaging systems may also damage components and electrical circuits or cloud the lens.

To avoid engagement by laser weapon systems, use artillery, mortars, or direct-fire weapons to suppress known or suspected laser device locations. Smoke can temporarily defeat some laser devices. When operating within the enemy’s line of sight, protect vulnerable systems by providing them cover or concealment. Cover sensor systems when not in use. If the mission requires movement, block the line of sight between friendly forces and enemy location with smoke, and/or use routes with minimal exposure time. Shoot-and-move tactics help prevent friendly positions from being pinpointed and targeted by laser devices. When searching with optical or EO devices, use as few as possible. Protect unused devices until they are needed.

High-Power Microwaves

Electric ammunition fuzes and many missile electronic guidance systems can be damaged by microwaves. Unprotected soldiers may experience warmth, pain, headaches, fatigue, weakness, and dizziness.

Terrain masking offers some protection from microwaves. The high-power microwaves operate in the millimeter wave spectrum; thus, smoke and dust have virtually no effect and should not be used solely to degrade their performance. A munition dust cloud does produce obscuration for a few seconds when the burst is in, or very near, the line of sight. In the far term, we will use projected millimeter wave obscurants onto known or suspected enemy microwave weapon locations to block or absorb the energy at its source.

Particle Beams

A particle beam is a directed flow of atomic or subatomic particles transmitted in a series of short pulses; it delivers large quantities of energy to targets in millionths of a second. The beam penetrates bad weather and smoke better than a laser beam and is much more destructive. The particle energy impacts in the form of heat, which melts or fractures the target. Particle beams may also create gamma and X ray when they strike metal.

Millimeter wave obscurant and type 3 IR obscurant may lessen some of the energy but will not be more than slightly effective. If a particle beam weapon is developed for ground combat, use the defensive measures taken against other direct fire weapons.

Electromagnetic Pulses

An EMP is a surge of electromagnetic radiation generated by a nuclear detonation or a pulse generator. An EMP travels hundreds of miles in a fraction of a second and can damage or destroy unshielded electrical equipment.

To protect electronic equipment against EMPs and microwaves, all cable and entry points must be shielded. The equipment should be completely encased in metal. Extra equipment or equipment not needed at the moment should be disconnected; small, electronic items should be placed in empty ammunition cans. Millimeter wave obscurant and type 3 IR obscurant may lessen some of the energy but will not be more than slightly effective.