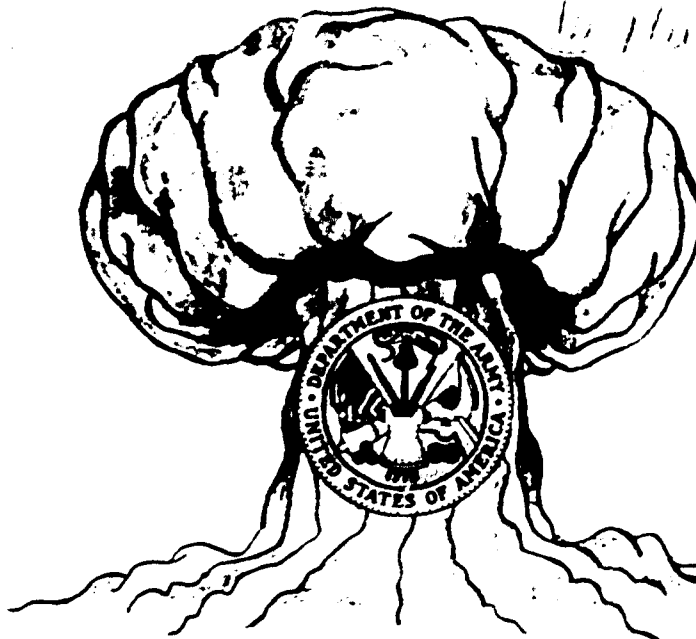# NUCLEAR NOTES NUMBER 4

NUCLEAR BLACKOUT
OF
TACTICAL COMMUNICATIONS

NUMBER FOUR IN A SERIES OF INFORMATION PAPERS ON TOPICS
ASSOCIATED WITH NUCLEAR WEAPONS, PRINCIPALLY DESIGNED FOR USE
BY TRADOC SCHOOL INSTRUCTORS AND MAJOR COMMAND STAFF OFFICERS.

AUGUST 1976
PREPARED BY THE

UNITED STATES ARMY NUCLEAR AGENCY
FORT BLISS, TEXAS 79916

The US Army Nuclear Agency recommends that issues of Nuclear Notes be retained and filed in a loose leaf binder. Previous issues are:

Nuclear Notes Number 1 - The Electromagnetic Pulse (EMP), June 1974

Nuclear Notes Number 2 - The Army Nuclear Survivability Program, October 1974

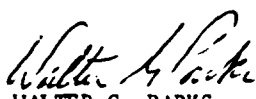Nuclear Notes Number 3 - The New Nuclear Radiation Casualty Criteria, May 1975

Local reproduction and distribution are authorized; however, headquarters that do so are requested to maintain a record of internal distribution so that changes, up-dates, and corrections may be properly disseminated.

86485

August 1976

FOREWORD

The series of papers, "Nuclear Notes," prepared by the US Army Nuclear Agency is intended to clarify and explain various aspects of nuclear weapons phenomenology and usage. These papers are prepared in as nontechnical a fashion as the subject matter permits. They are oriented toward an audience assumed to be responsible for teaching or in some way evaluating the tactics and techniques of employing nuclear weapons in a conflict situation. Their dissemination will hopefully provide to the US Army accurate, up-to-date information of critical importance to a reasoned understanding of nuclear weapons on the battlefield.

The principal author of this paper is Dr. John A. Berberet of the US Army Nuclear Agency. Comments and views of readers are desired and should be forwarded to: Commander, US Army Nuclear Agency, Fort Bliss, Texas 79916.

WALTER C. PARKS
COL, AD
Commanding

NUCLEAR BLACKOUT OF TACTICAL COMMUNICATIONS

INTRODUCTION.

The environment resulting from a nuclear burst produces damaging effects in most instances by interacting directly with personnel, materiel, structures, or terrain. For example, the blast wave produced by a nuclear burst can destroy structures; nuclear radiations can produce lethal effects in humans; and the electromagnetic pulse may cause the burnout of electrical and electronic components or destroy information stored in a computer. Nuclear blackout, referred to simply as "blackout" hereafter, is a unique nuclear weapons effect in that it does not result in any damage to materiel or personnel casualties; however, as a result of this effect it may be impossible for communications systems employing radio links to function during critical periods of time.

In this note, a description of the sources of blackout is provided; blackout interference to Army tactical communications systems is addressed; and several blackout problems that may be encountered in a theater nuclear war are discussed. Actions that may be taken to minimize blackout interference are also set forth.

WHAT IS BLACKOUT?

An atmospheric nuclear burst always produces large disturbances in the atmosphere. For bursts below about 25 km, the most significant disturbed region is a well defined fireball having dimensions ranging from fractions of a kilometer to tens of kilometers. If the burst occurs at shallow depths below the earth's surface, or at very low altitudes, i.e., a hundred meters or so above the earth's surface, large dust clouds are generated in the atmosphere in addition to the fireball.

For bursts at altitudes of about 80 km and higher, the burst perturbed regions extend far beyond the fireball and are measured in hundreds of kilometers. For bursts between 25 and 80 km, there is a transition from the well defined fireball to the extended perturbed regions.

When the transmission path of a radio wave is through a nuclear burst perturbed region, there may be degradation of the wave that will result in partial or total loss of the information being transmitted. The communication system is then said to have been "blacked out." Among other factors, blackout will depend on the frequencies of radio waves, which nominally range from 3 megahertz to 30 gigahertz for Army communications, Figure 1.

Radio noise will be radiated from the very hot fireball. This noise radiation may be superimposed on a radio wave being picked up by a communications receiver. If the intensity of the noise signal is great enough, the information being received may be partially garbled or made completely unintelligible. Such interference is also considered a form of blackout in this note.

WHAT ARE BURST PERTURBED REGIONS?

The burst perturbed regions of the atmosphere of most significance to blackout are ionized regions. Ionized regions are quite ordinary. A bolt of lightning is such a region, as is an electrical spark or arc. The gas in an operating fluorescent light is likewise ionized. Visible radiation is often given off from any highly ionized region. Thus, visible radiation is emitted from lightning bolts, sparks, and fluorescent lights. Ionized regions are electrically conducting and under certain conditions strongly interact with magnetic fields.

The fireball resulting from a low altitude nuclear burst is a good example of a very highly ionized region. It is composed of fission products, the vaporized portions of the nuclear weapon, and gases of the atmosphere. It is produced by the extremely high temperatures and nuclear radiations associated with the nuclear burst. The long duration (several minutes) of these high temperatures and the slow decrease of the nuclear radiation result in fireballs with ionization levels that will be significant to blackout, in some instances for more than an hour.

An ionized region contains ions and free electrons. Ions are atoms or molecules from which one or more electrons have been removed or to which an extra electron has become attached. Free electrons are electrons that are not attached to an atom or molecule. It is primarily the interaction of radio waves with these free electrons that produces blackout. As these free electrons recombine with atomic and molecular ions, blackout decreases.

Dust clouds produced by sub-surface, surface, and near-surface nuclear bursts may adversely interact with radio waves and thus are a second type of burst perturbed region important to blackout.
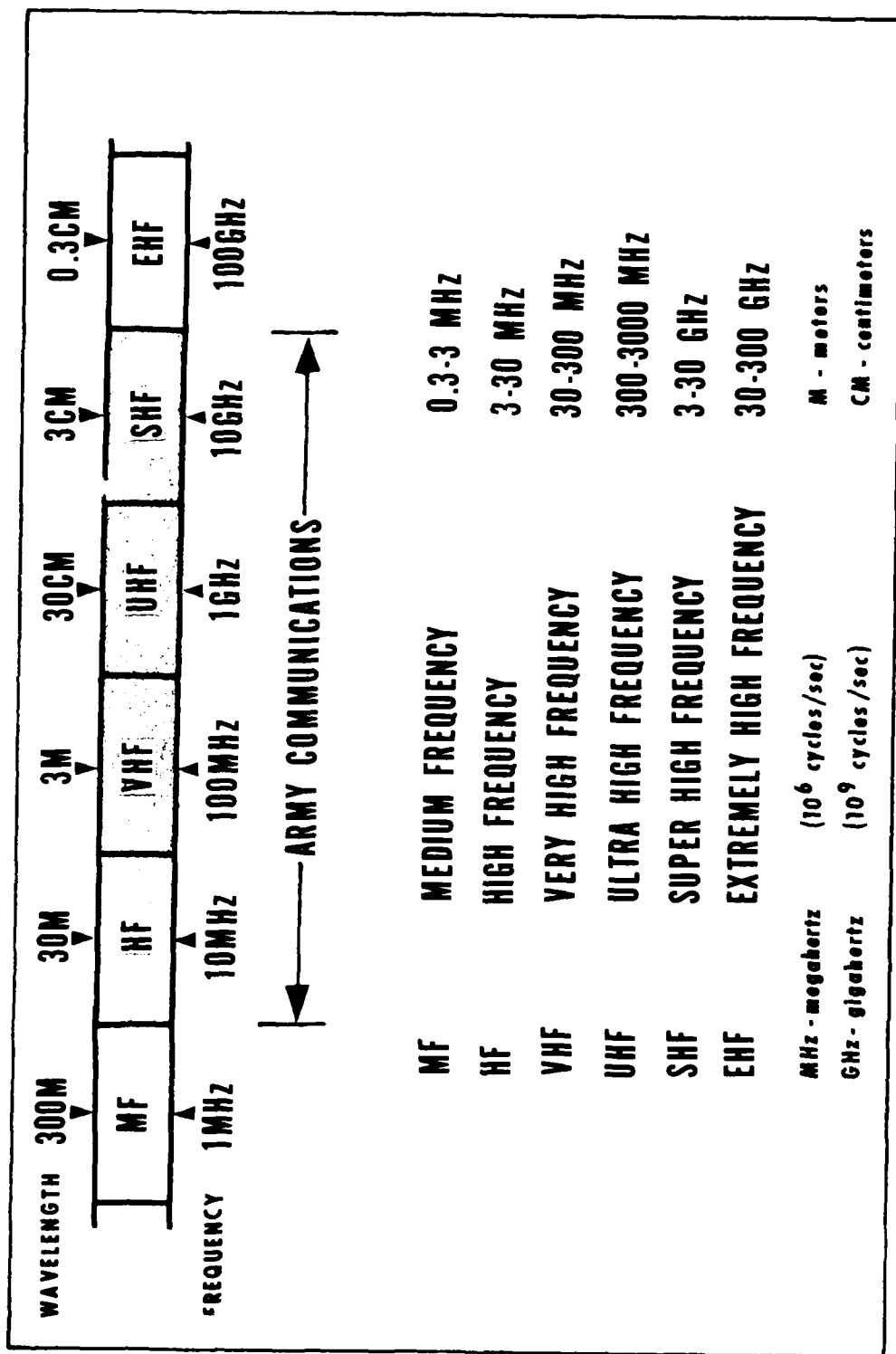
WAVELENGTH	300M	30M	3M	30CM	3CM	0.3CM
	MF	HF	VHF	UHF	SHF	EHF
FREQUENCY	1MHz	10MHz	100MHz	1GHz	10GHz	100GHz

←———— ARMY COMMUNICATIONS ————→

MF	MEDIUM FREQUENCY	0.3-3 MHz
HF	HIGH FREQUENCY	3-30 MHz
VHF	VERY HIGH FREQUENCY	30-300 MHz
UHF	ULTRA HIGH FREQUENCY	300-3000 MHz
SHF	SUPER HIGH FREQUENCY	3-30 GHz
EHF	EXTREMELY HIGH FREQUENCY	30-300 GHz

MHz - megahertz   (10^6 cycles/sec)   M - meters
GHz - gigahertz   (10^9 cycles/sec)   CM - centimeters

FIGURE 1. FREQUENCY SPECTRUM OF ARMY COMMUNICATIONS.

WHAT PARAMETERS ARE IMPORTANT TO BLACKOUT?

There are several variables that have a role in the blackout of Army communications. The most important of these are:

1. Atmospheric density. The density of the atmosphere decreases markedly with altitude. For example, at 150 km it is about one billionth of what it is at sea level.

2. Existing ionized regions. Such ionized regions are the naturally occurring ionized regions, called the ionosphere, produced by the sun's radiation and those produced by recent nuclear bursts. As illustrated in Figure 2, the naturally occurring ionized regions are the D region (50 to 90 km), which is ionized only in the daytime; the E region (90 to 120 km), in which there is a significant decrease in ion density at night; and the F region (above 120 km), in which the night-time ionization levels are only slightly less than those during the day. These regions play a significant role in HF skywave communications.

3. Earth's magnetic field. When an ion or electron travels through a magnetic field, it interacts with the field, and its path is usually changed as a result of this interaction. When nuclear bursts occur above about 80 or 100 km, there is a significant amount of interaction between the earth's magnetic field (see Figure 3) and the fireball from a nuclear burst. The motion and shape of the fireball are affected by this interaction. At lower altitudes, the interaction of the fireball with the atmosphere masks the effects of the earth's magnetic field on the fireball.

4. Altitude of the nuclear burst. Due to the high atmospheric density at low altitudes, the fireball* is well defined and relatively small. At high altitudes where the atmospheric density is much less, ionized regions are much larger and much more diffuse.

5. Nuclear weapon yield. The size and rates of change, e.g., fireball rise rate, of ionized regions generally increase with increasing yield.

6. Frequency of radio wave. Blackout interference from ionized regions will generally decrease with increasing frequency. However, interference from dust clouds increases with increasing frequency.

WHAT ARE THE CHARACTERISTICS OF BURST PERTURBED REGIONS PRODUCED BY LOW ALTITUDE BURSTS?

Low altitude bursts include those that occur within a few hundred meters above the earth's surface or a few meters below the surface. The burst perturbed regions of interest are ionized regions and dust clouds.

1. Ionized regions. The fireball, which initially is a very high temperature gas composed primarily of the radioactive products of the nuclear reaction and the vaporized warhead (called weapon debris), is highly ionized and is the major source of blackout from low altitude bursts.** When first formed, the fireball is spherical. It begins to rise and expand immediately upon formation. For yields likely to be encountered on the nuclear battlefield, the shape changes to that of a doughnut (torus) during the first few seconds. The rise rate gradually decreases; in about ten minutes the fireball reaches a stabilization altitude, approximately 10 km for a typical nuclear burst, and flattens out into the shape of a pancake. Thereafter, it continues to expand laterally. While these changes are occurring, the total ion content of the fireball and the ion density decrease due to both decreasing temperature and radioactive decay. These changes are significant for the characteristics of blackout interference that might be produced by these fireballs.

This fireball behavior for a near surface burst is illustrated in Figure 4 for yields of a few kilotons. The fireball diameter ranges from the initial diameter of about 100 m to 200 m to about 5 to 10 km at the stabilization altitude. The initial rise rate is about 60 meters per second.

---

*The fireball is the only significant ionized region for nuclear blackout of tactical communications produced by a low altitude nuclear burst.

**The nuclear radiation released at the time of the burst, called initial nuclear radiation, will strongly ionize the atmosphere outside the fireball. At low altitudes, this ionized region will last only for about a second or less and is not militarily significant for blackout of tactical communications systems. Similarly, the gamma radiation from the decay of radioactive materials in the fireball will cause some ionization outside the fireball. This ionization is also negligible as far as blackout for tactical communications is concerned.
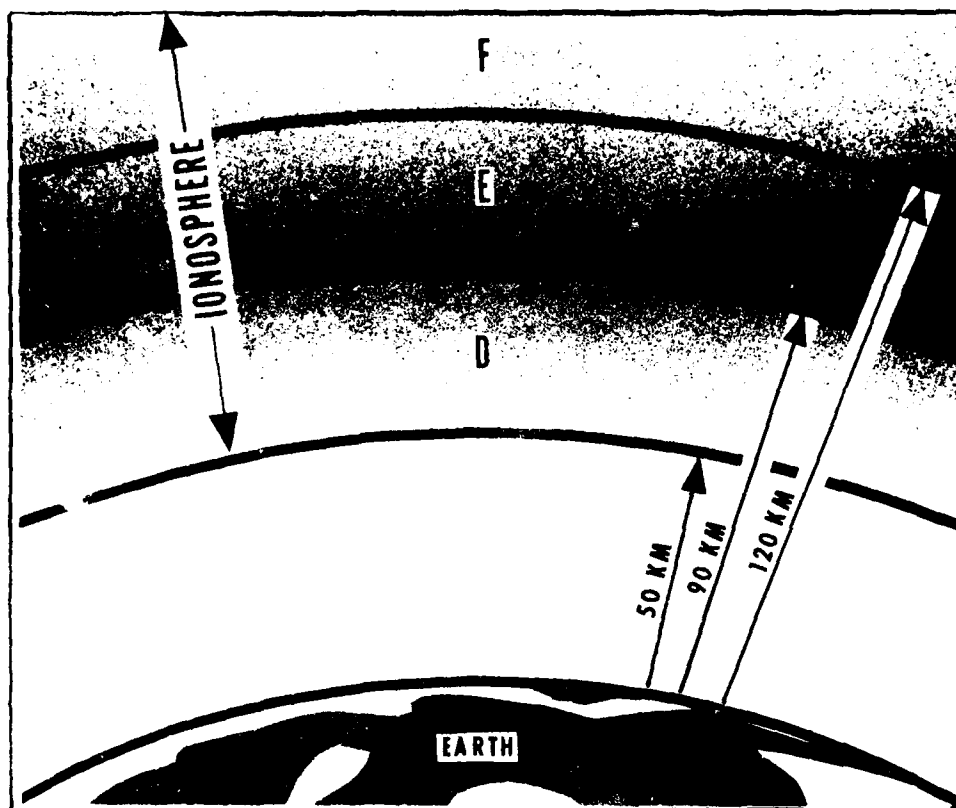
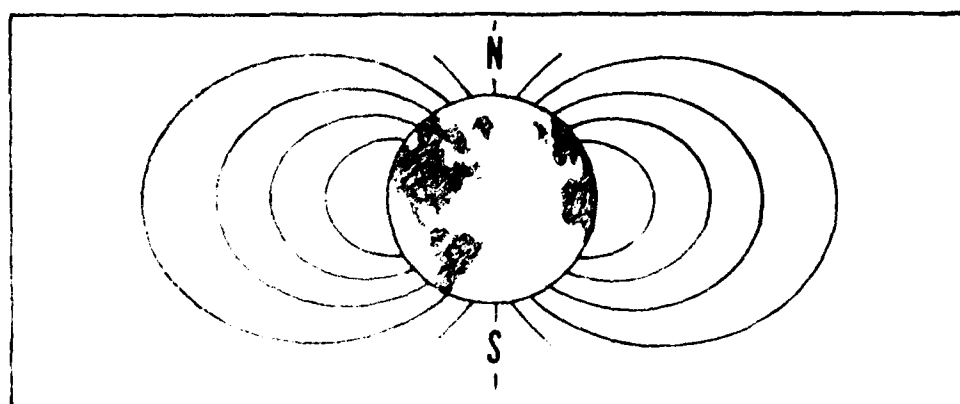FIGURE 2. D, E, AND F REGIONS OF THE IONOSPHERE.
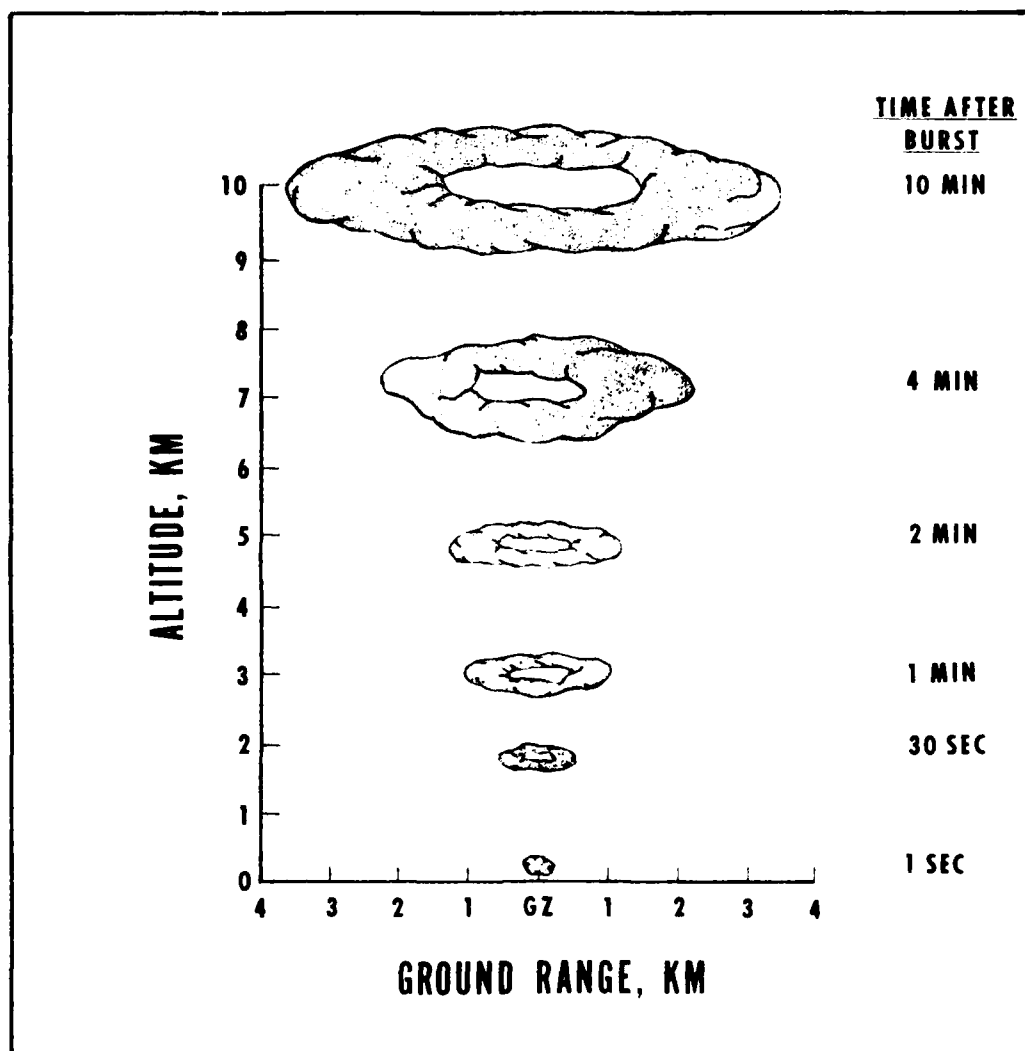

FIGURE 3. MAGNETIC FIELD OF THE EARTH.

FIGURE 4. FIREBALL CHARACTERISTICS OF A NEAR
SURFACE LOW YIELD NUCLEAR BURST.

These fireball characteristics are subject to changes by local atmospheric conditions, especially as the fireball rise rate decreases. When the fireball has reached stabilization altitude, its configuration will be strongly dependent on local winds.

In summary, low yield nuclear bursts at low altitudes produce well defined fireballs that expand laterally to a few kilometers in diameter and rise to a stabilization altitude of about 10 kilometers. The fireball shape may be affected by variations in atmospheric conditions, especially winds. Ionization levels decrease while these changes are taking place. The earth's magnetic field plays no significant role in the low altitude bursts.

2. Dust clouds. When a low altitude nuclear burst occurs close to the ground, a dust cloud will be formed. It may be formed as a consequence of the fireball interacting with the ground. When the fireball does not touch the ground, the dust cloud* may be produced by interactions of the thermal pulse, the blast wave, and the ground shock with the surface. A dust cloud is formed in a few tens of seconds after a burst; and for a low yield nuclear burst, it may extend outward 2 kilometers or more from ground zero, Figure 5. It may cover an area of many square kilometers and be approximately 30 meters or more in height. Duration of this dust cloud may be several minutes.

The area covered, density of dust, and height of the cloud will depend on such factors as the weapon yield, height or depth of burst, soil characteristics (including water content), and the presence of vegetation. These factors will also affect the particle size distribution of the dust, an important variable in determining the effect of a dust cloud on a radio wave.

When the altitude of the burst is sub-surface or low enough for the fireball to interact directly with the ground, large quantities of dust and earth debris will be entrained in the fireball and the cloud stem. Ejecta and the fallout of large objects from the fireball and stem combine with the blast wave and ground shock to enhance the surface dust cloud. Such a dust cloud in its early stages of formation is shown in Figure 6. Dust in the fireball may increase the interference with radio waves, particularly for UHF and SHF. The stem, which will last only a few tens of seconds, can also be a source of interference.

WHAT BURST PERTURBED REGIONS ARE PRODUCED BY HIGH ALTITUDE NUCLEAR BURSTS?

As with bursts at low altitudes, the fireball is the most significant ionized region resulting from high altitude bursts (bursts above 80 or 100 km) insofar as blackout of tactical communications is concerned. The development of the fireball resulting from the detonation of a nuclear weapon at an altitude of 150 km is shown in Figure 7. As it rises, its initial spherical shape changes to that of a cylinder with its axis parallel to the earth's magnetic field lines. As seen in Figure 7, the fireball has expanded several hundred kilometers along the earth's magnetic field lines in a few minutes.

The initial radiation from the burst and the decay radiations from the radioactive debris ionize large volumes outside the fireball in the D, E, and F regions. The formation of these around the fireball is shown in Figure 8. Of particular interest is the beta patch, a long lasting intensely ionized region produced below the fireball in the D region by beta particles (free electrons that are radioactive decay products).

As shown in Figure 8, the dimensions of all ionized regions produced by high altitude bursts are on the order of hundreds of kilometers, whereas those for low altitude bursts are only a few kilometers. The density of ionization in the high altitude ionized regions is ordinarily less; however, radio wave propagation paths through such regions are usually very long.

The high altitude ionized regions are long lasting, ranging from hours to tens of hours, due to the fact that ion recombination rates at the high altitudes are very small. Moreover, the decay gammas and betas from the radioactive debris continuously produce new ions in these regions.

There are two major reasons why the characteristics of high altitude bursts are much different from low altitude bursts.

1. Reduced atmospheric density. Since the density of the atmosphere is very much less at the higher altitudes, both nuclear radiations and weapon debris from a high altitude nuclear burst will travel much greater distances than those from low altitude bursts. The nuclear radiations, including radiations from the decay of radioactive materials, will ionize the atmosphere as they travel outward hundreds of kilometers from the weapon debris. Thus, the dimensions of the ionized regions

---

*This dust cloud may include smoke, depending upon the amount of combustible material in the vicinity of ground zero.

10
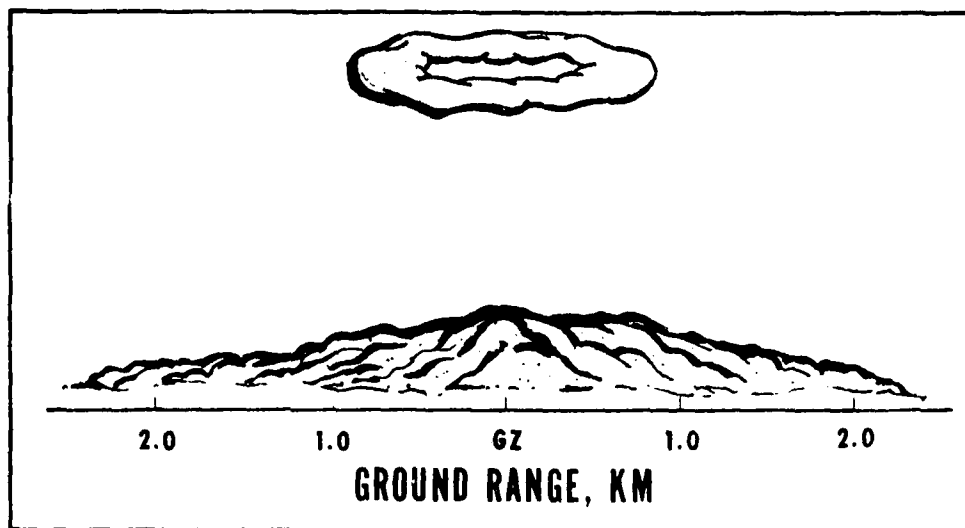
FIGURE 5. DUST CLOUD PRODUCED BY A LOW ALTITUDE
LOW YIELD NUCLEAR BURST.
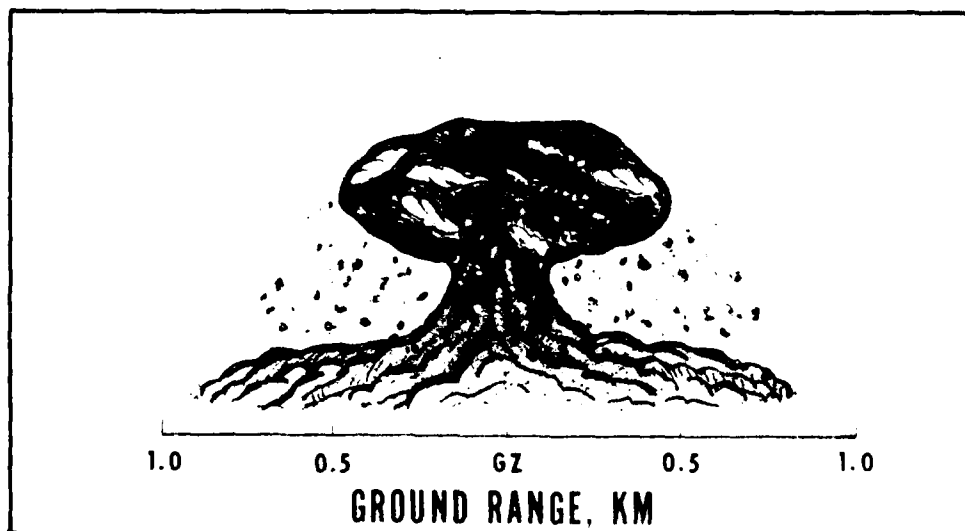
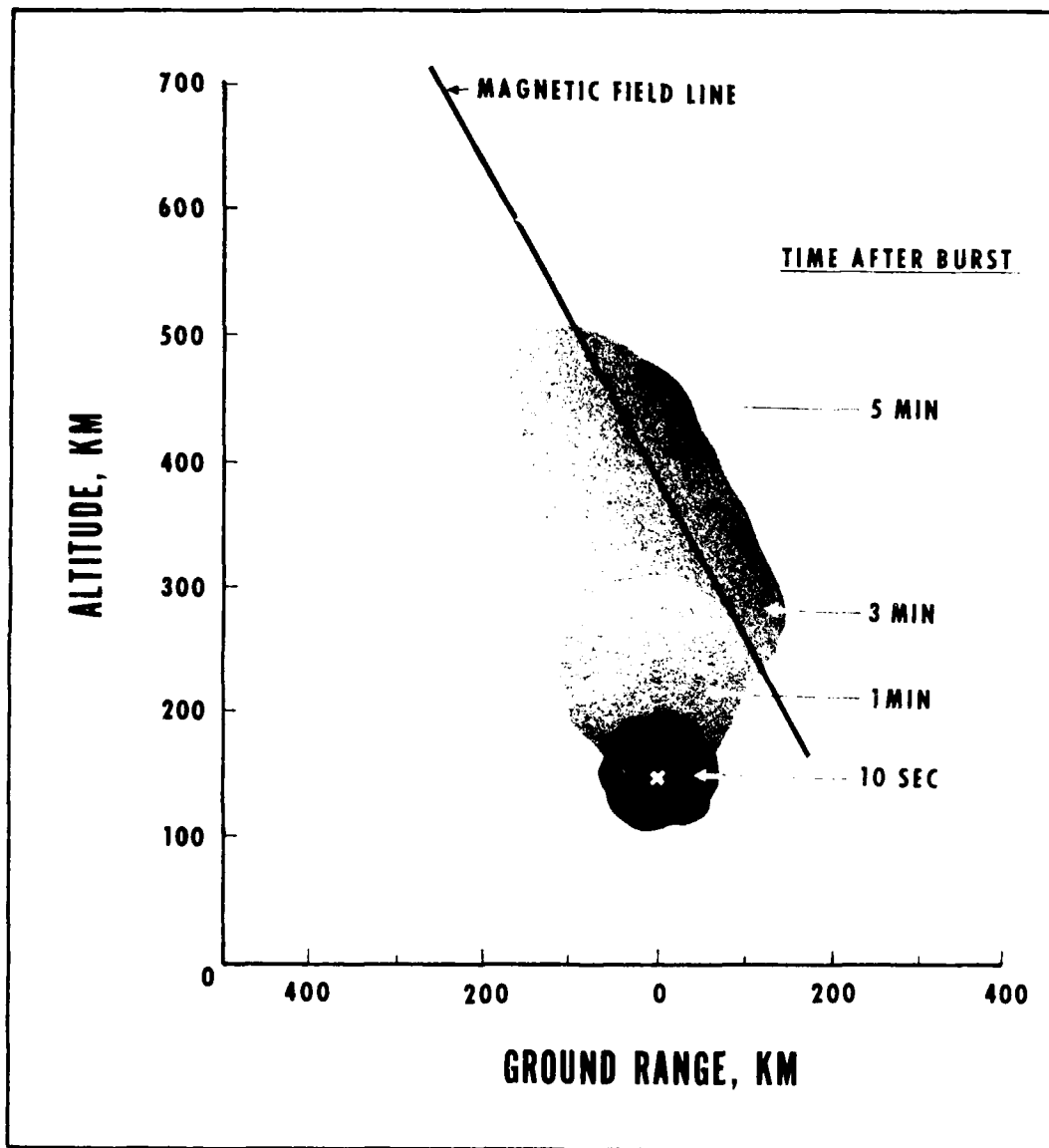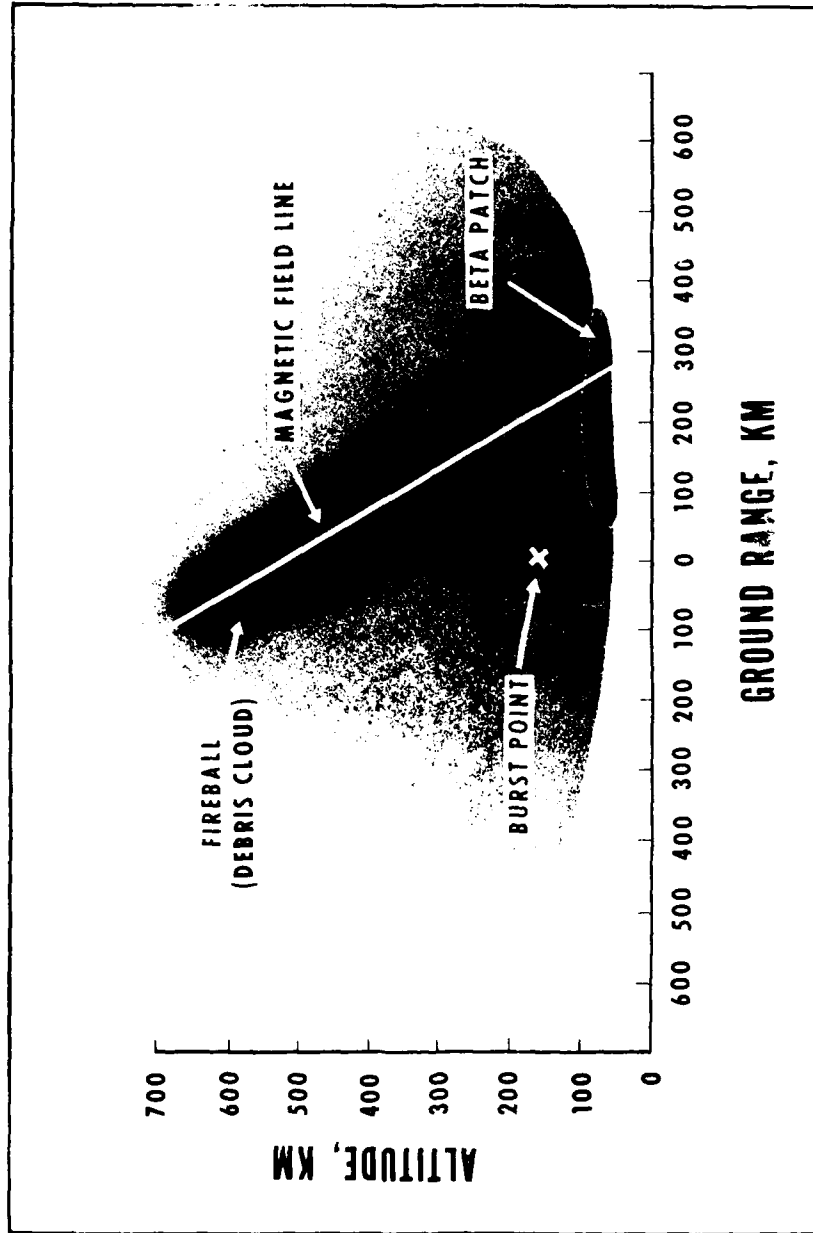FIGURE 6. DUST CLOUD PRODUCED BY A LOW YIELD
SURFACE NUCLEAR BURST.

FIGURE 7. DEVELOPMENT OF A HIGH ALTITUDE FIREBALL.

FIGURE 8. IONIZED REGIONS PRODUCED BY A HIGH ALTITUDE
NUCLEAR BURST AT 150 KM.

13

produced by a high altitude burst will be hundreds of kilometers rather than the few kilometers for low altitude nuclear bursts.

2. Interaction of ionized debris with the earth's magnetic field.

a. The ionized nuclear weapon debris will interact with the earth's magnetic field and initially move up and down along the earth's magnetic field lines. In addition to the movement of the ions along the magnetic field, there will be a general upward movement of the entire debris cloud. The ionized debris will travel much greater distances upward than downward due to the manner in which the ions interact with the magnetic field and the fact that the atmospheric pressure decreases in the upward direction. However, the density of ionization produced by the debris will be greater in the downward direction than in the upward direction.

b. Shortly after the debris expands along the earth's magnetic field lines, additional interaction with the magnetic field results in the debris particles becoming aligned in the form of ionized filaments, or striations, as they are commonly called, as shown in Figure 9. These striations will last about an hour.

For bursts above 150 km, the debris is restrained even less by the atmosphere, and interaction with the magnetic field is increased. The fireball becomes more diffuse, and the portion of the debris expanding upward may be channeled to the other hemisphere along the earth's magnetic field lines. The D and E regions will be ionized just as for the burst at 150 km.

For bursts occurring between the low altitudes and 100 km, the characteristics of the ionized regions will range between those for low altitude and high altitude bursts. The volume ionized increases with increasing burst altitude. Starting with bursts at about 25 or 30 km, the fireball will rise high enough so that decay radiation from the debris will ionize large volumes in the D region. Consequently, the size of the ionized regions starts to increase markedly with bursts above these altitudes.

HOW DO BURST PERTURBED REGIONS AFFECT RADIO WAVES?

The basic interactions of radio waves with an ionized region are refraction, absorption, and scattering. These interactions are similar to the interaction of optical waves with transparent media.

1. Refraction. In the optical case, a ray of visible light going obliquely into or out of a transparent material is bent or "refracted" as shown in Figure 10. This property of optical refraction is used in many kinds of optical instruments - for example, in eyeglasses. The amount of bending will depend on the color or wavelength of the optical radiation. The term "dispersion" is used to describe this dependency.

When a radio wave passes from the normal atmosphere through an ionized region, there will also be a bending, or "refraction" of the wave. Two examples of such refraction are given in Figure 11. As shown in these figures, the refraction of radio waves does not occur abruptly as in the optical case. Instead, it takes place gradually due to the gradual buildup and decrease of the electron density along the path of the wave in the ionized region.

This bending will vary with the frequency of the radio wave. As in the optical case, this is also called dispersion. If a radio wave from a wide band transmitter (such as is used for FM communications) passes through an ionized region, the wave of the different frequencies may be bent by different amounts. The frequency characteristics of the wave reaching the receiver may then not be the same as those which left the transmitter.

2. Absorption. Just as a visible light ray is absorbed to some extent in going through any media, a radio wave passing through an ionized region will be partially (or totally) absorbed. In the process of absorption, some of the wave energy is changed to thermal energy, and the energy of the beam is decreased. (The electrons in the ionized region are involved in absorption as well as in refraction.) The result is that the intensity of the radio signal that reaches the receiver is decreased. Low altitude fireballs are very strong absorbers for the first few minutes after they are formed.

3. Scattering. Scattering of visible radiation by dust in the atmosphere is often observed. A radio wave passing through a dense dust cloud or a low altitude fireball containing many tons of dust may be similarly scattered. In this process, some of the radio wave energy is directed out of the primary beam, resulting in a decrease in the intensity of the beam. Portions of the beam may be scattered in all directions. "Forward scattering" or "beam defocusing" occurs if a portion of the wave is scattered mostly at small angles with respect to the forward direction of the transmission path. If significant portions of the wave are scattered at angles greater than 90°, "back
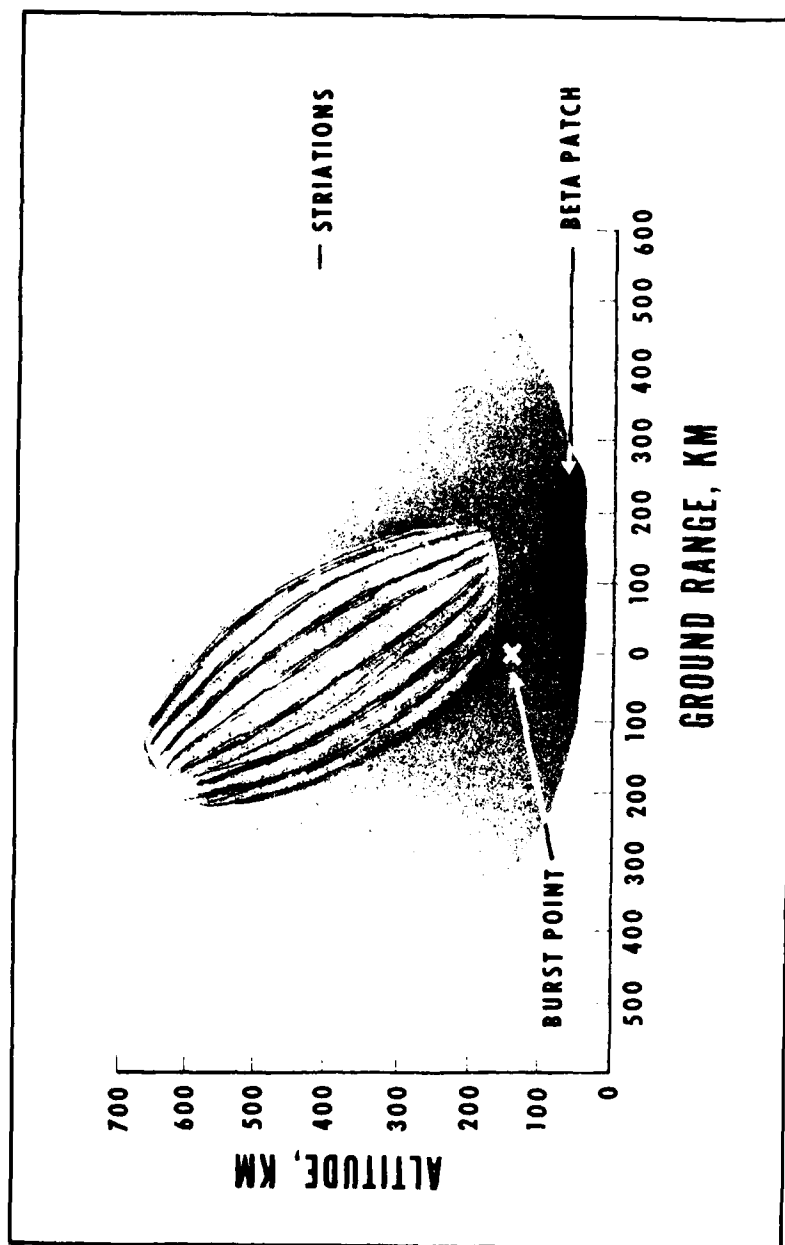
14

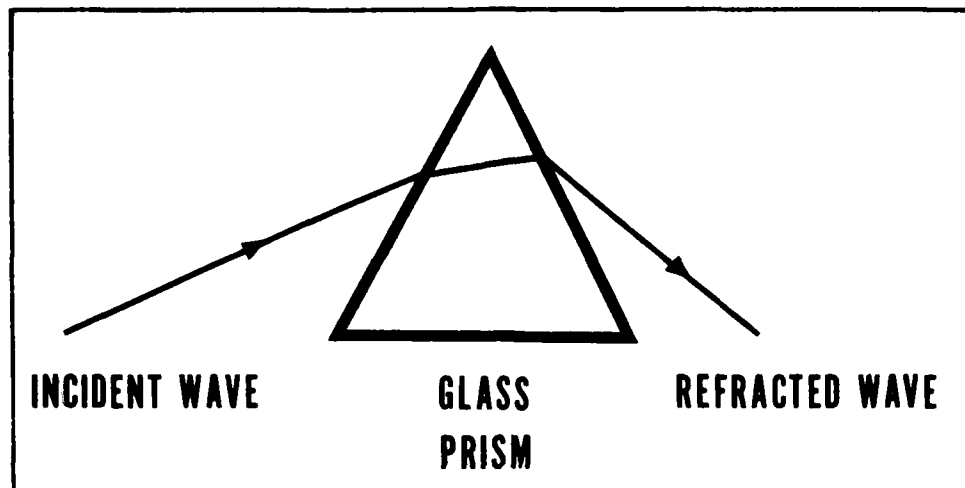FIGURE 9. STRIATIONS PRODUCED BY A HIGH ALTITUDE BURST.

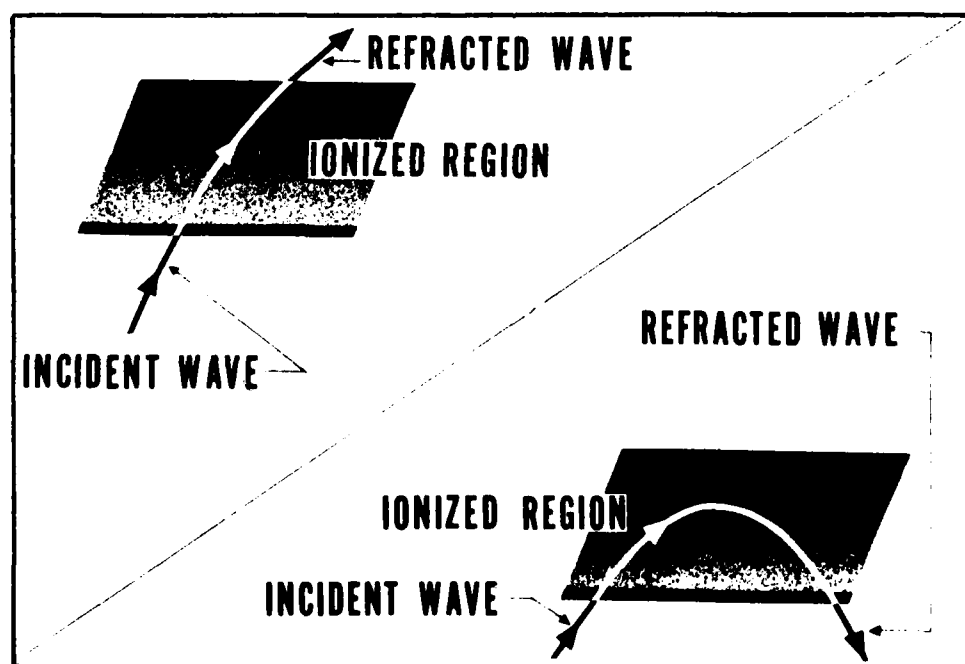**FIGURE 10. REFRACTION OF VISIBLE LIGHT BY A GLASS PRISM.**

FIGURE 11. EXAMPLES OF REFRACTION OF A RADIO WAVE IN AN IONIZED MEDIUM.

scattering" has taken place.

These basic interactions of radio waves with burst perturbed regions can lead to other kinds of interference. When absorption and scattering occur together or individually, they cause attenuation of the beam. The signal strength arriving at the receiver is reduced as a result. Under certain conditions, refraction processes can cause "defocusing" of a beam or even "beam splitting" and thereby reduce the signal strength of the beam. Such may be the case, particularly for HF skywave propagation, where a nuclear burst may completely change the refractive characteristics of the D, E, and F layers essential to the HF skywave mode of communication.

Multipath interference occurs when portions of a radio wave arrive at a receiver out of phase with each other as a result of having traveled on different transmission paths. When this form of interference occurs, intelligible radio communications may not be possible. An example of how refraction by a fireball may produce multipath interference is illustrated in Figure 12.

As a result of interactions with burst perturbed regions, signals arriving at a receiver may be varying rapidly in phase, signal strength, and direction of arrival. These three phenomena may be occurring individually or all simultaneously. The term "scintillation"* is used to describe such phenomena.** Due to rapidly changing ion conditions, particularly during striation formation and decay, there is special concern that both scintillation and multipath interference will cause the blackout of synchronous satellite communications when the transmission path is through the ionized regions produced by a high altitude nuclear burst.

As noted earlier, fireballs will radiate noise that can be a source of interference for radio communications systems. When noise is propagated along the main communication path, it may be picked up by the receiver antenna and cause interference. Moreover, due to the inherent characteristics of some antennas, noise may be picked up from nuclear bursts at large angles from the communication path and likewise cause interference.

HOW LONG WILL COMMUNICATION SYSTEMS BE BLACKED OUT?

The blackout of generic types of communications systems can best be addressed in terms of the mode of propagation employed by the respective systems. For Army communications, the following modes are employed:

1. Line of sight (LOS) systems.*** Tactical LOS communication systems will be employed primarily close to the surface of the earth. For them, blackout will result mostly from low altitude bursts. They may pick up noise from nuclear bursts, Figure 13. The fireball may interdict their transmission path and totally absorb the radio wave, Figure 14. Multipath effects may be produced as illustrated in Figure 12. Lastly, the transmission path may pass through the surface dust cloud, Figure 15, where the beam may undergo strong forward scattering.

With the exception of the forward scattering by the dust cloud, the duration of these types of interference would probably not last more than a few seconds to a few tens of seconds. The duration of interference from a surface dust wave is uncertain. In the worst case, however, it probably would not be more than a few minutes for communications systems operating in the higher gigahertz (SHF) frequency ranges. UHF systems would be affected less, and there would probably be little or no interference for VHF and HF communications. The durations of these interference effects are summarized in Figure 16.

2. Troposcatter systems. These systems will be subject to fireball interdiction just as LOS systems are, Figure 17. Refractions from fireballs above the scatter region (altitudes normally less than 10 km) may give rise to multipath interference. Surface dust clouds may cause some interference, but this would very likely be small for troposcatter systems due to the short transmission path through a surface dust cloud. Estimates of the duration of these effects are also summarized in Figure 16.

---

*The term "scintillation" as used here is in keeping with the long standing use of this term in radio-communications to describe rapid changes, e.g., fading, of radio signals.

**Rapid changes in polarization angle may also occur and contribute to scintillation effects.

***This discussion pertains to both single and multiple channel LOS systems.
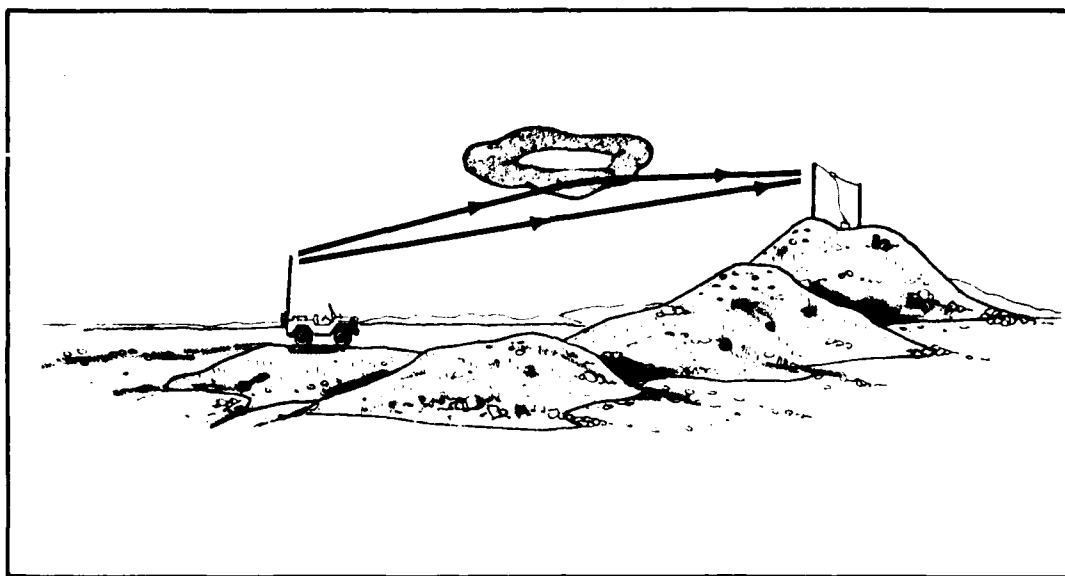
FIGURE 12. MULTIPATH INTERFERENCE PRODUCED BY
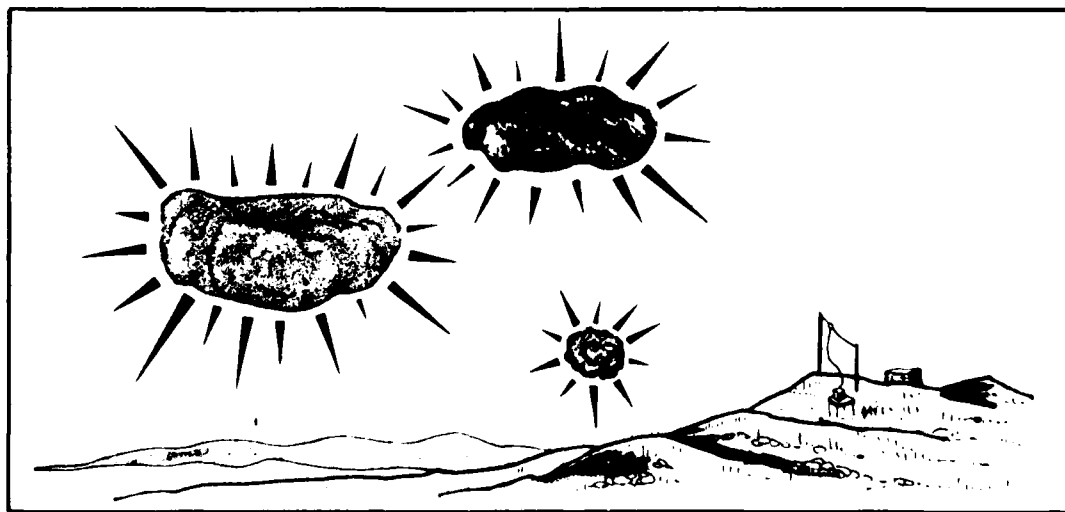REFRACTION OF A RADIO WAVE BY A FIREBALL.

FIGURE 13. NOISE RADIATED BY NUCLEAR FIREBALLS
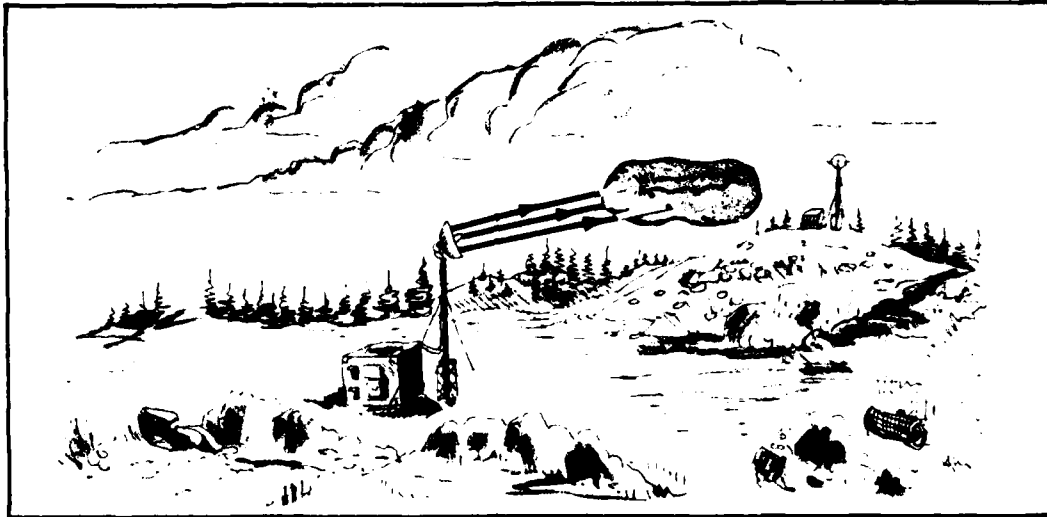AS A SOURCE OF RADIO INTERFERENCE.

FIGURE 14. ABSORPTION OF A RADIO WAVE BY A NUCLEAR FIREBALL.

FIGURE 15. FORWARD SCATTERING OF A RADIO WAVE BY A NUCLEAR DUST CLOUD.

BURST REGION	MODE OF PROPAGATION	FREQUENCY BANDS	BLACKOUT SOURCE	ESTIMATED DURATION OF BLACKOUT
Sub-Surface Surface Near Surface	Line Of Sight	VHF, UHF, SHF	Dust/Fireball	Few Seconds To Few Minutes
Low Altitude	Line Of Sight	VHF, UHF, SHF	Fireball	Few Seconds To Tens Of Seconds
Sub-Surface Surface Near Surface Low Altitude	Troposcatter	UHF	Dust/Fireball	Few Seconds To Tens Of Seconds
High Altitude	Troposcatter	UHF, SHF	Scatter From Fireball	Few Seconds To Minutes

FIGURE 16. BLACKOUT OF LINE OF SIGHT AND "TROPO" COMMUNICATION SYSTEMS.

FIREBALL

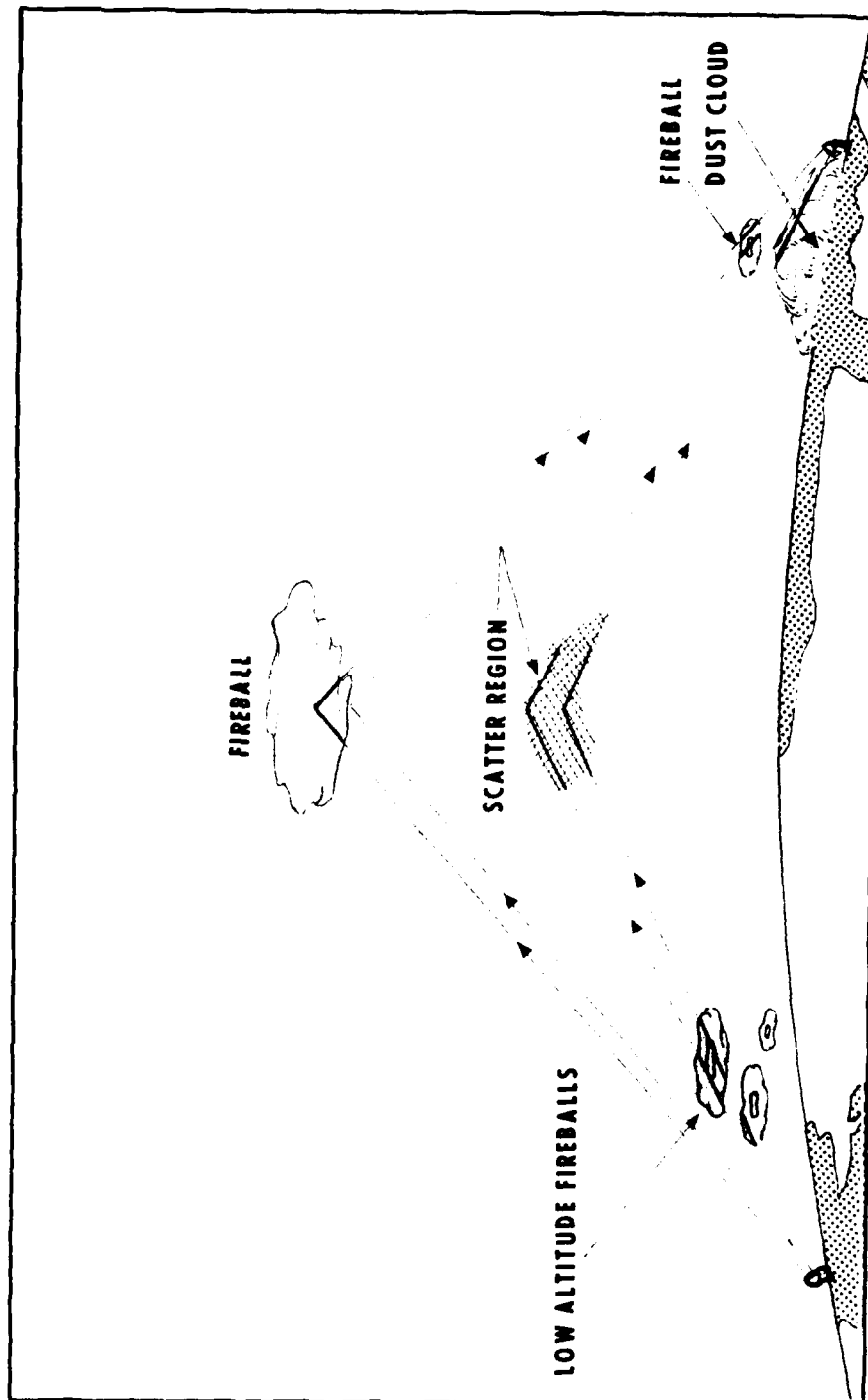LOW ALTITUDE FIREBALLS

SCATTER REGION

FIREBALL
DUST CLOUD

FIGURE 17. INTERFERENCE OF NUCLEAR BURSTS WITH TROPOSCATTER SYSTEMS.

3. High frequency (HF) systems. In a typical skywave mode of HF propagation, the HF wave is refracted back and forth between the earth and the E and F layers, Figure 18. The increase of ionization in the D, E, and F layers by a nuclear burst may have several effects on HF propagation. First, absorption can be increased, and the HF wave can be at least partially, if not totally, absorbed. The refraction characteristics of the E and F layers may also be significantly changed; thus, for the case where absorption has not been total, there will be a change in propagation characteristics. Where there has been intense ionization of the D layer, HF waves may be totally absorbed in this layer. Or, only a portion of the wave may be absorbed and the remainder refracted back to the earth. In this instance, there will thus be attenuation of the HF signal and changes in the HF propagation geometry, Figure 19.

Beam interdiction by the fireballs of low altitude bursts could cause some interference for both the skywave and groundwave modes of propagation. This interference will not be significant unless the bursts are close enough to the transmitting and receiving antennas to "fill" a significant portion of the main transmission path. Noise from the fireball will also be a source of interference. Interference from dust will be negligible.

The interference with HF skywave communications from high altitude bursts may last many hours. As shown in the summary of blackout effects on HF communications, Figure 20, the other types of interference discussed above are expected to last only a few seconds.

4. Tactical satellite communications. In the Army tactical satellite communications system now being developed, the satellite relay will be in a synchronous orbit approximately 35,400 km (22,000 mi) above the earth's equator. The satellite will employ frequencies in the UHF and SHF regions. Radio signals will go to the satellite and be relayed back to the earth to the receiver, as shown in Figure 21, for communications on a nuclear battlefield. The transmission path must pass twice through the earth's atmosphere, including the ionosphere.

Sources of interference to satellite communications from low altitude bursts will be noise emissions from fireballs and absorption associated with fireball interdiction. Since the transmission path for synchronous satellite systems will usually be closer to the vertical than those for other modes of propagation, the time during which the radio wave would be interdicted by a vertically rising fireball will be somewhat longer than for other modes of propagation.

The surface layer dust cloud may also be a source of some interference. However, the length of the transmission path of a radio wave to and from a synchronous satellite through a surface dust cloud will probably not be more than 30 meters or so. If the density of the dust is extremely high, it may provide some interference for the higher frequencies employed by the satellite.

High altitude bursts may be the most significant source of blackout interference for synchronous satellite communications. As pointed out previously, such bursts will ionize large volumes of the atmosphere above 50 km. If such a burst were strategically placed over the nuclear battlefield, most communication paths from the battlefield to a synchronous satellite (positioned at approximately the same longitude as the battlefield) would have to pass through the ionized region twice. As an example, in Figure 22 it is shown, for a properly positioned nuclear burst, how the communication path would have to pass through the fireball (the most highly ionized region) in going to and from the satellite. Radio waves passing through these high altitude ionized regions will be subject to attenuation, scintillation, and multipath effects. These last two effects may be quite significant when striations, as shown in Figure 9, are present.

It is expected that interference to synchronous satellite communications from high altitude bursts would last from a few minutes to hours. Interference from a low altitude burst would last from a few seconds to a few tens of seconds. The durations of these various forms of blackout are summarized in Figure 23 for communications employing a synchronous satellite relay.

Although the duration of interference attributable solely to blackout may be as short as a few seconds, this time may be long enough to break synchronization between the transmitter and receiver. It may then take up to a few minutes for synchronization to be reestablished, depending upon the characteristics of the specific equipment being employed. Thus, where there is a delay in resuming communications, the effective blackout time will be extended.

WHAT CAN BE DONE TO MINIMIZE BLACKOUT EFFECTS?

If blackout occurs, there are operational actions that may be undertaken to reduce outage times:

1. Blackout does not affect wire communications. Thus a very simple expedient is to communi-
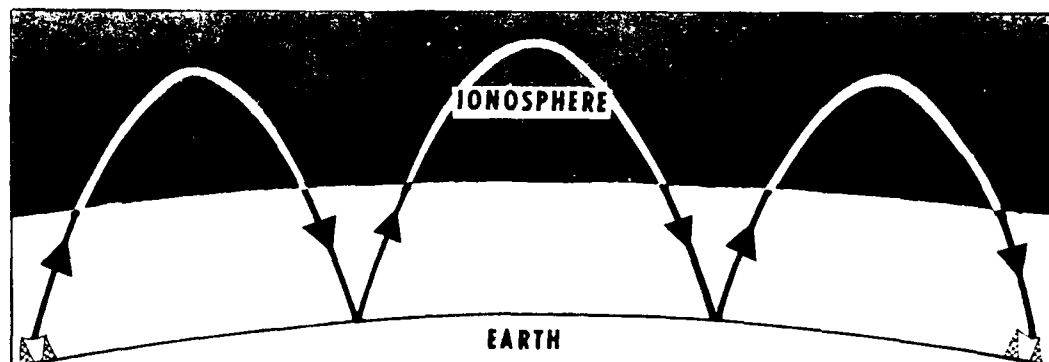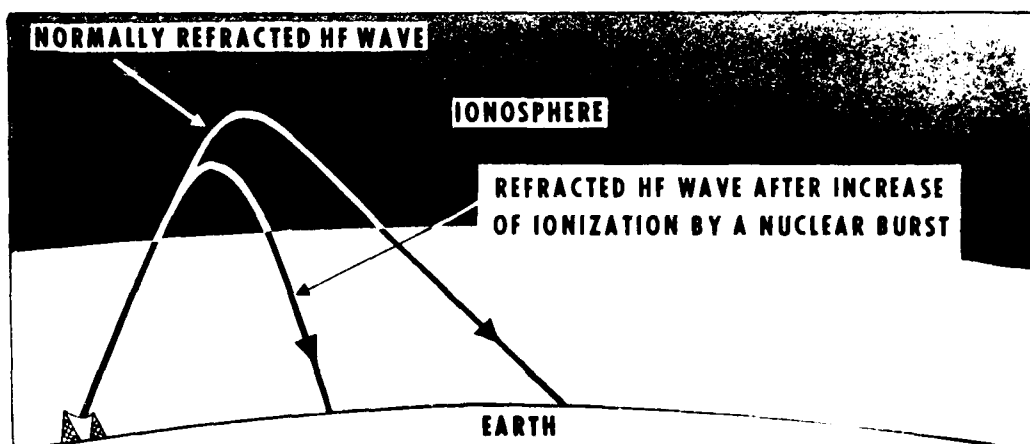
FIGURE 18. EXAMPLE OF HF SKYWAVE PROPAGATION.

FIGURE 19. CHANGE IN REFRACTION OF AN HF WAVE DUE TO AN INCREASE IN THE IONIZATION OF THE IONOSPHERE BY A NUCLEAR BURST.

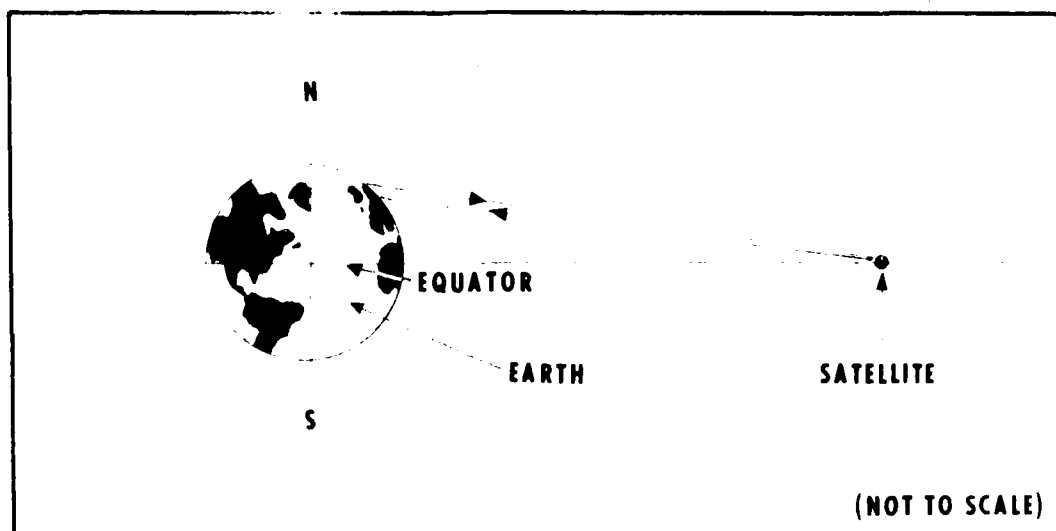| BURST REGION	MODE OF PROPAGATION	BLACKOUT SOURCE	ESTIMATED DURATION OF BLACKOUT
Sub-Surface Surface Near Surface Low Altitude	HF Groundwave, Skywave	Fireball	Negligible To Few Seconds
High Altitude	HF Skywave	Ionized Region	Minutes To Many Hours

FIGURE 20. BLACKOUT OF HIGH FREQUENCY COMMUNICATIONS SYSTEMS.

(NOT TO SCALE)

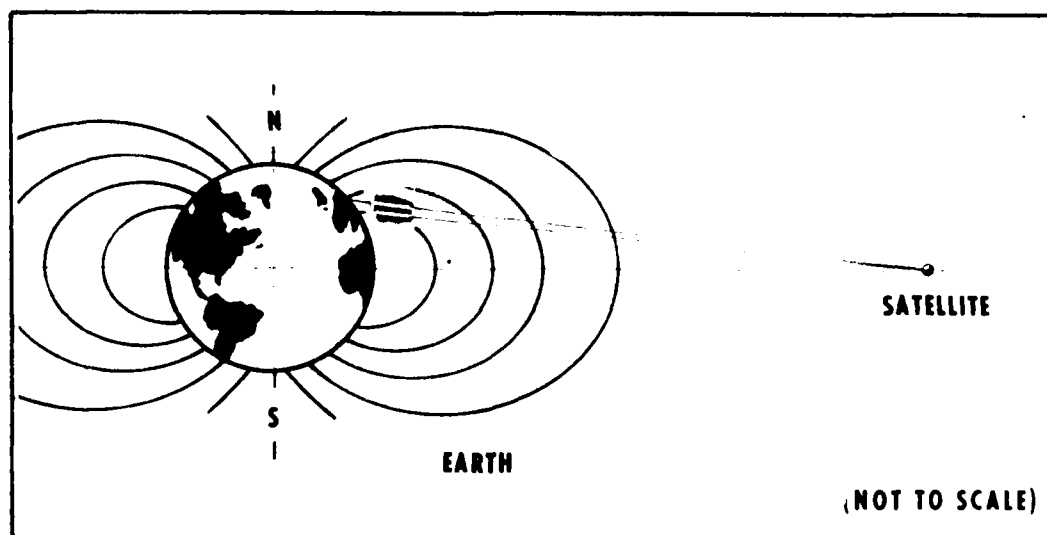FIGURE 21. TRANSMISSION PATH FOR SATELLITE RELAY COMMUNICATION SYSTEM.

(NOT TO SCALE)

FIGURE 22. TRANSMISSION OF RADIO WAVES FOR A SATELLITE RELAY PASSING THROUGH A HIGH ALTITUDE FIREBALL.

BURST REGION	FREQUENCY BANDS	BLACKOUT SOURCE	ESTIMATED DURATION OF BLACKOUT
Sub-Surface Surface Near Surface	UHF, SHF	Dust/Fireball	Few Seconds To Tens Of Seconds
Low Altitude	UHF, SHF	Dust/Fireball	Few Seconds To Tens Of Seconds
High Altitude	UHF, SHF	Ionized Region	Few Minutes To Hours

FIGURE 23. BLACKOUT OF SYNCHRONOUS SATELLITE RELAY SYSTEMS.

26

cate by wire when such facilities are available and there are no major hazards involved in using them.*

2. Another simple mitigation technique is the use of alternate routing. If the transmitter operator cannot reach the station he desires, he should bypass the blackout region by relaying the message through a third station.

3. If it is a multi-frequency transmitter that is being blacked out, the operator should attempt to communicate on alternate frequencies. If it is suspected that the interference is being produced by an ionized region, higher frequencies should be tried first. Where it appears that dust is the problem, lower frequencies should be tried first. These problems should be recognized in the assignment of alternate frequencies. Since blackout depends upon the mode of propagation, the use of a communications set with a completely different mode of propagation should be tried if the preceding measures do not work and such equipment is available.

HOW SIGNIFICANT WILL BLACKOUT BE ON THE NUCLEAR BATTLEFIELD?

The amount of blackout interference that will actually be encountered on a nuclear battlefield will never be known until such a war occurs. This is partly due to the uncertainties in the technical blackout data. It is due also in part to the uncertainty in the nuclear threat—how many nuclear bursts there will be in what period of time over what areas. In this regard, there is the question of whether there will be any high altitude bursts over the battlefield.

Despite these uncertainties, it appears that serious blackout problems may be encountered for three combinations of nuclear bursts and modes of propagation.

1. High altitude bursts and communications using synchronous satellite relays. It is pointed out in Figure 23 that communications using satellite relays may be blacked out for periods lasting several hours. This blackout period can apply to all satellite relay communications in an area of thousands of square kilometers. Since the Army is planning to employ relay satellites to handle 25 percent of its communications on the nuclear battlefield by the 1980's, blackout under these conditions could significantly impair the Army's ability to communicate.

2. High altitude bursts and HF communications. In Figure 20, it is pointed out that HF sky-wave communications may be blacked out for hours by a high altitude burst. Since HF skywave systems are employed in communicating over distances up to several hundred kilometers on the nuclear battlefield, this capability could be lost. This loss would be major if there were no backup communication relay links that could be used in place of the blacked out HF systems.

3. Dust clouds produced by low altitude bursts and LOS communication systems. Since blackout interference by dust has large uncertainties, it is difficult to evaluate how serious this type of interference will be on the nuclear battlefield. However, for the case of an intense enemy nuclear laydown, hundreds of square kilometers could be covered by dust for several minutes; thus many communications systems may not be able to operate during this period. An additional facet of this dust interference problem is the trend in the Army toward developing and employing LOS communications systems with higher and higher frequencies. Since dust-caused blackout increases with frequency, this trend to higher frequencies foreshadows an increasing blackout problem on the nuclear battlefield.

Aside from the foregoing instances, there are some bases for considering that blackout will not be a major problem on the nuclear battlefield. Blackout times resulting from low altitude fireball interdiction are short (a few minutes at most) for all modes of communication. Where communications are extremely important, there will usually be a high density of communications systems employing different modes of propagation. There is an appreciable probability that no more than a few percent of them would be blacked out at any one time. The blackout problem may also be alleviated somewhat by the mitigation techniques discussed earlier. Also, in contrast to other nuclear effects, blackout does not result in any damage to communications equipment.

---

*Although the use of wire communications mitigates the blackout of radio communications, wire systems may be susceptible to the electromagnetic pulse (EMP) from a nuclear burst (see Nuclear Notes Number 1, The Electromagnetic Pulse). Thus, the vulnerability of wire systems to EMP - especially long wire systems - should be known before they are relied upon as a major means of communicating.

SUMMARY.

High altitude bursts could cause widespread blackout effects for HF skywave and synchronous satellite relay communications for several hours. This interference would affect communications capabilities, including those of higher headquarters and nuclear delivery units. For other than the high altitude burst, blackout will last a few minutes at most, and then only when a fireball or dust cloud interdicts transmission paths. This form of interference will be the primary source of blackout for the communications systems of front line units.

AFPP-FBT