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AIR FORCE SYSTEMS COMMAND

THE EFFECT OF NUCLEAR BURST ON RADIO COMMUNICATION AND THE OPERATION OF RADARS

by

Ya. I. Fayenov, I. S. Krasik'nikov

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В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*<u>ye</u> initially, after vowels, and after ъ, ь; <u>e</u> elsewhere.
When written as ё in Russian, transliterate as yё or ё.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	$\sinh^{-1}$
cos	cos	ch	cosh	arc ch	$\cosh^{-1}$
tg	tan	th	tanh	arc th	$\tanh^{-1}$
ctg	cot	cth	coth	arc cth	$\coth^{-1}$
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

THE EFFECT OF NUCLEAR BURST ON RADIO COMMUNICATION AND THE OPERATION OF RADARS

Engineer-Colonel Ya. I. Fayenov and Engineer-Major I. S. Krasil'nikov

During the period from 1958 through 1963, several series of nuclear air bursts were conducted in the United States and Britain to determine their effect on the operation of radio-engineering means. During the tests, radars, high-altitude rockets, and artificial earth satellites were used to investigate the change in the Earth's magnetic field and to measure the power of X-ray and radiation emissions which accompany nuclear bursts and samples of the air were taken at various altitudes while spectral and thermal measurements of the burst's results were conducted.

The data published in the foreign press permit judging the processes which occur during nuclear explosions and their effect on the operation of radio and radar equipment. It is known that a colossal quantity of energy is released during bursts in a comparatively small volume of nuclear matter. Here, the construction of the charge and its carrier are converted into a heavily ionized high-temperature vapor-plasma of nuclei, electrons, and ions with a temperature of several tens of millions of degrees. Burst products are ejected from the burst zone at great speeds - neutrons, gamma-rays, α- and β-particles, newly formed nuclei of chemical elements - fragments of nuclei of uranium, plutonium, thorium, and the synthesis of the nuclei of hydrogen isotopes as well as electromagnetic emissions in a broad range of the spectrum.

The X-ray radiation which arises at these temperatures, just as the gamma radiations, neutron fluxes, and electrons released in all directions from the burst, strongly ionize the atmosphere and this leads to the arising of electromagnetic effects of two basic types which are opposite to one another in their nature. The first effect consists of the emission of the electromagnetic pulses of short duration and the second causes a change in the electrical properties of the atmosphere and can affect the propagation of radio waves of various bands.

The electromagnetic pulse appears as a result of the non-uniformity in distribution of the electrical charge around the burst zone and due to the interaction of the plasma which is formed during the burst with the Earth's magnetic field. The non-uniformity effect is the source for the emergence of an electromagnetic pulse during bursts on the Earth's surface, at low altitudes, and close to the upper limit of the atmosphere. With bursts at high altitudes the current-conducting rapidly expanding plasma interacts with the Earth's magnetic field and displaces it. As a result, an electromagnetic pulse is also formed.

Powerful radiation fluxes which collide with atoms and molecules of the surrounding air and ionize it at altitudes up to the upper limits of the atmosphere are released from the region of the nuclear burst with great velocities. The electrons which are formed here begin to move rapidly from the center of the burst. As a result of the atmosphere's heterogeneities in the lower, surface layers a large number of electrons are formed at lesser distances from the center of the burst than occurs with propagation upward.

Unevenness in the propagation of the burst products and emissions is a characteristic feature of bursts on the surface or close to the Earth. This is explained by the fact that the Earth's surface limits the expansion of burst products and causes the directionality of their propagation upward. With a burst high in the atmosphere, as is reported in the foreign sources, an extremely insignificant interaction between the air and the atoms and molecules of the emissions which are moving upward is observed and the radiation directed downward ionizes the air at much shorter distances from the center of the burst. In both cases, the electromagnetic pulse has a vertical direction of propagation. It is caused, as has already been noted, by the special features of the burst in different media of the atmosphere. It is necessary to note that regardless of where the burst occurred, a nonuniformity (asymmetry) of emissions caused by the construction of the charge and its character always exists. It can have any orientation.

The lighter electrons which have been formed due to ionization move from the point of burst at a greater speed than the positive, heavier ions. This relative displacement of the positive and negative charges also creates an electrical field which varies in time and, consequently, an additional electromagnetic signal. The electrons ionize the air during movement. A large quantity of "electron-ion" pairs is formed. Under the influence of the burst's radial electric field, a large number of electrons are ejected backward in the direction toward the burst region. Here a second current pulse is formed and, consequently, a secondary electromagnetic pulse.

The third source of electromagnetic emissions is the plasma which is formed from the atoms and molecules of the charge material and its carrier. The plasma is subjected to fluctuations. Their reason is the nonuniformity which is caused by design features, and the distribution of the burst energy and constantly proceeding processes of ionization and recombination within it. These fluctuations last for a short time which is sufficient, however, for the formation of an electromagnetic pulse.

Nuclear bursts are accompanied by powerful radiation. The neutron fluxes, gamma-rays, β-particles, and X-ray and ultra-violet emissions strongly ionize the atmosphere. The presence of free electrons in the atmosphere affect the operation of radio-engineering means. Acting on radio and radar signals, electrons can decrease the energy of the wave, i.e., weaken the signal and, when the wave moves from the region with one electron density to a region with another concentration, they distort the direction of radio wave propagation.

When interacting with an electron, the electromagnetic wave transfers a portion of its energy to it. If the electron does not lose the energy which has been received as a result of a collision with neutral atoms, it radiates a new electromagnetic pulse of the same frequency. In this case, the wave energy is not attenuated. But if the air density is considerable, the electrons frequently collide with its particles. A large portion of the excitation energy of the electron is transmitted to the air particles and the attenuation of the electromagnetic signal occurs.

A substantial weakening in the power of the signal occurs only with large concentrations of free electrons and considerable air density. Under other conditions, absorption increases with a decrease in the signal frequency. Negative and positive ions possess considerably less capability for absorption in comparison with light electrons.

When passing from a layer of the atmosphere with a lesser electron density to a layer with a greater electron density, the electromagnetic waves experience "distortion" of the direction of wave propagation toward layers with a lesser concentration. The greater the electron density and the lower the frequency, the stronger the "distortion."

Since the condition of the atmosphere affects the operation of many communication and radar systems, depending on the band of electromagnetic waves, yield, and height of burst the effect of its influence on the operation of these systems is different. Thus, in the very-low frequency wave (VLF) band signals are transmitted by means of reflection from the lower limit of the ionosphere and the Earth's surface. Additional ionization caused by the burst does not lead to noticeable attenuation of VLF. However, the distances which the wave passes through between the transmitter and the receiver depend on the altitude of signal reflection. If the electron density increases rapidly, reflection of the waves occurs at a lower altitude and it passes through a shorter distance. This causes the phase shift of the wave.

The most notable effect appears at great distances in a sudden phase shift of the signal. As the concentration of electrons decreases, the shift will disappear. For example, after a high-altitude burst accomplished in the United States (operations "Teak" and "Orange" at an altitude of 70-80 km and 40 km), the signals on a frequency of 18.6 kHz at the point of reception had a phase shift of up to 40°. Reception was accomplished approximately at 5000 km from the burst area. Furthermore, burst products, soil particles, water, and smoke located on the path of movement of the VLF wave also affected the passage of the waves and the operation of the radio communications equipment. Based on calculated data, American specialists state that a 50-megaton bomb detonated at an altitude of 80 km will cause an interruption in radio communication for approximately one day in a radius of about 4000 km. The size of the radius depends on the height of burst and the yield of the bomb.

The propagation of radio waves of long and medium bands occurs as a result of repeated reflection from the ionosphere and the Earth (spatial waves) as well as their passage along the surface of the Earth (surface waves). The spatial propagation is considered unreliable due to the strong absorption while surface propagation is used with a sufficiently powerful transmitter for communication over distances more than hundreds of kilometers. High-altitude bursts have a strong influence on the propagation of spatial waves and do not affect surface waves. Low-altitude bursts conducted in the area of wave propagation or close to it screen the receiver from the transmitter. The time of cessation of communication depends in this case on the altitude and type of burst as well as on the yield of the charge.

Shortwaves (SW) are employed for communication at distances of 80-8000 km. They are propagated by successive reflection from the ionosphere and the Earth. Each reflection is accompanied by a loss in energy and, therefore, reliable communication can be implemented under the condition of no more than 3 or 4 reflections from the ionosphere.

Bursts at altitudes less than 16 km do not have a noticeable effect on shortwave communication in the case where the direction of propagation of the waves does not pass through the area or cloud of a burst. With bursts at altitudes greater than 16 km, the brief disruption of communication is possible when the signals pass close to the burst area. As a result of the burst of a megaton charge during the day at an altitude of 80 km, communication may be disrupted in a radius of 1000 km under the effect of instantaneous radiation. From 17 min to 3 hours are required for its restoration depending upon signal frequency. The effect of the delaying emissions increases this time.

Communication can be disrupted from a burst of such a charge at altitudes of 16-72 km with consideration of delaying emissions within a radius of approximately 900 km during the day for five hours and can be completely restored only after several hours. A burst at altitudes of from 72 to 112 km at the same distance also leads to the disruption of communication; however, the time during which communication is disrupted will be less. Besides this, conjugate zones will be formed in each of the Earth's hemispheres.

Frequent cases of the disruption of SW communication were observed with high-altitude bursts. Thus, in the "Teak" and "Orange" experiments the disruption of communication at a frequency of 15 MHz for several hours was recorded even at a distance of up 1000 km. However, the American specialists admit that the phenomenon of communication disruption in the SW-band is still insufficiently studied.

Radio signals of the meter band have a sufficient penetrating capability. Primarily, this band is employed for communication over short distances within limits of direct visibility. Communication is also possible using spatial waves. In this case, a scattered signal is reflected from the ionosphere and only a small portion of it may land in the receiver. With the propagation of waves close to the burst area communication will be disrupted.

Waves of the decimeter and centimeter bands are used primarily for communication within limits of direct visibility between aircraft-and ground-based stations, as well as between satellites and ground-based stations. Waves with a frequency of 800 MHz are scattered in the air and communication along the Earth's surface at distances up to 1000 km is based on this property. Ionospheric disturbances do not affect the operation of stations along the Earth's surface. The disruption of communication is possible with surface and near-surface bursts in the case where they occur in a zone located between the receiver and the transmitter. This occurs due to the effect of ionization of the fire ball for several seconds and the shielding of the burst by the cloud for a long period of time.

The effect of a nuclear burst on electronic equipment is connected with the powerful electromagnetic radiation, one of the reasons of which is the rapid expansion of plasma which conducts burst products rather well in the Earth's magnetic field. The tendency toward the exclusion of the Earth's magnetic field from its interior region is inherent to plasma. This causes the latter's strong distortion. As a result of the interaction between the geomagnetic field and the charged particles in the expanding plasma and the strongly rarefied ionized surrounding gases, these disturbances are propagated in a direction away from the point of burst in the form of a magnetohydrodynamic wave. Interacting during its descent from the denser layers of the atmosphere, it is formed into a conventional electromagnetic wave.

Radar systems which are operating in the meter band or in bands which are close to it discover targets which are located below the ionosphere regardless of its condition which is caused by air bursts except for cases where the burst cloud is located between them. But if the signal passes through the ionosphere, the effect of the burst on the operation of the radar may be substantial since the signals are attenuated in this case. The strength of the attenuation effect on the operation of the radar depends on the altitude, burst yield, and radar type and frequency. In early-warning stations the loss in signal power leads to a decrease in the target detection range.

Radars for tracking and the guidance of antimissile missiles to targets are also subjected to the effect of bursts. Foreign specialists believe that the precision in guidance of antimissile missiles may be reduced substantially since, as a result of bursts, conditions are created which sharply deteriorate the combat capabilities of the BMEWS early warning and ICBM tracking system and the guidance of the "Nike-Zeus" antimissile missiles to them.

Considerable interference in the propagation of radar signals may arise as a result of ionization of the atmosphere after a nuclear burst. Ionization has the tendency to become uneven and to be propagated along channels of different density along directions of the force lines of the Earth's magnetic field. This impedes the propagation of the radar beam, causing a phenomenon which is similar to the twinkling of stars, the disordered reflection from local objects, or false reflection from ionized sections. In addition to the effect of nuclear bursts on the operation of radio-engineering equipment, American specialists assume the possibility of a harmful effect in other fields, too. They assume that the standing electromagnetic waves of great length which are formed will have such a high intensity that currents with a force of several thousand amperes will be induced in any electrical overhead conductors or underground cables and the conductors and cables will melt under their influence. In particular, such a phenomenon was observed with the bursts of bombs with a kiloton yield on a missile range in the state of Nevada when the oil fuses were activated in high-voltage transmission lines located at a distance on the order of 50 km from the point of burst. Scientists of the Commission on the Use of Atomic Energy determined that thermonuclear burst will also affect communication equipment which is located at a depth of 90 meters from the Earth's surface.

This is the estimate of the effect of nuclear and thermonuclear bursts on radio communication and radar location by American specialists.

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