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CENTRAL INTELLIGENCE AGENCY
WASHINGTON, D.C. 20505

1 February 1974

MEMORANDUM FOR: The Director of Central Intelligence

SUBJECT : MILITARY THOUGHT (USSR): The Improvement of Military Communications

1. The enclosed Intelligence Information Special Report is part of a series now in preparation based on the SECRET USSR Ministry of Defense publication Collection of Articles of the Journal "Military Thought". This article is a comprehensive assessment of Soviet military communications. It examines basic communications principles such as reliability, security and survivability in the nuclear environment and then makes recommendations for achieving these goals. The author treats both procedural and technical improvements in practical terms, including sophisticated techniques such as molecular frequency stabilization and laser communications. This article appeared in issue No. 1 (89) for 1970.

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David H. Blee
Acting Deputy Director for Operations

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Intelligence Information Special Report

DIRECTORATE OF OPERATIONS

COUNTRY USSR

DATE OF INFO. Early 1970

DATE 1 February 1974

SUBJECT

MILITARY THOUGHT (USSR): The Principal Ways of Improving the Quality of Military Communications

SOURCE Documentary

Summary:

The following report is a translation from Russian of an article which appeared in Issue No. 1 (89) for 1970 of the SECRET USSR Ministry of Defense publication Collection of Articles of the Journal "Military Thought". The author of this article is General-Mayor of Engineer-Technical Service V. Stishkovskiy. This article is a comprehensive assessment of Soviet military communications. It examines basic communications principles such as reliability, security and survivability in the nuclear environment and then makes recommendations for achieving these goals. The author treats both procedural and technical improvements in practical terms, including sophisticated techniques such as molecular frequency stabilization and laser communications.

End of Summary

Comment:

Gen.-Mayor Stishkovskiy has written many articles on signal equipment, military communications equipment and the effect of a nuclear burst on signal equipment. His most recent articles appeared in Tekhnika i Vooruzheniye, #1, 1972 and #19 for 1968; and Military Thought, the RESTRICTED version, #3, 1969. Military Thought has been published by the USSR Ministry of Defense in three versions in the past -- TOP SECRET, SECRET, and RESTRICTED. There is no information as to whether or not the TOP SECRET version continues to be published. The SECRET version is published three times annually and is distributed down to the level of division commander.

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The Principal Ways of Improving the Quality of Military Communications

by

General-Mayor of Engineer-Technical Service V. Stishkovskiy

The appearance of remote-controlled weapons of great destructive power has brought about the necessity of examining anew those communications means and systems which provide control over troops and military equipment. Old concepts about the very existence and the quality of communications between control points have undergone fundamental review.

At present the quality of military communications is determined by the following principal requirements: survivability and reliability of information received, security of communications, and the speed with which communications are established.

We will note that the organization and maintenance of uninterrupted and adequately high-quality communications in contemporary operations is a very difficult task. The solution of this task requires great technical and organizational skills, work experience, initiative, and persistence on the part of military communications personnel and an attentive attitude toward the needs and requests of communications personnel by commanders and chiefs at all levels.

One can say frankly that under conditions of heightened natural interference and artificial jamming, with the increasing mobility of troops and possible heavy losses of communications equipment in operations, it does not appear possible to organize reliable communications by means of only one type of communications. Therefore, we are talking about the integrated use of communications means: where shortwave and ultra-shortwave communications links (nets) are established between command posts, where radio-relay and tropospheric communications links are built, where underground cables are laid, and where messenger communications means (aircraft, helicopters) are used.

Let us examine in greater detail each of the above-mentioned requirements placed upon military communications.

The survivability and reliability (viability) of a communications system is defined primarily by its structure, i.e., by the principle and means which link the communications centers of control points. The communications circuit should be such that every subscriber of any communications center can obtain communications with every subscriber of another communications center in the desired time and with maximum speed. The survivability of a communications system is defined by its capability of maintaining assigned communications when one or several of its control points or communications centers are put out of action from the effect of nuclear or conventional weapons.

If one proceeds from old concepts concerning the organization of communications, then to provide communications in a front it is necessary to construct axial lines and separate communications links using cable and radio-relay lines and establishing, where necessary, monitoring and testing points. In the US, and also in our country, the establishment of a grid-type communications system was proposed, which involved, in a given theater of war, the construction of a network of radio-relay and cable links with supporting communications centers located at the intersections of axial and lateral lines, and with large unit and formation control points tied into the supporting communications centers. At present it is obvious that neither the first nor the second method can ensure the necessary communications system survivability and reliability, given the high mobility of troops. To attain the required characteristics of these parameters, it is now recommended that a combined communications system be constructed by skilfully and judiciously combining both methods indicated, i.e., by connecting control point communications centers between themselves, not only by direct links, but also through auxiliary centers. To obtain direct communications channels, shortwave and ultra-shortwave radio communications, tropospheric communications, and lastly, satellite radio communication systems are to be used.

The communications system which military communications personnel are striving for is close to the optimum as regards survivability; however, to achieve such a system is not always possible because of a lack of equipment and time. Accordingly, and naturally, we are not talking about the following obvious needs: to dependably shelter communications centers, antenna installations, and transmission lines from the direct effects of enemy weapons; to carry out circumvention and bypassing of urban areas; to provide for redundancy of communications lines by various kinds of equipment; and to install special devices (preferably automatic) for the rapid switching of combat communications control to alternate points when individual centers go out of action.

To increase the survivability, reliability, and jamming resistance of radio communications, especially when the enemy is employing radio jamming, organizational measures should be extensively carried out, including the following: operating without callsigns (or with frequent changes in them) and without acknowledgements, organizing secure radio nets and radio links, frequent changing of duty operators, transmitting radio messages simultaneously by direct and alternate channels, etc.

We understand <u>reliability</u> of a <u>communications system</u> as a whole to mean its ability to ensure the transmission of information on assigned links with a quality of communications which is acceptable under specific operating conditions. The parameter used in the signal troops to assess the reliability of a communications system is the factor of good working order (KID), which describes the probability, at any moment, of the required functioning of a communications system. It is defined as a ratio of the time during which communications were provided (the transmission of information was carried out) with satisfactory (prescribed) quality to the entire time spent in receiving a given communication.

The reliability of the equipment used largely defines the operating reliability of a communications system, which for the sake of simplicity we will assess as the number of hours of accrued operating time per failure. In view of the increasing complexity of communications equipment, the problem of increasing its operating reliability has become especially urgent. Thus, for example, if previously a telegraph communications network consisted of units of components and elements (tubes, resistors, condensers, etc.), now these number in the tens of thousands. It would seem that the probability of losing communications would increase. However, in actuality the measures taken are called upon not only to maintain, but even to raise the reliability of any communications.

Raising the operating reliability of communications means is brought about by developing equipment which has no electron tubes, by the widespread use of ready redundancy of equipment units and highly reliable power supply units, and by paralleling communications channels with various types of communications (shortwave and ultra-shortwave direct communications, radio-relay, cable, tropospheric links and others). Some military specialists advocate the development of compact telegraph and telephone equipment with a maximum number of channels (sixty or more). In our view this tendency is not warranted, because, although it affords certain gains in the cost of equipment per channel, it leads to decreased reliability. Here it is advisable to search for a well-grounded optimum. In our opinion, it lies within the limits of six to twelve to twenty-four channels for telephone communications and three to six to twelve channels for telegraph lines, depending on the required capacity of communications nets.

An essential factor determining the survivability and reliability of a communications system is the ability to operate the communications equipment available. We will not err if we state that knowledge of communications equipment by commanding officer personnel and crew personnel, and the presence of skills, training, and definite traditions in operating equipment will ensure fifty percent success in accomplishing tasks.

Jamming resistance is one of the most important parameters of communications means. It determines the magnitude of the ratio of signal voltage to jamming voltage at the output of the communications channel and defines the capability of the communications link to assure reproduction of the signals received with a certain reliability under jamming conditions. For various types of communications, differing magnitudes in the signal jamming ratio are required. In printing telegraphy operation this ratio must

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not be less than one, in non-secure radiotelephone--up to three, and in secure radiotelephone--over five.

Jamming protection is very important for all types of communications, and for shortwave communications systems it is of definite importance. This is explained by the fact that short waves are propagated in space to practically unlimited distances and each radio station has, in addition to and apart from its zone of effective operations, a zone of impeded operations. In connection with the sharp increase in the number of emitting devices, the average interference level in the past twenty years has increased five to ten times in frequency range. In shortwave frequencies the enemy also can easily produce deliberate jamming.

What measures are to be taken to raise the jamming resistance of shortwave communications?

A basic technical parameter, determining the capability of raising the jamming resistance of radio communications, is the stability of the radio transmitter master oscillator (exciter) and the receiver heterodyne, i.e., the frequency stability of the radio communications link. High stability permits producing radio sets which operate without having to hunt for the station to be worked when establishing contact and without frequency tuning during operation itself, i.e., radio sets which can establish communications immediately, even without callsigns (experience in operating military shortwave communications systems reveals that initial establishment of contact is pivotal when organizing communications, especially with a moving station). With high frequency stability it is possible to use sets provided with pushbutton automatic frequency tuning to previously tuned and fixed radio links and also to use such effective methods of secure communications as high-speed and super-high-speed "burst" communications on previously stipulated frequencies. With a two-time or three-time repetition of a "burst", 100 percent reliability can be achieved by the procedure of overlapping (automatic or manual) of the radio messages received. Lastly, high stability permits varying the bandwidths of the receiving channel by choosing optimum frequency shifts in frequency-keyed telegraphy, thereby offering the possibility of very effectively combatting pulse jamming.

In connection with the above, the frequency stability of shortwave radio sets is steadily increasing from model to model. If in highly stable crystal radio sets at the end of World War II the frequency shift amounted to 10^{-4} under the influence of destabilizing factors, and in radio sets produced in 1955-1960 it had a value of $5 \cdot 10^{-6}$, in radio sets produced in 1965-1969, the frequency shift amounts to only $5 \cdot 10^{-8}$, i.e., on an operating frequency of 20 Mhz, the frequency instability will not exceed one hertz. This is very high stability, approaching the stability of stationary reference oscillators of a standard time service. However, this stability is not the limit and in the future radio sets it will apparently be raised even higher (up to 10^{-10} to 10^{-12}), requiring a changeover from crystal stabilization to molecular stabilization, which has practically infinite capabilities.

At present, rubidium, cesium, and hydrogen master oscillators are in general use with subsequent frequency division of their oscillations up to the ultra-shortwave and shortwave bands. An oscillator stabilized by a rubidium gas cell is quite compact and has very high long-term stability (up to 10^{-12}), at a weight of approximately 20 kilograms. Cesium oscillators have somewhat less short-term instability (up to 10^{-10}) and are more bulky in size; however, their long-term stability is also extremely high. A quantum oscillator with hydrogen atoms provides the highest stability, independent of the duration of time (up to 10^{-18}), However, as yet the cost and size of the oscillator are so great that it cannot be used for military communications purposes. This trend of improving shortwave and ultra-shortwave radio sets is indisputably promising and justified, inasmuch as it permits developing radio-receiving devices with a bandwidth approaching the spectrum width of the signal received, thereby decreasing the probability that station interference will fall within the bandwidth of the receiver. However, in designing this it is necessary to find the optimum so that the requirement for high stability does not lead to excessively costly radio equipment.

The most important technical step which has significantly facilitated resolving the problem of raising the jamming resistance of shortwave radio communications is the use, without exception, in all new shortwave radio sets of single-band modulation (unlike ordinary radio transmitter

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amplitude modulation, where the signal contains the carrier frequency and two sidebands). This also became possible only when radio sets with highly stable frequencies became available.

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Single-band radio communications, compared to double-band, possess a number of substantial advantages. Because of the more efficient use of the rated power of the output stage tubes of the transmitter, the narrowing of the bandwidth of the receiver, and the exclusion of phase distortions (observable in double-band radio communications between carrier and side frequencies), its employment theoretically permits obtaining a received signal-level gain equivalent to a sixteen-time increase in radio link transmitter power (in actuality, approximately a ten-time power gain can be provided.). In addition, single-band radio sets require on the average twenty-five percent less electrical power than ordinary radio sets (in the first case, transmitters are shut down during pauses in conversation, thus not expending power.). Finally, single-band modulation possesses that valuable quality of permitting, by narrowing the spectrum of transmitted frequencies, the inclusion within a portion of the shortwave band of twice the number of communications waves, a feature which is particularly important in military communications.

It is also necessary to emphasize that the introduction of single-band modulation definitely hinders the enemy's production of radio jamming. Estimates indicate that to neutralize single-band radio communications the enemy has to increase the power of the jamming radio station not less than ten to twelve times and raise the stability of the radio-jamming carrier frequency by an order of one or two. It is obvious that widespread use of single-band radio sets makes it rather complicated to do this.

Rapid tuning of the radio link frequency should be considered one of the basic methods of avoiding deliberate enemy jamming on any waveband, and particularly in the shortwave band. To provide this, the preliminary installation of two to ten communications frequencies which can be quickly shifted by pushing a button, should station interference or deliberate jamming appear, has been stipulated for all new radio sets. Pushbutton tuning of radio communication frequencies also affords great organizational advantages: it permits instantaneous

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switching of the communications link and the station being worked. The final stage in the development of automated radio sets must be to provide the capability for pushbutton setting of any frequency in the radio set's band, and also the remote frequency tuning of a station being worked when radio jamming materializes at the receiving location. The latter circumstance stems from the following causes. When carrying out long-range shortwave communications, the station transmitting the message does not know the reception quality of its message and cannot detect the appearance of jamming on the receiving channel. The message reception quality can be determined only at the receiving location itself. Therefore, it is necessary to have radio links so automated that an operator will be able, when jamming materializes at the receiving location, to retune simultaneously his receiver and the transmitter of the station being worked (at a distance of up to several thousand kilometers) by pushing a single button. To accomplish this, the duplex radio link must have simultaneously in every link two communications channels as it were: an operating channel and a remote retuning control channel. The ideal variant is a radio set where such retuning of the transmitter and receiver will occur automatically whenever jamming appears or when communications quality is degraded because radio waves are passing poorly through the ionosphere. Such a radio set of the future may be named self-tuning or adaptive.

In the broad sense of the word, adaptive communications system (link) is the convenient term given to a system in which optimization of transmission, reception, and processing of the signals is accomplished as a result of uninterrupted evaluation of the quality of communications by determining the parameters of a channel and the quality, expressed as reliability, or received information. Measuring the parameters of a channel may be carried out either directly during the operating phase or by sending a probing signal. Accordingly, it would be expedient to send the latter, without interrupting the transmission, by superimposing it on the transmitted information in such a manner that it did not suppress the basic signal. On such an operating communications link it is necessary to have and to restore constantly the acceptable relationship of error occurrence probability at the output of the communications system to the level of the signal-to-noise ratio at the input of the radio receiver channel. This procedure will allow one to always know what is the minimally acceptable signal level at the receiver site which permits information to be received with adequate reliability. Further improvement in the control of shortwave long-range radio communications will be, in our opinion, the use of computers to estimate the optimum relationships between present-day radio link parameters, the jamming level, and the level of the signal received.

With a precisely organized ionospheric service, it is possible, naturally, to provide jamming-resistant communications and automated adaption of radio communication links. When processing radio data in the operational control of a communications system, it is necessary not only to consider the published long-range and short-range forecasts and recommendations for the selection of optimum communications frequencies, but also to continuously observe ionospheric conditions and the loading of the band or the assigned table of frequencies of interfering stations, atmospheric and industrial interference, and deliberate jamming. Only rapid reaction to the condition of the "ether" will make it possible to maintain a high enough jamming-resistance level in the radio links.

In medium-power and high-power shortwave radio sets there are provisions in radio-printing telegraphy for both single-channel and two-channel mode operation with push and release frequency shifts at 125, 250, 500 and 1,000 hz. It must be noted that the single-channel mode provides considerably greater jamming resistance than the two-channel mode; therefore, to raise the quality of communications, important transmissions should be sent in the single-channel mode. When operating in the two-channel mode, it is advisable to send operating information on the first channel (it is of higher quality) and to handle procedural requests on the second channel.

The above-indicated four variant frequency shifts for radio-printing telegraphy communications were provided for in the design of the radio sets to increase radio communications jamming resistance by allowing the choice, during operation, of the minimum frequency shift permitted by radio link stability. The operating experience of radio sets with the troops has shown that the desired effect is not obtained in practice (although in theory this gain is unquestionable when there is noise interference because

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keying with frequency shifts is done with inadequate skill and often leads to the loss of communications because the stations being worked often set up diverse, and frequently non-optimum, shifts. Therefore, in our opinion it would be advisable on all new radio-printing telegraphy sets to reserve only a single frequency shift, at 250 hz, for both the single-channel and the two-channel mode; it will be suitable for operation with Ministry of Communications stations (200 hz shift). In this case, control of radio stations is simplified and the number of crystal filters and knobs is decreased.

To achieve two-channel and multi-channel radio-printing telegraphy operation on shortwave radio sets, it is opportune to recommend secondary multiplexing of the single-band channel by signals on subcarrier frequencies (on twelve to eighteen telegraphy channels) with subsequent coherent averaging of diverse combinations of channels on which the same information (averaging by frequency) is transmitted. According to theory, it is known that when there is optimum averaging of the signals transmitted by various independent channels, the resulting signal-to-noise ratio is equal to the sum of these ratios in the individual channels. Accordingly, the greater the number of channels, the closer the jamming resistance of the resulting radio channel is to the jamming resistance of the channel without fading. If one were to employ also the averaging of the signals received on two radio receivers with spatially dispersed antennas (averaging in space), then the jamming resistance and quality of communications would be significantly raised in radio-printing telegraphy operation. In practical work it is necessary to choose the number and order of averaged subcarrier channels so that the signal-to-noise ratio, even if in only a single channel, is large enough, taking into account selective fadings and the possible appearance of station interference. In case there is poor radio wave passage and a high interference level, one can transmit the same information by all, let us say, twelve channels and having averaged these channels at the output, achieve good quality, stable, printing telegraphy operation. With good signal passage (in daytime on a fully radiated path) it will be possible to provide radio-printing telegraphy operation using three to six channels.

To receive the telegraphy communications channel with very high jamming resistance, it is advisable to have in medium-power and high-power shortwave radio sets a super-narrow-band operating mode, with transmission speed being lowered significantly, naturally. Such a mode may be employed when transmitting over shortwave radio sets, weapons control signals, radio telemetry, and warnings, i.e., signals with a limited amount of transmitted information. It has been established that in order to transmit telecode information by radio channel with adequately high quality at a speed of one baud, a bandwidth of one hertz is required. This means that at a telecode transmission speed of, say 10 bauds, a radio channel width of only 10 hertz is required if, of course, link instability is disregarded. It is very difficult to strike such a narrow band with jamming.

It is also advantageous to use super-narrow-band shortwave radio communications in the telephonic mode, particularly when combined with special equipment. In this case the voice signal, having a band frequency of 3,100 hz is "squeezed" (compressed) in a special speech converter device--vocoder--and converted into a sequence of doubled impulses at a speed of 1,200 bauds. It is possible to store such impulse information in a special memory device and then to transmit it with a ten to twenty time reduction in speed, i.e., with speed of 60 to 120 bauds, which even an ordinary telegraphy channel can provide. Thus, the possibility has opened up of transmitting speech by telegraph communication links. If a cipher message is also superimposed on the indicated impulse sequence, then the transmission will be secure.

The correct choice of antenna devices for a radio station assembly is of great importance in providing for the jamming resistance of radio communications, particularly for shortwave communications, because the type of antenna and its effectiveness--its amplification factor and directivity--largely determine the jamming resistance of radio communications. Depending on the distance desired, and the communications frequencies used, the choice of antenna is dictated by the following: a whip antenna is used for short-distance operation and for non-directional activity--on the move; a weakly directional dipole antenna is for intermediate distances (up to 1,000 kilometers), and directional (rhombic) antennas are for long distances (more than 1,000 kilometers).

Recently so-called roof antennas of overhead radiation, which provide communications on the move and at brief stops, have been widely disseminated. They amount to dipole antennas emplaced in an efficient way on the roof of a special vehicle body or of an armored personnel carrier. Their use during prolonged halts is not recommended because, not being very efficient, they are unable to provide reliable communications under every condition.

Acutely directional antennas must play a significant role in raising the jamming resistance of shortwave radio communication links. However, since the direction of communications is changed frequently, especially when radio communications are carried out from mobile installations (an aircraft, a ship, a motor vehicle), the development of variable-direction antennas has acquired great importance. By using an acutely directional antenna on a fixed communications link we immediately gain two advantages: we raise the equivalent power of the transmitter and signal level at the input of the receiver, thanks to increasing the amplification factor of the transmitting and receiving antennas, and we avoid interference from sources which do not fall within the radiation pattern of the antenna. In this manner, the signal-to-noise ratio is significantly raised at the output of the communications channel. The introduction of antennas with electronic control of the radiation pattern direction is held back by technical development difficulties, and also the complexity, cumbersomeness, and high costs of such antennas. However, the present-day development of radio electronics will clearly permit accomplishing this task in the near future and the spatial selection of a signal will become an important means of raising radio communications jamming resistance.

Radio communications jamming resistance can be raised significantly by means of a straight increase of the power of radio, radio-relay, and tropospheric communication link transmitters on all wavebands. In so doing, the transmitters should have, of course, special devices which will allow operators, at will, to reduce the power from fifty to ten percent in order to decrease the zone of interference activity when there is good radio wave passage.

One cannot agree with the opinion of several specialists who consider the tendency to raise the power of radio transmitters as erroneous. We think that increasing the power, together with other measures, is an important factor in achieving a high signal-to-noise ratio at the receiver site and in obtaining high-quality, reliable radio communications under any situational conditions where other methods would be unacceptable or of limited effectiveness. At the same time, it is necessary to emphasize that to solve the problem of providing high-quality jamming resistant communications only by a straight increase of power is a practical impossibility, for in this case it would be necessary to raise the power of radio transmitters by approximately a hundredfold at all echelons of control, which is unreasonable and technically infeasible.

Reliability of information received. The appearance of remote-controlled weapons and electronic computers has created the need to transmit a considerable volume of information in the form of current impulses at a relatively high speed. This type of data transmission has received the name of telecode communications. In the broad sense, with the help of telecode communications, such tasks as the following are accomplished: collection of information from terminal points for processing at the central point, transmission of directives from the central station to the action installation, central station responses to requests received; transmission of information between two or more computers, and lastly, carrying out all types of communications (telegraph, telephone, phototelegraph, videotelephone, etc.) in a converted (impulse) form.

Telecode information, compared to other types of communications, has a number of significant advantages. It provides the following important technical capabilities: building unified communications nets from a center to an action installation; linking various control and communications systems; remote switching of messages for an unlimited number of addressees; simultaneously rendering secure all messages transmitted; automatically monitoring the condition and quality of the communications channels; and sharply raising the reliability of the information received.

The volume of data transmitted by means of telecode communications is growing from year to year. In the literature it is indicated, for example, that in the US, in the period 1970-1980, the number of digital messages will equal the number of telephone conversations on the country's telephone system, which will have 150 million telephone subscribers.

At present, in Soviet and foreign telecode communications systems, speeds of from 1,200 to 480,000 bauds are employed (in the US up to 1.2 million bauds), with use both as telephone and special telecode communications channels. In transmissions on telephone channels, direct current impulses are converted into signals within the audio frequency spectrum, with reverse conversion in the receiver device. Special modulators-demodulators (modems) are used for this. To obtain undistorted communications, telephone channels should have high qualitative indexes. The higher these are, the higher the speed of telecode communications that is provided, with allowance for the magnitude of reliability.

It has been established that under ideal conditions a speed of up to 6,000 bauds may be obtained on a normal telephone channel (300-3,400 hz). In actual practice, speeds of 1,200 have been achieved, and in individual cases, speeds of 2,400 bauds by using special devices (filters) to correct channel characteristics.

The reliability of telephone communications is characterized by audibility, determined by the ratio of the number of correctly received elements of speech to the overall number of transmitted elements in sounds, syllables, or words (sound, syllabic, or word articulation). For excellent telephone communications, audibility in sounds should not be under ninety-three percent, in syllables not under eighty percent, and in words not under ninety-eight percent. To increase audibility a number of technical measures are employed: increasing the linearity of the characteristics of the transmitter and receiver devices, improving the quality of microphones and telephones, and by providing reliable contacts in switchboard equipment. It is advantageous to use special devices which raise the reliability of telephone communications.

The reliability of telecode communications is assessed by the ratio of the number of impulses received with distortions to the overall number of transmitted impulses and characterized by the magnitude of reliability loss. The allowable reliability loss in ordinary telephone communications is $3 \cdot 10^{-2}$, i.e., distortion of three characters per 100 transmitted (three percent) is allowed. In telecode communications employed in automated troop control and weapons control systems, this norm is raised considerably, to an accuracy of 10^{-5} to 10^{-6} for medium-class systems and to an accuracy of 10^{-7} to 10^{-8} for high-class systems.

Research and actual operation of communications links reveals that the reliability of even the most stable channels is considerably below the indicated magnitudes. Thus, at a transmission speed of 1,200 binary digits a second, reliability loss is: 10^{-2} to 10^{-3} for ultra-shortwave channels, 10^{-3} to 10^{-4} for radio-relay channels, $5 \cdot 10^{-3}$ to $5 \cdot 10^{-4}$ for tropospheric channels, 10^{-3} to 10^{-4} for wire (cable) channels, and 10^{-1} to 10^{-2} (at a speed of 150 bauds) for shortwave channels. From the data cited it is evident that, excluding shortwave channels, where direct high-speed transmissions are, generally speaking, impossible (because of the peculiarities of the effect of the ionosphere), it is necessary to raise by several orders of magnitude the reliability of almost all types of channels.

Special technical devices are used to raise the reliability of telecode communications; in so doing, the greater the demands made upon the devices, the more complex and expensive the devices, the lower their reliability, and the harder it is to solve the task of raising the quality of communications in a system. Therefore, it is extremely important to determine accurately and thoroughly the requirements for reliability of telecode communications and to try not to overstate them. Incidentally, comments are appropriate concerning the speed chosen for transmitting information, inasmuch as it often happens that there is a fascination with excessive speeds. In our opinion, it is advantageous in troop communications links to limit shortwave channel transmissions to speeds of from 150 to 300 bauds, and ultra-shortwave, radio-relay, and tropospheric transmissions to speeds of from 600 to 1,200 bauds, keeping in mind that a speed of 1,200 bauds can provide for the transmission of an extremely large volume of data (equivalent to the simultaneous operation of twenty-five ST-35 telegraph instruments). To transmit large streams of data between computers, and also within specialized control systems, it is advisable to use higher operating speeds of 4,800, 12,000, and 48,000 bauds by three-channel and twelve-channel groups with frequency multiplexing of the communications trunk (stvol) or by special telecode group positions.

A number of technical methods of raising the reliability of data received are known (corrective codes, multiple transmission, detecting and correcting errors, automatic interrogation and correction of errors, etc.), but all of them are based on the use of data redundancy introduced into the communications channel, thereby entailing an additional time expenditure and partially lowering the efficient use of communications channels. Hence it is obvious that these methods should be selected and used only in cases of genuine necessity.

The simplest methods that might be used to raise the reliability of telegraph (telecode) communications are: by two-time or three-time repeated transmission of a message with subsequent collation at the receiver location, by transmitting the same data on two independent communications channels, by decreasing to a maximum the transmission speed by dividing up the data and sending it on several (six to twelve) subcarrier frequencies on a telephone channel, and by read-back transmission of the data received with subsequent correction of the errors.

<u>Security of communications</u> may be characterized by its three constituents: security of the very fact that there are communications, security of the distinguishing characteristics of the communications, and lastly, security of the content of the information transmitted. In an ideal case, complete communications security could only be ensured by having all three constituents present.

Wire communications, by a cable buried in the ground to a depth of at least one meter, provide greatest security, with other conditions being equal; shortwave radio communications provide the least security.

It is almost impossible to conceal the very fact that communications are in progress when electromagnetic wave radiations (in radio, radio-relay, tropospheric, satellite, and optical links) are employed, but by employing particular types of radiations, bands, waves, and highly directional antenna devices, it is possible to lower significantly the probability that an enemy may intercept transmitted information. To this end, all branches of the armed forces and their arms should widely employ the super high-speed and high-speed mode in shortwave communications. In doing so, communications should be established according to a prearranged program on pre-established frequencies, without using callsigns, with preliminary tuning of the radio transmitters without going on the air, and with return acknowledgement of the receipt of information on other communications frequencies. A radio transmitter should remain on the air from fractions of a second to tens of seconds. It is necessary to remark that the high-speed operating mode, as revealed by test of new equipment, and two-time and three-time repetition, sharply increases the reliability of shortwave radio communications. This mode is a positive means of coping with signal fading during transmissions (by reducing transmission times, which also means reducing the probability of coincidence with moments of fading; repetitive transmissions, generally speaking, permit avoiding the harmful effects of fading). In this case, it is advisable that the operating speed be no higher than 150 to 300 bauds, inasmuch as raising it will lead to considerable distortion because of the effect of the heterogeneity and non-linearity of the ionosphere.

A significant trend in ensuring security of the very fact that there are communications is the employment of ever higher frequencies for radio-relay and tropospheric communications links. Research which has been carried out has revealed that in order to detect, for example, a radio-relay link operating in the centimeter waveband (five to seven centimeters) with highly directional radio-frequency emissions (beam angle from two to three degrees), it is necessary that the detecting receiver be in alignment with the radio-relay link. Since the operating range of a radio-relay station transmitter is 30 to 50 kilometers, the intercepting equipment must be located in enemy territory or aboard airborne means patrolling along that line. Obviously, this is not a simple task, either in peacetime or in wartime. Shifting into the optical band (using laser beams for communications) is even more effective in this respect; however, these communications are unstable because of strong atmospheric absorption (rain, snow, fog). In addition, when establishing communications under troop service conditions, it is very difficult to determine the exact direction of the station to be worked and to ensure accurate antenna orientation. From this point of view, and in our opinion, the optimum waveband for radio-relay and tropospheric links should be considered to be from two to six centimeters for strategic and operational echelons and from a half meter to three meters for tactical echelons.

Security of the distinguishing characteristics of an operating (emitting) radio station has great importance, since an enemy can determine by them the subordination of the radio station, the type of information transmitted by the station, and the traffic volume of the particular communications link. Distinguishing characteristics which can be attributed to a radio station are: station callsigns and the procedure for changing them, the alternating of communications frequencies, characteristic features of the operating radio transmitter (telegraph operating tone, shape of impulses, attenuation speed of shunting processes in telegraphy, frequency stability), types of operation by the station (single band or ordinary telephone, single or double sideband, number of telegraph channels, frequency deviation in telegraphy and the modulation index in frequency modulated telephone), personnel training level and their operating discipline, use of preliminary enciphering or on-line provision of security, the locations of transmitting centers and the distances separating them from proposed command posts. As can be seen by this far from complete list, the possibilities for enemy radio intelligence collection are quite broad.

Through constantly gathering and thoroughly systematizing and analyzing radio intelligence and other information, enemy specialists are able to establish a radio station's subordination to a specific headquarters, to determine a command post's deployment site, a large unit's mobility and the frequency with which it redeploys its command post, the nature of the tasks being carried out by the large unit, and the importance of that large unit (unit) in the operation being prepared (or in process). That is why considerable attention should be devoted to security of a radio station's distinguishing characteristics. In the requirements levied against new equipment to be developed, this matter must be specially stipulated and its realization has to be achieved. Many of the distinguishing characteristics can be eliminated or substantially negated by organizational procedures. As is known, transmitting operations of shortwave radio stations in the defense, during redeployment, or in the concentration area, are forbidden or sharply restricted; the strictest radio discipline is established, transmissions are conducted without callsigns, and communications frequencies are changed frequently. To hinder the enemy from determining the areas of command posts and troop groupings, radio transmitters have to be put a certain distance away from command posts. In our opinion, the optimum distances should be considered to be 1 to 2 kilometers for a division, 5 to 10 kilometers for an army, and 20 to 25 kilometers for a <u>front</u>. A further extension of these distances will not provide the desired effect but merely lead to a large expenditure of remote-control means and to a worsening of communications reliability.

In individual cases, when it is necessary to deceive the enemy, we recommend massing radio emissions from all available types of radio means, the transmission of dummy radio messages, and the conducting of fake non-secure radiotelephone conversations. Against the background of such "radio chaos" it is easy to accomplish the required tasks of regrouping or concentrating the troops.

Security of the content of information transmitted is the most important feature of control and communications means. To provide this is the first task of military communications personnel. To provide security for transmitted information, enciphering and coding devices are extensively used with the troops and also equipment for on-line automatic provision of security for telephone, telegraph, phototelegraph, and telecode transmissions. The integrity of the security provided is classified as either temporary or guaranteed. Equipment for temporary integrity is basically intended to operate at the tactical level (it is simpler and cheaper, smaller and lighter) and equipment providing guaranteed security is for the operational level of control.

However, it is necessary to strive to develop a single type of equipment that provides guaranteed security. This task can be resolved with least complexity (as has already been proved) by using a single transmission method of pulse telecode transmission for all types of data. Future communications systems must be of this type only.

Speed of communications is characterized by two constituents: the speed with which communications are established and the speed with which information is transmitted. The establishment of communications may be initial or repeated (after a break) and is determined by the time spent establishing contact, (station to be worked is heard) and adjustment of the channel and terminal equipment (setting the input and output signal levels, checking the voltages and currents of the telegraph equipment, tuning the terminal equipment, correcting the modulation and keying of subscriber links, etc.). Speed of communications is a very important feature of a communications system, since, other conditions being equal, it determines the efficiency (time) of conveying necessary instructions or reports to the station being worked. Therefore, in new communications systems all measures for providing the required speed of communications should be adopted.

It is important that direct communication shortwave and ultra-shortwave radio stations be assured of quick establishment of contact and shifting to new communications frequencies (day, night, and alternate). In new radio sets this is done automatically by pressing a button, but the quality of the communications received depends on the stability of the transmitter frequencies and the receiver heterodyne, since when there is considerable frequency drift, the signal will fall at the edge of the receiver bandwidth and be heavily distorted. Crystal oscillators of radio sets assure, as already mentioned, high stability; however, in time their frequency will drift considerably (because the crystal plates age). Therefore, the frequencies of master oscillators should be checked systematically and adjusted according to the primary and secondary reference frequencies. Unfortunately, this is not properly organized everywhere among the troops. In our opinion, a special frequency adjustment and "information" service should be established within the signal troops, primarily for medium-power and high-power shortwave radio stations.

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The speed with which communications are received from subscriber to subscriber on branched communications systems, composed of cable and radio-relay links, depends primarily on the operating precision of communications switching centers at terminal and relay points. In the ideal circumstance, such a system would have only automatic switchboards, with which a subscriber, having dialed a particular number, could receive any other required subscriber incorporated into the system. The solution to the problem indicated includes three important aspects: providing high quality, stability, and identical parameters to the channels of communications system being switched, composed of various links; developing automatic switchboards which would not only switch channels over to the required link, but also choose optimum communications links and bypasses; and organizing an automatic monitoring and control system for all of this, especially in the complex, fast-changing conditions of a combat situation, even when a portion of the communications system goes out of action. This problem can be solved besides, if all types of analogue information are converted to pulse information.

A lot of time is spent adjusting channels and terminal equipment. If this is unavoidable during initial establishment of contact, then in follow-up establishment of contact (after a technical stoppage) this is completely unwarranted and impermissible. Experience has shown that the greatest amount of time is spent in synchronizing and adjusting the security-providing device (in telegraph operation), since the stability of the reference oscillators of the security-providing device does not assure synchronized connecting in after a stoppage. This gives rise to a requirement--to raise sharply the stability of the above-cited reference oscillators to a magnitude which will provide synchronized connecting in after a prolonged stoppage of operation.

In carrying out measures to shorten the time for adjusting channels, particular attention should be devoted to raising the quality of modulation and keying in the subscriber links and the quality of remote control of radio stations. To attain high speed in establishing contact, these links should be prepared beforehand and thoroughly. To this end, radio-relay stations may be used with the most efficiency at reduced distances. In so doing, and to provide for the necessary camouflaging of control points,

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antennas on lowered masts or antennas fastened to vehicle bodies should be used.

In this article, we have discussed only the basic questions, the solution of which contributes to raising the quality of military communications; we do not claim to have completely exposed the problem. Several partial suggestions and recommendations may, in our opinion, contribute to a clarification of the problem as a whole and to a solution of specific questions which trouble military communications personnel and operations personnel.

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