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AN INTRODUCTION TO SHORT SIGNALS

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ABSTRACT

The object of this report is to provide a background on the short-signal problem for those not already acquainted with the subject. The report is divided into two parts. The first part is an attempt to justify the employment of such systems by outlining their military advantages and the conditions which must be met to use them successfully. The second part is an outline of the nature of the problems which arise in intercepting short signals and in locating the position of the transmitter.

CONTENTS

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- W.L. Haney -

I — SHORT SIGNALS FOR MILITARY COMMUNICATIONS

An arbitrary definition of a short signal is made for the purpose of this report. It is a signal of less than one-half second duration, which passes a complete message and occurs infrequently. This short message can be made up by compressing a message of conventional length, or by using a very small number of words. The time of one-half second is chosen because this is about the minimum reaction time for most people. This implies a degree of automation and some form of memory in the system.

The military advantages of short signals are:

1) greater security,
   a) of message content
   b) of transmitter location,

2) reduced susceptibility,
   a) to jamming
   b) to destruction by weapons,

3) interference reduction,

4) greater circuit reliability,

5) use of automation.

Without further explicit statement, all of the military advantages of a rapid, reliable, communication system follow; e.g., surprise, flexibility of command, ability to exploit favourable opportunities, and so on. A system of this type, known as "Kurier", was introduced in the last stages of World War II by the Germans in order to exploit its military advantages. A single transmission was capable of sending a message of a few words in about one-half second.

The prime advantage to a user of a system of this kind is greater security, since interception of a signal of this type is difficult because of the low probability of having a receiver tuned to the right frequency at precisely the right time. Strategically, this can be important, since the proportion of unintercepted messages will be higher than in a conventional system, for the same cost and effort to the interceptor. Tactically, it is important since the location of the transmitter cannot be determined easily. Action against a specific circuit, either by jamming, or destruction by weapons, will be difficult because of reduced intercepts and lack of position data.

The use of such a system can be justified on other grounds. Interference caused by a large number of transmitters in a small area can be relieved by the compression feature of such a system. If a message can be sent in a very short time, many more transmitters can be used on the same frequencies within ranges at which interference can occur.

The automation features of short signals are also of military interest. Frequently, it is necessary to transmit data in a simplified, pictorial, or tabular form. Devices which can perform this function are useful to commanders, or others who are occupied with many duties, and require new information with a minimum of delay or interruption, and in a readily understood form. Burst transmissions are ideally suited for this purpose. A data link to a pilot in a supersonic jet is a typical example.

Recent experiments in this country indicate that a very short signal system provides a high degree of circuit reliability on HF circuits if proper advantage is taken of propagation phenomena. Such a system selects a good circuit in frequency and time, which is free from interference, and passes the message in a very short period. Suitable design permits high data rates, free from multipath distortion.

There are also special circumstances which favour the use of a short-signal system. Submarines, for example, which conceal themselves by submerging are not yet able to transmit directly to base underwater. Rapid surfacing and a short transmission may be an acceptable substitute. Similarly, the high mobility and dispersion of modern ground forces require improved location security, as well as increased demand for communication for command purposes. In the air, the reduced vulnerability to jamming, as well as the automation and concealment aspects of these systems are attractive. Also, such systems are almost ideal for clandestine communication.

The modes of operation of the circuits, in electronic jargon, can be "open loop", or "closed loop". Closed loop operation means that information is fed back to the source to allow the source to correct the action in such a way as to get best results. Open loop operation does not require feedback or acknowledgement, and so only one way transmission occurs. It is a broadcast type of operation, requiring only minimum acknowledgement, or none at all, from the receiver.

The requirements for successful operation of a short-signal system are as follows:

a) a thorough background of propagation theory and practice, especially when the system is used below 50 mc/s;

b) a large and effective organization of multiple receivers;

c) a rigid control system,
   i) for security,
   ii) for timing;

d) a competent technical organization,
   i) for exploration of new techniques,
   ii) for maintenance.

The first requirement is most important for very long distance communication if the ionosphere is used. A good frequency prediction service is required, with the necessary scientific and practical background. The development of a closed loop sounding system requires a good theoretical background, at least in the development stages.

The second condition, a large receiving organization, follows from the first for long distance communications. Since a priori knowledge is not likely to be completely accurate, several receivers spaced over a large area can increase the probability that one or more of the receivers will actually receive the signal. This requirement may be reduced in the case of sounding systems of the automatic closed loop type. Interference from non-cooperating transmitters may make the use of an extensive receiving system an advantage, since an interfering signal may not be heard at all receiving locations.

The third condition, a rigid control system, arises from the necessity, in the open loop type of operation, of pseudo randomization of frequency and time usage to prevent frequency and time patterns from becoming known. Lack of control in these systems will lead to a poor standard of circuit reliability and to security breaches. In the closed loop, or feedback type of system, strict control may be required for synchronizing both ends of the circuit. Such synchronization is a necessity, if freedom of choice of frequency and high transmission rates are to be maintained.

The fourth requirement, for a competent technical organization, applies to the whole organization and includes research and development, long term planning, procurement, production, inspection, and operational use. Short-signal techniques will demand the best in these technical departments.

Because of the automation required in short-signal operation, a high degree of reliability will be required in the terminal equipment. This will need first class engineering in design, production, installation, and maintenance. Equipment which is not maintainable or maintained will be useless in this type of service.

To summarize, short signals have many advantages for military use. They offer greater security, reduction of interference, increased circuit reliability, and the possibility of automation.

The present state of the art is such that several different short-signal systems could be implemented. To use them advantageously requires a competent scientific and engineering background, an effective procurement organization, and a well trained operating and maintenance staff.

II — THE NATURE OF THE INTERCEPTION PROBLEM

In the previous part of this report the use of short signals was justified on the grounds of security against location and interception. In what follows the intercept problem will be examined in a general way, without going into technical detail, and particularly without considering the various methods of modulation which might be encountered. While the emphasis is on the HF frequency bands, the difficulties and conclusions apply with equal force throughout the spectrum. High directivity, line of sight, and other higher frequency conditions are not considered.

By a previous definition we allocated a transmission time of less than one-half second, to occur at infrequent intervals, the choice of frequencies being determined by propagation conditions, method of operation, interference conditions, and equipments used. In general, we will not know in advance the time of occurrence, the frequency used, or the location of either one or both the terminals of the circuit.

A short outline of the probable methods of operation follows.

a) Simple Broadcast

Transmissions are made on a programmed time-frequency schedule. Such schedules can be simple or complex.

b) Reciprocal Transmissions

These are transmissions made by out-stations after observation of reception of several control transmitters at various locations, all transmitting more or less continuously. These transmitters may be used for other purposes at the same time as a cover; e.g., for press or time signals. The strongest and most interference-free transmission is chosen. The out-station transmitter is then set up a specified number of kilocycles from the chosen transmission, and at a specified time a transmission is made.

c) Automatic Sounding Systems

These are an extension of the above system in which the control transmitter and out-station receivers shift frequency in synchronism, so that the out-station receivers are always tuned to the control transmitter.

An out-station wishing to make a transmission, inserts the message into the equipment which waits until a signal, which is free from interference, is received from the control station above some predetermined signal strength. On receipt of such a signal the equipment automatically makes the transmission.

The problem of location and interception of signals of the kind specified can be divided into three major sections:

i) low probability of intercept,

ii) recognition of a short signal,

iii) reaction time.

In the normal intercept problem it is possible to tune over the band to some extent, to look for new signals. If a new signal is found, time is usually available to examine it, to see if it is of interest. Time may be available to take some kind of action, e.g., to start a recorder, summon others to listen, or to get a bearing on it.

Under the conditions expected for the short signal, it will be impossible to search in frequency. The receiver must be on the right frequency when the transmission occurs. It will often be difficult to distinguish between a short signal and a burst of static, the click of a light switch, or other man-made interference. Particularly, no time will be available to alert others. If any measurements are to be made,they must be taken during the short-signal burst.

These difficulties arise because the user of the system has prior knowledge of the frequency, the type and time of transmission. This knowledge allows him to design an automated system which will receive the burst transmission with a high degree of probability, to recognize a true signal and reject a false signal, and do this at the required speed. The interceptor can attempt to overcome the advantage which the user has, but he will always be less efficient than the user unless he has the same a priori knowledge.

Because of the short transmission time of one-half second or less, it is clear that some form of memory will be required in the intercept system. It will be required to assist in recognition, and to overcome delays caused by the reaction time of human operators, and the electrical and mechanical delays of equipment, in addition to any uncertainty and delay in communication between various parts of an intercept system. The precise nature of the memory will depend upon the amount and rate of information gathered. Existing systems depend upon magnetic recording where the amount of information to be gathered is very large and where a permanent record is desired. Other systems use a two-stage memory the first stage of which may have a capacity of a few seconds or minutes. The data in this memory is retained only long enough to check that nothing of value is contained in it. If a short signal is believed to be recorded in this short-term memory, it is re-recorded onto the second stage or permanent storage device for detailed examination. The useless portion is erased and the short memory is then available for new recording. Some systems have a continuous record of the last "x" minutes or seconds, in which the oldest portion is erased just prior to recording new information. This temporary storage may be a cathode-ray tube, or a tape loop.

The magnitude of the problem becomes apparent when it is realized that each possible communication channel must be monitored on a full time basis, to ensure intercept, and each communication channel must have the full output recorded at least temporarily under the conditions outlined. A rough estimate of the effort may be obtained from the following example. It is assumed that some 4 mc/s portion of the spectrum will contain a short burst. If we allow 10 kc/s bandwidth for the message, then 400 receivers of 10 kc/s bandwidth will be required to intercept the burst. This assumes that there is no overlapping on the part of the receivers, that the signal will not be concealed by interference, and that the receiver is in an area where the signal strength is high enough to be heard. Since all of these factors, and in addition the need for recognizing the signal, increase the odds against hearing the signal, several times the number of receivers mentioned above will be required to obtain the highest probability of intercept.

More sophisticated equipments have been considered. These are intended to record and display all the signals in a large bandwidth, say four megacycles per second, and to take and record bearings of all the signals. Such an equipment will require about 2500 tubes, and must have a recording system which is very close to the limit of the state of the art. The space required must be air-conditioned, and is estimated at about 4000 cubic feet to house the equipment and operating staff. It is expected that about 15 operators per shift will be required. The cost of such an installation is estimated to be about one million dollars.

A major problem with an equipment of this kind, is the recognition of short signals occurring in the large number of other signals, along with the expected number of false alarms. False alarms can be caused by various natural noises, as well as man-made noises. In addition, ionospheric sounders and other legitimate tests may be mistaken for short signals. Propagation anomalies may also be troublesome; for example, signals reflected by meteors may appear to be short signals.

The problem of location of sources of short signals is of the same nature as the intercept problem, with added difficulties. These difficulties are first, that the bearing must be obtained or recorded during the period of signal transmission. Simple direction finders of the switching or spinning goniometer type require some time to measure the bearing, and so may not be usable for the shortest signals. The Watson-Watt, or instantaneous direction finder does not have this shortcoming, but it requires two receivers per direction finder, which must be identical.

The second problem is that a geographically extensive net of direction finders is required to obtain a fix. At least two direction finders must be tuned at all times to the same frequency or frequencies, or they must be capable of tuning to the same signal and obtaining a bearing while the signal lasts. In addition, accurate time synchronization is required in the memories of the direction finders for identification.

Increased error in direction finding will be a third problem. When the signal can arrive by two or more paths an error will be caused by wave interference. This error can be reduced by taking a number of bearings over a period of time. One-half of a second will not be long enough in most cases, and a serious error can result. If a transmission is short enough to be completely received on the shortest path before any part of it arrives by another path, this error will not occur, and in fact the accuracy achieved will often be better than in the "averaging" case. The wave interference error may also be reduced by the use of very large direction-finding antennas, which average the bearing in space, rather than time.

An adequate solution to the problem of recording a bearing in a short time is not simple, particularly if there are interfering signals.

Most of the problems exist for conventional signals. Completely satisfactory solutions have not been found in that case. The solutions for the short signal situation will be more complex, and less likely to be completely satisfactory under the conditions outlined in the initial assumptions.

Where little or no previous knowledge of a communication system of this sort is available, it can be seen that interception is difficult. However, if some knowledge of the system can be gained in some other way, the problem becomes simpler. If the frequencies to be used are known, or the way in which frequencies are chosen is known, the heavy requirement for continuous watch may be lessened. If the modulation characteristics are known, a recognition device becomes possible, and the operator and memory requirements may alter favourably. Similarly, if approximate location of the terminals is known, especially that of the out-station, simplified equipment may be used in the immediate vicinity of the out-station because of the very strong signal available. This may be of use against the submarine or clandestine type of operation.

However, even though a particular system may become known, there remains a requirement for technical search, since it is quite possible that more than one type of short-signal system may be in use at one time, or that new and improved systems may be developed from time to time.

To summarize, the use of communication systems using infrequent short transmissions adds difficulties to the intercept problem. These added difficulties all arise directly from the reduced time used in the system, and from the interceptor's lack of the prior knowledge available to the user of the system. The difficulties may be classed as low intercept probability, recognition, and reaction time.

If such systems are introduced widely, both strategic and tactical intercept at all frequencies throughout the spectrum will require new and complex equipments to recover the initiative gained by the communicator using such systems.

The economic and manpower problems forced on the interceptor are formidable. If the technical search problem is to be solved, it will require use of the latest techniques and developments and will force the development of new devices and methods.

Because much of the advantage in the use of a short-signal system arises from the user's prior knowledge of the system characteristics, it follows that the strictest security should be observed for systems in use, or proposed.

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