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THE ABILITY OF IFF MARK X TO ASSIST IN THE RECOGNITION OF HOSTILE CRAFT

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NAVAL RESEARCH LABORATORY

WASHINGTON, D.C.

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THE ABILITY OF IFF MARK X TO ASSIST IN THE RECOGNITION OF HOSTILE CRAFT

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ABSTRACT

While it is desired that an IFF system provide security such that reception of an authorized signal is sufficient to indicate a friend, Mark X does not have this capability, nor is any modification of existing equipments likely to accomplish this end. Rather, such security will be found only in a new system resulting from the long-range research program. The initial security by concealment of IFF equipment is highly questionable. The possibilities of super weapons delivered by single planes increase the likelihood that the enemy would go to considerable effort to appear as a friend. In the meantime, use of the Mark X IFF with well designed operational doctrine can provide an effective preparation for possible hostilities. The system as it exists, coordinated with communication and navigational systems, would provide an effective aid in recognition of questionable targets although at a cost of considerable operational effort. An adequate doctrine for such use needs to be established.

A modification to provide a small number of reply codes suitable for simultaneous reception and distinctive display would be desirable to permit coding by craft characteristics. This alternative method would relieve some of the operational effort in use of the system.

PROBLEM STATUS

This is an interim report on the general IFF program.

AUTHORIZATION

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THE ABILITY OF IFF MARK X TO ASSIST IN THE RECOGNITION OF HOSTILE CRAFT

INTRODUCTION

The IFF Mark V system derived its major security through the use of the "slow code" which was deleted in the IFF Mark X system. The joint agreement for adoption of the Mark X IFF includes provision for later modifications to improve the security of the recognition function. However, we must be prepared, if the need arises, to use the equipment as initially installed to provide as much security as possible. Because IFF Mark V planning anticipated the use of slow code, such plans are of little value for Mark X IFF.

This paper proposes to discuss how IFF Mark X might be used in time of war as a useful electronic recognition system. An understanding of the capabilities of IFF Mark X is necessary for two reasons. One is that we must be prepared to get the most out of it in case of necessity, and the other that any evaluation of a proposed modification must be in terms of the improvement expected over the unmodified system.

Evaluation of the system for IFF purposes sometimes tends to become confused with its performance of other functions. The IFF Mark X, in addition to IFF, is expected to aid in detection, aircraft control, navigation, and emergency signaling.

Though the IFF Mark X system may not perform all auxiliary functions that might be desired, or perform those it does in a completely satisfactory manner, such considerations should not enter into its evaluation for IFF alone. This paper will be restricted to discussions of the basic function of recognition of the hostile nature of a detected target and to those security aspects designed to prevent an enemy deceiving us to appear as a friend.

The IFF techniques are in a period of transition. During the last war a simple transpondor system was reasonably adequate to indicate to the operator of radar detection equipment which planes were friendly. That the enemy made no extensive attempts to deceive us can probably be attributed to the newness of such systems and to the magnitude of the practical difficulties he would encounter, as compared to the advantages he would expect to attain. While major technical improvements

have been made, the present solution is still a simple transpondor system. On the other hand, the conditions of the last war no longer exist. The capabilities of electronic systems are appreciated by all. In the future we may expect weapons of very great destructive nature carried by a single plane or missile, a fact making it much more attractive to effect deception with a single craft. To meet such a situation, and also to include the requirements imposed by anticipated high speeds, the future requirements of IFF dictate security techniques far beyond the present-day state of the art. We therefore have a period of transition where the simple techniques are inadequate and the desired requirements cannot be fulfilled. Temporarily, at least, advantage must be taken of any techniques which will assist in providing the required security, even though they may require considerable operational effort.

In general, there are two ways in which secure recognition may be effected. One is by an IFF system so coded and operated that reception of an authorized signal is sufficient to determine that it originated with a friend. This type of system will satisfy the major future requirements as to security and is the subject of long-range research. The second method, the only one now available, places dependence on the judgment of the individual who effects recognition as a result of evaluating available information concerning the target in question. Any electronic system so used in this evaluation is thus merely an aid to the recognition, although when operational conditions justify no further information may be necessary. The danger lies in placing too great a dependence on continuance of such conditions and the consequent lack of preparation for quickly obtaining and utilizing the necessary additional information which, when considered as a composite picture, will provide a degree of security.

INFORMATION USEFUL FOR RECOGNITION

The present IFF problem which Mark X is expected to assist in solving is simply one of determining the friendly or hostile nature of targets detected by radar. But in addition to the information furnished by Mark X, there is other information which may assist in the recognition.

Knowledge of the Exact Location of Our Craft

Assuming continuous control and adequate exchange of target-position information within an area and between adjacent regions, no further information is required. The difficulty arises from the enormous effort

required and the inability of such a system to recover quickly or to operate independently after a disruption by overloading or damage.

Behavior of a Specific Detected Object

Actions not expected of our craft – for example, flying of planes in a prohibited area, course, or altitude – serve to indicate a possible enemy. Likewise, actions expected of our craft under certain conditions serve to indicate probable friendly nature. For example, the execution of specified turns or maneuvers at prescribed locations when returning to base would logically be expected of our own planes.

Data Derived from Detection Equipment

The radar usually measures accurately the range and azimuth of a target and may likewise determine its altitude within limits. Also, speed can be roughly calculated. The operator may estimate the size or number of planes in a flight. All this information, when correlated with expected aircraft flights, assists in the evaluation.

Responses to Command

When communication with all aircraft, on a command channel, is feasible (voice, automatic, etc.), commands may be given to carry out certain procedures. These commands may be coded, and the results observed provide an indication of the character of the plane. For example, certain maneuvers may be executed or modes of interrogation in the IFF Mark X system may be momentarily altered. Such techniques are unsatisfactory when high speed is required and of course there is always the question as to whether the plane is enemy, whether it failed to receive the command, or whether it is unable to reply.

While much of this information can be furnished by normally available equipment, and although its usefulness is largely a matter of training and organization, certain doctrines must be established to exploit fully the capabilities of the existing equipments. It is therefore intended to examine how the Mark X IFF system could be used or modified to utilize its capabilities more completely.

When Mark X becomes operational, without doubt recognition will in the beginning be based largely upon the reception of the transpondor signal. That is, security by concealment from the enemy of the type of IFF equipment being used will be depended upon. Such use requires no

further discussion other than a warning that we may over-estimate our ability to conceal the system from enemy powers and that alternative methods of obtaining security must be available any time after hostilities begin. When concern arises over the possibility that the signal may be arising from a captured or fabricated transpondor on an enemy craft, we may ask what additional security precautions can be taken? Any or all sources of information mentioned in the first part of this section may be utilized. This discussion will, however, be restricted to the utilization of the Mark X equipment. It must be realized from the beginning that the additional security must be attained at a considerable operational effort, for the system is not designed to provide security in itself.

CODING BY COMMAND

The system is provided with three modes of interrogation which may be manipulated in response to a command. It is assumed that: a transpondor response to the normal (number one) mode of interrogation may be expected from friendly and enemy planes alike; voice communication is possible at all times between all friendly planes within radar range and the point of interrogation; the enemy may monitor the voice transmission; and the use of interrogation modes in friendly craft is controlled. If the identity of a target is questionable, all craft may be requested to shift interrogation mode. For example, if an enemy were asked in voice code to operate in mode two, and if he does not understand the code, it may be expected that he would not switch to mode-two operation at this particular time. He could, of course, have been set to this mode previously, so that the response must be examined before the command as well as after.

Such a broadcast command has several objections. First, the enemy can soon learn to interpret the commands by observing our transpondor responses. Secondly, if commands are extensively used, confusion will result. The pilots will be busy flipping switches, and the interrogator operators will be confused by the responses to someone else's commands.

The confusion can be greatly reduced by centralizing the recognition responsibilities. Interpretation by the enemy could be greatly reduced by an area restriction and coding doctrine. For example, assume the craft are equipped with a navigation system which will provide them with their location within a grid system or within a sector from a reference point. This would permit a two-way improvement. First, the command may be addressed to the grid or sector in which the questionable

response lies. This reduces the confusion and limits the observations which an enemy could make. Secondly, the response to a command could be a function of the grid or sector. This would increase the difficulty of enemy interpretation of the commands.

As presently designed, the airborne transpondor is capable of being set by the pilot to respond to two interrogation modes in addition to the normal mode. As an illustration, the pilot could be provided with a chart showing the proper response, for that time of day, to each command dependent upon the grid or sector in which he finds himself. Possibilities of overlapping areas must of course be recognized. The first word of the command would select the area to which the command is addressed, and the second would determine the response to be given by the pilot. If desired, the command could be prefaced with a word to distinguish this IFF operation from other commands and communications that may be transmitted over the same voice channel.

By manipulations of the two additional modes, a variety of possibilities are available, for example, mode two momentary, mode three momentary, or mode two followed by mode three. Also, a mode could be left on until a second command were given to change or turn off. It appears that the two controllable modes would be ample. This doctrine provides an appreciable increase in security where it is applicable. It suffers from being slow and incapable of handling a high rate of command interrogations. Further, it is dependent upon good voice communications with all planes and adequate navigation or homing equipment.

CODING BY CRAFT CHARACTERISTICS

Suppose we assume that continuous communications with all planes is impossible, thereby eliminating the possibility of the command technique. What can be accomplished with Mark X to increase the security when the enemy may be expected to respond to our interrogation? Any coding in this case must be predetermined. Any universal code (code of the day) can easily be determined by the enemy soon after we use it and therefore offers no appreciable security.

A rapid change of reply code, chronometer controlled, has been suggested. However, to obtain any appreciable security merely by selecting an authorized code, the change would have to be so rapid as to place severe requirements on the chronometer. An alternative more adaptable to the system and available techniques is to use a coding which requires some interpretation difficult for the enemy to make but which can be

made known to our forces via the secure communication channels, thus permitting security to be attained with relatively slow code-change techniques. This might be accomplished by making the code a function of operational missions, etc. The IFF Mark X system provides interrogation modes and frequency channels which might be used to designate the various characteristic groups. However, to read any of these codes, the interrogations must be made in turn, an undesirable feature although it could be resorted to in case of necessity.

The more satisfactory method of coding by craft characteristics requires a modification* of the equipment which will permit simultaneous reception and presentation of all codes. Although this method would probably not provide any greater security than coding by command, it would relieve the requirements on the communication and navigation systems and require less operational effort.

The doctrine to be employed would have to be fitted to the expected tactical situation. Characteristics forming a distinctive set of conditions to be associated with a particular code might be: mission, geographical area including air lanes, time-space relations, altitude of flight, speed of craft, and kind and number of craft. The characteristics associated with a particular code should be so chosen that the code may easily be associated with other intelligence. For example, if a plane were responding with a code signifying "anti-submarine patrol," but if the radar indicated its altitude as 30,000 feet, obviously suspicion would be aroused.

OTHER CODING METHODS

In an IFF system such as the Mark X, coding techniques might be suggested other than coding by command and by craft characteristics.

Interrogation Code

Unless some means could be devised to prevent the same key from working more than once, the use of a particular interrogation code as a key to unlock the transpondor is not considered as having any

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Easton, R. L., Furlow, W. M., Lynch, D. W., Rhodes, L. T., and Ruhlig, A. J., "An Experimental Omni-Channel Receiver for an IFF System," NRL Report R-3432, dated March 16, 1949, Secret.

worthwhile security, since in the very nature of an IFF system the enemy can, by observation, determine the key. The interrogation code is primarily useful for channeling and, by itself, is not as satisfactory for obtaining security as reply-coding.

Code of the Day

Methods involving a "code-of-the-day" have had long-standing use in recognition procedures. However, the nature of an IFF system, and a general knowledge of electronic techniques, permit an enemy to learn the code in use merely by monitoring. It has no dependable security features for present or future operations. Because of the way in which it can be broken, no increase in the number of codes can recover any security whatsoever.

Rapid Code Change

Closely related to the "code-of-the-day" technique is the method of rapid code changes. To be effective, however, the code must be changed as rapidly as we expect an enemy to discover the correct code. If only a single code is used at any instant, the ease by which it could be discerned by monitoring reduces the technique to one only bothersome to the enemy. He would only have to operate his countermeasures organization continuously. Further, the change would have to be so frequent, if the enemy's effort is to be materially increased, that we would have to provide either accurate chronometer control on individual equipments or wide area synchronization. Such a system would require only a few codes capable of being recognized electronically. The major modification would be in the timing, code-changing, and random-selection mechanism.

Cryptographic Encipherment

A higher degree of security results from a method in which a multiplicity of codes are so used that determination of the correct code to appear as a friend requires the enemy to make an extended analysis beyond the interception of the signals. If the time for this analysis can be made long enough, the ultimately desired security can be attained. If, however, the analysis can be made in some shorter time, chronometer control (or other appropriate synchronization) may be used with tolerances so relaxed as to avoid many practical difficulties. The number and types of codes required would depend upon the cryptographic mechanism used to maintain the security over the interval of time between code changes.

MODIFICATION OF THE IFF MARK X SYSTEM

The existing IFF policy requires consideration of a change in the original Mark X equipments to provide improved security. Further, some consideration is being given to coordinating the common system of traffic control with the military IFF. Such coordination can be achieved only if the tactical security of the IFF system is not jeopardized. A common conception of the problem is that it is merely necessary to modify the IFF Mark X with a "black box" for use by the military to provide secure IFF, while the common features are used by both military and non-military. While ideally the reception of an IFF signal should be sufficient to indicate a friend, it is not expected that this type of security can be provided except by a completely new system resulting from the long-range research program. Basically, all suggested modifications to the IFF Mark X system involve provision of additional codes. Whether any increase in security results depends not so much on the coding method as upon how these codes are used in connection with operational procedures. Increasing the number of codes by a large amount may not provide an increase in security, because there is no way in which they can be used to advantage. Such a modification cannot be justified for IFF unless it can be shown to be adaptable to tactical use.

Of the techniques available for attaining security with the basic IFF Mark X system, the method of coding by command would not be materially improved by a modification. The alternative method termed "Code by Craft Characteristics" was shown to be capable of reducing the operational effort materially, but the system was not particularly suitable to such use without modification. The main feature is the provision of a sufficient number of suitable reply codes for describing the craft characteristics. The present transpondor permits, in addition to the normal mode one, only three code combinations of the interrogation modes, that is, mode two, mode three, and modes two and three which are operationally useful. This is not sufficient. The greater the detail which can be described, the better the security which can be attained.

But there is a limit to the operational complexity which can be introduced without excessive increase of effort or loss of effectiveness. The exact number of codes can be determined only after establishing a doctrine, but probably at least ten could be used operationally and 25 would be an upper limit. There is the technical question, however, of generating and presenting these several codes in a satisfactory manner. If a composite display is to be used, the number of distinctive characters which can be produced has a practical limit. For PPI display, pulse distortion in azimuth, range, or both may be used

without any great complications. Such a display has been described* together with a proposed modification which requires a new responsor but which now uses the unmodified transpondors by utilizing the reply frequencies of the Mark X system for the codes. This particular method was suggested because it could be introduced smoothly (no equipment would be incapacitated during installation changeover); because no modification of the large number of transpondors was required; and because garbling of the reply codes by formation flying would not occur.

CONCLUSIONS

Should there be hostilities, the response from IFF Mark X transpondors would undoubtedly be trusted, for a limited time, to indicate the friendly nature of the craft whence they came. However, the more extended knowledge of electronic systems among all nations, and the greater benefit to be derived from a successful mission with a super weapon, are in favor of greater enemy effort than during the last war to break down our recognition system.

A considerable improvement in security can be attained with the IFF Mark X system if used in conjunction with a communication system to command manipulations of interrogator modes from questionable craft in accordance with an area coding doctrine. Efficient utilization of this technique implies centralization and coordination of recognition responsibilities.

An alternative method of improving the security, with advantages over the previous one in that the operational procedures are reduced, would utilize codes to designate particular combinations of craft characteristics so that recognition could be based upon correlation of the IFF coded information with intelligence concerning the tactical situation. Though a considerable number of codes could be provided by the interrogation modes and operating frequency channels, the system as it now exists would permit the reception of only one code at a time without retuning. It would, therefore, require a code-by-code examination of questionable targets. But a modification which would permit the simultaneous reception and presentation of all reply frequencies would make this method attractive. Further, such a modification would appear to provide for the efficient utilization of the Mark X's capabilities.

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*Ibid.

Modification more extensive than the provision of a small number of reply codes to permit electronic decoding and distinctive presentation does not appear advantageous for IFF alone. However, additional codes and techniques might improve the ability of the system to provide auxiliary functions. The system which can provide the desired form of IFF security is a subject of long-range research, and its attainment by means of a modification to Mark X is very unlikely; rather, it would require complete equipment changes.

RECOMMENDATIONS

It is recommended that a new doctrine be formulated for the use of IFF Mark X which would take full advantage of its abilities to give security of recognition in case of hostilities. A doctrine based upon manipulation in response to commands, suitable for universal use, should be practiced from the date of the equipment installation. Extension of this doctrine to area coding should be available, and training should be accomplished during peacetime.

It is also recommended that the requirements be established which would permit utilization of coding by craft characteristics. This includes the preparation of a suitable doctrine in conjunction with a possible modification of the equipment.

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