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PRELIMINARY EVALUATION OF THE X-5 RADALARM

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OTTAWA

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ABSTRACT

A brief description of the X-5 Radalarm is given. Test equipment and experimental methods are described. Results obtained with the AN/FPS-3 operating as a GCI and as an EW radar are discussed. The results indicate that the X-5 installed at an early warning site has a maximum range that is about 6% less than that of an alerted operator. Suggested modifications to improve the operation of the X-5 Radalarm are included.

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TEXT

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INTRODUCTION

The X-5 Radalarm is an adjunct to the radar set AN/FPS-3 for automatic early warning. It will sound an alarm if a sufficiently strong radar return is obtained from a target within its alarm zone. The alarm zone consists of a complete or partial ring, 5 miles wide, surrounding the station. The radius of the ring can be adjusted from 8 to 200 nautical miles. The Radalarm was designed for early warning operation of the AN/FPS-3; under these circumstances the PRF is 200, pulse width is 6 μsec and antenna rotation speed is 3.3 rpm. For operation at a different PRF and pulse width changes in component values are necessary.

An X-5 Radalarm unit was obtained on loan from the USAF for evaluation by the RCAF with the aid of NRC. The unit was installed at an AN/FPS-3 site and a preliminary evaluation carried out.

TEST EQUIPMENT

The equipment used consisted of a test target generator and the H-12, L-Band Signal Generator (serial no. 318) used for MDS (minimum detectable signal) measurements. At the evaluation site, the signal generator could be operated from the radar maintenance room, with the output fed through the antenna slip rings to the directional couplers. For the following experiments, the lower beam directional coupler was used. The test target generator provided a delayed pulse output, gated in azimuth, for the signal generator. The width of the azimuth gate could be varied and was adjusted by comparing the presentation on the PPI indicators of the test target and weak signals from real targets. Measurements were made with an oscilloscope to ensure that the test target was less than 1° wide. The strength of the test target appearing on the indicators and at the input of the X-5 depended, of course, on the attenuator setting of the H-12 signal generator.

METHOD OF TESTING ALERTED OPERATORS

Before each test, the signal generator was adjusted, a MDS on the type-A oscilloscope taken, and the limit-to-noise ratio noted (5:1 in all cases considered here). Although the limit-to-noise ratio does not affect the X-5 Radalarm, it plays an important part in the detectability of targets on the PPI indicators. Two sets of measurements were made with the following radar constants:

a) PRF - 200; pulse width - 6 μsec; antenna speed 3.3 rpm.
b) PRF - 400; pulse width - 3 μsec; antenna speed 5 rpm.

It was decided to make use of the two PPI indicators in the radar maintenance room. Alerted operators were used, since the target's position which remained stationary, was known to them. The strength was decreased until the target disappeared. The attenuator setting was then increased by one-db steps until the target was just visible on the PPI indicators. This was taken as the MDS of the indicators. One db less than this value meant that the target was invisible. The strength was again increased until the operators felt sure they would see and plot the target. This was taken as the normally visible target strength on the PPI indicators. Trials repeated over a period of four days, using different operators, produced identical results with the normally visible target being consistently 2 db stronger than the minimum detectable one. Results appear in Table I.

METHOD OF TESTING X-5 SENSITIVITY

The X-5 Radalarm was allowed to run for several hours and then thoroughly checked before commencing tests. The test target strength was reduced until it produced no ringing in the X-5. The strength was then increased by one-db steps. At each strength increase, the number of alarms rung for fifty revolutions of the antenna was noted, with the position of the target in the alarm zone randomly altered each revolution. The increase by one-db steps was continued until the position where 100% alarms were rung for fifty revolutions.

Use was made of a special unit to provide a PRF of 200 for the X-5 when the main radar was operating at a PRF of 400, a pulse width of 3 μsec. and an antenna rotation rate of 5 rpm. The procedure in the preceding paragraph was repeated. The results of both sets of tests appear in Table I.

RESULTS

TABLE I

SENSITIVITY OF RADALARM AND ALERTED OPERATORS

PRF	Pulse Width (μsec)	Antenna Rate (rpm)	MDS on A-type Oscilloscope (dbm)	MDS on PPI (dbm)	Normally visible target (dbm)	X-5 Sensitivity Alarm 10% (dbm)	100% (dbm)
200	6	3.3	-61	-51	-49	-51	-49
400	3	5	-61	-51	-49	-47	-45

Note: The loss in the cable from the signal generator to the directional coupler and in the directional coupler has not been added to the above results, as this is a constant.

From Table I, it is seen that with the values of PRF, pulse width, and antenna rotation rate for which the X-5 Radalarm was designed, (200, 6 μsec and 3.3 rpm), the results for the normally visible target on the PPI indicators and 100% alarm rate are identical. However, it was recently shown (see NRC Report ERB-376) that with limit-to-noise levels of 3 : 1 at the output of the FPS-3 normal receiver, the normally visible target would appear at -50 dbm on the indicators. Thus an alert operator would see a target whose signal strength was 1 db less than that required for 100% tripping of the X-5 alarm. This 1 db corresponds to a change in maximum radar range of 6%. It should be pointed out that although the limit-to-noise ratio affects the detectability of PPI indicators, it does not affect the X-5 Radalarm unit. The X-5 Radalarm video circuit includes an automatic gain control which adjusts the gain for changing noise levels.

The probable reason for the variation in alarm rate over a 2-db change in signal strength is due to the division of the alarm zone into 12 smaller equal zones. If the target overlaps two of the smaller zones, it will take a stronger signal to trip the alarm than if the target signal falls entirely within one sub-zone. This argument is borne out since with 100% tripping of the alarm, two sub-zone alarms are often tripped whereas with 10% tripping never more than one sub-zone is tripped.

The results of the second part of the tests show that, with the addition of one tube to the X-5 circuit, the X-5 can be made to work on the 400 PRF of the FPS-3. However, the loss in sensitivity is 4 to 5 db (loss in range about 33%). By adding 25 tubes to the circuit,* the X-5 could be operated on the 400 PRF without this large decrease in range. On the other hand, the value of the X-5 on a GCI station is questionable where the operators can be considered to have been alerted by an EW System.

The instruction manual (Lincoln Manual No. 11) on the Radalarm unit quotes a false alarm rate, due to the normal noise output of the FPS-3 receiver, of one per day. The author is prepared to accept this figure, as at no time when the equipment was being tested (total of about 24 hours) was there an alarm rung which did not correspond to a target, permanent echo, or weather return.

SUGGESTIONS FOR FURTHER EVALUATION

The next part of the evaluation program could be the movement of the X-5 Radalarm unit to an FPS-3 site used for early warning. There it should be placed in operational use in the scan room, and evaluation of performance and false alarm rate carried out by the regular operators.

Two factors govern the range at which the alarm zone is set. The first is that at the longer ranges, more low flying aircraft will cross the alarm zone without being detected. The second factor is the distance between early warning sites. If, at two

* In order that an aircraft flying at a speed of 500 mph or less will remain within the alarm zone for a minimum of two antenna rotations, the number of sub-zones must be changed when either the antenna rotation speed or pulse length is altered, if radalarm sensitivity is to be maintained.

sites equipped with Radalarms, the sum of the two X-5 ranges is less than the distance between the two stations, then an aircraft can slip between the two sites without ringing an alarm. Therefore, the optimum range appears to be two-thirds the distance between two sites, or approximately 100 miles. However, at this range, on a level radar site, the X-5 will miss targets that fly across its alarm zone at heights of 7000 feet, or less. The optimum range can perhaps be better determined during the operational trials.

PRESENT STATUS

The X-5 has not been modified since receipt from the USAF. However, a jumper has been installed on one of the terminal boards in order that the buzzer may be used for alarm in place of the bell. This saves confusion with the fire-alarm bells on the station.

SUGGESTED MODIFICATIONS

1. A short (30-μsec) time constant capacitor-resistor network was found necessary for proper action of the video circuit in the X-5. With an oscilloscope, it was found that permanent echoes were overloading the video amplifier. This decreased the normal gain of the amplifier for a period of 300 μsec following the permanent echoes. The network was placed in a small metal box and can be connected between the video output of the normal receiver of the FPS-3 and the video input of the X-5 by means of standard 50-ohm cables. For a permanent installation, the logical position for the short time constant network would be between the attenuator (V501) and the amplifier (V502).

2. The fail alarm circuit should be provided with a gain control. It was found that when the alarm range was set at 60 miles, the output of the fail alarm circuit varied with the number, range, and strength of permanent echoes. This variation was great enough to trip the fail alarm buzzer, although the remaining circuits were functioning satisfactorily.

3. The fail alarm buzzer ought to be provided with a switch to allow disconnection of the buzzer while adjusting the equipment or when the main radar is on 400 PRF. The switch could also operate the standby light in order that the switch will not be inadvertently left in the "off" position during operations.

4. The zone position indicator (V508) circuit should be provided with a potentiometer control of the amplitude of the outer marker. In its present form, the outer marker is invisible when the inner marker of the zone is at normal brilliance on the PPI monitor.

CONCLUSIONS

The results of the trials described in this report indicate that the detectability of an alert operator is about equal to that of the X-5 Radalarm unit with the present dependable limit-to-noise levels ratio of 5 : 1 now in use with the FPS-3. If the limit-to-noise ratio is reduced to 3 : 1, the alert operator could detect a target whose signal strength was 1 db less than that required for 100% tripping of the X-5 Radalarm. Thus the operator would have a maximum range of detectability about 6% greater than the X-5. It must be emphasized that this is an operator not subject to operator fatigue and other factors such as display degradation. The false alarm rate of the X-5 due to normal noise is probably about one per day. Operating the X-5 on a PRF of 400 with the minimum of additional circuitry reduces its maximum range by about 33%. Finally, with further operational evaluation, the X-5 Radalarm in its role of an alerted automatic operator may prove to be a useful complement to the regular radar operators.