



A PROPOSED IR IMAGING SYSTEM FOR TRACKING OF MISSILE
IR SIGNATURE IN AN ANTITANK-COUNTERMEASURES SCENARIO

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ABSTRACT

The recent generation of anti-tank guided missiles uses the reticle seekers to track the IR signature of the missile. The presence of a modulated jammer in the field of view of such a seeker will break the tracking process resulting in a miss of the guided missile.

This paper suggests an IR imaging system immune to IR jamming. The system consists of a thermal camera, image acquisition electronics, frame difference operator, a nearest neighbour classifier, and a Kalman filter. The frame difference operator provides a real time processor for rejecting slowly changing and complex background. The resulting image is modeled as stationary cluttered background with a moving missile. The K.F. is used to steer a window in the image field centered at the predicted missile position. The nearest neighbour classifier provides a suboptimal measure of the current missile position. This system has been simulated on a digital computer. The simulation results show the effectiveness of this system in rejecting both natural and artificial decoys without degrading the required miss distance.

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1. INTRODUCTION

The main problem in this paper is how to detect, select and track an IR signature in the presence of counter-measures, in cluttered IR imagery. In the reticle systems the signal corrupted by noise can be detected but can not be classified as the desired target to be tracked.

This paper proposes an imaging system replacing the reticle system by a thermal camera equipped with an image processor performing image digitization and scene analysis. While the image digitization enables the digital computer to process the video signal generated by the thermal camera, the scene analysis simplifies the problem of selecting the correct target to be tracked by suppressing most of the unwanted signals from the background as well as the signals from fixed targets.

The recognition of the desired object can be achieved by specifying some important features according to which the classification is based. These features include in general-the target motion, speed, intensity level, shape, ... etc. In the proposed system we specify the motion and the intensity level as the most informative features for the guided missile. In this case an image containing the background, the missile, and jammers is processed through frame difference operation, for background and fixed targets suppression, followed by thresholding operation for rejecting the remaining undesired objects. A selector is used for selecting the required object from the limited number of objects resulting from the image processor. Detecting, classifying and selecting the guided missile signal, an optimal estimator is needed to create the tracking window and to generate the correcting commands needed for the guidance process.

The paper contains five sections. The system concept is introduced in section 2. Section 3 deals with the system description, while the system performance is analysed in section 4. The general conclusion is presented in section 5.

2. SYSTEM CONCEPT

The system function is to detect the intended target automatically and to track it without human intervention. The system concept is based on generating tracking window, the centre of which is the predicted position of the missile given by the dynamic estimator. The tracking window has two different sizes such that the probability of detection is maximized in the acquisition phase and the probability of jamming rejection is maximized in the terminal phase. Scanning the tracking window only can save time and limit the number of objects to a certain number, N , of candidates from the total number of objects provided by the image processor. The selector examines these N objects more closely and selects that object having the minimum displacement from the predicted position of the missile one step ahead.

Hence the proposed system consists of :

- . Thermal camera.
- . Image processor
- . Nearest neighbour classifier.
- . Dynamic estimator.

In this system, Fig.(1) , the thermal camera scans the field of view and generates averaged outputs of an array of infrared detectors. The image processor includes three sub-processors, data acquisition unit, frame differencing , and thresholding circuits. The image processor recieves the

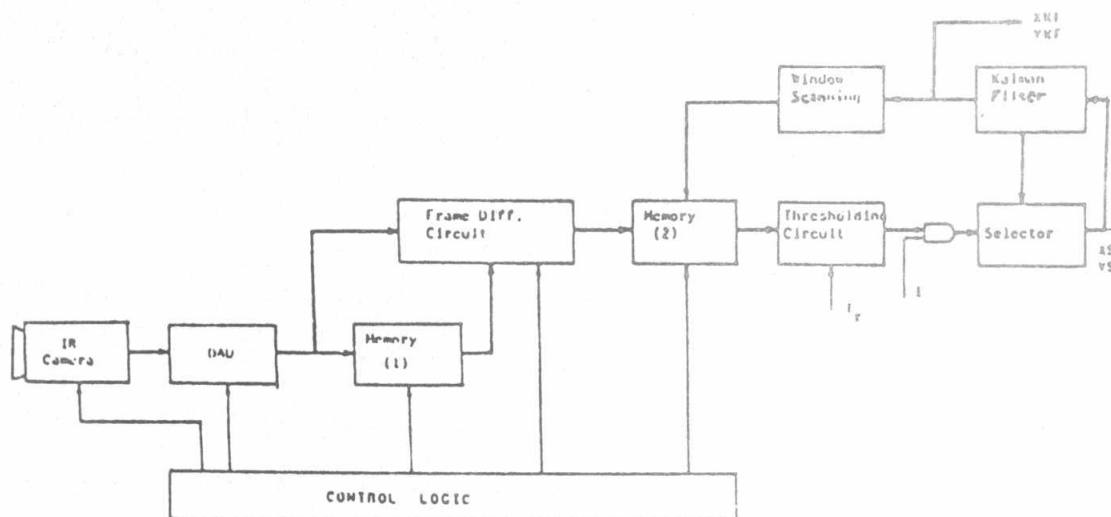


Fig.1. The block Diagram of the proposed system.

video signal from the IR camera and performs the following functions:

- . Image digitization (sampling & quantization).
- . Background suppression.
- . Removing of clutter and fixed jammers.
- . Identification of a number, N , of objects located within the scanning window.

The selector has two types of information to choose the desired target: the array of coordinates of N objects and the dimensions of the tracking window.

From these data and according to the prescribed criterion of the nearest neighbour rule, the selector chooses the object having minimum distance from the centre of the tracking window and provides its coordinates to the X and Y channels of the estimator.

The Kalman filter-as the proposed dynamic estimator-is used to steer the tracking window in the image field centered at the predicted position of the missile and to provide the filtered estimates used to generate the correcting commands.

The proposed system is applied to the anti-tank guided missiles. The following simple interception model is used

$$V(t) = a_m(t) - a_r(t)$$

$$a_m(t) = \frac{-a_m}{T} + \frac{U}{T}$$

where:

Y ... is the relative lateral displacement in the image plane perpendicular to the initial line of sight (Los).

V ... is the relative lateral velocity in the image plane.
 am... is the missile acceleration.
 a_t ... is the target's lateral acceleration which is treated as a random forcing function.
 τ ... is the overall delay time of the system.
 U ... is the system control.

4. PERFORMANCE ANALYSIS

The performance capabilities of the proposed system are evaluated and the resulting missdistance is compared with the accepted limits determined by the dimensions of the tank in the image plane. The following assumptions are considered:

- The background is stationary
- The missile is a point source.
- The accepted missdistance is 3x2 pixels.

In this analysis, the model developed in the previous section is used to generate sample-by-sample simulation considering the measurement noise operator induced error, and noise due to presence of jamming. The following cases are investigated:

- i- The jammers' distribution is random with zero mean and variance 3 pixels.
- ii- The jammers' distribution is random with zero mean and variance 5 pixels.

The following results are obtained:

- In the first case the obtained mis-distance is 0.8 pixel in the pitch plane fig.(2), and 0.6 pixel in the Yaw plane fig.(3).
- In the second case the obtained mis-distance is 3.2 pixels in the pitch fig.(4) , and 1.4 pixels in the Yaw. fig.(5).

Several computer runs with different parameters were executed and analysing the obtained results it was found that a tracking window of dimensions 5-by-5 pixels in the acquisition phase, can preserve the higher oscillations of the missile trajectory in this phase with approximately an unaffected misdistance in the terminal phase due to the convergence characteristics of the system.

A tracking window of dimensions 3-by-3 pixels in the terminal phase improves the counter-counter measures capabilities and in the same time provides an accepted missdistance. A switching time of 1 second from the wide tracking window to the narrow one resulting in an accepted misdistance.

Considering the proposed system with the chosen dimensions of the tracking window and the chosen switching time, and considering a noise level of zero mean and variance of 2 pixels which represent the jamming conditions for anti-tank guided missiles (ATGM), we obtain the missdistance of 0.4 pixel in the pitch plane fig.(6), and 0.6 pixel in the yaw plane fig.(7) , and the estimation errors during the whole time of flight are shown in fig.(8), for pitch plane and fig.(9), for yaw plane.

5. CONCLUSION

The proposed system performs the following objective functions:

- background suppression.
- single IR signature detection and tracking.
- counter measures rejection.

Several techniques are used for achieving these functions as follows:

- the frame difference operator provides a real time processor for rejecting slowly changing and complex background.
- choosing an optimal thresholding level for the intensity will reduce the probability of false detection.
- exploiting the apriori information about the dynamics of the missile and its initial position and thus the ability to predict its position one step ahead can save time of scanning the whole image and reduces the probability of confusion with jammers.
- generating a tracking window with two sizes increases the probability of detection in the acquisition phase and increases the probability of jamming rejection in the terminal phase.

For stationary background and a point source missile it was found that a tracking window of 5-by-5 pixels in the acquisition phase and 3-by-3 pixels in the terminal phase with a switching time of one second can provide an accepted error limits of (0.4x0.6) pixels.

However, this approach can be applied to any IRGM systems, the simulation results show that it is effective in AIGM, but less effective in anti-aircraft GMs, which are of rapidly changing dynamics.

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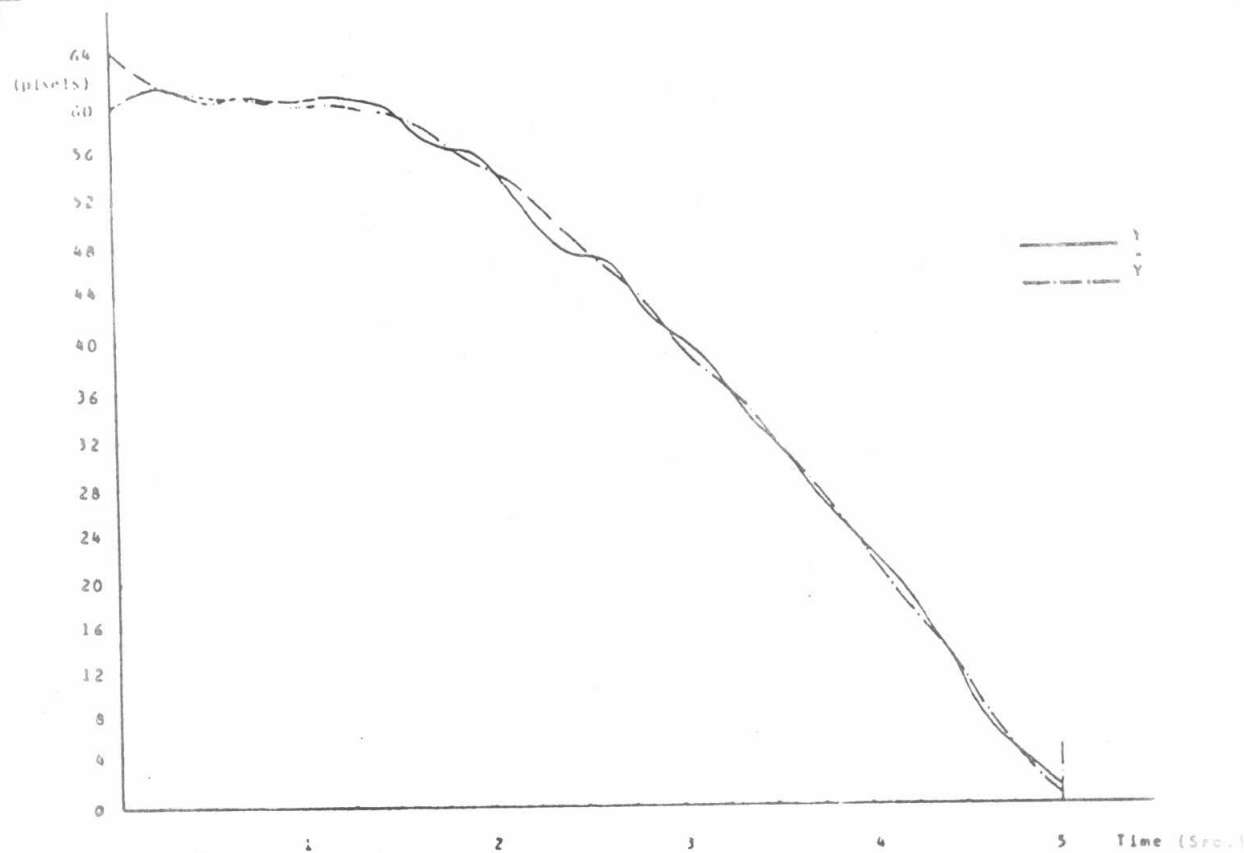


Fig.2. System behaviour for jammer's distribution of 3 pixels variance.
(pitch plane)

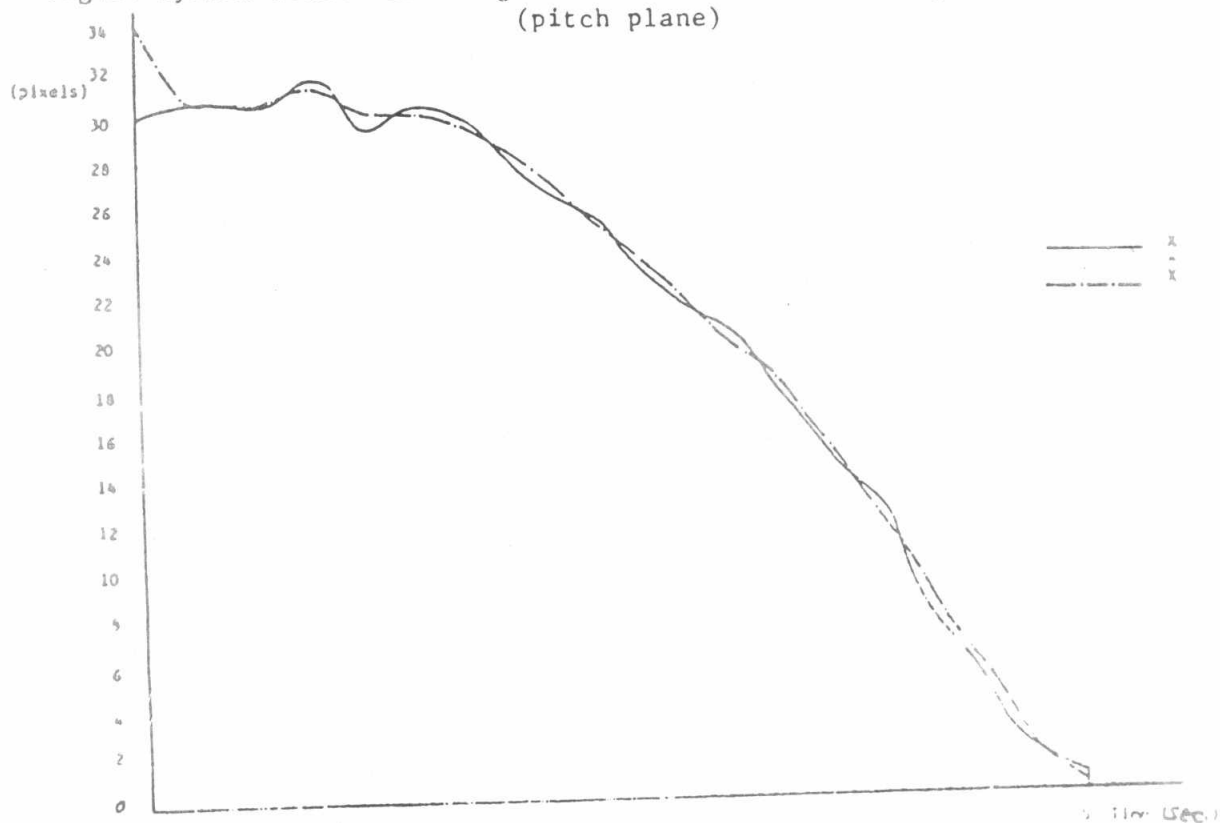


Fig.3. System behaviour for jammer's distribution of 3 pixels variance.
(Yaw plane)

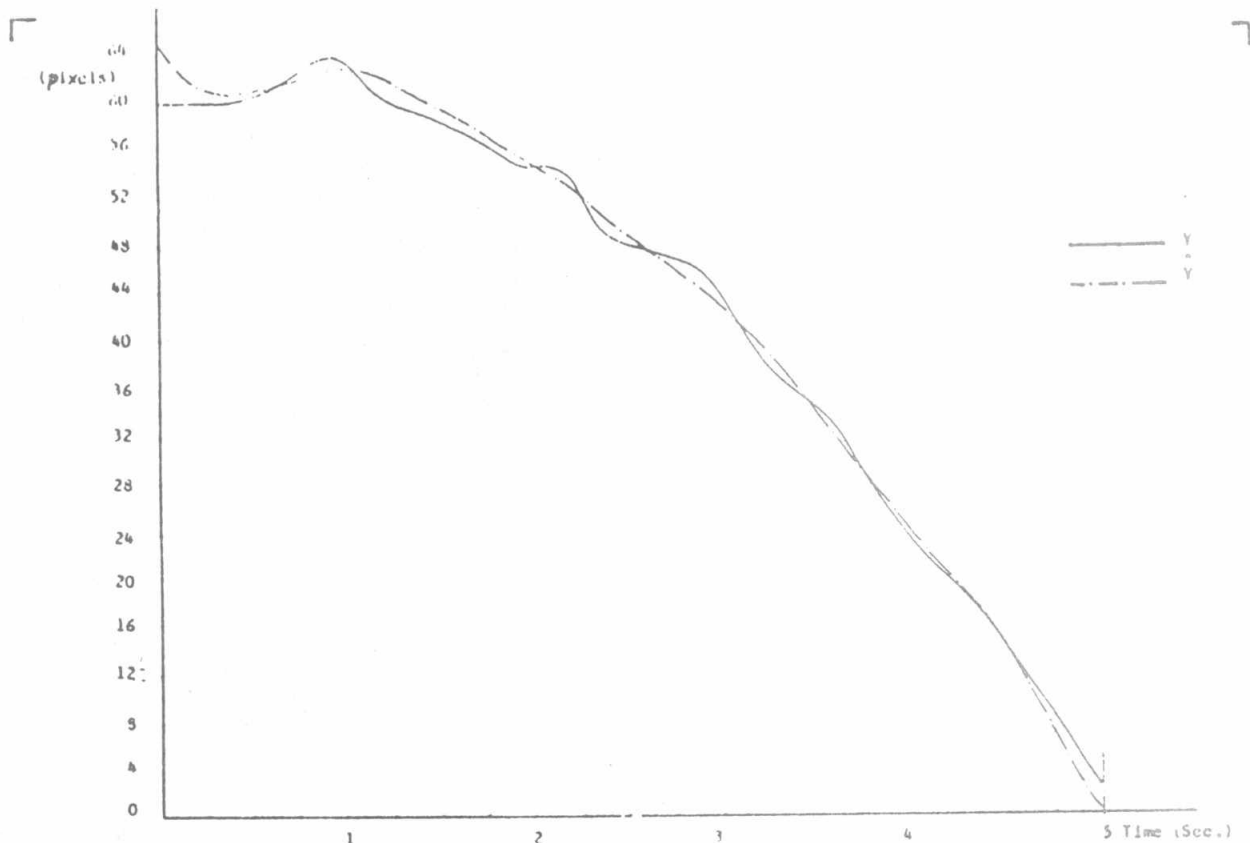


Fig.4. System behaviour for jammer's distribution of 5 pixels variance.
(pitch plane).

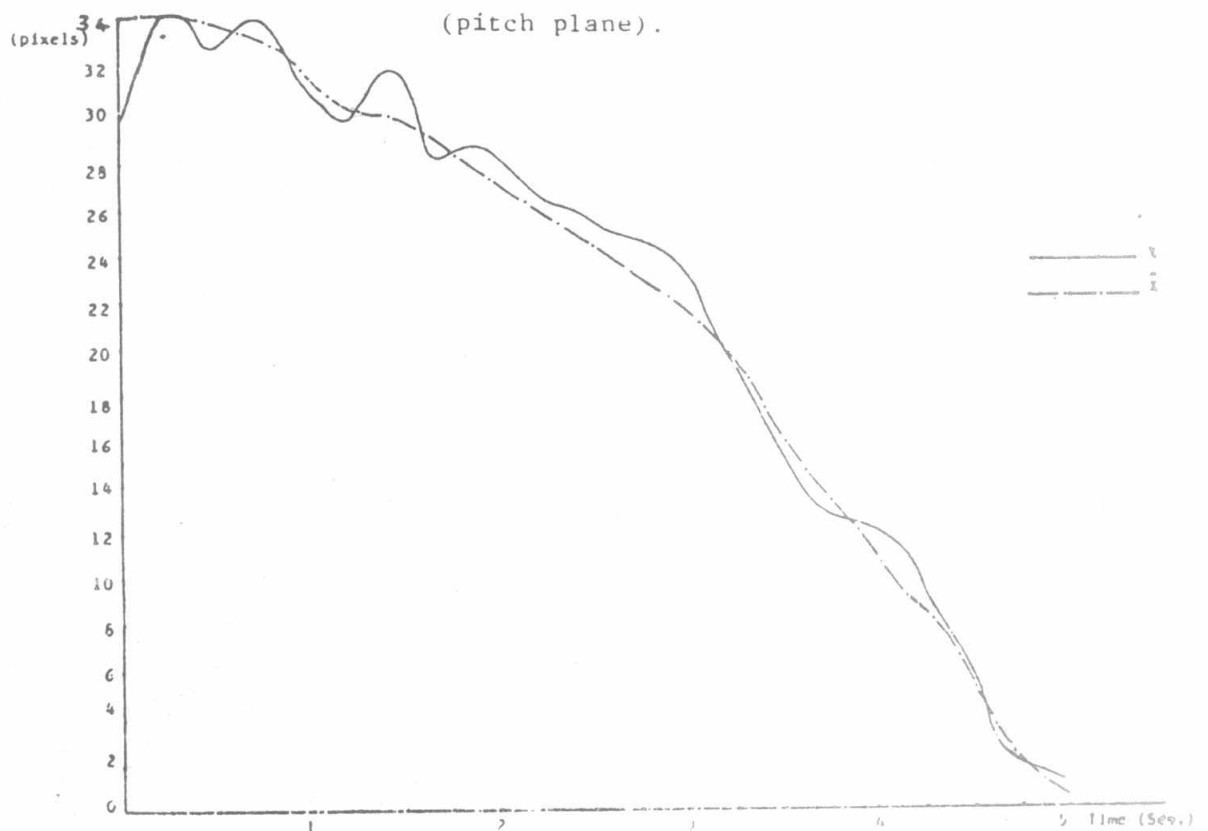


Fig.5. System behaviour for jammer's distribution of 5 pixels variance.
(yaw plane).

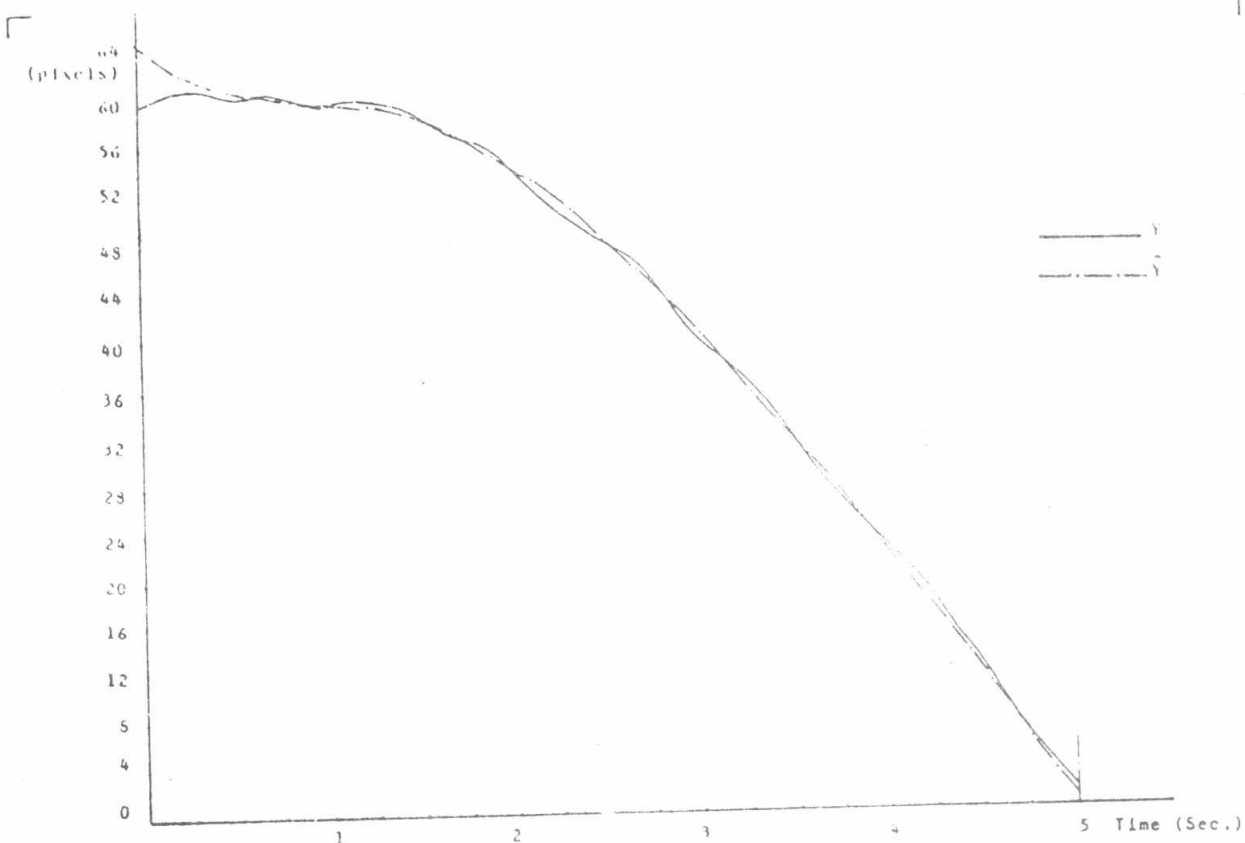


Fig. 6. System behaviour for jammer's distribution of 2 pixels variance.
(pitch plane).

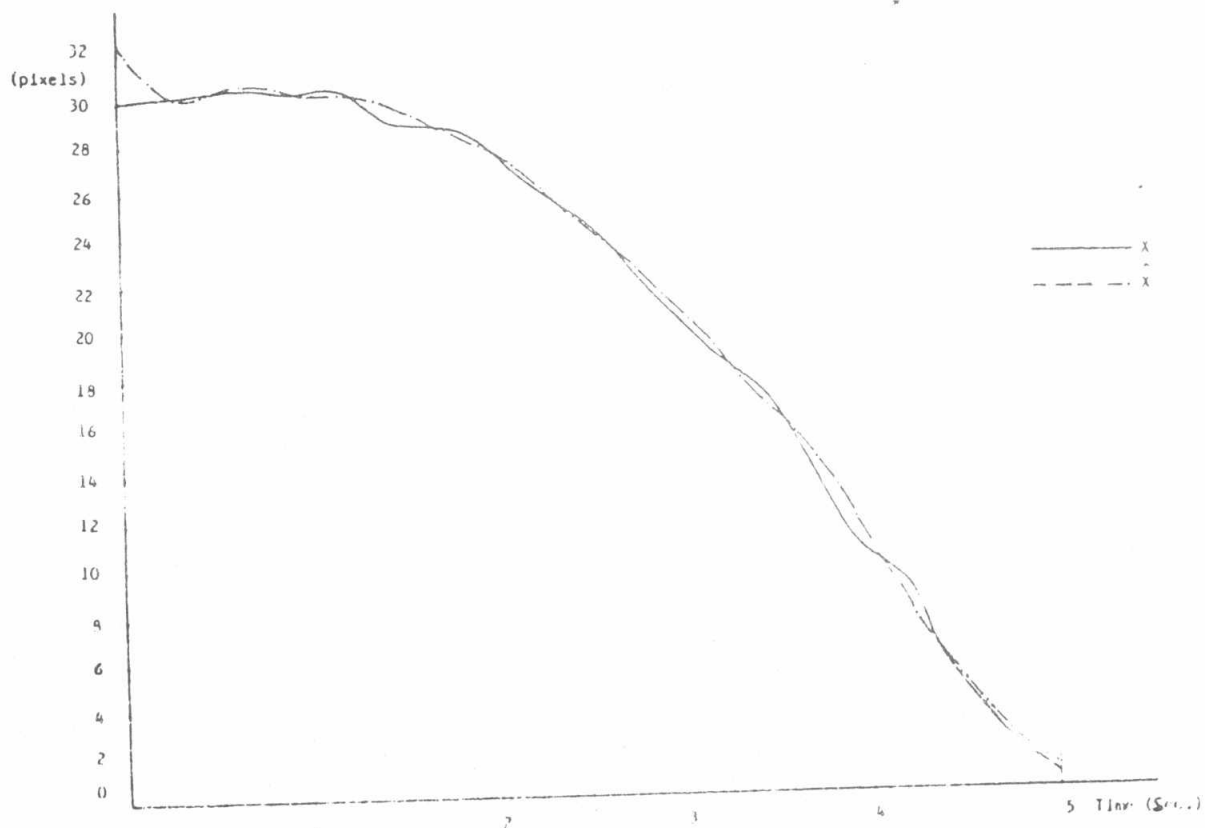


Fig.7. System behaviour for jammer's distribution of 2 pixels variance.
(yaw plane).

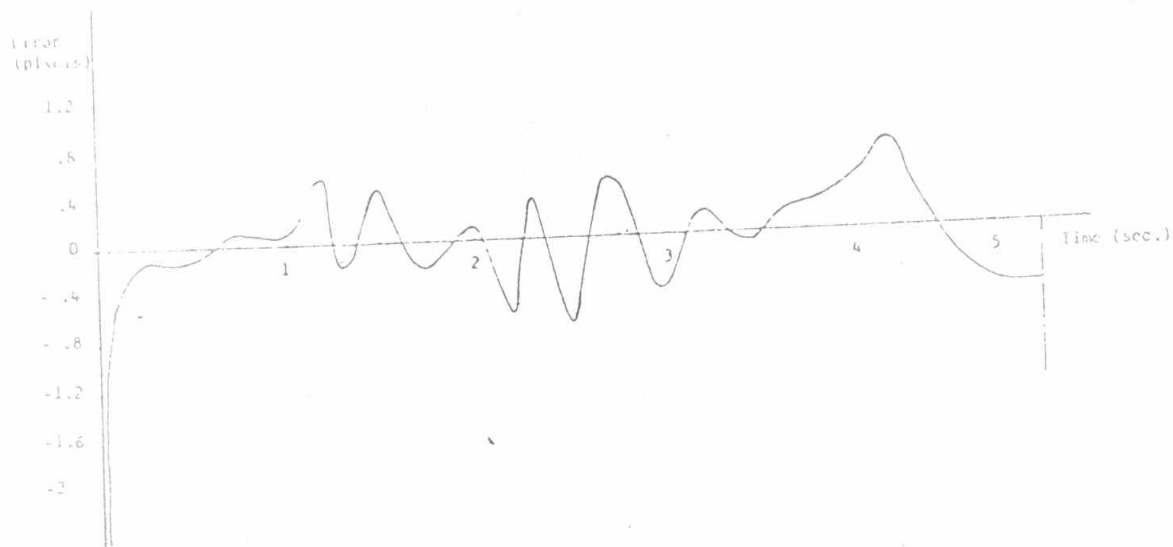


Fig . 8 : Estimation error in pitch plane.

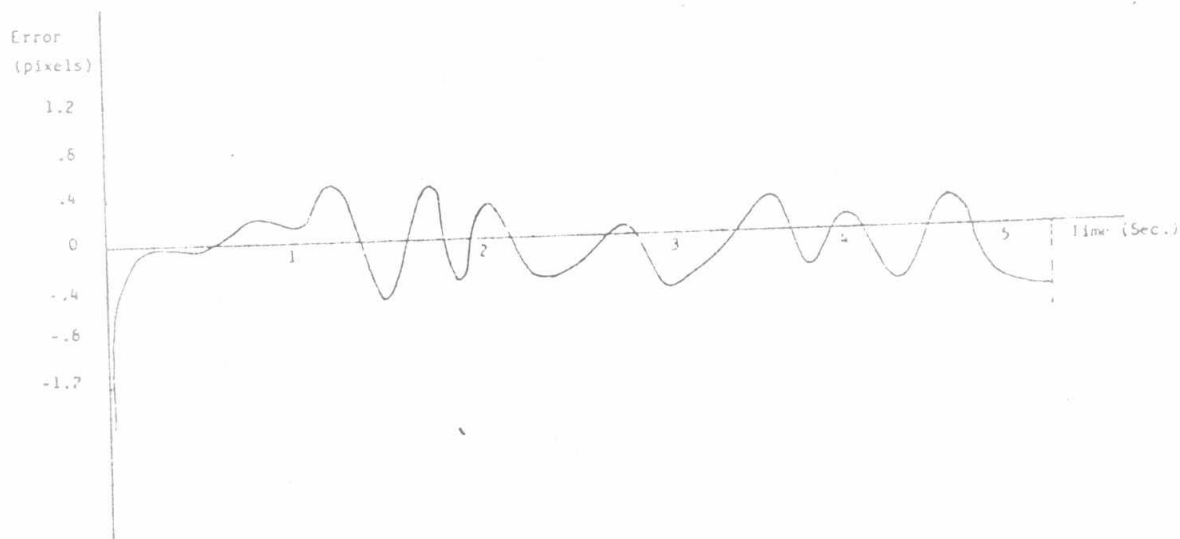


Fig. 9 : Estimation error in yaw plane