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Quarterly Progress Report Number 1 for Period Ending 1 June 1969

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Commander
Naval Ship Systems Command
Department of the Navy
Washington, D. C. 20360

Attention: Mr. Kenneth Buske
Code 00V1C

Hugh A. Reeder

Dear Sir:

This first quarterly progress report, submitted in accordance with the data requirements of the subject contract describes the work accomplished from the beginning of the contract to 1 June 1969. The purpose of this contract is to investigate means of reducing requirements placed on the computer by the sequential likelihood ratio (SLR) processor developed under NObsr 93352.

Any method of reducing computer requirements probably will constitute a departure from strictly optimum operation. Therefore, the object of this study is to find those means of reduction which provide both a reduction in data handling requirements and a minimum departure from optimum operation.

The merit of various methods of reduction may be judged on the basis of whether a significant reduction in computer requirements is obtained and whether the departure from optimum operation is acceptable.

In this study a comparison is made between unmodified SLR processor performance and the performance of the SLR processor when modified. The reduction in computer requirements is →

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measured by determining the average number of status units generated by the modified and unmodified SLR processors. Deviations from optimum performance are measured by comparing the ratio of the average track intensity to the average clutter intensity for a fixed clutter density generated by the modified and baseline systems. This comparison is further simplified for graphical presentation by choosing the intensity threshold such that the marking probability for each intensity level is the same for the modified and baseline systems. This makes the denominator of the ratio the same in both systems and the numerators of the ratios can then be compared directly.

END ABSTRACT

As the first means of reducing computer requirements the technique of rejection of multiple linkages was chosen. According to this technique a new, single-ping event may link with several multi-ping events contained in the status file, or, conversely, one status unit* may connect with several single-ping events. The multiple linkages can affect computer loading significantly, especially when the design S/N is low and/or the input threshold is low. Since a strong target with a large joint log likelihood ratio may link to a small noise sample, a false track with a respectable log likelihood ratio may result. While it is true that this track is discarded soon, it must, nevertheless, be carried in the computer for that time.

This problem can be controlled if the number of linkages which a new single-ping event can make with existing status units is limited. This can be accomplished in two ways. First, and simplest, is to allow a new single sample to link with no more than N multi-ping event status units. All linkages are made and the N status units with the largest likelihood ratios are accepted for retention in the computer. Using Fig. 1, this process would produce the following results. Since event 1′ is in the volume of suspicion of event 1, the linkage (1, 1′) would be made. Event 2′ is in the volumes of suspicion of events 1 and 2; hence, the linkages (1, 2′) and (2, 2′) would

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*A status unit is a track history packet associated with one suspected target track. A status file, on the other hand, is the collection of all status units that exists at the end of an echo cycle.

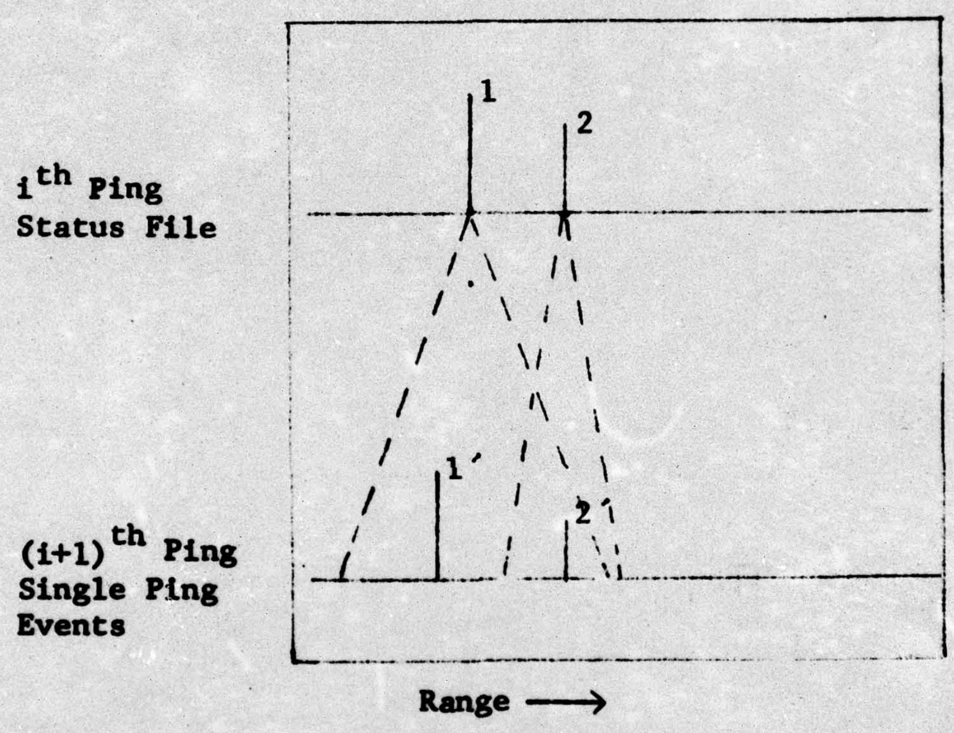

Fig. 1 A POSSIBLE LINKAGE SITUATION IN THE SLR PROCESSOR. THE HEIGHT OF EACH MARK IS PROPORTIONAL TO THE LOG LIKELIHOOD RATIO OF THE EVENT.

be made. If N, the number of linkages to be retained, were one, the larger of the linkages (1, 2′) and (2, 2′) would be retained - in this case (1, 2′). For this example, linkage (1, 1′) and (1, 2′) would be retained in the new status file. The second, and more difficult procedure, is to link each multi-ping event (status unit) with up to N single-ping events. This method ensures each multi-ping track has the opportunity to be linked. Again using Fig. 1, event 1 would be linked to events 1′ and 2′ and the larger linkage (1, 1′) would be retained if N were one. Also, event 2 would be linked to event 2′ to form the linkage (2, 2′). The results to be stored in the status file for this second case would be (1, 1′) and (2, 2′). This second method is somewhat more desirable because, if event 2 represented a target track and event 2′ the continuation of it, the second method retains the proper track and the first does not. However, a special set of circumstances must be fulfilled for this phenomenon to occur. Also, if N is increased from one, the chances of false rejection will be decreased.

The two methods of limiting linkages were implemented in the SLR processor. The modified processors were used to process the same data that the baseline SLR processor used. The design signal-to-noise ratio, the assumed average target signal-to-noise ratio that determines the log likelihood ratio, was set at 12 dB for these experiments. Past experience has shown this value to be a good tradeoff between computer loading and detection capability. In order to save computer time, 40 target tracks, each with an average signal-to-noise ratio of 12 dB, were run simultaneously. The targets were placed in the ping cycle with sufficient separation to ensure there would be no interaction between tracks. This nominal signal-to-noise ratio was used because the detection probability using the SLR processor is so high for larger track signal-to-noise ratios that the effects of the linkage limitations would have been masked. On the other hand, if a much lower track signal-to-noise ratios had been chosen, the random variation of the target peaks from ping to ping would become the most important factor in determining detection, not the changes brought about by linkage limitations. The results of the experiment are presented in Figs. 2 through 5. Figures 2 and 3 present the data obtained by implementing

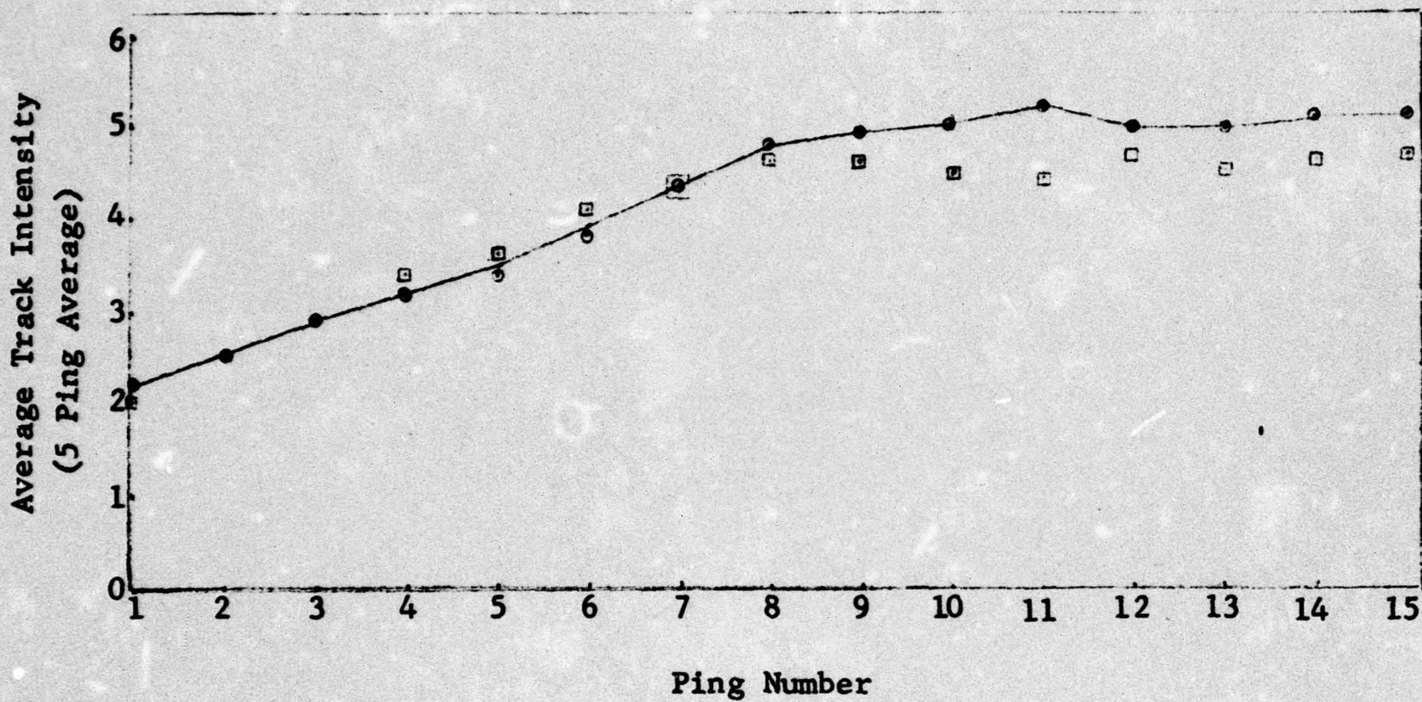

Fig. 2 AVERAGE TRACK INTENSITY VS PING NUMBER. EACH SINGLE PING EVENTS ALLOWED TO LINK WITH THE INDICATED NUMBER OF STATUS UNITS.

- . Unlimited Linkages Allowed
- ● Two Linkages Allowed
- ▣ One Linkage Allowed

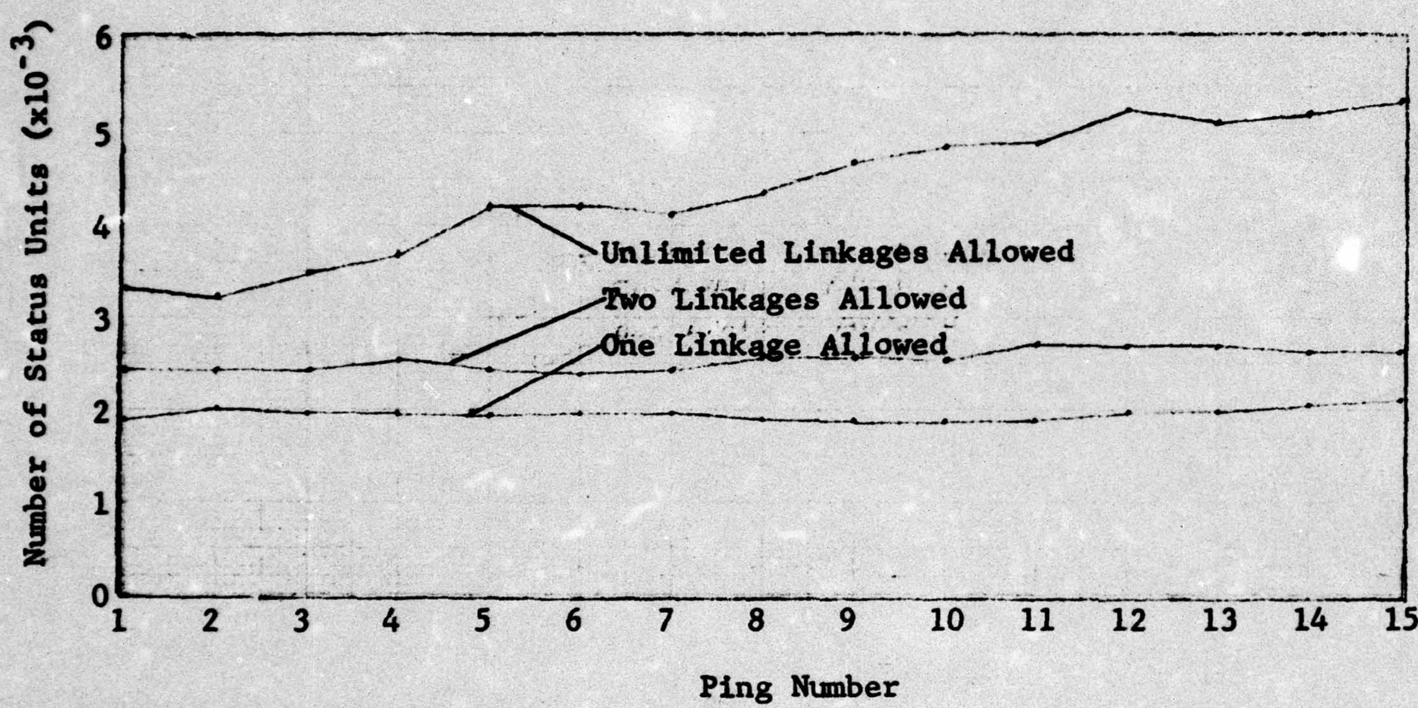

Fig. 3 NUMBER OF STATUS UNITS VS PING NUMBER (NOISE ALONE CONDITIONS). EACH NEW SINGLE PING EVENT ALLOWED TO LINK WITH THE INDICATED NUMBER OF STATUS UNITS.

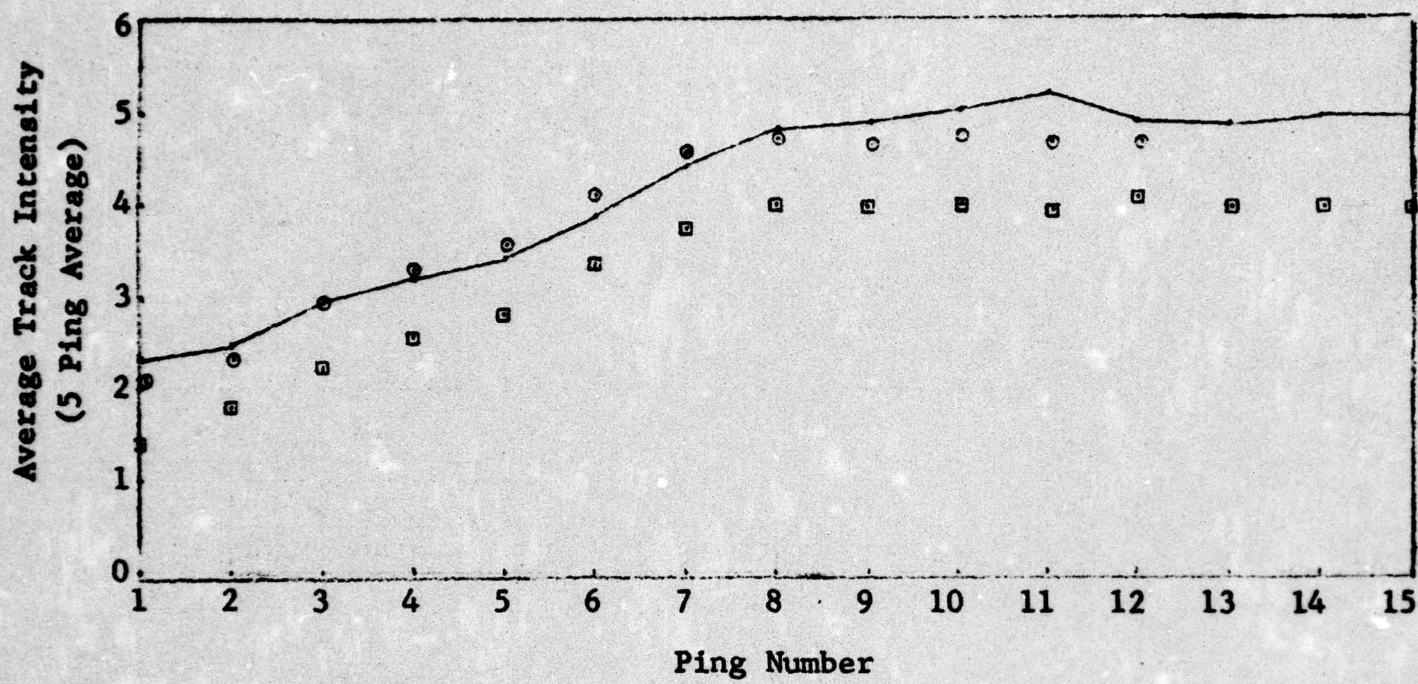

Fig. 4 AVERAGE TRACK INTENSITY VS PING NUMBER (NOISE ALONE CONDITIONS). EACH STATUS UNIT LINKED TO THE INDICATED NUMBER OF SINGLE PING CONDITIONS.

- Unlimited Linkages Allowed
- Two Linkages Allowed
- One Linkage Allowed

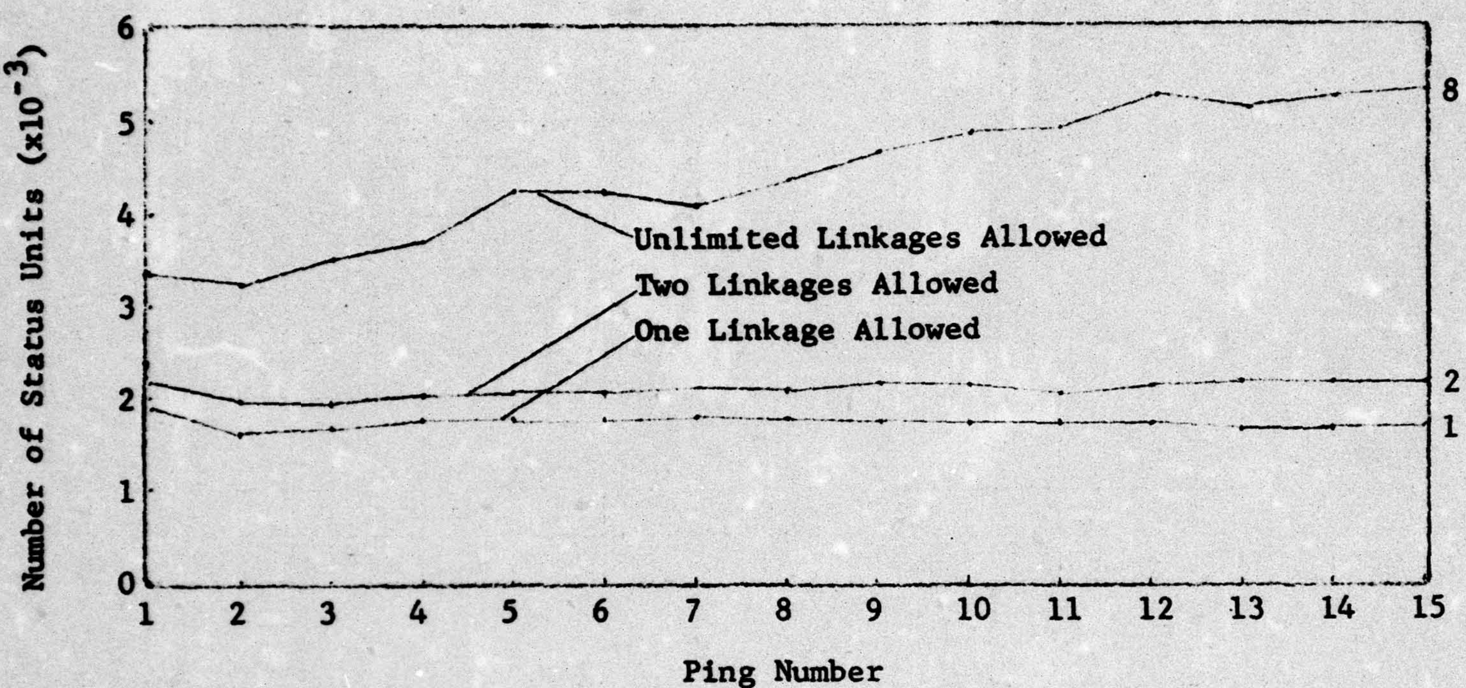

Fig. 5 NUMBER OF STATUS UNITS VS PING NUMBER (NOISE ALONE CONDITIONS). EACH STATUS UNIT LINKED TO THE INDICATED NUMBER OF SINGLE PING EVENTS.

the first method of limiting multiple linkages; that is, each new single-ping event is allowed to link with the indicated number of multi-ping events. Figure 2 shows that the average track intensity is not significantly reduced by limiting the number of linkages to one or two. Figure 3 shows that the number of status units is significantly reduced. Figures 4 and 5 show the results of implementing the second method; that is, allowing each multiple-ping event (status unit) to link with up to N single-ping events. The results are similar to the first method except that when the number of linkages are reduced to 1 a significant decrease in track intensity occurs.

The most reasonable interpretation for these general results is that although it is possible to form linkages with many single-ping events or with many existing status units, there is one linkage whose joint log likelihood ratio is quite often of greater magnitude than that of other attendant linkages. Thus, while the number of status units is significantly reduced, the average track intensity -- which depends directly on the joint log likelihood ratio -- is not appreciably reduced.

In conclusion, it appears that limiting the number of linkages does indeed significantly reduce the computer loading without significantly reducing the track intensity. It is recommended that the first method; that is, allowing each single-ping event to link with N multi-ping events, be adopted, since it is considerably simpler in computer coding and storage requirements. The numerical value for N will depend on the computer loading acceptable and the minimum detectable signal-to-noise ratio desired. Based on the present experiment a value of 2 for N appears reasonable. It combines a significant decrease in computer loading with little or no degradation in detection.

During the next reporting period another method of reducing computer loading will be studied. This method will vary the design signal-to-noise ratio in order to achieve the specified computer loading. This problem is important from two points of view; one, assuming a particular computer is available for SLR processor implementation, the proper design S/N must be determined in order not to exceed the available storage. On the other hand, it is desirable to utilize all the available storage in order that as much information as possible be processed by the SLR processor. Previous results show that increasing the design S/N decreases computer loading but increases the minimum detectable signal-to-noise ratio. Consequently, it is possible and desirable to determine the "best" design S/N as a function of available storage.

This particular study will utilize the basic analysis tools developed in a previous report* for the prediction of the best design S/N. These procedures relate the computer requirements to the basic sonar processor and decision and tracking parameters. For this study the minimum allowable design S/N consistent with available computer storage will be determined as a function of computer storage. The minimum design S/N is chosen in order to minimize the detectable signal-to-noise ratio.

In addition a study will be made of display clutter rates for the SLR processor. This study will consider the probabilities of the occurrence of various tracks due to noise which is complicated by the fact that noise tracks may branch or join. Also, the probabilities depend on the number of independent samples in each volume of suspicion and the lower decision threshold as well as the design signal-to-noise ratio. If exact, sufficiently simple probability statements can be found, this study will aid the study of changes to the SLR processor as well as predicting clutter rates for operational considerations.

Very truly yours,

Hugh A. Reeder

Hugh A. Reeder
Project Director

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*Reeder, H. A., "Estimation of Computer Requirements for a Detection Technique Based on Sequential Hypothesis Testing," TRACOR Document No. 68-352-U, March 1, 1968.