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Radar, Image Processing, and Interpreter Performance

The use of non-coherent averaging for processing radar imagery resulted in improved interpreter performance.

Abstract: *A test was conducted to determine to what extent a novel radar processing technique (non-coherent averaging) improves the detectability of targets imaged by SAR systems. Eight radar interpreters performed a radar exploitation task using both conventional and non-coherent processing methods. Comparative performance measures of detection accuracy scores and timeliness were calculated. The results indicated that, for analysis of the imagery with the non-coherent technique, interpreter performance was superior to that using conventional image processing techniques.*

Introduction

Since the development of the coherent synthetic aperture radar (SAR) system in the early 1960's, scientists, engineers, and information processing personnel have looked for methods aimed at enhancing the radar information extraction process. Of the techniques developed, only one, non-coherent averaging, seems to possess the potential for improving the extraction of target information from radar imagery.

Non-coherent averaging is a means of producing a radar map which enhances the target signal in relation to the peak background noise. A number of methods for implementing non-coherent averaging have been devised by research personnel at the University of Michigan. The results of this work indicate that under some target conditions, non-coherent averaging does increase target detectability.

In conventional processing of SAR data, Figure 1, the unfocused or doppler phase history (dph) is illuminated with monochromatic coherent illumination. The dph diffracts the light energy into a zero term and two first order terms which are focused in the Fourier Transform Plane by the first spherical lens.

A knife edge block in the transform plane passes one of the first order side bands while blocking the other first order side band and zero terms, Figure 2. The 2nd spherical lens then focuses the range information into the output plane, P_3, oblique to the range information. By changing the orientation plane of the dph, there is an angle in which the range and azimuth information are co-planar. A photographic record is then made which produces the radar map.

In the non-coherent averaging mode, the passed information sideband is divided as in Figure 2. Each segmented area is then sequentially sampled and the entire information band is averaged on one photographic record. Theoretically the target signal is constant throughout the frequency range while the noise is considered random. This results in a smoothed map, which increases target detectability (i.e., spurious noise peaks are eliminated). Although the ratio of the peak signal to peak noise has increased, there is a loss of target resolution and the peak signal to RMS noise is decreased.

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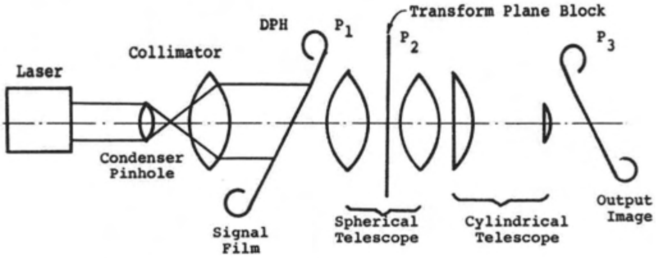

FIG. 1. Conventional processing of SAR data.

While the non-coherent averaging concept theoretically and in some cases experimentally provides "more" information to the interpreter than conventional image processing, a qualitative evaluation of this concept was necessary to determine if this additional information could actually improve interpreter performance. This paper compares experimentally the image interpreter performance of a controlled group of radar interpreters utilizing conventional radar processing and non-coherent processing as a function of time.

TEST DESIGN

In order to determine if non-coherent averaging does, in fact, improve the extraction of information from radar imagery, it was first necessary to obtain sufficient test imagery which fulfilled the following requirements: (1) It had to contain a sufficient sample of tactical and strategic targets along with reliable ground truth information, and (2) it had to be processed using both the conventional procedure and the non-coherent technique.

To satisfy this criteria, test imagery was collected which contained a sufficient number of targets, was of good image quality and was representative of the target scenario. Each area contained from 0 to 45 radar signatures consisting of both tactical and strategic targets. The imagery of all test missions selected was processed utilizing both the conventional and non-coherent techniques. Every test subject (interpreter) viewed each of nine test passes twice, one with the non-coherent processed imagery and once with the conventionally processed imagery. The order of viewing each mission and the processing method was selected randomly.

Each subject was an experienced photo interpreter with specific training in the exploitation of radar imagery. All subjects were chosen from as homogeneous a group as was available to eliminate as much subject deviation as possible. Each subject was directed to the area to be searched and was instructed to search each selected image area. Working as quickly and accurately as possible, they were to detect and locate all visible imaged targets which appeared in the test area only. The test subjects counted orally the number of targets as they detected them. The number of target responses were recorded every 5 seconds up to 40 seconds.

The original test design called for a statistical analysis for 27 test areas. However, ground truth photography acquired to verify target number and type covered only three of the 27 areas. Therefore, most of the results presented in this report are for the three areas verified by ground truth. In one case, trends were developed utilizing all 27 test areas. In this case it was necessary to compute false alarm statistics from the three test areas and extrapolate the results for all 27 test areas.

In addition to the test subject scores, the radar imagery was examined at leisure (untimed) under magnification by a control group. These control data were not introduced in the analysis; however, it did permit

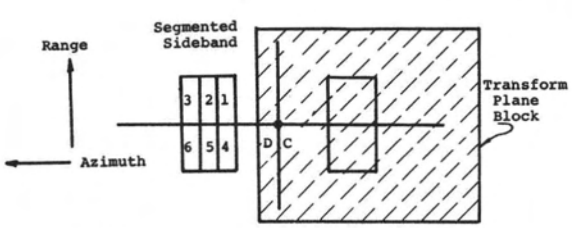

FIG. 2. Conventional recording of DPH.

more control to be exercised over the test design and subsequent analysis of the timed experimental data.

Analysis of Data

The data were analyzed using the detection-completeness and detection-accuracy score as a function of time. The completeness measure was defined as the total correct detections divided by the total possible targets whereas the accuracy score was defined as the total correct detection divided by the total correct detections plus the incorrect detections.

Since the test areas were limited in size, the test utilized a directed search approach. The subjects were directed to the areas of interest and their target detection responses were recorded as a function of time. In all the cases, the errors were errors of commission which resulted in completeness percentages of 100%.

The accuracy results which were subject averaged for the three test areas are shown in Table I. The accuracy scores, which ranged from 51% to 65% for areas 3 and 4 were fairly constant for both processing methods. Area 2 however had significantly higher accuracy scores for both processing methods. In fact, the accuracy score (91%) for the non-coherent processing method for Area 2 is abnormally high. Other than the fact that Area 2 contains more targets than the other areas (approximately twice as many), no apparent reason for this disparity can be shown. Although the accuracy scores for the individual test areas vary from 91% to 51%, the average accuracy scores for all these areas are approximately equal. No significant trends were developed through the accuracy analysis of the data; therefore, an analysis of the number of targets detected as a function of time was conducted. Table II shows the cumulative number of targets detected by all subjects at 5 second intervals up to 40 seconds as a function of processing method. Figure 3 portrays this data graphically.

Table 1. Accuracy Results.

Area	Non-coherent Processing Accuracy Percent	Conventional Processing Accuracy Percent
#2	91%	76%
#3	51%	52%
#4	56%	65%
Average	69%	66%

The detection curves for both processing methods are basically the same for all three areas. Area 2, however, displays a rate inversion at approximately the 15-20 second image. This inversion occurs at the false alarm level and continues until the 40 second mark. Again no explanation can be given for this anomaly.

The curves for all three areas, however, portray one significant difference. Using the non-coherent processing method, the test subjects detected targets faster during the first 15 seconds than they did using the conventionally processed imagery. In order to verify the trend of faster target detection for the non-coherent processing method, a time analysis was conducted for all 27 test areas to determine the specific number of targets detected during the first 5, 10, and 15 second intervals for both processing methods. For each of the three time intervals the number of responses detected per test area for each subject were recorded. The total number of possible responses is 216 (27 test areas times 8 image interpreters). The ordinates for Figures 4, 5, and 6 represent the number of positive responses for all test subjects over the 27 test areas. The abscissa represents the number of targets detected per response after 5, 10, and 15 seconds for Figures 4, 5, and 6 respectively. What actually is being depicted by these graphs is the decomposition of the 216 responses into the number of targets detected per response as a function of time. At the end of the 5 second interval, Figure 4, 150 null responses were recorded for the conventional processing method versus 77 null responses for the non-coherent processed imagery. Null responses are those in which no targets were detected after 5, 10, or 15 seconds. Out of the possible 216 positive responses, 65 positive responses were recorded for the conventional processing method while 139 positive responses were recorded utilizing the non-coherent processing method. This indicates that approximately twice as many positive responses were recorded using the non-coherent process for the first 5 second time period than for the conventional processing method.

As can be seen from Figure 4, there are more targets detected per positive response with the non-coherent processing than for the conventional processing imagery. This trend for the null responses and more targets detected per positive response for the non-coherently processed imagery is repeated for the 10 and 15 second time periods also (Figures 5 and 6 respectively).

In summarizing the data from Figures 4, 5,

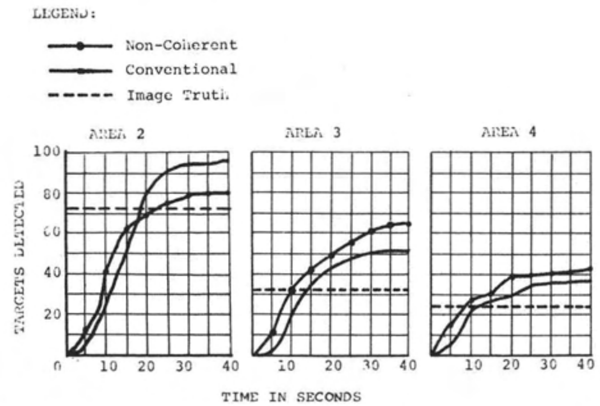

FIG. 3. Total number of targets detected per area as a function of image processing and detection time.

TABLE 2. NUMBER OF TARGETS DETECTED AS A FUNCTION OF TIME.

Area	Type of Processing	5	10	15	20	25	30	35	40	Image Truth
		Time in Seconds								
2	Non-coherent	9	37	62	68	75	78	79	79	72
	Conventional	2	26	53	80	92	94	94	95	
3	Non-coherent	11	33	43	49	55	61	63	63	32
	Conventional	1	21	37	45	49	51	52	62	
4	Non-Coherent	16	27	31	39	40	41	41	43	24
	Conventional	5	22	27	30	35	36	36	37	

and 6, it becomes obvious that the targets contained in the radar imagery are detected more rapidly utilizing the non-coherent processing method than using the conventional proecessing method.

RESULTS

Prior to this analysis of the non-coherent processing technique, qualitative and unsubstantiated comments from image interpreters indicated that the non-coherent processing technique afforded faster and more confident detection of radar targets than had been experienced utilizing conventional processing methods.

Due to the directed search approach utilized in the test design both processing methods had detection completeness scores of 100%. The detection accuracy scores for the three test areas were also approximately equal (69% for the noncoherent method and

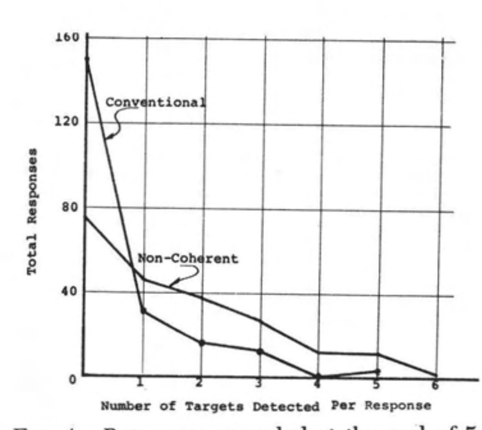

FIG. 4. Responses recorded at the end of 5 seconds as a function of the number of targets detected per response.

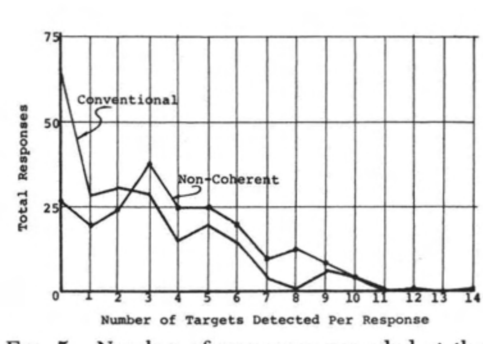

FIG. 5. Number of responses recorded at the end of 10 seconds as a function of the number of targets detected per response.

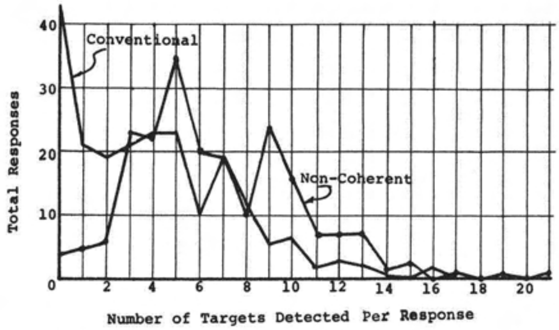

FIG. 6. Number of responses recorded at the end of 15 seconds as a function of the number of targets detected per response.

66% for the conventional method).

Although the test evaluation did not demonstrate that the non-coherent method was superior in terms of detection accuracy, it did conclusively demonstrate that the non-coherent technique did allow the image interpreter to detect the radar targets significantly faster. However, had more photographic ground truth been availble, it is felt that the detection accuracy score for the non-coherent processing would have proven significantly superior to those obtained utilizing the conventional processing method.

It must be remembered that the results are based upon a small number of data samples; therefore, any conclusions derived are somewhat fewer and more tenuous than would normally be the case. The following conclusions however still appear to be warranted by these data.

During the shorter time intervals, 5, 10, and 15 seconds, the number of targets detected using the non-coherent processing method was significantly higher than the number of targets detected using the conventional processing method. Whether this time differential would significantly affect an operational situation is a question yet to be answered.

Using the non-coherent processing method, targets which ordinarily would be lost in the background noise are enhanced, thus decreasing detection time and reducing the search time.

The optimum use of the non-coherent processing technique is not for enhancing radar imagery containing relatively strong targets in a flat background (i.e., road, desert, etc.) but for the enhancement of moderate or partially covered targets (vehicles under trees) in noisy background.

Although the data presented are extracted from a limited number of experimental samples, it is hoped these data will substantiate the need for the continual development of unique interpretation systems for the optimum extraction of information from remotely sensed data.

REFERENCE

1. Robert W. Lewis, Mixed Integration Processing of Synthetic Aperture Radar Data, Aug 1972, AFAL-TR-215.

Articles for Next Month

Michael A. Crombie and *David L. Ackerman*, Line-of-Sight Determination from Digitized Imagery.

Richard H. Duncan, Compilation Base Orientation by Graticule.

Alan D. Jones, Photographic Data Extraction from LANDSAT Images.

Major David F. Maune, Ph.D., Photogrammetric Self-Calibration of Scanning Electron Microscopes.

Dr. Eugene L. Maxwell, Multivariate Systems Analysis of Multispectral Imagery.

K. C. Saxena, M. Sc., A.M.I.S., Independent Model Triangulation—an Improved Method.

Carl H. Strandberg, Environmental Disaster Control Analysis.

S. A. Veress and *R. S. Tiwari*, Fixed-Frame Multiple-Camera System for Close-Range Photogrammetry.