PRELIMINARY REPORT ON THE
OBSERVATION OF SNORKELS AND SEA
CLUTTER USING COHERENT
AIRBORNE RADAR

Report R-27
20 November 1952

THIS DOCUMENT CONTAINS INFORMATION AFFECTING THE NATIONAL
DEFENSE OF THE UNITED STATES WITHIN THE MEANING OF THE
 Espionage Laws, Title 18, U.S.C., Sections 793 and 794. DIS
 TRANSMISSION OR DISSEMINATION OF ITS CONTENTS IN ANY WAY
 TO AN UNAUTHORIZED PERSON IS PROHIBITED BY LAW.

Prepared by:

W. J. Koszta
G. J. Nowell
W. C. Prothe
C. W. Sherwin

CONTROL SYSTEMS LABORATORY
UNIVERSITY OF ILLINOIS
URBANA, ILLINOIS
Contract No. DA-11-022-ORD-721
Sea clutter, snorkel and periscope signals, are observed along the ground track, using an airborne, X-band coherent radar. The signals from one pulse length (1/2 μ-sec) located at a fixed range ahead of the aircraft are envelope detected, processed by a box-car circuit, recorded on tape, and frequency analyzed. The overall resolution of the system is 10 cps in frequency or 1/3 knot in velocity.

Sea clutter spectra are 50 to 100 cps wide at half power with negligible power extending outside a 200 cps band.

Snorkels and periscopes produce sharp peaks 10 to 15 cps wide at half power, which usually go through several strong fluctuations in intensity during the one second observation time.

In some of the samples an increase in the intensity of the sea clutter spectrum is observed during target detection. This is the signal due to the wake.

Thus the coherent system makes it possible to accurately compare signals from snorkel or periscope, wake, and sea clutter.

The radial velocity of the target with respect to the sea clutter can be measured to about one knot. If this velocity exceeds 3 or 4 knots, the snorkel signal is free from interference by the sea clutter.

It is clear that coherent radar improves snorkel detection and identification, but further experiments and analysis are necessary to accurately measure this improvement.
I. Introduction

Coherent radar is distinguished from non-coherent radar in that the transmitter maintains a record of both the phase and amplitude of the transmitted signal. The returning echo is added to this recorded signal before detection. The output of the detector then contains beat frequencies between the recorded signal and each of the echoes. If two echoes come from scatterers which have different radial velocities with respect to the transmitter, they will each produce a distinct beat frequency with the recorded signal. The two echoes will also beat together to produce a third frequency which is present in non-coherent radar, and therefore can be called the non-coherent signal. The situation for three targets is shown in Figure 1. The coherent signal appears after detection only if a record is kept of the ref. transmitted, i.e., only if the signal C, Fig. 1, uniquely related to the transmitted signal is still present when the echoes arrive. A simple way to get C is to use an echo box which is set ringing by the transmitted pulse.

In general, due to the detection operation, every frequency beats with every other frequency. The high frequency terms at

* * * Experimental observations were conducted with the cooperation of the Bureau of Aeronautics under project BuV 59/Al-1.
Different Radial Velocities with Respect to The Transmitter

twice the input frequencies and at the sum of the input frequencies are filtered out. The different terms are studied by ordinary frequency analysis.

If one has $N$ frequency lines in the original echo, there are $\frac{N(N-1)}{2}$ lines in the non-coherent spectrum, which thus

Figure 1: Frequency Spectra of Three Targets Moving at Different Radial Velocities with Respect to The Transmitter.
becomes very complex for large $N$. On the other hand, in the coherent part of the detector output the original $N$ lines still appear separately with their original spacing and their correct relative intensities.

It appears that the coherent signal contains more information about the echoes than does the complex non-coherent spectrum. Furthermore, the coherent spectrum is capable of direct interpretation since the doppler effect classifies each target according to its velocity relative to the transmitter. Any target moving with uniform velocity will consistently return its echo in a very narrow frequency range.

Coherent radar improves the detection of moving targets particularly when the target motion is large enough so that the echo is displaced, frequency-wise, out of the surroundings or clutter. Figure 2 shows how a moving target maintains its sharp frequency spectrum after detection in the coherent radar, but for non-coherent radar the moving target signal is as broad as the clutter.

For snorkel detection, the expected velocities are only a few knots. Also, the spread in velocities of the scatterers on the sea surface is only a few knots. Thus, the situation on the right half of Fig. 2 is typical of the snorkel problem.
Most of the studies of sea clutter and snorkels have been made by studying the non-coherent spectrum - for example, its auto-correlation. Since in a non-coherent system so much information is lost in detection, processing the data from such systems is not as rewarding as is the study of the coherent spectrum itself.

Some work with C-W radar has been done on the problem, but unless different range intervals are separately classified.
and unless transmitter-receiver isolation is excellent, poor signal to noise conditions will be encountered on small targets*. Some work on pulsed doppler, coherent radar is underway at Sylvania**, but to our knowledge, no measurements have been taken to date. Russell Varian*** has proposed a pulsed coherent system for snorkel detection.

---


II Potential Value of Coherent Radar in ASW

The experiments described here are aimed at getting information on the fundamental nature of the coherent signals from sea clutter, snorkels, periscopes, ships, floating debris, etc. From calibration runs over the ground and over Lake Michigan it was observed that an over-all system resolution of 10 cps (1/3 of a knot) along the ground track is feasible. Thus a 10 cps change out of $10^{10}$ cps can be observed and yields accurate information about the state of motion of the radar echos - even with the transmitter located on an aircraft. Of course, the aircraft must fly at a uniform velocity or its own acceleration must be sensed, and the data corrected.

The part of the echo which comes directly from the snorkel or periscope, which are uniformly moving objects, should be extremely sharp in frequency. The echo from the wake should be diffuse in frequency due to the turbulent motion of the water. The relative intensity of these two kinds of echos is extremely important in the design of optimum detection systems.

The echo from sea clutter should disclose the actual velocity distribution of the scatterers. Scatterers are grouped radial velocity bins which are 1/3 of a knot wide.
Accurate radar cross sections on the echoes from the snorkel and from the wake with respect to sea clutter and also with respect to standard targets, can be measured with coherent radar using frequency analysis.

Light surface vessels should show their acceleration due to roll and pitch. 0.1 g acceleration will, in one second, change the doppler frequency by 60 cps, which is six times the resolution of the coherent system. Thus surface targets should show characteristic frequency modulated echos while snorkels or periscopes should show very constant frequency echos.

Floating debris might also be recognized by its characteristic accelerations.

In fact, in any appreciable sea state, the only surface target which is not accelerating and is therefore capable of giving a really constant frequency echo is a snorkel or periscope. It is anticipated, therefore, that target recognition will be a significant contribution of coherent radar.

Since only those particular reflectors on the sea that happen to be in the same 10 cps frequency bin (1/3 knot velocity bin) as the snorkel, will compete with the direct snorkel signal; detection in sea clutter should be greatly enhanced.
In particular, when the snorkel has a velocity with respect to the sea, exceeding 3 or 4 knots either toward or away from the search radar transmitter, it should be completely separated from sea clutter. This sensitivity to target motion greatly aids detection and is also a factor of importance in target recognition. Floating debris cannot produce this effect, for example. Since at the moment of detection one component of the target velocity is observed, one is aided in predicting the future position of the target.

Detectability of snorkels in thermal noise is also considerably enhanced if coherent radar is employed. The coherent signal has to compete with only 10 cps of thermal noise, and if an appreciable fraction of the snorkel-generated echo is coherent, longer ranges at lower power are possible.

A corner reflector rotating on an arm several feet in radius, such that the tangential velocity is greater than 5 or 6 knots, would give characteristic signals easily recognizable on a coherent radar, even in sea clutter. A wind-powered device of this sort might be very useful on life rafts. Similar identification means are possible for surface vessels.

Data processing which makes possible snorkel detection with
the lowest possible transmitter power is important in reducing the effectiveness of counter-measures. Side looking, low side lobe antennas* coupled with improved detectability due to better data processing (e.g., coherent radar and frequency analysis) offer the potentiality of detecting the submarine in the same few seconds that it detects the search radar.

To evaluate these potentialities, it is clear that one needs direct experimental data on the nature of the echoes from the sea and the submarine from a coherent radar. In these experiments one does not need to change the transmitted signals in any way, except to require that the transmitter be above average in frequency and amplitude stability. Basically, one improves the data processing. All the information such as that contained in this report is always present in the radar signals, but it is thrown away due to lack of equipment to extract it.

Once the nature of the signals is better understood, the data processing equipment can be better designed, and its cost can be more accurately weighed in the light of its advantages.

* Such as are under development at the Philco Corporation
In particular the photographically recorded time v.s. frequency graphs discussed later in the report permit a direct and realistic comparison of non-coherent v.s. coherent radar under identical conditions.
III Outline of the Experiment and Equipment

We used a C-46 aircraft* carrying a coherent radar
(modified APQ-13, 40 KW, peak power, 1/2 µs pulse, X-band)
with an echo box whose useful ringing time was 2½ sec. or
4000 yds. The pulse recurrence frequency is 2080 cps. The
beam (horizontal polarization) is fixed along the ground track
with a range gate of one pulse length duration set at R.
Scanning is accomplished only by the aircraft motion, and
some care is needed to fly directly toward the target.

The video signals due to the reflections from the illuminated
patch and the echo box are passed through a "box car" circuit and
recorded on one channel of a dual channel tape recorder
(Magnecorder, type PT6BAH). The electro-mechanical section is
operated in flight by a Carter JR100CW4 60 cps converter.
The audio signals can also be heard over the inter-communication
system. Sections of the tape during and adjacent to the time
that the illuminated patch passes over the target are later
cut out and analyzed. (Hewlett Packard Harmonic Wave Analyzer,
Model 300 A, equipped to automatically scan and record in 5 cps
steps.) The overall frequency resolution of the recording and
analysis is 10 cps.

* Supplied through the cooperation of Aircraft Radiation Laboratory,
Wright Patterson Air Force Base, Dayton, Ohio.
Figure 3: Sketch of the Method of Operation. The target is observed on or near the ground track of the aircraft. The aircraft flies with the illuminated patch at a fixed range in front. The transit time of the target through the illuminated patch is identified by aural detection of the box-car demodulated video signal from the illuminated patch.

The original doppler frequency of a 150 knot aircraft approaching a target in the illuminated patch is $4800 \text{ cps}$, (32 cps per knot) but due to the sampling action of the 2080 cps pulse recurrence frequency, the frequency spectrum of the patch is most easily observed near 800 cps (as a side band of the p.r.f. line at 4160 cps, reflected through the origin.
giving, therefore frequencies in the original order). At 170 knots ground speed, the 5500 cps doppler signal appears near 800 cps as the side band from the p.r.f. line at 6320 cps and therefore the frequencies appear in reversed order. Only the interval from zero to one half the p.r.f. is analyzed since the same information is repeated at higher frequencies.

The non-coherent frequency spectra are also observable. Since the echo box signal is usually about the same amplitude as the sea clutter echoes, the beat frequencies among the clutter echoes themselves ("inter-clutter modulation") although confined to low frequencies, are approximately as strong as the radar echoes beating with the echo box. This inter-clutter modulation can be made relatively small by making the echo box signal larger.

An automatic gain control circuit with a time constant of 0.15 seconds maintains the video pulse level of the radar at a nearly constant level. This unfortunately makes it difficult to accurately compare the relative intensity of spectra spaced more than a few tenths of a second apart.

However, in general, the echo box signal was at least 2 to 3 times the amplitude of the target signal so that, on the average, the presence of a signal reduced the voltage gain of the I.F.
amplifier by less than 50 per cent. Future experiments will be performed with a fixed I.F. gain since this permits a more accurate measure of the relative strength of the direct snorkel echo and the echo from the wake.

Power supply hum at 440 cps (and sometimes 880 cps) was present in varying intensity. This could be minimized by careful tuning of the echo box. There may have been some further noise at other frequencies due to transmitter instability but it has not been identified against the sea clutter background. Thermal noise was in general negligible.

Figure 4 shows the principle parts of the experimental system.

Figure 4: Block Diagram of the Principle Parts of the Experimental Coherent Radar
The experimental runs were made out of the Naval Air Station at Key West, Florida with the excellent cooperation of members of the Air Development Squadron One.

The observations reported here were made on October 20, 1952, against the submarine CHIVO. Sea state and wind data are not available in as much detail as would be desirable. The runs began at 10:15 with a sea state 3 and a 20 knot wind, and ended with a sea state 1 and a 6 knot wind.

The CHIVO has an underwater exhaust and two periscopes. No. 1 is a search periscope and no. 2 is an attack periscope.

Further data was taken on the submarine AMBERJACK on October 21 and October 22, and will be reported later.
IV Results

(A) Sample 62 (Photo 1 and top line on Photo 2)

Photo 1 shows a series of eleven frequency vs. amplitude spectra which cover an elapsed time of about 4 seconds. Each spectrum is made from a strip of tape 1/4 second in length, so each spectrum contains 500 pulse samples. The analysis is made in 5 cps steps. The centers of successive strips of tape are spaced about 1/3 second. It takes about one second for the illuminated patch to pass over any given point on the surface. The spectra numbered 5, 6 and 7 show a relatively sharp spike (12 to 15 cps at 0.7 amplitude) due to the snorkel. All the other spectra show only sea clutter, power supply at 440 cps and also at 880 cps. Table I and also the top part of photo 2 show that in sample 62 the submarine is moving at 6 knots in a direction nearly right angles to the heading of the aircraft, however, the snorkel echo is displaced about 60 cps from the center of the sea clutter spectrum, in the direction of lower frequency. These spectra have the doppler frequencies in their original sequence, since the ground speed is 151 knots.

After making allowance for wind, we conclude that the snorkel has a velocity of about 0.6 knots away from the aircraft.

* Note: Photo 1 refers to the first page of photographic prints Photo 2 to the second page, etc.
This should cause a displacement of the snorkel of about 20 cps in the low frequency direction from the average sea clutter frequency. The observed shift of 60 cps exceeds the 20 cps due to the snorkel motion. It is likely therefore that there is a net velocity of the scatterers on the sea surface with respect to the water mass of the order of 1 knot in a direction approaching the aircraft. More data on the wind and sea swell are needed for positive conclusions. It is clear, however, that measurements of the frequency shift between snorkel and sea clutter are capable of giving accurate information about net motion of the sea surface scatterers with respect to the water mass.

There is no evidence in this sample of any appreciable increase in the sea clutter power at the moment of snorkel detection.

(B) Sample 55 and 57 (Second line on Photo 2)

In this example, the submarine is approaching the aircraft with a speed of 6 knots. The snorkel signal appears displaced from the center of the clutter spectrum by 190 cps toward lower frequencies. Thus the order of the frequencies is reversed.
showing that the ground speed of the aircraft is 170 knots rather than the only other alternative of 150 knots. The aircraft must have a tailwind of 27 knots, since the air speed was 143 knots.

Here we have an ideal example of snorkel detection since the target has enough velocity with respect to the sea clutter to be completely separated from it. Also the target is sharp in frequency.

There is some evidence that the clutter power increased during snorkel detection (due to echo from the wake) but the uncertainty introduced by the A.G.C. circuit makes this conclusion tentative. It is clear that automatic gain control must be disabled on subsequent tests of this type.

(C) Sample 58 (Third line on Photo 2)

This is an attack periscope with a surface speed of 6 knots in sea state 1. It happens that the two coherent spectra overlap since they both fall near half the pulse recurrence frequency, appearing as mirror images of each other.

The component of the periscope surface velocity in the direction of the aircraft is approximately 5 knots which means that there should be a displacement between the sea clutter and the
periscope of about 150 cps. Unfortunately this displacement lands the periscope signal associated with the first clutter spectrum right in the middle of the second clutter spectrum and vice versa. A more favorable choice of ground speed or p.r.f. could have prevented this complication.

There is evidence that the sea clutter echo increases during periscope detection, indicating that the wake is contributing to the over-all signal power.

(D) Sample 60 (Fourth line on photo 2)

An attack periscope is observed in sea state 1. An appreciable fraction of the signal power appears to be coming from the wake. Even though the submarine is travelling at nearly right angles to the aircraft course, there appears to be a 60 cps (2 knot) displacement between clutter plus wake signals and the direct periscope signal.

(E) Sample 69 (First line on photo 3)

A snorkel and search periscope are observed with a 5 knot radial velocity with respect to the clutter. Spectra 1 and 3 show that the sea clutter ends abruptly at about 650 cps, and the broad signal due to the target appears centered at about 750 cps. Power supply ripple appears at 880 cps.
The lack of the sharp frequency spike characteristic of the target is probably caused by the snorkel echo being momentarily small compared to the wake and sea clutter. The time v.s. frequency photographs which were made on some samples, which are discussed later, show that there are strong fluctuations in both the direct snorkel echo and in the wake echo. In all cases so far discussed, the 1/4 second sample of signal was selected without the benefit of the over-all picture which is provided by the time v.s. frequency photographs.

(F) Sample 63 (Second line on photo 3)

A snorkel plus search periscope are observed from a direction at right angles to the submarine course. The main target echo occurs at 610 cps and the sea clutter in spectra 1 and 3 appear to have their centers above 700 cps. In spectrum 2, where the target is observed, it is hard to judge the center of the sea clutter spectrum, however the strong non-coherent signal at 140 cps suggests that the target signal is definitely displaced with respect to the center of the sea clutter. This may be a case where the sea clutter has a velocity of 2 or 3 knots with respect to the water mass.

(G) Sample 61 (Third line on photo 3)

This is a case where the sea clutter spectrum can not be definitely located, but the strong snorkel signal with no
identifiable wake echo is observed.

(H) Sample 70 (Fourth line on photo 3)

The snorkel and periscope are observed shifted about 120 cps (4 knots) with respect to the sea clutter as is expected from the submarine velocity. The large non-coherent signal between 100 and 200 cps is due to the beat frequency between the sea clutter and the moving target. There is evidence of considerable wake echo.

This particular sample was analyzed with the time v.s. frequency method described in the next section. On the film record, the signals between 100 and 200 cycles clearly identify the presence of the moving snorkel. The film also shows the build-up of sea clutter echo due to the wake, and, of course the strong narrow frequency snorkel echo itself.
V. Time v.s. Frequency Analysis

After most of the preceding samples had been cut up for analysis, a new method of processing the data was set into operation.

A four second sample of tape containing a signal is played repeatedly on the analyzing Magnecorder. The loop includes a 1/4 second sample of tape on which is recorded a 7 KC signal. A 1/4 second sawtooth sweep generator is clamped to its starting position at the onset of the 7 KC signal, and then released when it ends. This sweep is directly coupled to a Tecktronix 512 D.C. oscilloscope giving the vertical sweep. The horizontal sweep is provided by a potentiometer on the slowly rotating shaft which is driving the Hewelett Packard Analyzer. The analyzer progresses 5 1/4 cps during each cycle of the tape. The 20 KC output signal from the analyzer is rectified and direct coupled to the grid of the C.R.T. Thus the intensity of the C.R.T. continually presents the power level in the analyzer filter. Since this filter is about 5 cps wide at half power, it averages the data for about 1/5 second.

The film has a dynamic range of about 1/4 db and presents a detailed ordered picture of all the different frequencies during the four seconds.
The fourth page of photographs shows two target samples analyzed on film. Accompanying each of the time v.s. frequency photographs are two amplitude v.s. frequency spectra taken during the indicated 1/4 second intervals. The time v.s. frequency plots are particularly useful in showing the scintillating frequency patterns of the sea clutter and wake. They also show the time fluctuations of the direct snorkel signals.

In examining the non-coherent spectra in the time v.s. frequency plots of photo 4, it is important to remember that very little data is recorded below 100 cps. This is due to the limitations of the tape recording equipment. Some observations which will be reported later, were made with a modified box-car circuit*. This displays the entire non-coherent spectrum as a side band of the pulse recurrence frequency. When the complete non-coherent spectrum is recorded, a direct comparison of the detection efficiencies of the coherent and non-coherent is possible.

---

* C.S.L. Report I-41, N. Knable, October 8, 1952.
<table>
<thead>
<tr>
<th>Sample Number</th>
<th>#62b, a, o</th>
<th>#55ab, #57</th>
<th>#58b, a, o</th>
<th>#60b, a, o</th>
<th>#69b, a, o</th>
<th>#63b, a, o</th>
<th>#61b, a, o</th>
<th>#70b, a, o</th>
</tr>
</thead>
<tbody>
<tr>
<td>Snorkel Height</td>
<td>4 3/4 ft</td>
<td>3 1/2 ft</td>
<td>--</td>
<td>--</td>
<td>4 1/2 ft</td>
<td>5 1/4 ft</td>
<td>4 1/4 ft</td>
<td>3 3/4 ft</td>
</tr>
<tr>
<td>above water</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Periscope Height</td>
<td>--</td>
<td>--</td>
<td>4 1/2 ft</td>
<td>6 ft</td>
<td>5 1/2 ft</td>
<td>6 1/2 ft</td>
<td>--</td>
<td>5 1/2 ft</td>
</tr>
<tr>
<td>above water</td>
<td></td>
<td></td>
<td>(attack)</td>
<td>(attack)</td>
<td>(search)</td>
<td>(search)</td>
<td></td>
<td>(search)</td>
</tr>
<tr>
<td>Moving Target Vel.</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>(in knots)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moving Target Heading</td>
<td>000</td>
<td>180</td>
<td>260</td>
<td>260</td>
<td>000</td>
<td>000</td>
<td>180</td>
<td>000</td>
</tr>
<tr>
<td>(true bearing)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Air Speed</td>
<td>14.8</td>
<td>14.2</td>
<td>14.3</td>
<td>13.9</td>
<td>14.8</td>
<td>14.2</td>
<td>14.4</td>
<td>14.8</td>
</tr>
<tr>
<td>(in knots)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plane Alt. in Feet</td>
<td>1000</td>
<td>1000</td>
<td>1100</td>
<td>1000</td>
<td>1000</td>
<td>1000</td>
<td>1000</td>
<td>500</td>
</tr>
<tr>
<td>Plane Heading</td>
<td>267°</td>
<td>360°</td>
<td>110°</td>
<td>0°</td>
<td>220°</td>
<td>275°</td>
<td>22°</td>
<td>40°</td>
</tr>
<tr>
<td>(not ground track)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Range in Yards</td>
<td>2500</td>
<td>4000</td>
<td>2500</td>
<td>2500</td>
<td>2500</td>
<td>2500</td>
<td>2500</td>
<td>4000</td>
</tr>
</tbody>
</table>

Constants for the Experiment: PRF: 2080 p.p.s.; Antenna Half Power Width = 4.7°; Antenna positioned approximately along the ground track; Duration of Samples Analyzed = 1/4 sec.; Analyzer Integrating Time Constant = 1 sec.

The wind and sea state were recorded by the submarine at the beginning and at the end of the experimental run as follows: At 10:15, wind velocity = 20 knots, wind direction = 190°, sea state = no. 3; at 16:00, wind velocity = 6 knots, wind direction = 240° and sea state no. 1. All the above observations were made on October 20, 1952.
Table II (Samples in Photo 14)

<table>
<thead>
<tr>
<th>Sample Number</th>
<th>71</th>
<th>73</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time Observed</td>
<td>13:31:15 (10/20/52)</td>
<td>14:14:05 (10/20/52)</td>
</tr>
<tr>
<td>Snorkel Height</td>
<td>4 3/4 ft</td>
<td>3 3/4 ft</td>
</tr>
<tr>
<td>Moving Target Vel.</td>
<td>6 knots</td>
<td>6 knots</td>
</tr>
<tr>
<td>Moving Target Heading (true)</td>
<td>000</td>
<td>260</td>
</tr>
<tr>
<td>Air Speed</td>
<td>114.8 knots</td>
<td>148 knots</td>
</tr>
<tr>
<td>Aircraft Altitude</td>
<td>500 ft.</td>
<td>1000 ft.</td>
</tr>
<tr>
<td>Aircraft Heading (not ground track)</td>
<td>50</td>
<td>106</td>
</tr>
<tr>
<td>Range</td>
<td>2500 yds.</td>
<td>2500 yds.</td>
</tr>
</tbody>
</table>

In the time v.s. frequency plots in photo 14, it is difficult to see the original sea clutter spectrum except when it is reinforced by the wake. The amplitude v.s. frequency graphs, taken at the indicated times, show more detail, however.

The scintillation of the constant frequency snorkel targets is clearly visible in both 71 and 72. This type of display...
is useful in target identification.

The "Sinufly" type of data processing equipment now under development at the Control Systems Laboratory is designed to perform rapid frequency analysis of many range intervals simultaneously. With adequate storage tubes this system could be made to give a display similar to the time vs. frequency plots in Photo 4.

VI Acknowledgements

SEA GLUTTER & SNORKEL
SAMPLE NO. 62
OCTOBER 30, 1962
SEA CLUTTER & SNORKEL
SAMPLE NO. 569, 6-57
OCTOBER 20, 1957

270°
143 KNOTS

SUB 60 KNOTS

SEA CLUTTER & PERISCOPE NO. 2
SAMPLE NO. 569, 5-57
OCTOBER 20, 1957

270°
230°
143 KNOTS

SEA CLUTTER & PERISCOPE NO. 2
SAMPLE NO. 569, 5-57
OCTOBER 20, 1957

270°
230°
143 KNOTS

FREQUENCY (CYCLES/SEC.)
THIS DOCUMENT CONTAINS INFORMATION AFFECTING THE NATIONAL DEFENSE OF THE UNITED STATES WITHIN THE MEANING OF THE ESPIONAGE LAWS, TITLE 18, U.S.C. SECTIONS 793 AN 794. ITS TRANSMISSION OR THE REVEALATION OF ITS CONTENTS IN ANY MANNER TO AN UNAUTHORIZED PERSON IS PROHIBITED BY LAW.