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QUARTERLY PROGRESS REPORT NUMBER 7. 1 FEBRUARY-30 APRIL 1968.(U)

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DEFENSE RESEARCH LABORATORY

THE UNIVERSITY OF TEXAS AT AUSTIN

14 August 1968

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QUARTERLY PROGRESS REPORT NO. 7
UNDER CONTRACT NObsr-95181 (U)

For the Period 1 February - 30 April 1968

NAVAL SHIP SYSTEMS COMMAND
Contract NObsr-95181
Project Serial No. SF 1010316, Task 8614

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(11) 14 August 1968

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UNDER CONTRACT NObsr-95181

For The Period 1 February - 30 April 1968

NAVAL SHIP SYSTEMS COMMAND
Contract NObsr-95181
(15) Project Serial No. SF 1010316, Task 8614

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I. INTRODUCTION

(U) The power spectra of linear FM sonar data for two different submarine aspects have been computed. These results are compared with each other and with the power spectra of the associated reverberation data.

(U-~~FOUO~~) In conjunction with the Signal Physics Division of the Defense Research Laboratory (DRL), a different technique for displaying analyzed sonar data has been investigated. This display consists of quadrature sampled data and correlations that are plotted with the computer as projections in three dimensions.

(U-~~FOUO~~) A meeting was held between the Texas Instruments, Inc. (TI), Equipment Branch and the DRL Computer Science Division. The subject of the meeting was concerned with application of TI's method of curve fitting in some types of data analysis.

The basic shape of the lag window applied to the autocorrelation dominates the shape of the Cepstrum. A good solution to this problem is found to be a clipped cosine bell.

II. POWER SPECTRA

(U) In order to gain a better intuitional feel for the analysis of actual sonar data, several power spectra were computed for two different submarine aspects. These spectra were computed by squaring the modulus of a discrete finite Fourier transformation. The transmitted signal was a linear FM upsweep with a bandwidth W = 625 Hz, pulse length T = 0.1024 sec, TW = 64, and the return data was sampled at four times the carrier frequency, F_0 = 5000 Hz. Only the frequency band of interest was plotted, and each scale was normalized. Figures 1 and 2 show the power spectra for a beam aspect submarine. Of particular interest is the low frequency ripple in the power spectra. This is the information that Cepstrum and other correlation techniques use to decompose the data into highlights. As an interesting calculation, the distance between the large peaks in Fig. 1 is about 122 Hz. This information can be related to a physical distance as

$$\frac{5000 \text{ ft/sec}}{122 \text{ Hz}(2 \text{ path length})} \approx 20 \text{ ft} \quad .$$

The beam of this particular submarine is approximately 27 ft. Even though this was a rough calculation, the numbers are of the same magnitude. The purpose of the study was to demonstrate why the power spectra of the stern aspects shown in Figs. 3 and 4 are so much different than the spectra of the beam aspects. This is to be expected because the highlights of a stern aspect would be separated more in time than the highlights for a beam aspect. Since the frequency domain is inversely proportional to the time domain, the ripple in the spectra for a stern would be much more closely spaced than the ripple in the spectra for a beam aspect. The characteristics

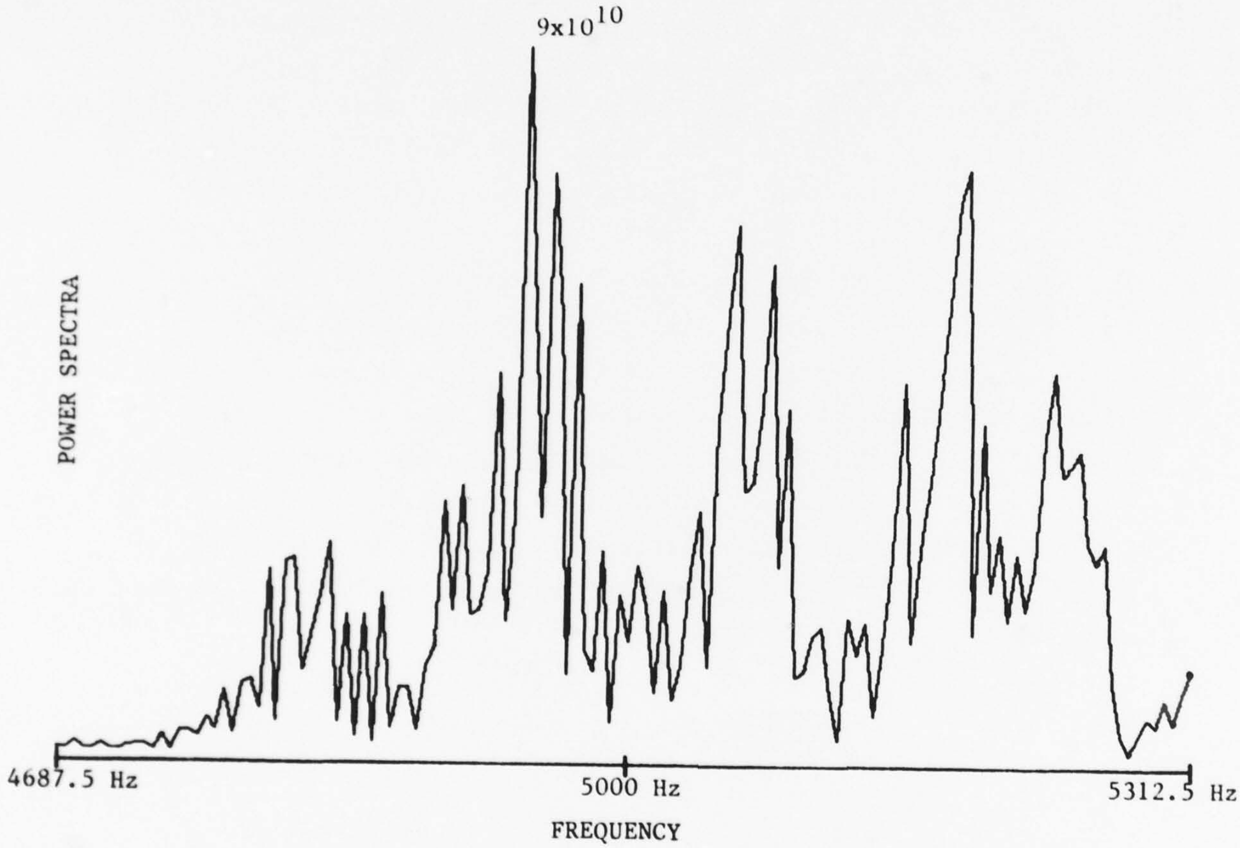

FIGURE 1

POWER SPECTRA OF BEAM ASPECT SUBMARINE DATA (U)

SEQUENCE: 24
TAPE: 109

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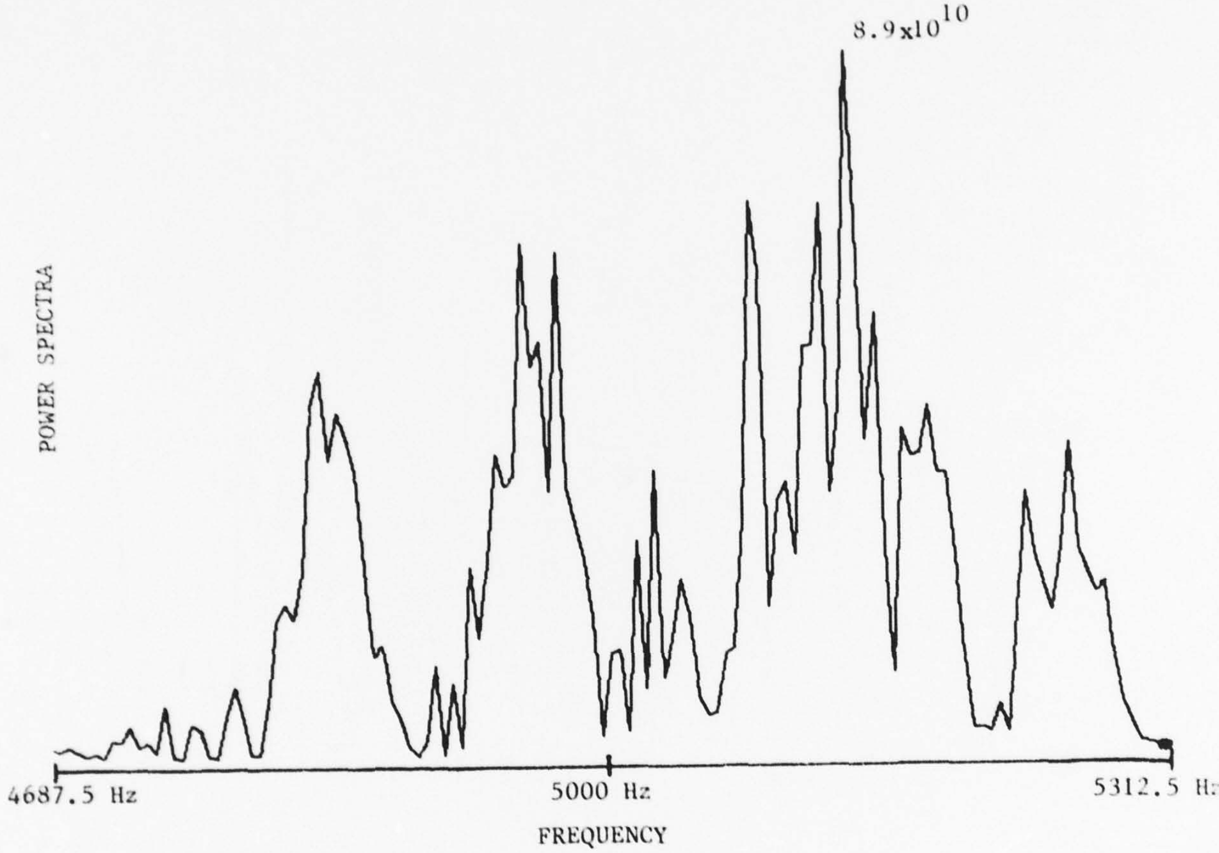

FIGURE 2

POWER SPECTRA OF BEAM ASPECT SUBMARINE DATA (U)

SEQUENCE: 23
TAPE: 109

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AS-68-1014
GEE:gk
8-1-68

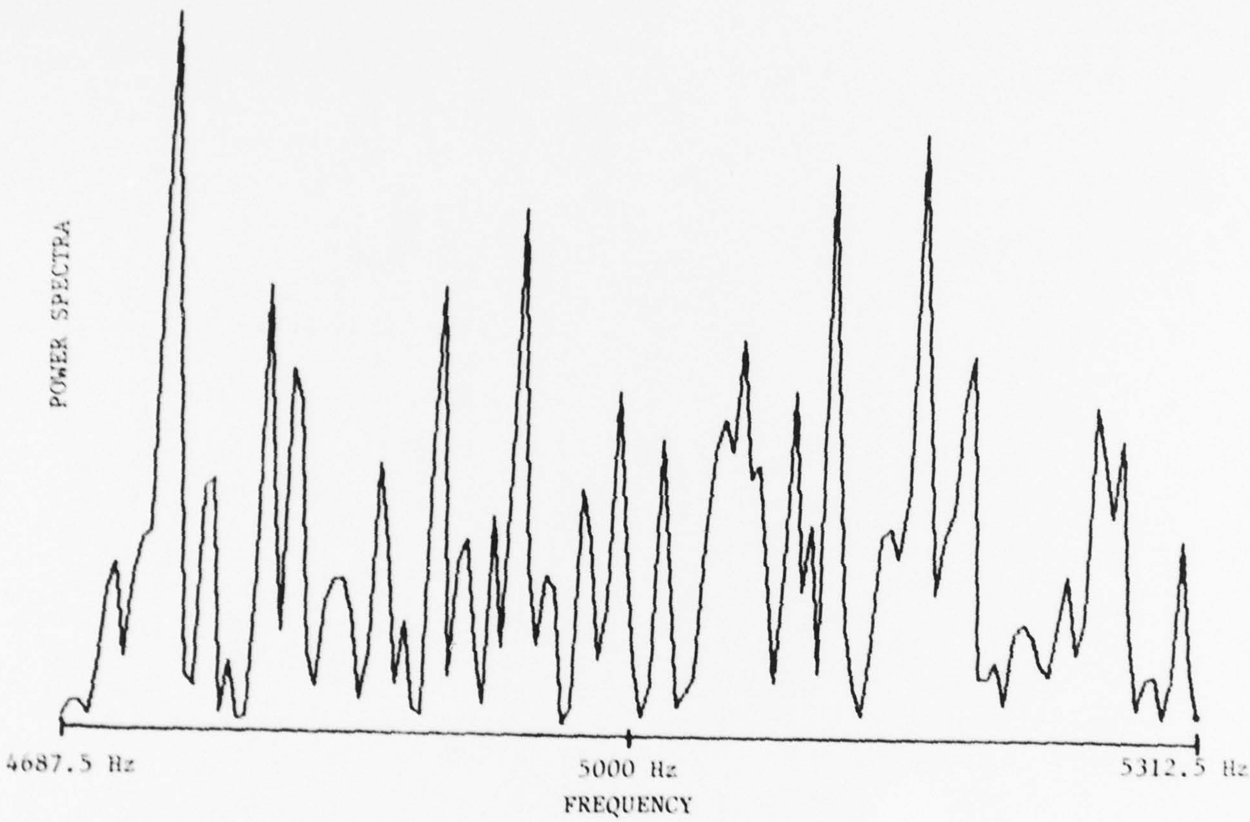

FIGURE 3

POWER SPECTRA OF STERN ASPECT SUBMARINE DATA (U)

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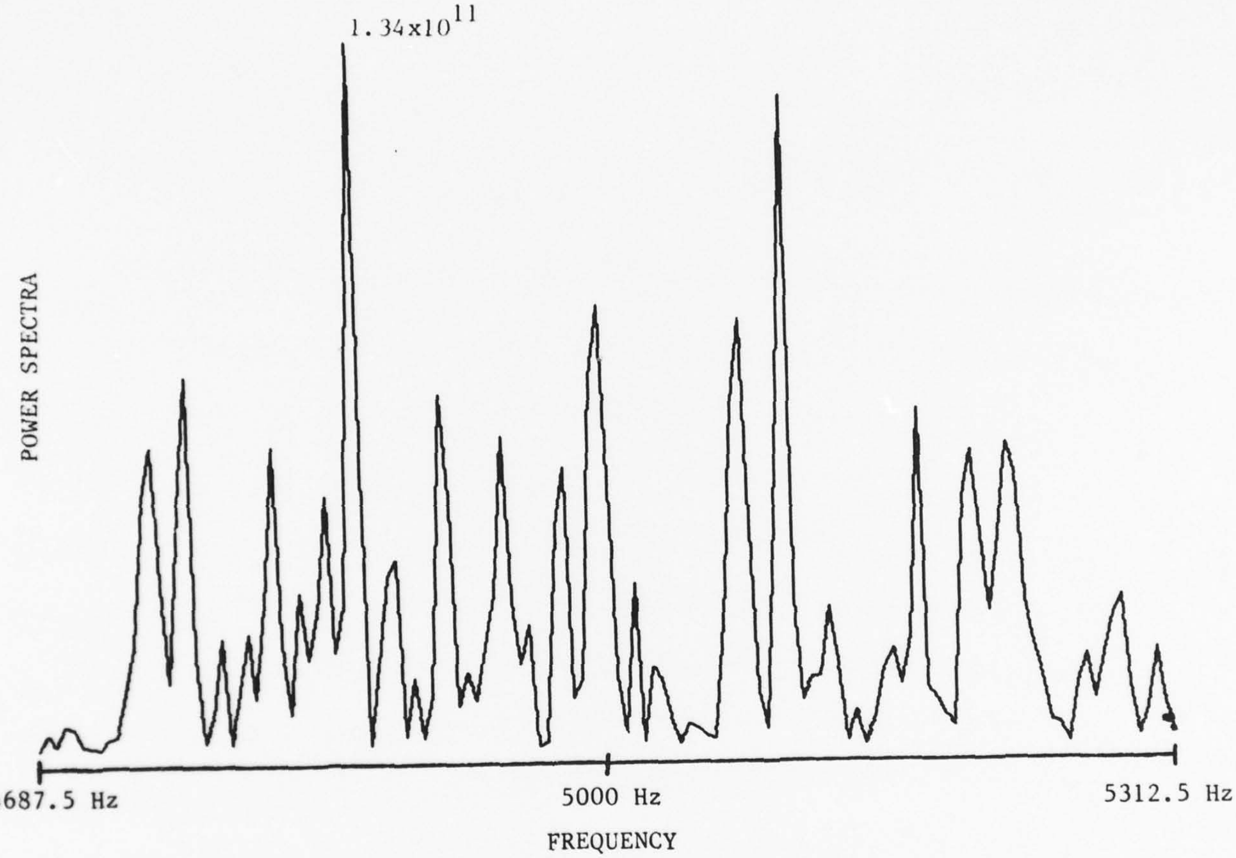

FIGURE 4

POWER SPECTRA OF STERN ASPECT SUBMARINE DATA (U)

SEQUENCE: 31
TAPE: 76

DRL - UT
AS-68-1016
GEE:gk
8-1-68

(C) of the power spectra for the reverberation shown in Figs. 5 and 6 are not much different than those for the stern aspect. It is felt that the peaks in the reverberation spectra will be randomly spaced and will not transform back to give apparent highlights, but this remains to be seen.

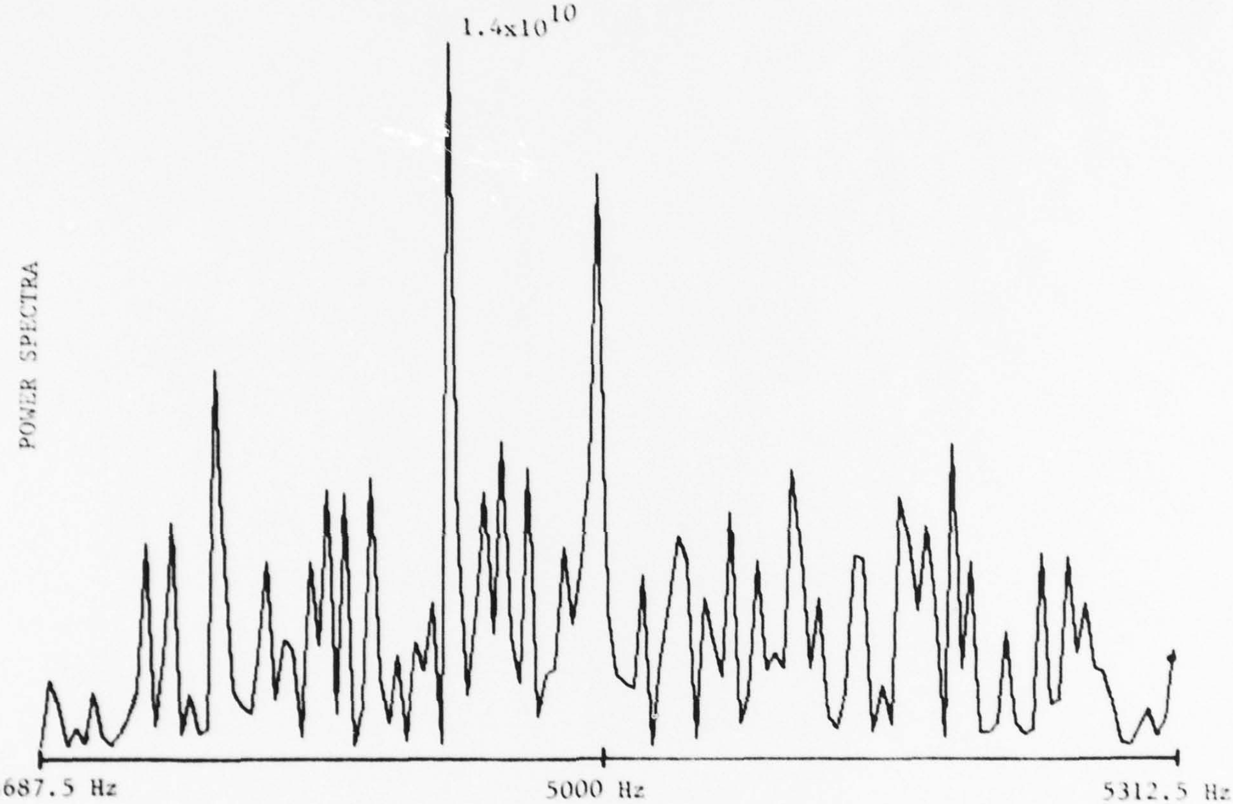

FIGURE 5

POWER SPECTRA OF REVERBERATION DATA (U)

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GEE:gk
8-1-68

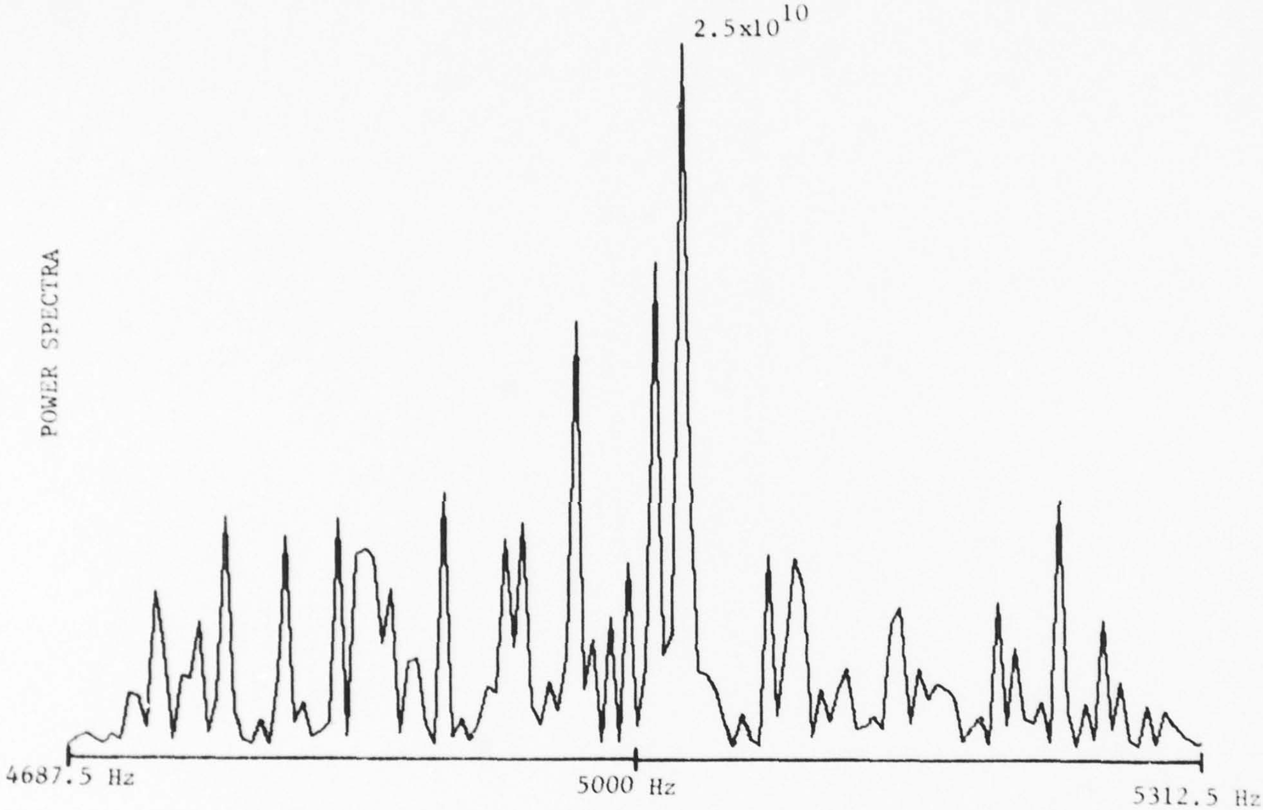

FIGURE 6

POWER SPECTRA OF REVERBERATION DATA (U)

SEQUENCE: 32
TAPE: 109

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AS-68-1018
GEE:gk
8-1-68

III. THREE-DIMENSIONAL PLOTS

(C) For active sonar a potentially powerful tool in signal processing is the detection of phase in returning highlights with respect to the transmitted signal. This phase information can be used in addition to locating highlights in time and measuring their amplitudes. As reported in Quarterly Progress Report No. 5 on Contract NObsr-95181 (U) it was demonstrated on artificial data that Medgyessy analysis (impulse response) would compute the phase, location in time, and amplitudes of highlights. However, with real data the present method of computing a Medgyessy analysis gives poor results. So far the results have been very fuzzy, looking much like white noise. This is attributed to the fact that narrow band data are treated as wide band data. The assumption is that noise outside the band is masking the expected result. It is felt that a smoothed Medgyessy analysis can be computed, but this has not been tried.

(U-~~FOUO~~) Another way of approaching the problem of phase detection is to process the data in quadrature.[*] With this type of processing, it is suggested that the results be displayed in three dimensions, $x(t)$, $y(t)$, and time t.[**] As an example, consider the two plots in Fig. 7. These plots were computed from artificial data where a linear FM upsweep was used as a transmitted signal. The difference between the two plots is the TW product. The transmit signal was crosscorrelated

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[*] O. D. Grace and S. P. Pitt, "Quadrature Sampling of High Frequency Waveforms," to be published in correspondence section of The Journal of the Acoustical Society of America.

[**] Narrow band signal $s(t) = x(t) \cos \omega_0 t + y(t) \sin \omega_0 t$; x and y are the quadrature components and ω_0 is the carrier frequency.

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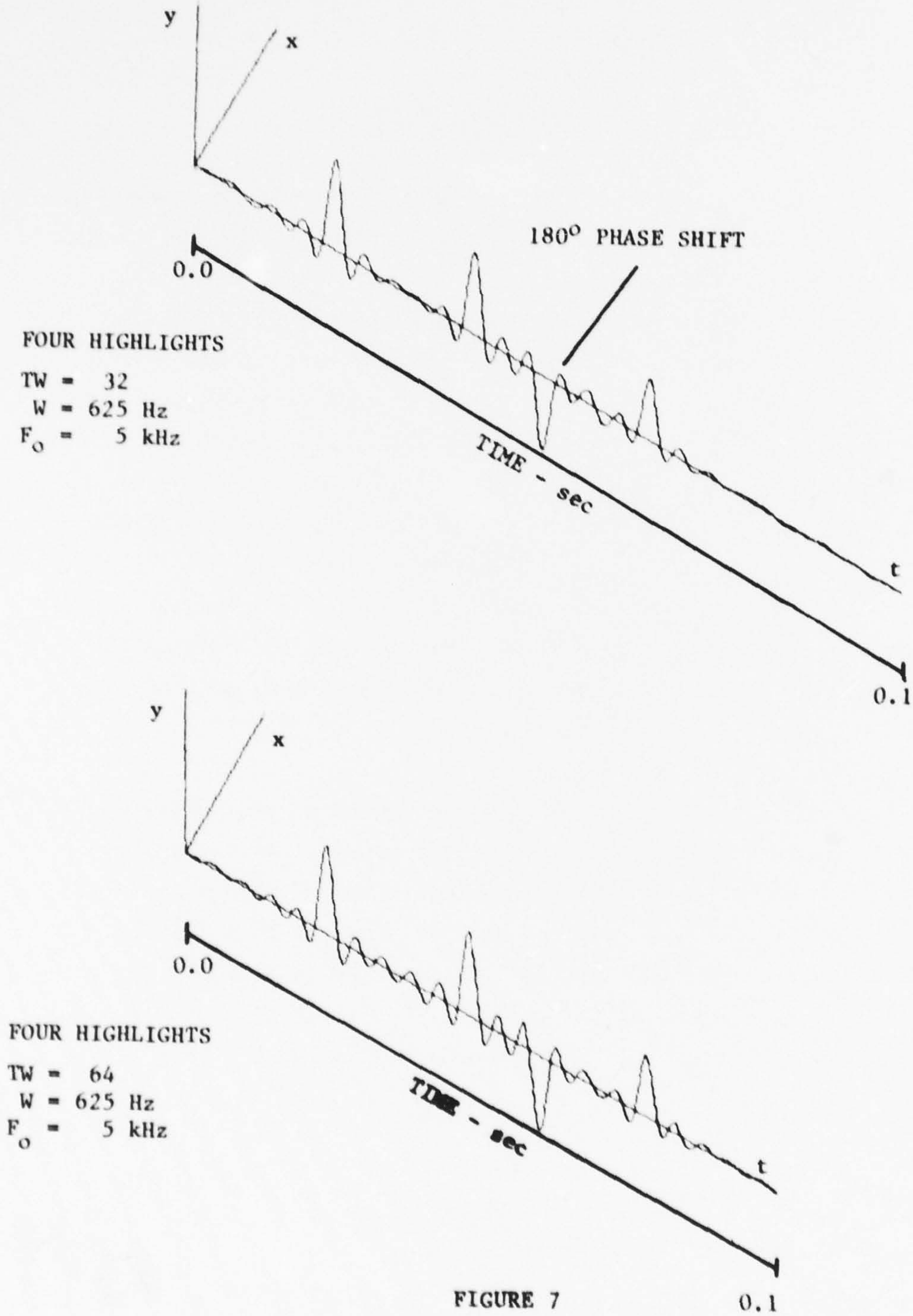

FIGURE 7

THREE-DIMENSIONAL PROJECTIONS OF TWO QUADRATURE SAMPLED CROSSCORRELATIONS (U)

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8-1-68

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with four returning highlights, where the third highlight was 180 deg out of phase with the transmitted signal. These curves demonstrate that the quadrature components of a crosscorrelation plotted in three dimensions will indicate phase, location in time, and amplitudes of highlights.

(C) Quadrature sampled crosscorrelations were computed for some bow aspect data. The results are shown in Fig. 8. It appears that the second and third returns are upside down (shifted 180 deg) with respect to the first return. Just how this happened is not certain. It is known that the target was snorkeling at a range of 3500 yd, and that the sea surface was glassy calm in this particular sea test. A pure conjecture is that the two returns are acoustic mirror images of the target from the surface, which would be shifted 180 deg.

(C) Another bow aspect is shown in Fig. 9, and consists of the quadrature sampled return and the crosscorrelation. These were sampled at a lower rate, and there is noticeable looping in the plots. The looping in the correlation looks a little suspicious, and one is always plagued by the thought that some obscure programming error has crept into the results. The point to be made by Fig. 9 is that the quadrature sampled return may produce a characteristic picture, but the results are difficult to interpret. However, the quadrature sampled crosscorrelation is "easy" to interpret. In particular, each main "blip" represents a highlight; its angle with respect to the y-axis represents its phase, and its position on the t-axis represents its location in time. It is clear that there is phase distortion of the highlights in the real data. That is, some of the "blips" are neither straight up nor straight down (0 deg or 180 deg). This is difficult to see on a two-dimensional surface; some stereoscopic views (not shown) were made of the returns and of the correlations. These were made by producing a plot similar to Fig. 9 in red color, rotating the time-axis 5 deg about the y-axis,

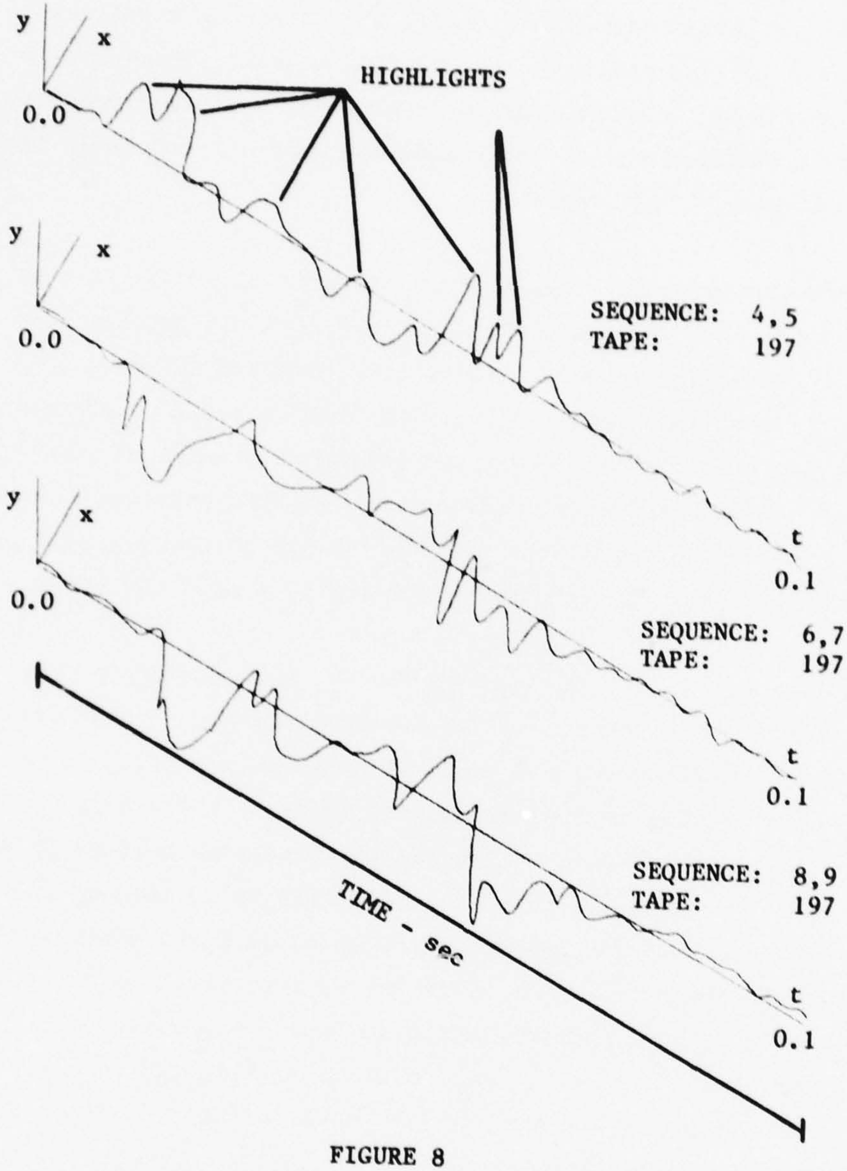

FIGURE 8

THREE QUADRATURE SAMPLED CROSSCORRELATIONS

FOR BOW ASPECT SUBMARINE (U)

TW = 32

W = 625 Hz

F_o = 5 kHz

LINEAR FM UPSWEEP

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GEE:gk
8-1-68

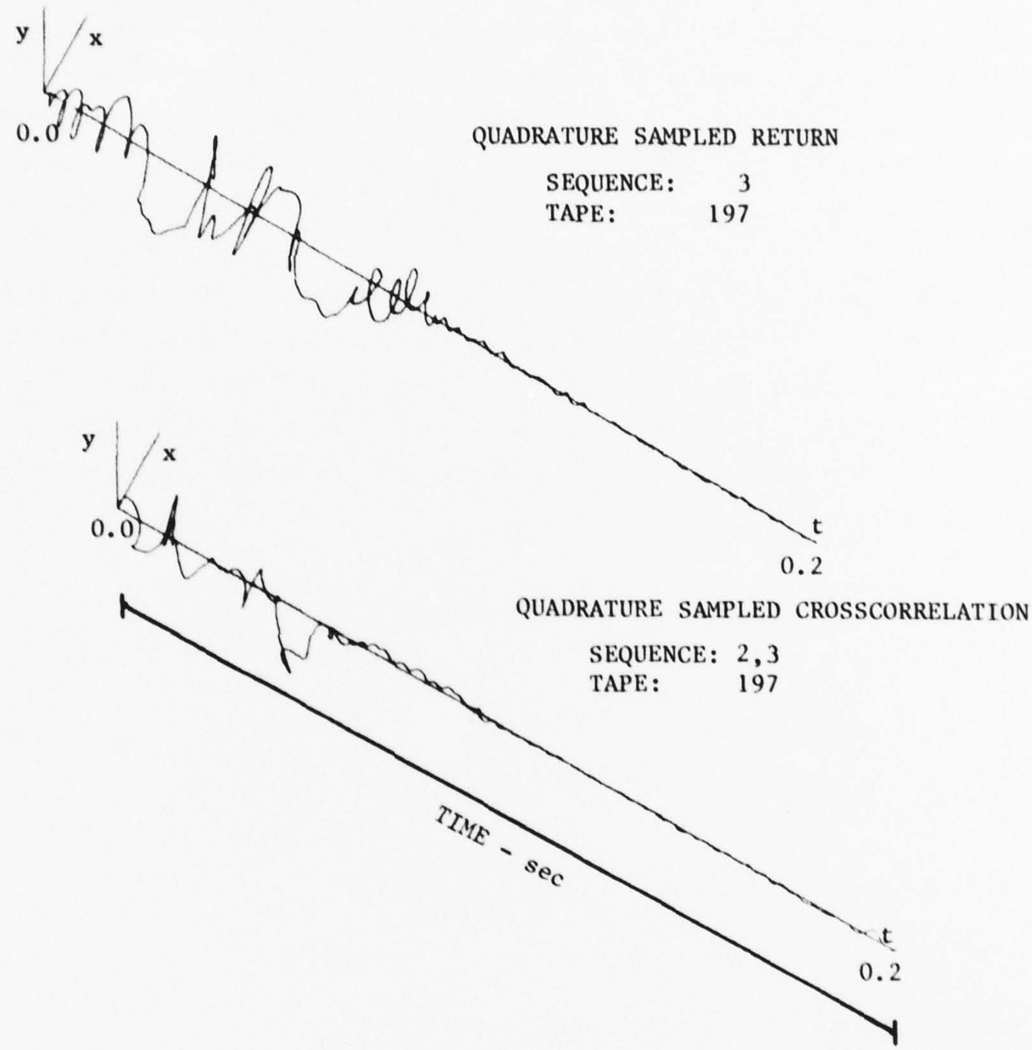

FIGURE 9

QUADRATURE SAMPLING (U)

TW = 32
W = 625 Hz
F_o = 5 kHz

LINEAR FM UPSWEEP

DRL - UT
AS-68-1021
GEE:gk
8-1-68

and plotting a second projection in green color. When viewed through color filters (red for one eye and green for the other), the result appears as a single black line projected above the paper background. With a little practice, the data can be seen spiraling around the time-axis, and in theory at least, one can see phase distortion, amplitude, and location in time, all in one picture.

(U-FOUO) If it is felt that displaying sonar returns in three dimensions would be of value, then in practice it would be an easy thing to do. For example, a color television could be used to project the two stereoscopic views in different colors and then the results viewed through different colored lenses. This is well within the capabilities of present technology.

IV. LAG WINDOWS FOR CEPSTRUM

(U-~~FOUO~~) In Quarterly Progress Report No. 6 on Contract NObsr-95181 (U), it was stated that the basic shape of the lag window applied to the autocorrelation dominates the shape of the Cepstrum. A good solution to this problem is found to be a clipped cosine bell.

(U-~~FOUO~~) To see the significance of this, Fig. 10 shows a lagged Cepstrum computed with three different lag windows. Window HANN 111 is

$$1/2(1 + \cos \pi t/T_m) \quad ; \quad 0 \leq t \leq T_m \quad ,$$

where T_m is the greatest lag time. The result is certainly smoothed, but all of the interesting highlights were wiped out. The HANN 212 is

$$1/2(1 + \cos \frac{\pi}{2} t/T_m) \quad ; \quad 0 \leq t \leq 2\,T_m \quad .$$

The result is a stretched HANN 111; but the autocorrelation was truncated at T_m, and this introduces a spike into the Cepstrum which HANN 212 does not smooth enough. The clipped cosine bell is

$$1 \quad , \quad 0 \leq t \leq 0.9\,T_m$$

$$1/2\left(1 + \cos \pi \frac{t - 0.9\,T_m}{0.1\,T_m}\right) \quad , \quad 0.9\,T_m \leq t \leq T_m \quad ,$$

which means that the last 10 percent of the autocorrelation is smoothed, and the remaining 90 percent is unbiased. This gives a

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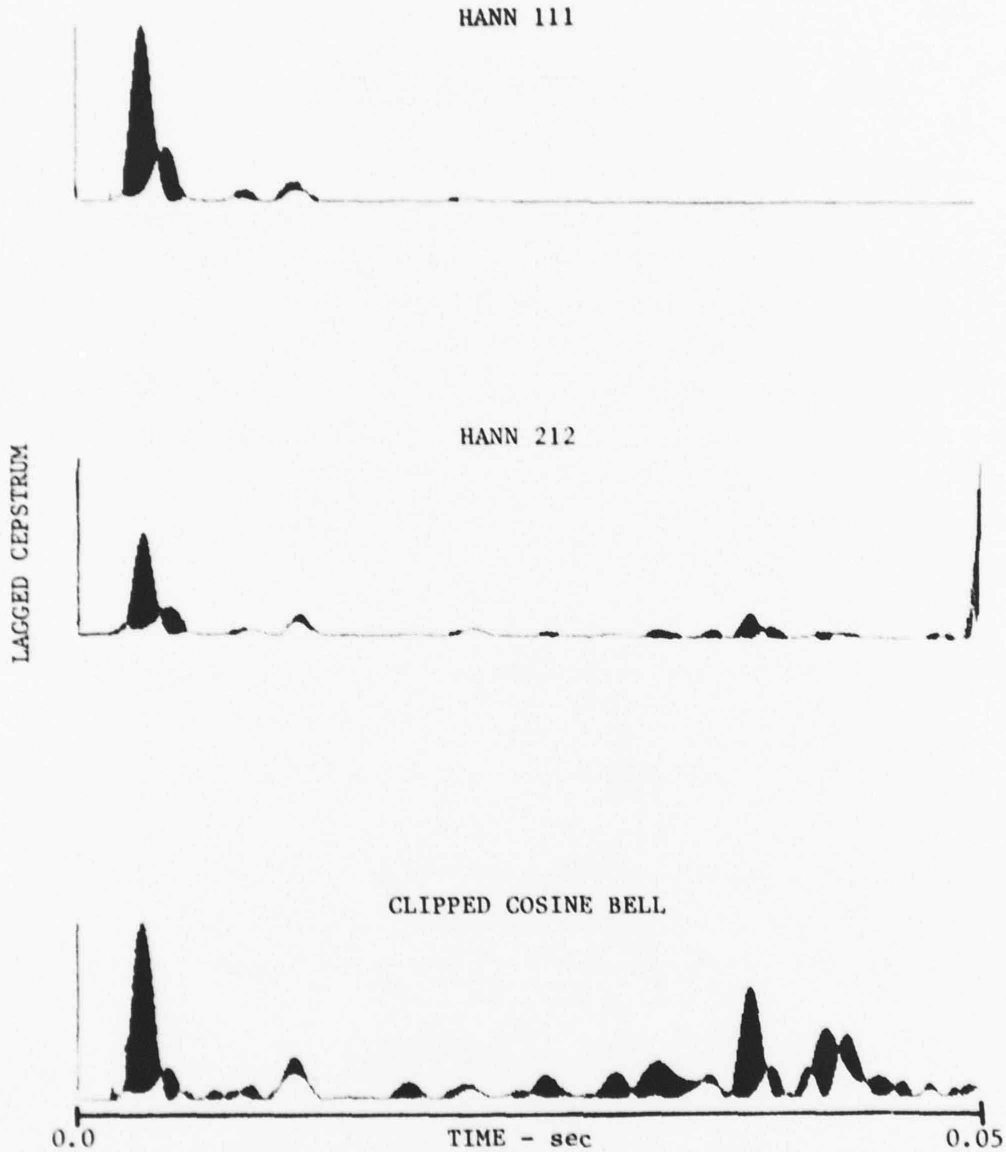

FIGURE 10

EXAMPLES OF THREE WINDOWS USED IN LAGGED CEPSTRUM (U)

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TAPE: 197

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GEE:gk
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good result in the Cepstrum. The highlights are unbiased, and the spike at the point of truncation T_m is smoothed to zero.

(U) Using the clipped cosine window, some time varying Cepstrums were computed for bow aspect data. The envelopes of the Cepstrum were computed and are plotted in Figs. 11, 12, 13, 14, and 15. The original data records of each return consisted of 6000 points sampled at four times the carrier frequency F_o = 5 kHz. The transmitted signal was a linear FM upsweep with a bandwidth W = 625 and TW = 32. On each return, five overlapping blocks of data were taken and a lagged Cepstrum was computed for each block. Each block consisted of 2596 points, and 1500 lags were taken for each Cepstrum. The sampling epoch of each block was shifted by 500 points, starting at point number one. The time between points is DT = 1.0/20000 Hz. Therefore, 500 points represent 500/20000 Hz = 0.025 sec.

(U) The most significant feature of this analysis is to show that the Cepstrum results are almost independent of the sampling epoch. The target resolution in all five returns started around point number 1500. If the sampling epoch starts within 500 points or 0.025 sec of the target resolution, then the Cepstrum results are about the same. This is a good feature of Cepstrum and gives it an advantage over other types of data processing that depend on a sampling epoch coinciding with target resolution for pattern recognition.

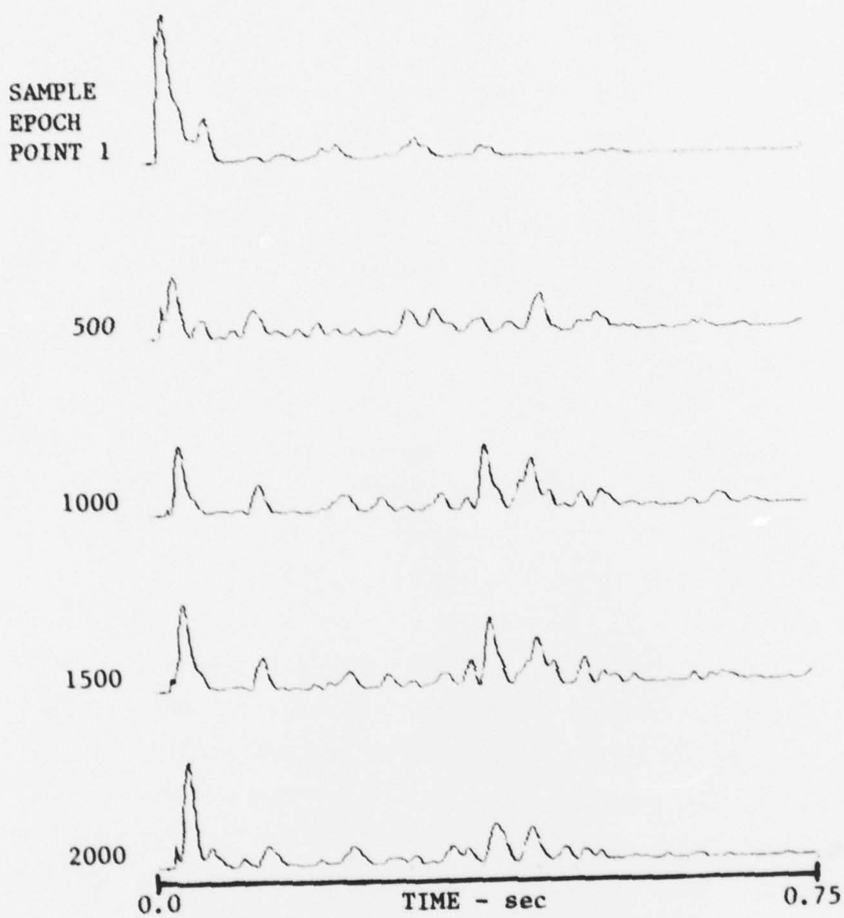

FIGURE 11

TIME-VARYING LAGGED CEPSTRUM ENVELOPE

FOR BOW ASPECT SNORKELING SUBMARINE (U)

SEQUENCE: 3
TAPE: 197

TW = 32
W = 625 Hz
F_o = 5 kHz

LINEAR FM UPSWEEP

DATA LENGTH: 2596 POINTS
max LAG: 1500

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8-1-68

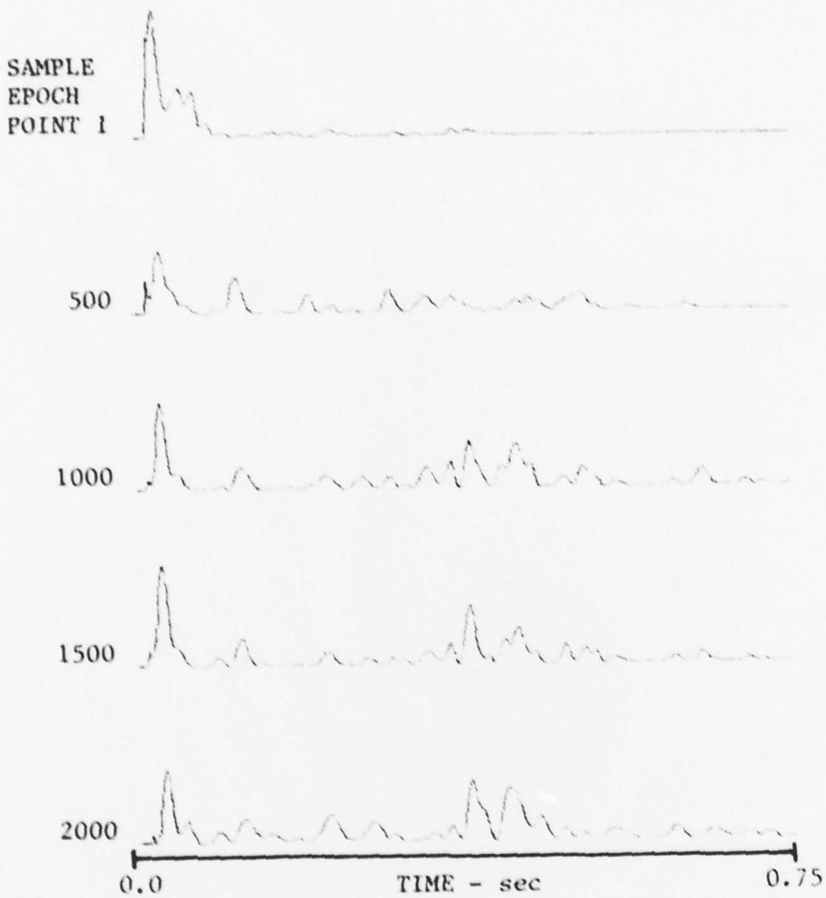

FIGURE 12

TIME-VARYING LAGGED CEPSTRUM ENVELOPE

FOR BOW ASPECT SNORKELING SUBMARINE (U)

SEQUENCE: 5
TAPE: 197

TW = 32
W = 625 Hz
F_o = 5 kHz

LINEAR FM UPSWEEP

DATA LENGTH: 2596 POINTS
max LAG: 1500

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GEE:gk
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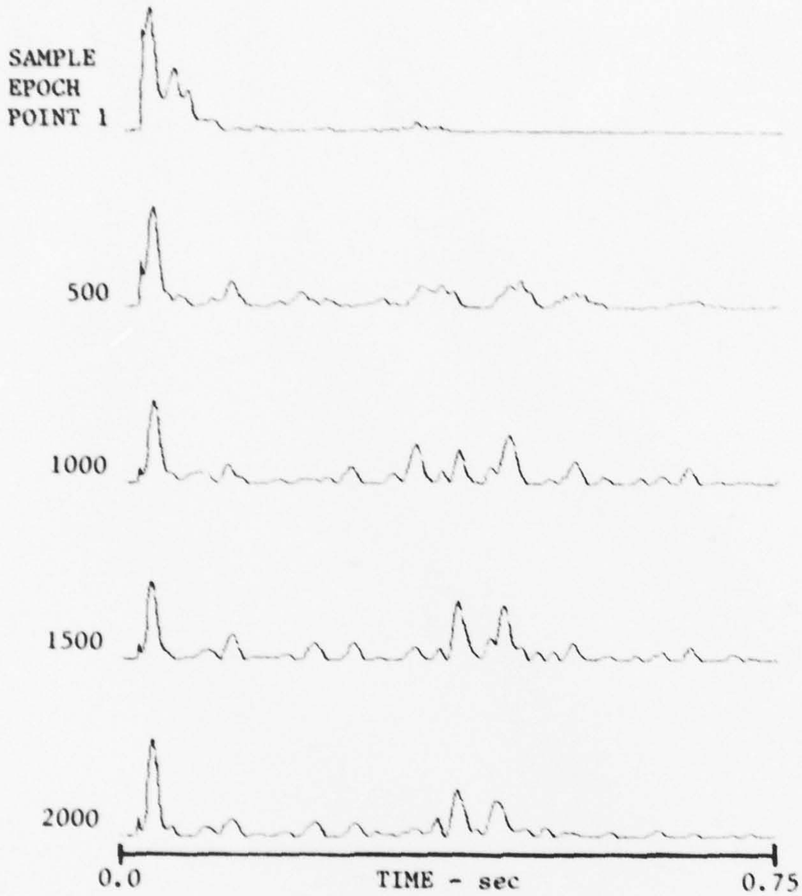

FIGURE 13

TIME-VARYING LAGGED CEPSTRUM ENVELOPE

FOR BOW ASPECT SNORKELING SUBMARINE (U)

SEQUENCE: 7
TAPE: 197

TW = 32
W = 625 Hz
F_o = 5 kHz

LINEAR FM UPSWEEP
DATA LENGTH: 2596 POINTS
max LAG: 1500

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GEE:gk
8-1-68

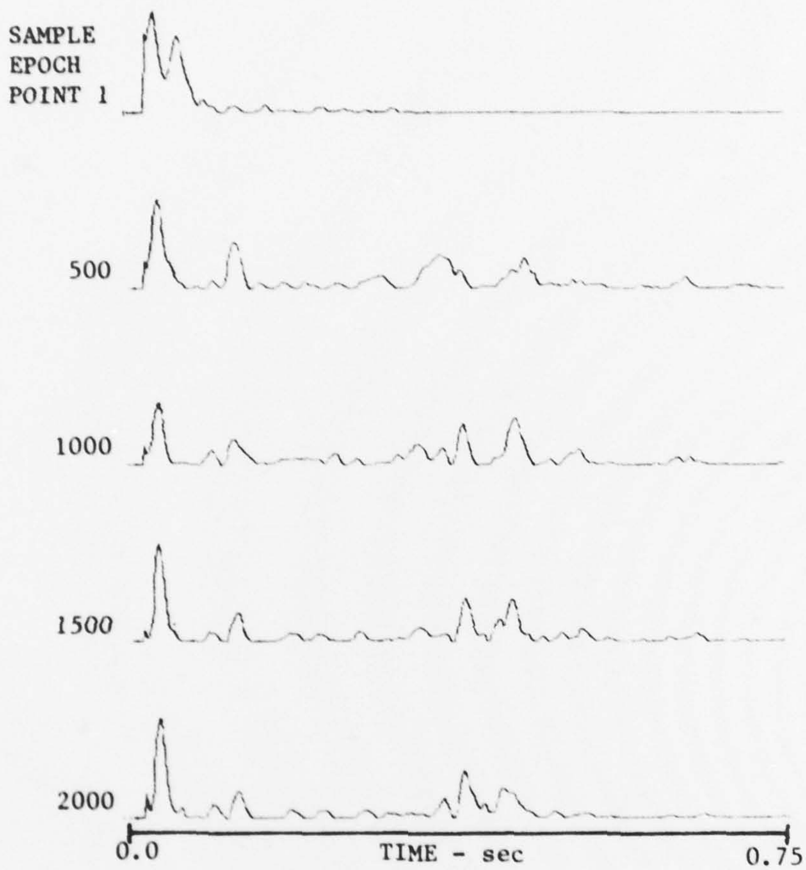

FIGURE 14

TIME-VARYING LAGGED CEPSTRUM ENVELOPE

FOR BOW ASPECT SNORKELING SUBMARINE (U)

SEQUENCE: 9
TAPE: 197

TW = 32
W = 625 Hz
F_o = 5 kHz

LINEAR FM UPSWEEP
DATA LENGTH: 2596 POINTS
max LAG: 1500

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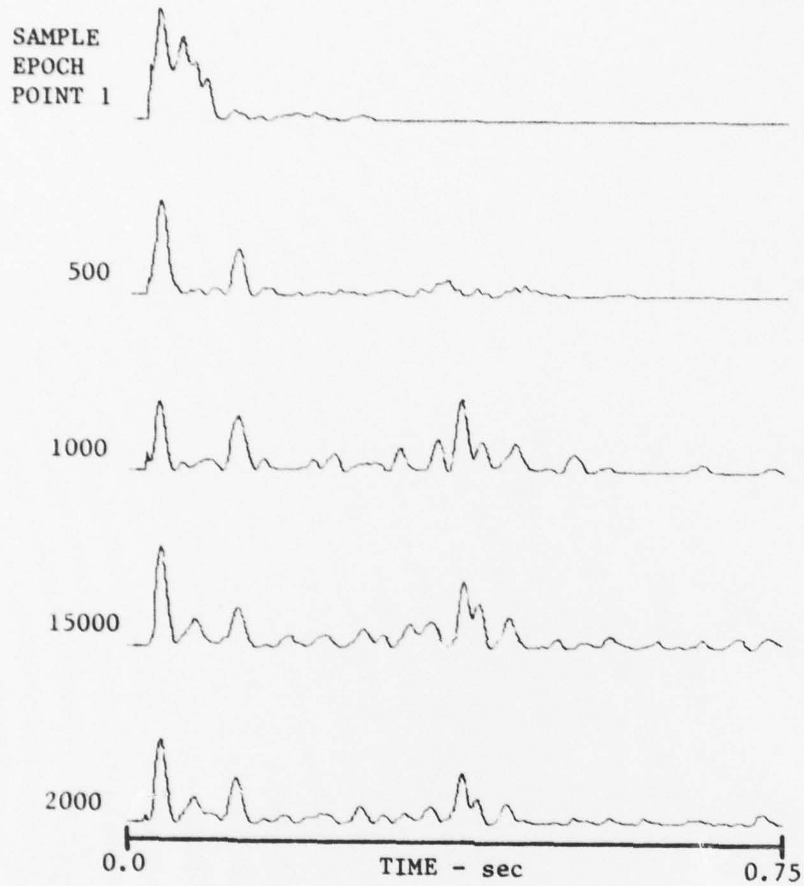

FIGURE 15

TIME-VARYING LAGGED CEPSTRUM ENVELOPE

FOR BOW ASPECT SNORKELING SUBMARINE (U)

SEQUENCE: 11
TAPE: 197

TW = 32
W = 625 Hz
F_o = 5 kHz

LINEAR FM UPSWEEP

DATA LENGTH: 2596 POINTS
max LAG: 1500

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V. MEETING WITH TEXAS INSTRUMENTS, INC.

(U-~~FOUO~~) On 29 May 1968 a technical meeting was held between the Texas Instruments' Equipment Branch and the DRL Computer Science Division. TI was represented by Messrs. MacDonald and Rice and Dr. Spitznoggle. DRL was represented by Messrs. Ellis and Shooter and Miss Webb.

(U-~~FOUO~~) The purpose of the meeting was to discuss applications of curve fitting techniques that have been implemented by TI. As an introduction to DRL, Mr. Rice agreed to make an analysis of some unequally spaced time-series data supplied by Miss Webb. The data represent the light modulation of stars and is of no interest to the Navy except as a demonstration of a type of analysis.

(U-~~FOUO~~) Since DRL is interested in pattern recognition, it is suggested by TI that if an equation were computed describing a spectrum or a correlation (pattern), then it might be easier to detect differences between equations than, for example, correlations.

(U-~~FOUO~~) These ideas will be pursued further, and the results of Mr. Rice's analysis will be reported later.

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Commander
Naval Ship Systems Command (SHIPS 00V1C)
Department of the Navy
Washington, D. C. 20360

Dear Sir:

Fig. 7 entitled, "Three-Dimensional Projections of Two Quadrature Sampled Crosscorrelations" (U) and Fig. 10 entitled, "Examples of Three Windows Used in Lagged Cepstrum" (U) in Quarterly Progress Report No. 7 (U) under Contract NObsr-95181 were classified CONFIDENTIAL in error. Fig. 7 was numbered AS-68-1019 and Fig. 10 was numbered AS-68-1022. Both figures were dated 8-1-68. They are UNCLASSIFIED.

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