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SUS SIGNAL DATA PROCESSING(U)

FINAL REPORT ON INVESTIGATIONS CONDUCTED UNDER THE DIAGNOSTIC PLAN FOR CHURCH ANCHOR AND SQUARE DEAL SHOT DATA(U)

by

M. S. Weinstein (USI)
G. Ellis (ARL/UT)

April 14, 1975

NATIONAL SECURITY INFORMATION
Unauthorized Disclosure
Subject to Criminal Sanctions

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The CHURCH ANCHOR and SQUARE DEAL Exercises were concerned with acquiring environmental acoustic data for two ocean areas. A large number of explosive signals (SUS) were used to measure acoustic propagation loss. Signals were received and recorded on a number of different systems. Subsequently, these data were processed by a number of different organizations.

An examination of preliminary data disclosed a number of possible discrepancies and unusual features. These included unusual (Contd)

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features in a number of CHURCH ANCHOR propagation loss plots, different propagation loss values obtained when the same recorded data was processed at different laboratories, and propagation loss measurements made with one array significantly lower than measurements made with another system in the same general area of the SQUARE DEAL experiment, although the runs compared were for different tracks.

An investigation, referred to as a "diagnostic plan", was subsequently undertaken to investigate these matters. This document reports the results of that investigation. It was found possible to explain or correct for most of the discrepancies.

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ABSTRACT(U)

(U)The CHURCH ANCHOR and SQUARE DEAL Exercises were concerned with acquiring environmental acoustic data for two ocean areas. A large number of explosive signals (SUS) were used to measure acoustic propagation loss. Signals were received and recorded on a number of different systems. Subsequently, these data were processed by a number of different organizations.

(U)An examination of preliminary data disclosed a number of possible discrepancies and unusual features. These included:

- A number of CHURCH ANCHOR propagation loss plots contained features which were not readily understood. These features had an apparent correlation with temporal variations in ambient noise, and generally occurred when the signal to noise ratio was poor.
- Different propagation loss values were obtained when the same recorded data was processed at different laboratories.
- Propagation loss measurements made with the Western Electric survey array were significantly lower than measurements made with the ACODAC system in the same general area of the SQUARE DEAL experiment. Although the runs compared

were for different tracks, the propagation loss differences were sufficiently high to question the validity of the results.

(U)An investigation, referred to as a "diagnostic plan", was subsequently undertaken to investigate these matters. This document reports the results of that investigation.

(U)It was found that by applying advanced analytic techniques the CHURCH ANCHOR data could be edited to remove spurious data which had been introduced by the combination of poor signal to noise ratio and ambient noise fluctuations. Some of the reasons for the different propagation loss values obtained by various organizations when processing recorded data were identified, and a statistical analysis was performed to establish probable accuracy levels. The difference in propagation loss measurements made with the ACODAC and the survey array was determined to be due, at least in part, to significantly different bottom loss conditions along the two paths.

EXECUTIVE SUMMARY(U)

(U)The CHURCH ANCHOR and SQUARE DEAL Exercises were concerned with acquiring environmental acoustic data for two ocean areas. A large number of explosive signals (SUS) were used to measure acoustic propagation loss. Signals were received and recorded on a number of different systems. Subsequently, these data were processed by a number of different organizations.

(U)An examination of preliminary data during May and early June 1974 disclosed a number of possible discrepancies and unusual features. These included:

- A number of CHURCH ANCHOR propagation loss plots contained features which were not readily understood. These features had an apparent correlation with temporal variations in ambient noise, and generally occurred when the signal to noise ratio was poor.
- Different propagation loss values were obtained when the same recorded data was processed at different laboratories.
- Propagation loss measurements made with the Western Electric survey array were significantly lower than measurements made with the ACODAC system in the same general area of the SQUARE DEAL experiment. Although the runs compared

were for different tracks, the propagation loss differences were sufficiently high to question the validity of the results.

(U)In order to investigate these matters, a Diagnostic Plan was developed and forwarded to the Manager, Long Range Acoustic Propagation Project (LRAPP). This plan was approved by the Manager, LRAPP, on June 19, 1974. The plan was subsequently modified and expanded as interim results indicated the need therefor.

(U)The plan called for investigations in three specific areas:

- CHURCH ANCHOR data editing.
- Data processing comparisons and accuracy analyses.
- Model computation comparisons with data from the SQUARE DEAL Exercise.

(U)The CHURCH ANCHOR data was edited to a level satisfactory for use in the final report. This was accomplished by eliminating data points demonstrated to be artifacts because of poor signal to noise ratio. Guidelines have been developed and established for future editing of propagation loss data.

(U)The data processing comparisons and accuracy analysis provided an understanding of the reasons for the observed differences in propagation loss when data is processed at different facilities. Small differences can be introduced by a number of different factors. These include:

- Variability of results when the same recording is processed at the same facility at different times.
- Differences between duplicates and original recordings.
- Differences between digital (FFT) and analog (filter) processing.
- Differences in the signal integration time at different facilities.
- Differences in procedures for estimating ambient noise levels.

(U)The propagation loss values determined by ARL have been used as a base for comparison with the results obtained at other facilities. ARL and NUSC comparisons were made using recordings from three ACODAC hydrophones used in SQUARE DEAL for the 25, 50 and 160 Hz bands. Subtracting the NUSC propagation loss values from the ARL values yielded average differences of +0.5 to -1.0 dB, with standard deviations of 0.4 to 0.7 dB. Using two ACODAC hydrophones and the frequency bands of 50, 100, and 200 Hz, the comparable values for the comparison with WECO processing were +1.2 to -0.5 dB for the average values, and 0.6 to 1.2 dB for the standard deviations. Thus, these three processing systems (ARL - WECO - NUSC) yield very comparable results with no significant bias of average propagation loss. By contrast the comparable figures for the comparison of ARL and WHOI data for three hydrophones and the 50 Hz band are 1.2 to 2.4 dB for the average values and 1.2 to 1.7 dB for the standard deviation, when the signal to noise ratio is greater than +3 dB. When the signal to noise ratio is between 0 and +3 dB, the average value and the standard deviation increase significantly. Thus, WHOI processing yields propagation loss values one to two decibels lower than those obtained at ARL, WECO, or NUSC.

(U)A comparison of the survey array and ACODAC propagation loss data with predictions showed reasonable agreement if the bottom loss along the track to the survey array is low, and the track to the ACODAC includes a high bottom loss segment at a distance greater than 200 nmi. Time expanded displays of the received signals have confirmed that the above bottom loss conditions are present. Part of the interpretive difficulty which arises is due to the limited amount of experimental data. The survey array data extends out to a maximum range of about 100 n.m.

By contrast the ACODAC is overloaded at short range, so that data points do not start to accumulate until the range is in excess of 100 n.m., and are sparse out to 200 n.m. Thus, the best that can be said is that the difference in SUS propagation loss observed with the ACODAC and survey array is consistent with the difference in the environment, and is not a basis, in itself, for questioning the accuracy of the data from either system.

SUS SIGNAL DATA PROCESSING (U)

1. Background (U)

(U) The CHURCH ANCHOR and SQUARE DEAL Exercises were concerned with acquiring environmental acoustic data for two ocean areas. A large number of explosive signals (SUS) were used to measure acoustic propagation loss. Signals were received and recorded on a number of different systems. Subsequently, these data were processed by a number of different organizations.

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- A number of CHURCH ANCHOR propagation loss plots contained features which were not readily understood. These features had an apparent correlation with temporal variations in ambient noise, and generally occurred when the signal to noise ratio was poor.
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- CHURCH ANCHOR data editing.
- Data processing comparisons and accuracy analyses.
- Model computation comparisons with data from the SQUARE DEAL Exercise.

(U)This document reports the results of that investigation.

2. Acknowledgements (U)

(U)The study reported herein was conducted under the direction of the Manager, LRAPP. The initial diagnostic plan was prepared by Dr. M. S. Weinstein of Underwater Systems, Inc., Mr. G. E. Ellis of the Applied Research Laboratories, University of Texas, and Mr. R. Nowak of the Woods Hole Oceanographic Institution. Dr. Weinstein coordinated the study on behalf of the Manager, LRAPP. He was ably assisted by Mr. W. E. Wallace of Underwater Systems, Inc. and Mr. G. E. Ellis, whose staff was responsible for a substantial portion of the data processing and interpretation discussed in the report, and also provided technical liaison with the participating facilities as the need arose.

(U)In regard to apparent differences in propagation loss observed between the ACODAC and WECO Survey Array systems, this report (Section 6) is limited to a discussion of the two tracks which suggested the existence of a problem. Mr. D. Sullivan of Arthur D. Little is separately comparing the propagation loss for a number of SUS and CW tracks, using data from the ACODAC and WECO survey array systems. His work should shed additional light on this problem, and will be reported separately.

(U)Other participating organizations and the respective Principal Investigators were as follows:

Acoustic Environmental Support Detachment (AESD)

Dr. J. S. Hanna

Naval Underwater Systems Center (NUSC)

Mr. R. Martin

Western Electric Co. (WECO)

Mr. R. Scudder

Others were called upon for assistance as needed.

(U)During the conduct of the study large discrepancies were observed in the processing of ambient noise data at WHOI when using duplicate tape recordings. A task team was assembled to assist in uncovering the cause of the difficulty. This team consisted of Dr. Weinstein of USI, Chairman, Mr. L. Breaker of NAVOCEANO, Mr. E. Mitchell of BK Dynamics, Inc., and Dr. A. F. Wittenborn of Tracor.

(U)The authors are indebted to Mr. W. E. Wallace of USI for preparation and assembly of this report under their direction.

3. Editing of CHURCH ANCHOR Data(U)

a. <u>Noise Correlation and Signal-to-Noise Ratio</u>(U)

(U)Initial plots of CHURCH ANCHOR SUS data derived from ACODAC recordings consisted of propagation loss (PL) vs. range and various types of PL differences between hydrophones or frequencies. Discounting the overload problem, which is very severe, the remaining data showed some peculiar and confusing results. Figure (1), taken from Reference (2), shows sample data, deliberately chosen as the worst, which illustrates the difficulty. Note that PL increases rather steadily with range except near 300 n.m., where the PL is anomalously low. The first clue to the cause of this anomaly was found when the ambient noise and S/N ratio plots were examined in conjunction with the PL plot. The three plots on the left of Figure (2) show this comparison for the event of Figure (1) (18 m source) south of the site. (The range scale in Figure (2) is reversed as compared to Figure (1) south of the site.) The three plots on the right show that the same effect is present with the 91 m source.

(U)The ambient noise level is exceptionally high when sources are near the 300 n.m. range (suspected to be due to radiation from a nearby ship), while the S/N ratio is low. This suggests that these PL measurements are invalid. To understand this effect, it is necessary to review how the PL measurements are made.

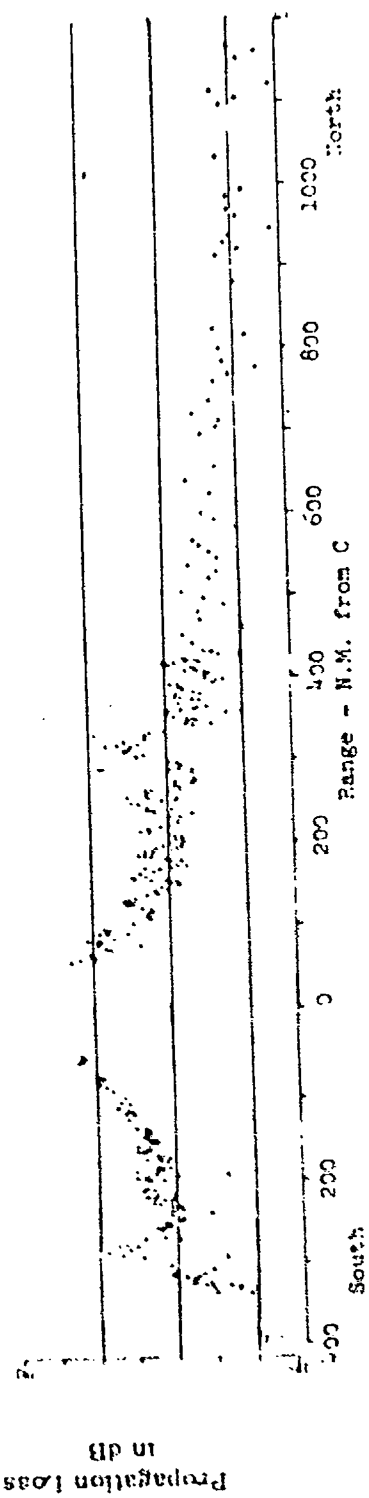


Figure (1). (C)Un-edited propagation loss curve (U).

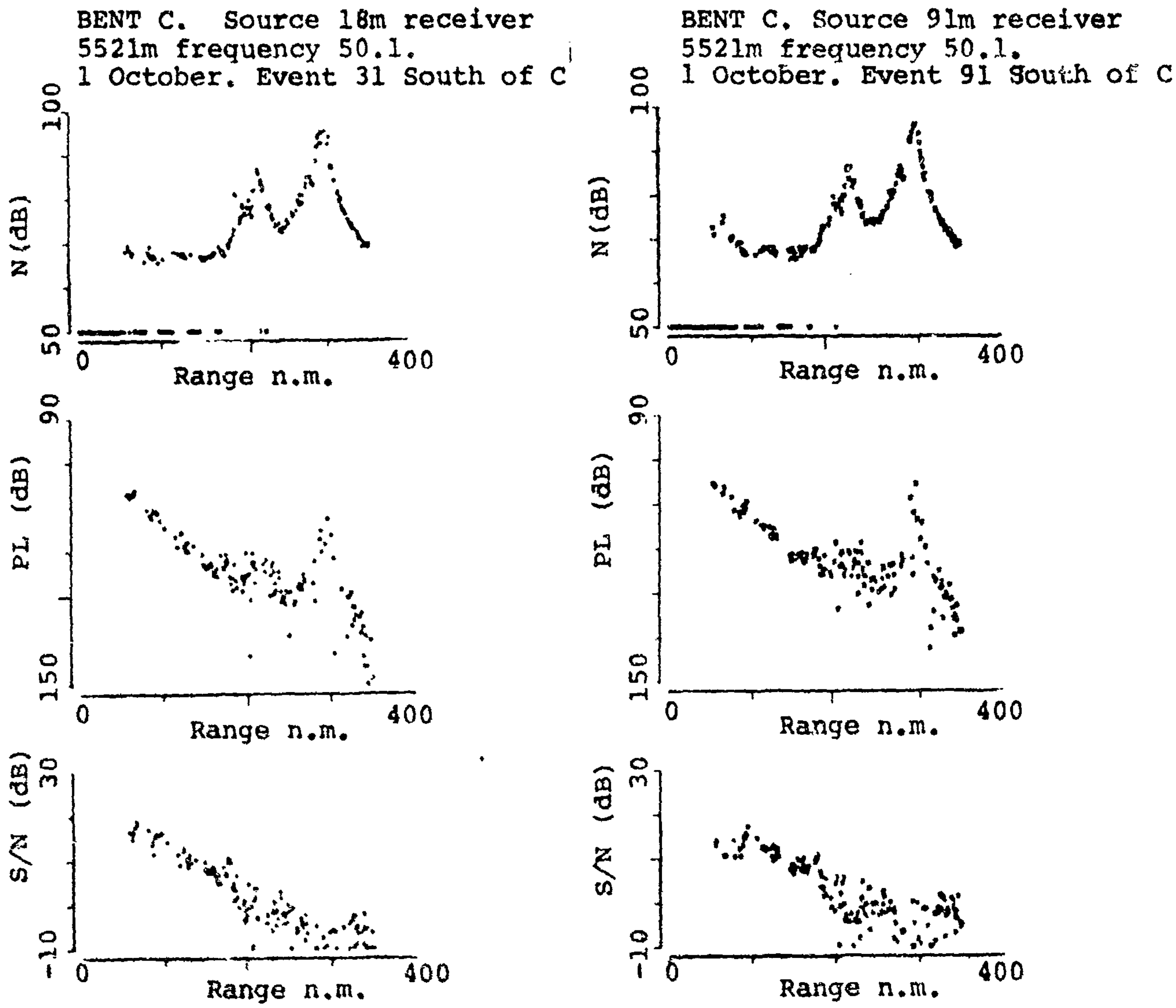


Figure (2). Example of propagation loss and noise correlation.

(U)To determine PL, the total energy of the SUS signal plus noise is measured during the period that a signal is received. A sample of the noise background is taken for the 10 seconds prior to the epoch of the signal. It is assumed that the best estimate of the noise component of the signal energy measurement is the noise in that 10 second period. The SUS energy is estimated by subtracting the measured noise energy from the total signal plus noise energy measured during the signal period.

(U)Figure (3) shows the error that may be introduced in the calculated PL as a function of S/N, by a change in the noise level that may have occurred between the noise measurement period and the signal measurement period. As can be seen the error increases as S/N decreases. For low signal to noise ratio an increase in the noise level between the noise and signal measurement periods causes the apparent propagation loss to decrease.

(U)To reduce this source of error we decided to impose strict S/N requirements on the data to be reported. Using only data with S/N > 3 dB removed many artifacts, but also removed many points which were apparently valid, leaving very few data points. The compromise arrived at was to reject data points with S/N < -3 dB, indicating on the plots the ranges of points so rejected, and to re-plot

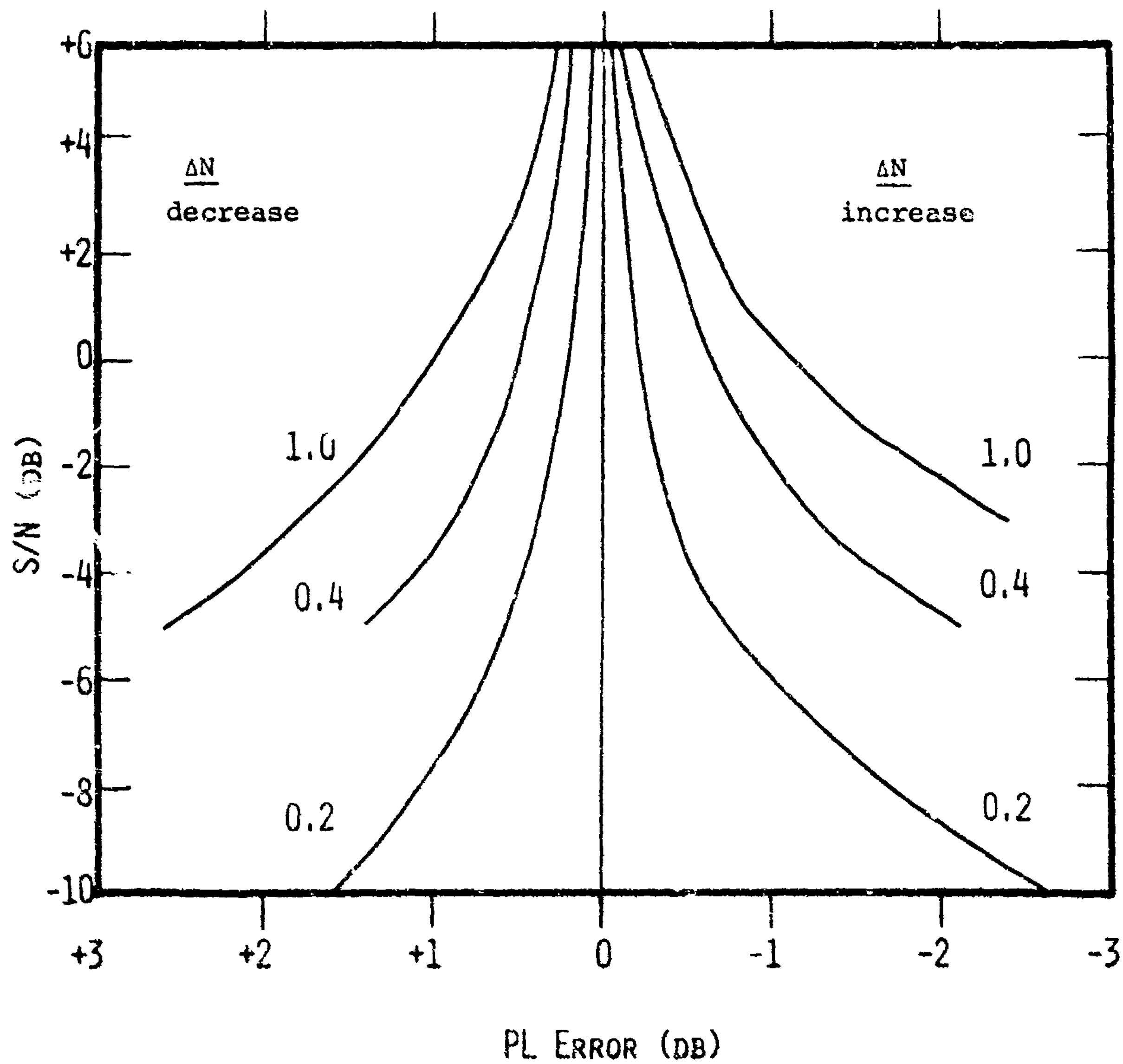


Figure (3). PL error as a function of S/N for indicated changes in noise level.

the remaining data using symbols to differentiate among data points with S/N > +3 dB, between 0 and +3 dB, and between -3 and 0 dB, thus permitting the user to exercise judgement in the acceptance of the data. Figure (4), taken from Reference (3), shows in the top portion the re-plot of Figure (1) (the scale of the reproduction requires the use of a magnifier to differentiate among the symbols). The symbols along the range scale indicate those data points omitted from the plot because of S/N < -3 dB. The symbols above the plot indicate the ranges at which overloads occurred. Note that while the elimination of low S/N data points has clarified the plot for the 18 m source, the anomaly at 300 n.m. south is still present for the 91 m source.

(U)One of the advantages of the above editing process is a reduction in the number of suspect data points. This permits the cost effective application of more advanced techniques for identifying artifacts. It is known that the nulls and peaks in the source spectrum, due to the bubble pulse, are retained in the spectrum of signals at long range. Fortunately, narrow band FFT processing was a part of the automated processing procedure, so that the spectra could be examined. If the signal spectrum looked like a shot the data point was accepted, if it did not it was rejected.

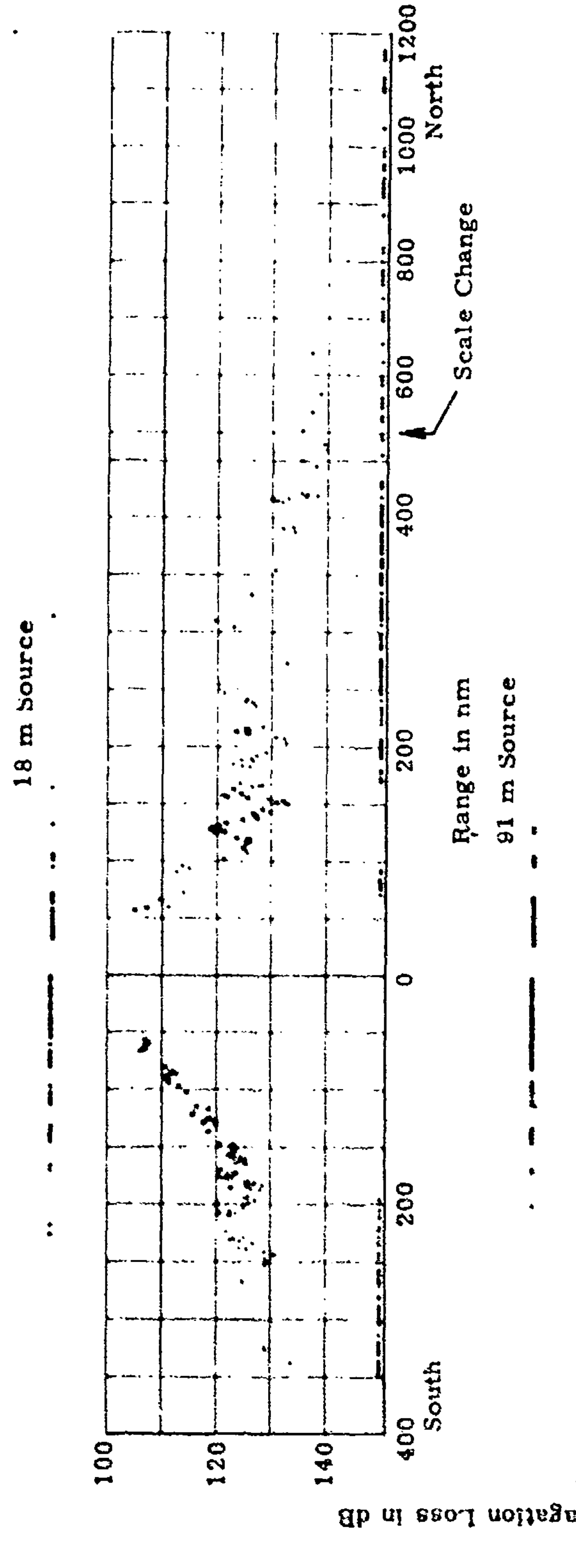


Figure (4). (C)PL curves with low S/N data points removed(U).

(U)The next set of figures, taken from Reference (4), compare spectra for contaminated and uncontaminated shots. Figure (5) shows the spectrum for signal plus noise on the left, and the noise alone at the right for a 300 foot shot for a high S/N ratio. Note that the signal plus noise shows pronounced scalloping with strong nulls spaced at about 25 Hz, consistent with the source spectrum. The noise spectrum is totally different. Figure (6) shows similar results for a lower S/N ratio. The signal plus noise spectrum is still good. Figure (7) shows the results for a contaminated sample. Note that the signal plus noise spectrum does not show the null sequence and is quite similar to the noise spectrum. This is a case where signal plus noise is dominated by a noise burst, and this data point is therefore rejected.

(U)Examining the remaining suspect data points and employing the criterion described, additional data points were rejected with the results shown in Figure (8), taken from Reference (5). The artifacts have been removed and the remaining data points may be relied upon. Further investigations of noise fluctuations permitted the establishment of estimated uncertainty bars in the various signal-to-noise bins, Reference (5).

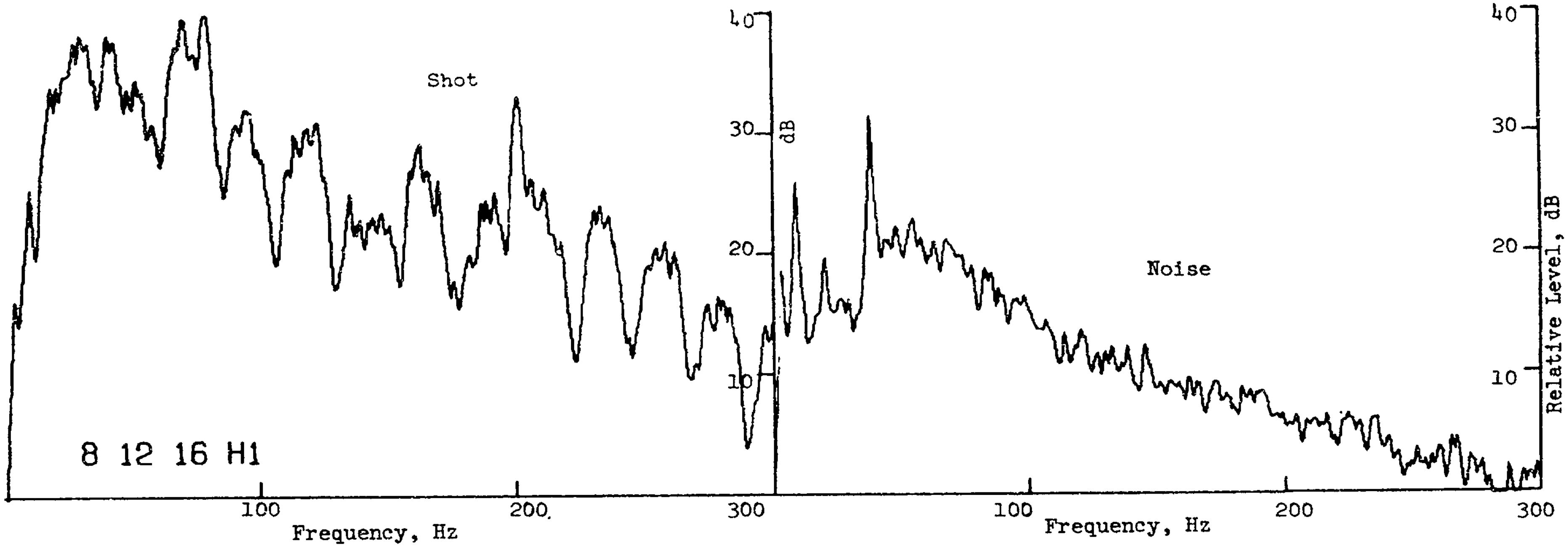


Figure (5). Power spectra of shots and noise - 8/1216/H1.
S/N at 50 Hz (1/3 octave) +13.2 dB.

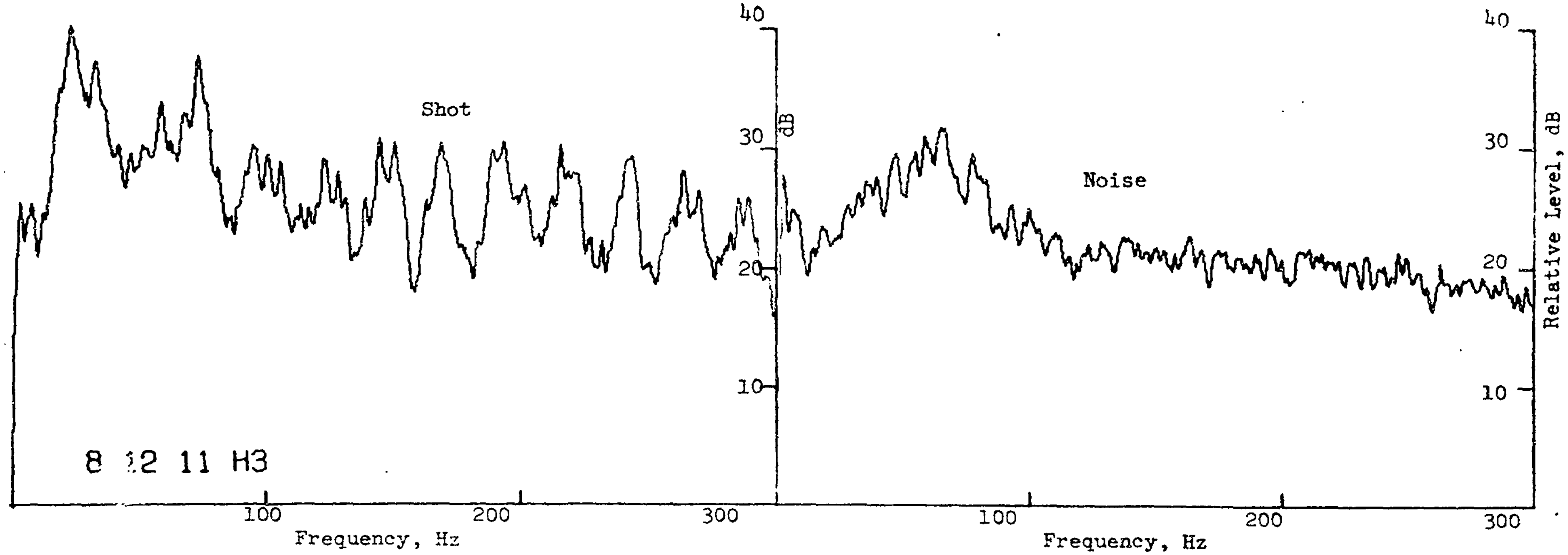


Figure (6). Power spectra of shots and noise - 8/1211/H3.
S/N at 50 Hz (1/3 octave) -2.6 dB.

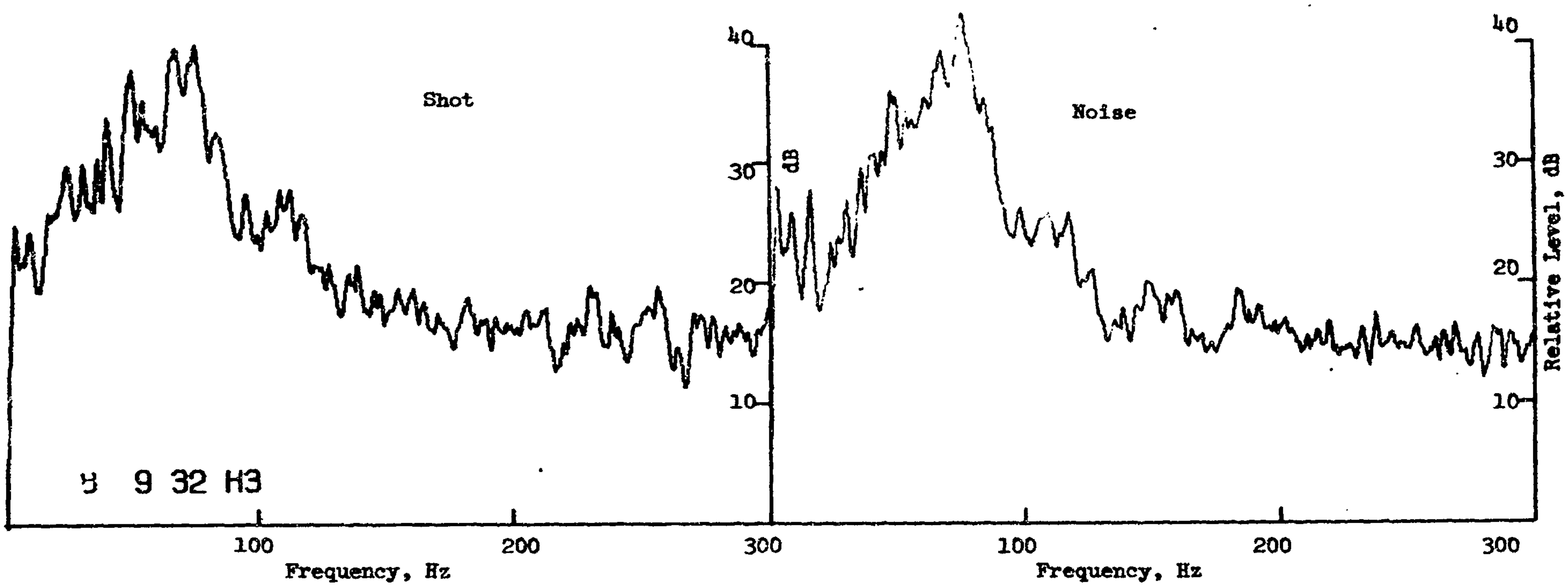


Figure (7). Power spectra of shots and noise - 8/0932/H3.
S/N at 50 Hz (1/3 octave) -16.6 dB.

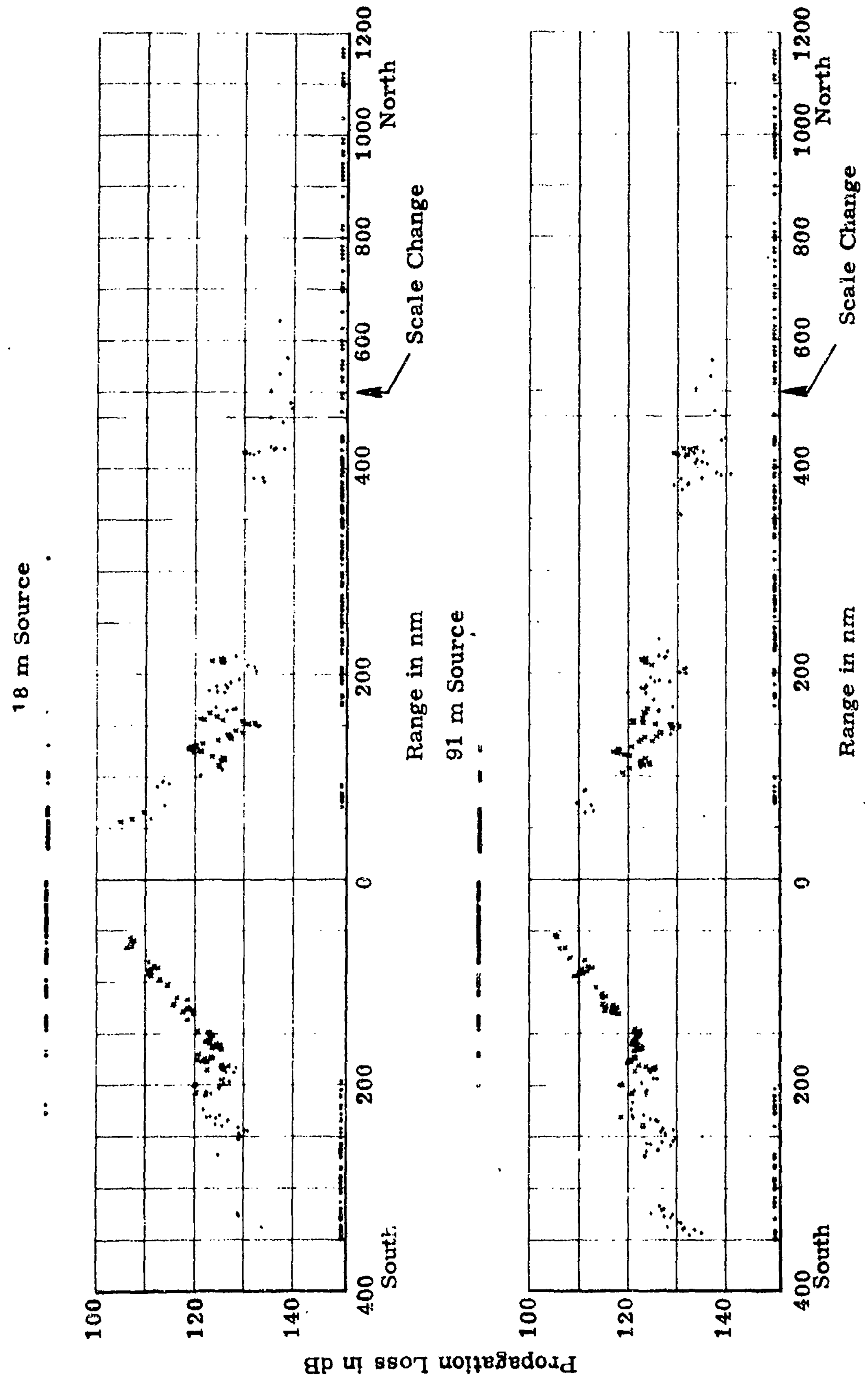


Figure (8). (C)Completely edited PL curves(U).

(U)The results discussed in this section so far are reported in more detail in References (4) and (6).

b. Other Investigations(U)

(U)Several other questions arose in the interpretation of the SUS propagation loss data obtained with the ACODAC system, which are unrelated to the above discussion of editing procedures. These were investigated and are reported in this section, for completeness.

(U)1. One set of data for a hydrophone at ACODAC Site D was remarkably free of overloads, and appeared to be an excellent set for model studies. Unfortunately, model computations were in marked disagreement out to about 300 n.m., and in fact the experimental PL appeared to be too high by any reasonable yardstick. It developed that the ACODAC overload indicator was inoperative, so this data set had to be rejected. This work is reported in Reference (7).

(U)2. It was observed that the replotted PL data appeared to be limited to a narrow range of values for each hydrophone. This was examined for internal consistency; no gross errors in ACODAC receiver gain were found. This is reported in Reference (8). Because of the logic employed in the ACODAC to set up the gain on the 800 foot shot, the range of PL measurements which can be made is determined by the ambient noise level and the dynamic range of the tape recorder, and not the peak signal level.

(U)3. Because of the large number of overloads no data is available for the shorter ranges. At somewhat longer ranges some of the data is overloaded and some is not. The presumption is that the propagation loss for the overloaded data would be lower than for the data which is acceptable. While this is probably true in most cases, it is noted that overloads are determined by the signal peak, while propagation loss also depends on the number of multipaths. Thus the propagation loss for some overloaded signals can be comparable to, or even somewhat lower than observed at adjacent ranges. An attempt was made to see if a maximum PL could be assigned to overloaded data as a qualitative aid to model evaluation. It was found that the maximum PL could be identified to only within about 10 dB. Thus, it does not appear that any of the overloaded data can be salvaged, even for qualitative purposes. The best that can be said is that the average PL in regions of substantial overload is likely to be somewhat less than indicated by the acceptable data. This will be discussed further in Section (6) of this report.

(U)4. One of the questions raised in the interpretation of the CHURCH ANCHOR data was whether the propagation loss determined with SUS and CW sources agreed. Although there were only a limited number of cases in which SUS and CW tracks overlapped, the agreement was reasonably good. An example is shown in Figure (9), taken from Reference (5). When the differences in PL for different frequencies, or different hydrophone depths are considered, the trends observed for the SUS and CW sources were also in reasonably good agreement. For this latter case SUS data was used only when the S/N ratio was higher than 0 dB.

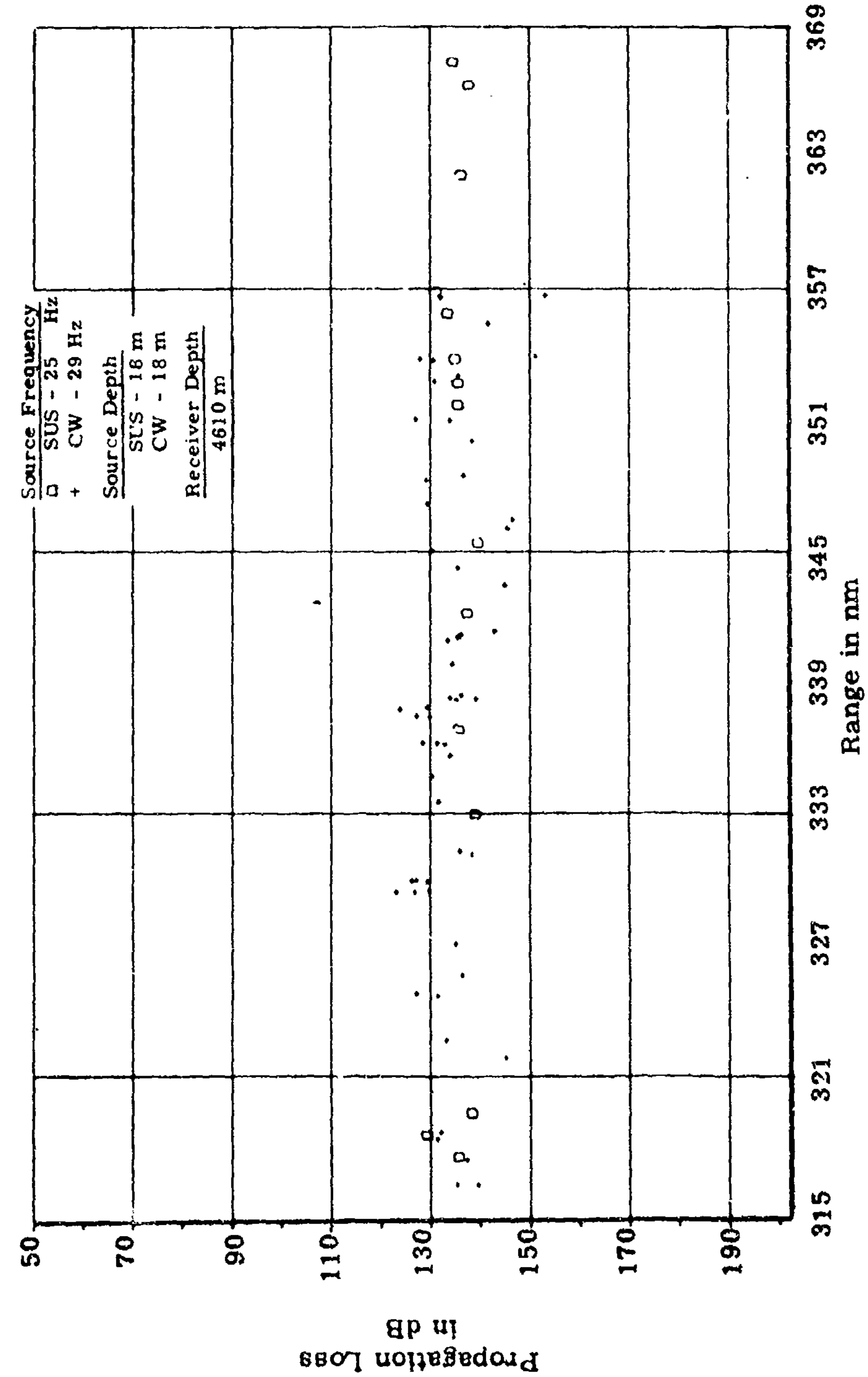


Figure (9). (C) Comparison of SUS and CW propagation loss at site D(U).

4. Processing System Comparisons(U)
Propagation Loss

a. Introduction(U)

(U)As discussed earlier, one of the purposes for conducting this investigation was to examine the apparent differences in PL measured with ACODAC and the Survey Array for two different SUS runs. Since the data was processed at different facilities, and since some differences in results for the same data processed at different facilities had already been observed, a pre-requisite to further analysis was to determine how the different systems compared. To accomplish this duplicates of tape recorded signals were rotated between facilities and shot-by-shot comparisons were made. The results of the analyses are discussed in this section of the report.

(U)The processing systems compared were located at ARL/UT, WHOI, NUSC, and WECO.

(U)ARL employs a fully automated digital system, with narrow band FFT processing. Energy in adjacent bands is summed to achieve a 1/3 octave band. Time summation is employed to determine the pre-signal noise levels, and the signal plus noise levels. WHOI uses analog 1/3 octave filters followed by digital summation to achieve the same results.

The NUSC system operates in similar fashion, except that it includes more sophisticated controls for production processing of large amounts of data. The WECO system employs an 18% analog filter followed by a conventional energy integrating shot processor. When comparing results, the WECO data was band corrected to 1/3 octave. Additionally, it should be noted that WECO generally processes data on board ship, while the comparisons discussed in this report were made with a laboratory processor. The WECO processing equipment is of essentially identical design, but the actual hardware is different.

b. <u>ARL Processing Repeatability</u>(U)

(U) Since the results obtained by ARL were compared with the results obtained by all other processing systems, repeatability at ARL was investigated. Comparisons were made of original and duplicate tapes for both CHURCH ANCHOR and SQUARE DEAL, comparison of a SQUARE DEAL tape originally processed in January, 1974 and then reprocessed in June, and a comparison of the all-digital ARL processor with an equivalent analog filter processor. For the latter comparison, the output of one hydrophone was split to form two input channels; one channel was processed according to the standard digital procedure, and the other channel was filtered with a 1/3 octave analog filter prior to digitizing and summation as is done at WHOI. The full reports of all these comparisons are contained in References (11), (12) and (13).

(U) Table (1), derived from these references, shows sample data from these reports. The first set shows comparisons between an original and a duplicate tape for CHURCH ANCHOR data, the second set is similar for SQUARE DEAL, the third shows the SQUARE DEAL duplicate against itself about 6 months apart, and the last set compares digital and analog filtering at ARL. With the exception of the "ALL S/N" data from CHURCH ANCHOR, the average differences are fairly small. The standard deviations are somewhat higher, but are less than 1 dB.

Table (1)

ARL repeatability, 50 Hz
(1/3 octave analysis)

	PL		Noise		S/N	
	μ*	σ*	μ	σ	μ	σ
CHURCH ANCHOR, Original - Duplicate, Hydrophone #5						
S/N > 3dB	0.07	0.47	-0.08	0.66	-0.21	0.89
S/N > 0	0.12	0.49	-0.15	0.59	-0.17	0.87
All S/N	0.31	2.10	-0.21	0.57	-0.40	2.33
SQUARE DEAL, Original - Duplicate, Hydrophone #3						
All S/N	0.30	0.44	-0.63	0.29	+0.14	0.57
SQUARE DEAL, Duplicate January vs Duplicate June, 1974, Hydrophone #3						
All S/N	0.02	0.14	-0.25	0.24	--	--
SQUARE DEAL, Digital vs. Analog Filter Processor						
All S/N	0.07	0.51	+0.32	0.80	-0.50	0.95

*μ - mean difference
σ - standard deviation

c. ARL/NUSC Comparisons (U)

(U)ARL furnished NUSC a designated seven hour segment of SQUARE DEAL ACODAC data for processing on their hybrid analog/digital analyzer. The results of the processing were then returned to ARL for comparison with the ARL outputs from the same data. The results are reported in Reference (17). Sample results are shown in Table (2). Comparing Table (2) with Table (1) for the ARL repeatability indicates that the standard deviation is about the same. The average difference is somewhat higher, and varies from about +.5 to -1.0 decibels. We conclude that there is no significant difference in the results obtained by data processing at ARL and NUSC.

Table (2)

Means and standard deviations of differences in PL and ambient noise. Comparing processing at NUSC and at ARL. SQUARE DEAL AlC.
(1/3 octave analysis)

	Hydrophone 1		Hydrophone 3		Hydrophone 5	
Frequency	μ	σ	μ	σ	μ	σ
ARL-NUSC Difference in PL						
25 Hz	-.97	.61	.50	.47	.03	.74
50 Hz	-.24	.41	.47	.51	-.15	.56
160 Hz	-.52	.39	.39	.44	-.44	.57
Difference in Ambient Noise						
25 Hz	2.38	1.47	.58	1.26	1.28	1.85
50 Hz	.77	.93	-.28	.81	-.15	.76
160 Hz	1.37	.88	-.08	.72	1.32	.86

(Format of NUSC output made S/N comparison inconvenient.)

d. ARL/WECO Comparisons (U)

(U) A shot by shot comparison of 190 shots was used for the comparison. Since the WECO processor operates in real time, and no facilities were available for playback of the ACODAC tape at the original recording speed, the ACODAC tapes were forwarded to NUSC for duplication to WECO specifications. WECO processed the data in their normal fashion. The results are summarized in Table (3). The maximum difference observed between ARL and WECO processing was about 5 dB. The average difference is somewhat larger than for the ARL/NUSC comparison, and the standard deviation is about twice as high, generally about 1.2 dB. It is likely that at least a portion of this increase is due to the tape duplication process, which was not straightforward. Considering this additional source of error, we judged the ARL and WECO results to be essentially equivalent, with one possible exception. The WECO PL values appear, on average, to be about .5 dB lower than the ARL values. Whether this is due to differences in processing procedure or to the tape duplication could not be ascertained.

Table (3)
Comparison of propagation loss determinations
(ARL - WECO)*

Frequency	Hydrophone 3		Hydrophone 5	
	μ	σ	μ	σ
50 Hz	+1.2	1.2	+1.1	1.2
100 Hz	0.0	1.2	+0.8	0.6
200 Hz	-0.5	1.2	+0.4	1.1
Total All Frequencies	+0.2	1.4	+0.8	1.1

*ARL employs 1/3 octave bands, WECO 18% bandwidth.
All measured levels reduced to 1 Hz bandwidth.

e. ARL/WHOI Comparisons(U)

(U)Table (4), derived from Reference (9), shows a comparison of a series of over 300 shots from the SQUARE DEAL Exercise. The SUS propagation loss at 50 Hz, 1/3 octave bandwidth, is compared. ARL used a duplicate tape recording and WHOI used an original tape recording. Each organization used their normal processing procedures, which include an independent determination of the signal integration time. The data is broken down by S/N categories. The first three lines show the results for S/N > 3 dB, for three hydrophones. The PL determined by ARL ranges from 1.17 to 2.35 dB higher than at Woods Hole, with standard deviation ranging from 1.24 to 1.73. The composite of the three data sets yields 1.81 dB higher loss at ARL and a standard deviation of 1.67.

(U)If we consider only S/N greater than zero and less than +3 dB, the number of data points available is reduced to 53. The average PL difference goes up significantly to 3.05. For S/N between -3 and 0 dB the data is insufficient for statistical analysis. The table lists the individual differences, and similarly for S/N less than -3 dB.

(U)These results indicate that there is a significant difference in results from processing at ARL and WHOI, and the difference increases as S/N decreases.

Table (4)

ARL/WHOI comparison, 300 shots from
SQUARE DEAL data, 50 Hz.
(1/3 octave analysis)

S/N Category	Hydrophone	μ*	σ	Number of Data Points
S/N > 3dB	#1	+2.12	1.24	270
	#3	+2.35	1.73	243
	#5	+1.17	1.54	321
S/N > 3dB	Composite	+1.81	1.67	834
3dB > S/N > 0	Composite	+3.05	2.12	53
0 > S/N > -3dB	#1	+5.1		
		+5.3		
		+5.9		
	#5	+5.1		
		+1.3		
		+0.9		
		+0.6		
		-5.5		
S/N < -3dB	#5	+5.8		
		-0.9		

*ARL Duplicate-WHOI Original

(U) Since the signal integration times were independently selected by ARL and WHOI, 100 shots were selected for reprocessing at WHOI using the same integration times as those used at ARL. The noise estimation period used by ARL and WHOI overlapped sufficiently (about 80%) so that no attempt was made to exactly duplicate noise estimate periods. The results are shown in Table (5), derived from References (10) and (24). A comparison of the initial and the recomputed differences consistently shows a reduction in the average difference and the standard deviation, although they are still large enough to cause concern. Thus, differences in integration time contribute to the observed difference in processing at WHOI and at ARL. This is probably also true for the results obtained by WECO and NUSC, but was not investigated since the overall comparisons were acceptable.

(U) The data shown in Tables (4) and (5) were obtained by processing a duplicate recording at ARL and the original recording at WHOI. To investigate the effect of tape duplication, the original recording was forwarded to ARL and 100 shots selected for reprocessing. The results are shown in Table (6), group (a). For comparison, group (b) repeats the all S/N data from Table (5) for the recomputed data. Group (c) repeats the data from Table (1) for the ARL comparison of original and duplicate recordings from SQUARE DEAL

Table (5)

Comparison with WHOI recomputation
using ARL signal and noise integration times.
(1/3 octave analysis)
100 shots from SQUARE DEAL data, 50 Hz

S/N Category	Hydrophone	μ Init.	μ* Recomp.	σ Init.	σ Recomp.
S/N > 3dB	#1	+2.13	+1.85	1.55	1.36
	#3	+2.16	+0.95	2.06	1.52
	#5	+1.47	+1.08	1.28	1.05
3dB > S/N > 0	#1	+3.76	+3.02	2.80	1.78
	#3	+5.36	+1.99	1.64	1.12
	#5	+1.50	+1.36	1.82	1.05
ALL S/N	#1	+2.59	+ 2.20	1.97	1.56
	#3	+2.40	+ 0.99	2.19	1.45
	#5	+1.66	+ 1.09	1.57	1.28

*ARL Duplicate-WHOI Original

Table (6)

PL comparisons with ARL and WHOI using original tape, using same integration times, all S/N data points, 50 Hz. (1/3 octave analysis)

Hydrophone No.	μ	σ	No. of Points
(a) ARL-WHOI, Original/Original			
1	+2.7	1.8	30
3	+1.6	1.5	30
5	+2.1	0.9	27
(b) ARL-WHOI, Dupl./Original			
1	+2.2	1.6	84
3	+1.0	1.4	92
5	+1.1	1.3	65
(c) ARL-ARL, Original-Dupl.			
1	+0.4	0.6	55
3	+0.3	0.4	59
5	+1.1	0.7	71

for hydrophone 3, and adds data for hydrophones 1 and 5. It is apparent from a comparison of these results that the difference in the ARL and WHOI data is not due primarily to processing different tape recordings at the two facilities.

f. Summary of Propagation Loss Comparisons (U)

(U) In summary, the measured propagation loss at ARL, NUSC and WECO are in good agreement. The differences observed are due to a combination of factors which include repeatability, analog or digital filtering, signal integration time, basic processing procedures including digital or analog energy summation and ambient noise estimates, and differences between original and duplicate tape recordings. No single factor has been identified as the major factor. By contrast, the WHOI propagation loss values are one or two decibels down, and the standard deviation is higher.

5. Repeatability of Ambient Noise Processing at WHOI(U)

(U)Since the propagation loss determination at WHOI was significantly different from that at ARL, data processing repeatability at WHOI was examined. The investigation centered on ambient noise measurements and the use of duplicate tapes. It is important to note, in the latter connection, that SQUARE DEAL data previously processed by WHOI was accomplished with the original tapes, so the difficulties discussed later in this section regarding the use of duplicates do not affect that data. The following discussion is based on Reference (14) supplemented by additional data.

(U)Figure (10) shows a comparison of two consecutive passes of an original SQUARE DEAL ACODAC tape recording. Five consecutive 10 second samples were taken and processed in 1/3 octave bands from 16 to 250 Hz. The differences between the two passes are plotted. The upper data set was obtained with operator care; that is, care was taken to insure that there was sufficient rewind of the tape after the first pass and sufficient lead in for the second play to stabilize the machine and properly lay up the tape. The average value of the difference is zero, and the standard deviation is 0.36 dB. The lower scatter plot shows similar results for another time segment, but without care on the second pass. That is, tape rewind and lead in were not sufficient to stabilize the machine and to lay up the tape. Degradation is present over the entire frequency band, and is particularly

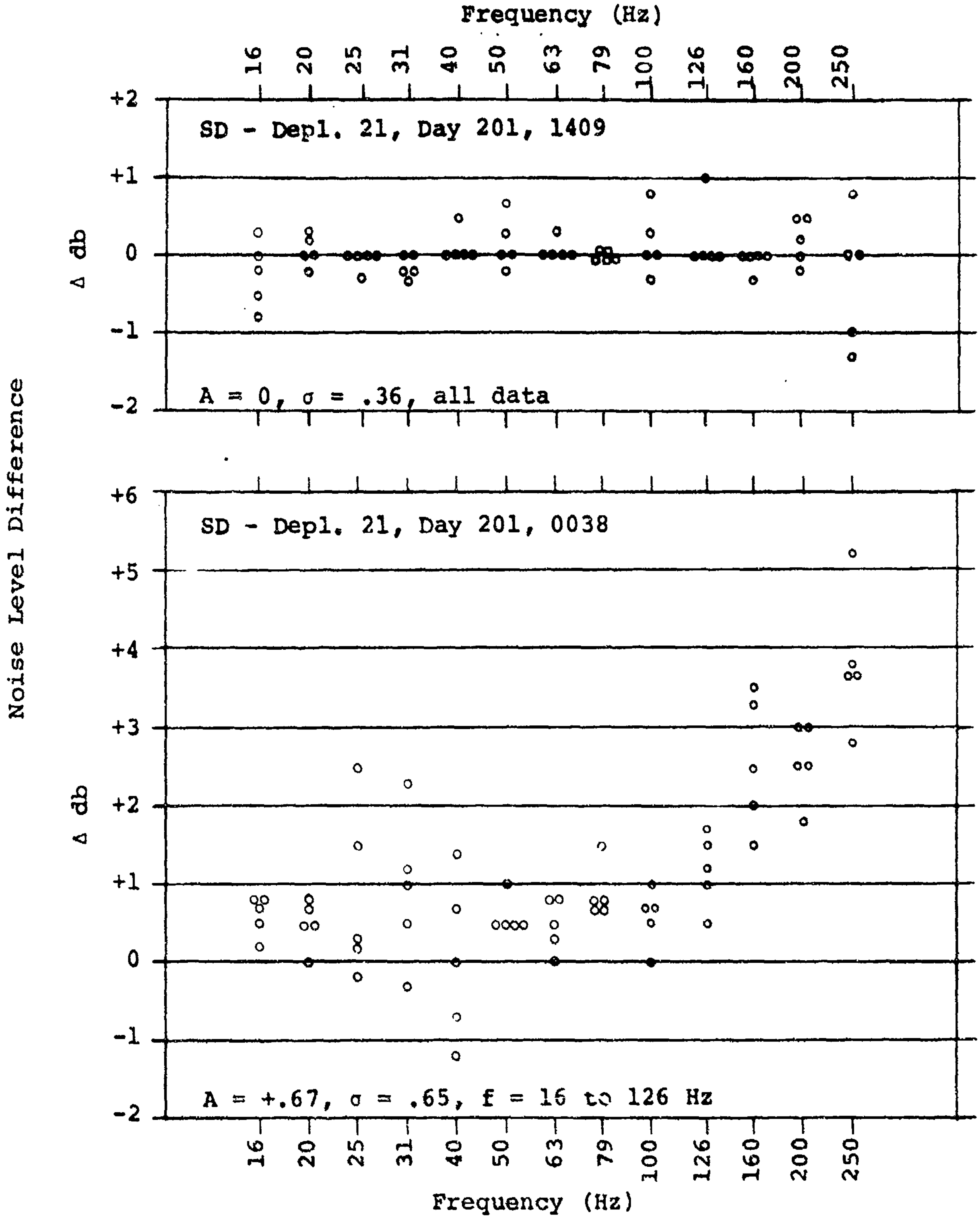


Figure (10). SQUARE DEAL ambient noise differences. Original II - Original I. 1/3 octave bands, five 10 second samples.

Top: With Care

Bottom: Without Care

bad at 160 Hz and above. For the 16 to 126 Hz data, the average value is +0.67, and the standard deviation is 0.65 dB. Thus, even for this restricted frequency range there is considerable additional degradation.

(U)This indicates the potential existence of an operator problem with the results dependent upon the care taken to stabilize the machine and the tape. When performing production runs the standard practice at WHOI is to start the tape and run through completely without interruption. The repeatability shown by the upper data plot then applies, provided that the tape had been carefully rewound before processing.

(U)To demonstrate that the requirement for special operator care is directly related to the use of the direct record mode a duplicate tape recording was prepared in the FM mode. Figure (11) shows a sample of an FM-FM comparison without any special operator care being taken; i.e., in ordinary usage. The average value is +0.03 dB and the standard deviation is 0.31 dB. This is about what was obtained in comparing the original against the original with care. It is important to note that the use of FM duplicates eliminates only operator carelessness and, to a lesser extent, gradual degradation of the tape recorder playback system. It does not correct for any problem introduced by the initial direct recording and the first playback to produce an FM duplicate.

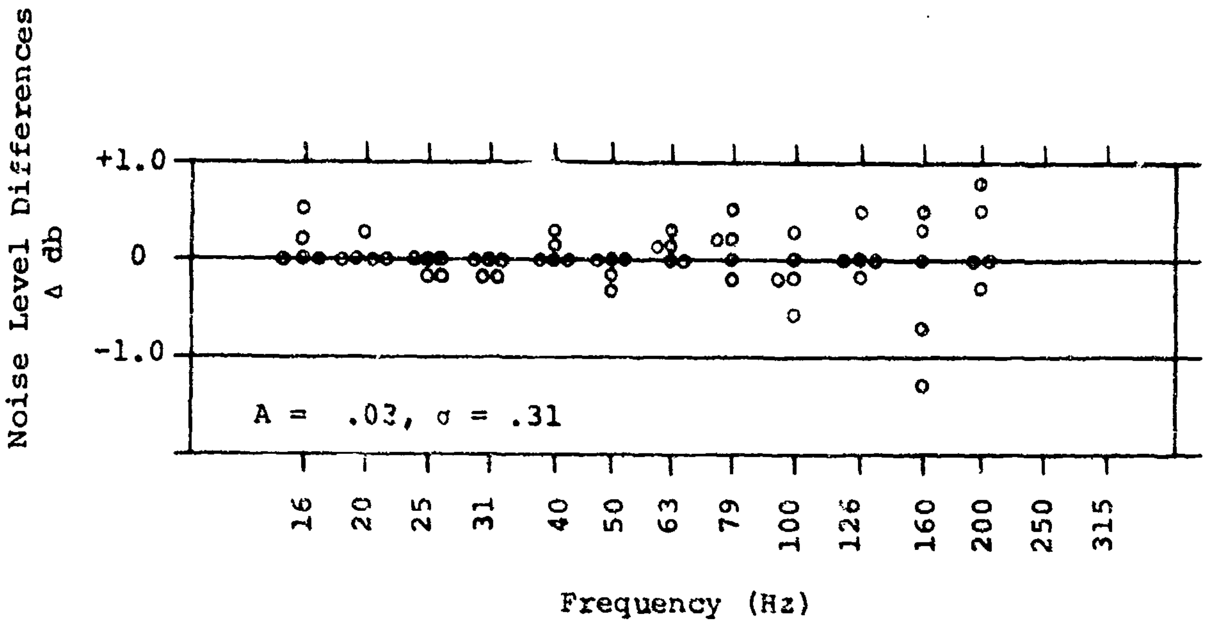


Figure (11). SQUARE DEAL ambient noise comparison FM 1 - FM 2. 1/3 octave bands, five 10 second samples.

(U)The original and a duplicate Direct Record magnetic tape were compared next. Figure (12) shows a scatter plot of levels from the original (circled points) and duplicate (crosses), done with care. Many plots for CHURCH ANCHOR and SQUARE DEAL data were made, of which this is a sample. On this scale the comparison looks reasonably good, except for frequencies of 200 Hz and higher. Note, in particular, the tendency of the duplicate data to increase in level above 160 Hz. This will be discussed later.

(U)Figure (13) shows a plot of the differences in the levels shown in Figure (12). Starting at 200 Hz the difference increases drastically with increasing frequency. If the frequency region of 16 to 160 Hz only is considered, the average value is 0 dB and the standard deviation is 0.71 dB.

(U)Figure (14) shows similar differences for the CHURCH ANCHOR data. One can immediately see that this is much worse. The SQUARE DEAL and CHURCH ANCHOR ACODAC set-ups were different in several respects. SQUARE DEAL included calibration in all 1/3 octave bands; CHURCH ANCHOR included calibration only at the frequencies indicated with an asterisk on Figure (14). For intermediate frequencies calibration interpolations were therefore necessary.

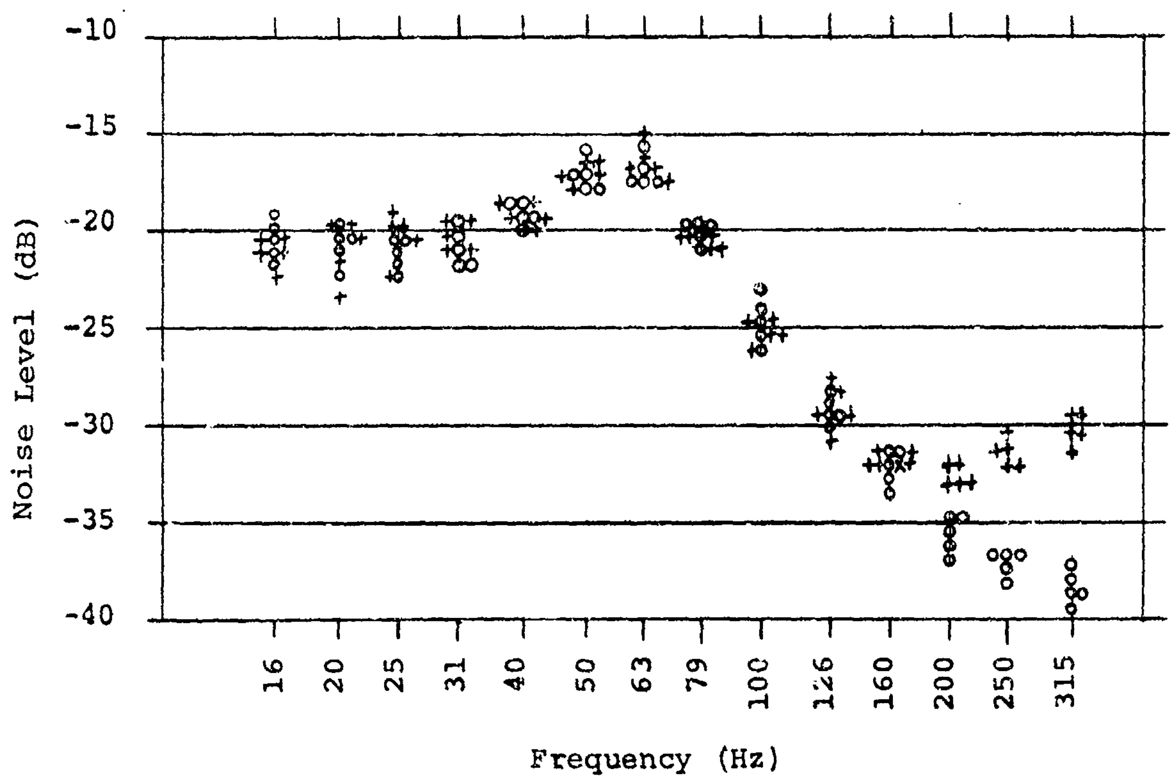


Figure (12). Spectral noise levels. SQUARE DEAL depl. 21, hyd. #5, day 201, 1409. 1/3 octave bands, five 10 second averages.

+ Duplicate

o Original

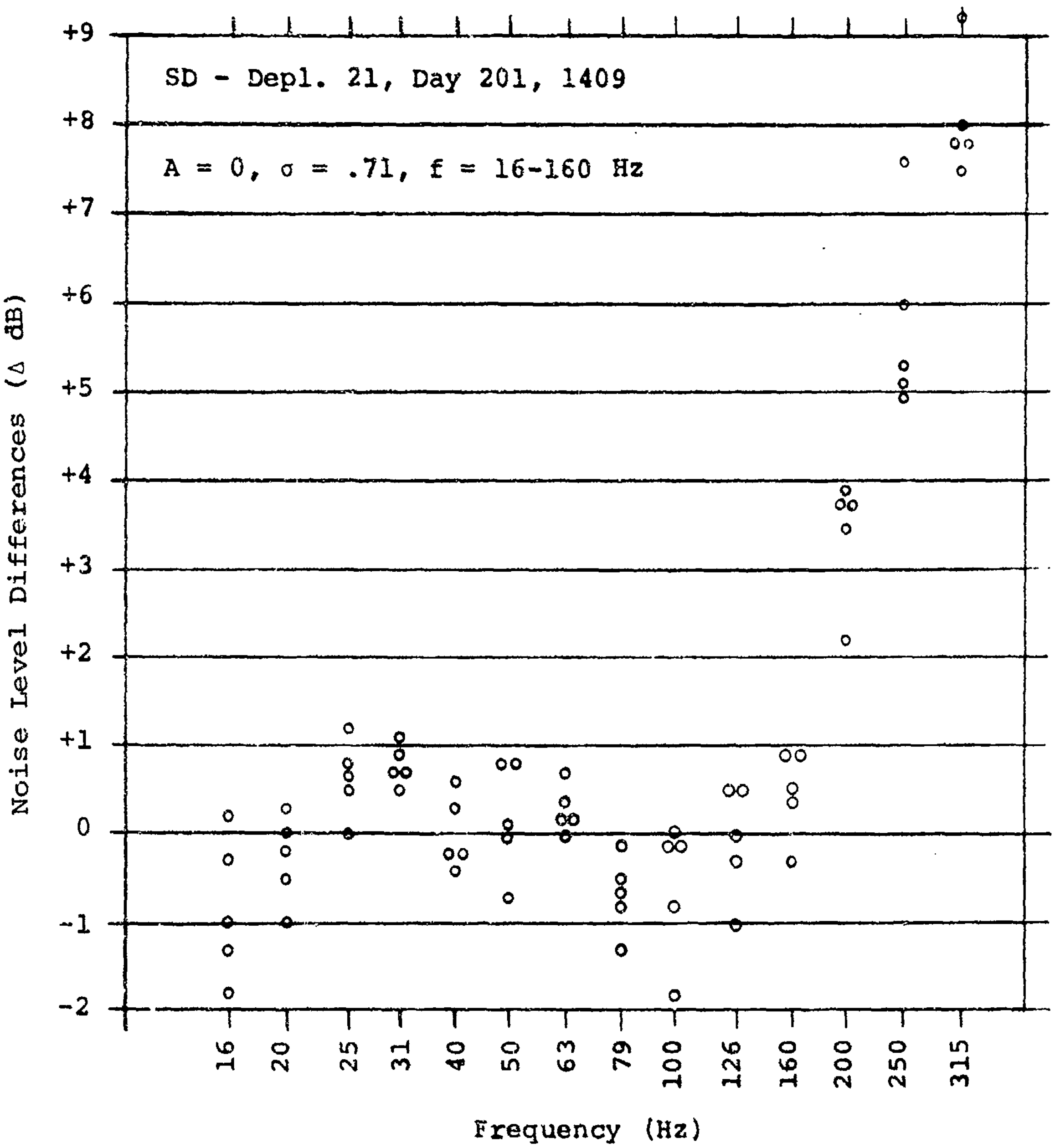


Figure (13). SQUARE DEAL ambient noise comparison. Duplicate - Original. 1/3 octave bands, five 10 second averages.

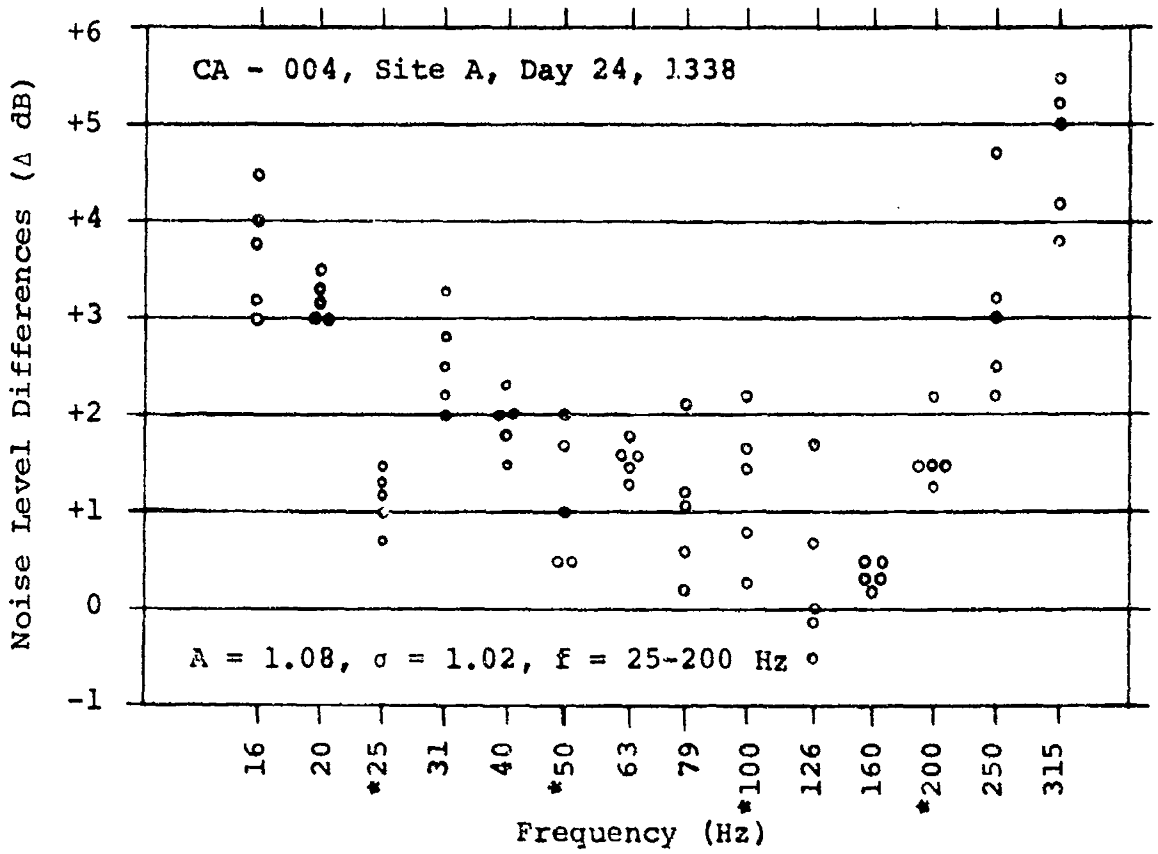


Figure (14). CHURCH ANCHOR ambient noise comparison. Duplicate - Original. 1/3 octave bands, five 10 second averages.

*Calibration frequencies

The data deteriorates outside the calibration frequency range; i.e. at low as well as at high frequencies. If the 25 to 200 Hz interval only is considered, the average value of the differences is +1.08 dB and the standard deviation is 1.02 dB. This is significantly higher than the repeatability when care is taken, or the above cited values for the comparison using SQUARE DEAL recordings.

(U)To examine the effect of the calibration interpolation, we have taken the differences at the calibration frequencies only, for five sets of data, obtaining an average value of +1.44 dB and a standard deviation of 0.71 dB. The average value of the difference is somewhat higher and the standard deviation is somewhat lower than that obtained for the total data set between 25 and 200 Hz. Thus, there is no indication that interpolation of the calibration signals between 25 and 200 Hz was a major cause for the large differences observed.

(U)Table (7) is a summary of the statistics already discussed, permitting a quick appraisal of the situation. It must be remembered, however, that outside the restricted frequency bands indicated in the table the differences are always positive and large.

Table (7)

WHOI ambient noise difference summary

Comparison	Frequency (Hz)	μ	σ
Original-Original			
With care	16-250	0	.36
Without care	16-126	+.67	.65
Duplicate-Original (SQUARE DEAL)	16-160	0	.71
Duplicate-Original (CHURCH ANCHOR)	25-200	+1.08	1.02
Cal. freq. only	25,50, 100,200	+1.44	.71

(U)It was concluded that the differences observed were due to degradation introduced during duplication of the magnetic tapes and a further investigation was conducted to determine the reasons. An original and a duplicate of a SQUARE DEAL tape were used for this purpose. Reference (15) is the report of the team which conducted the investigation.

(U)Figure (15) from Reference (15) shows ambient noise broadband, at 50 Hz 1/3 octave and at 200 Hz 1/3 octave for the original tape. The scale is 50 dB, or 1 dB per millimeter. The broadband is slightly clipped by the Brush recorder, which should be discounted. On the left there is a 10 dB gain change, which is followed well in all frequency bands. To the right there is a calibration signal. Just prior to the calibration signal, the hydrophone inputs are opened for 1/2 minute. This time period permits a look at the noise floor. As can be seen, the ambient noise level is well above the noise floor in all three cases.

(U)Figure (16), also taken from Reference (15), shows comparable results for the duplicate tape. For broadband and 50 Hz the 10 dB gain change is properly followed, and the signal is well above system noise. For 200 Hz, the gain can only change by 5 dB before the noise floor is

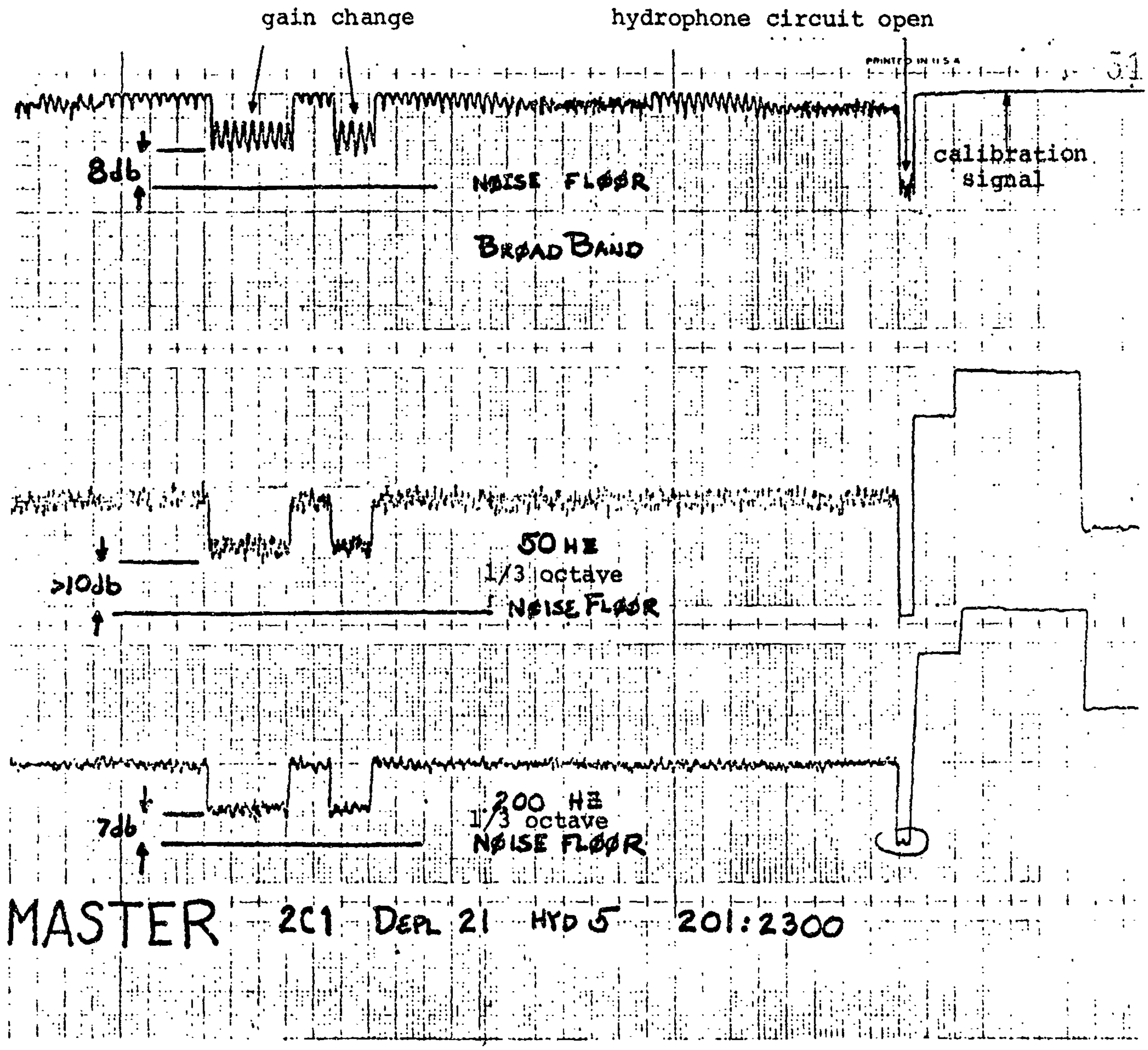


Figure (15). Ambient noise - master tape.

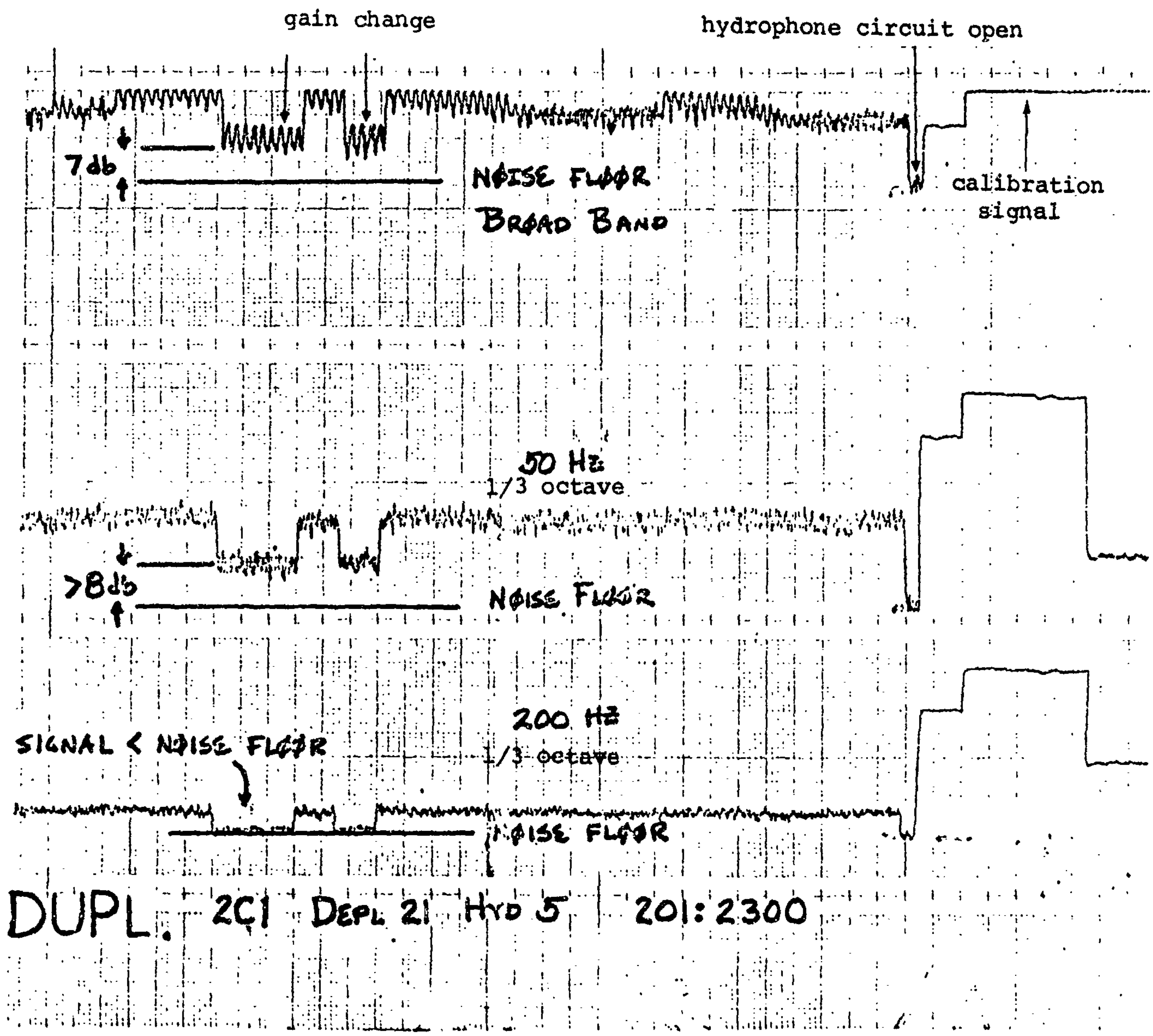


Figure (16). Ambient noise - duplicate tape.

reached. If the noise floors for the original and the duplicate are compared, it is seen that they are within one decibel.

(U)Figure (17) from Reference (15) shows a comparison of the calibration data at the beginning of the tape for the original and the duplicate, for Channels 1 through 3. Note that the recorded level on the duplicate is lower, and the spectral shape is different, falling off markedly at the higher frequencies. Figure (18) shows the same results for Channels 4 through 6, for which the fall-off is generally worse. Channel 5, the channel used for the ambient noise comparisons, appears to be one of the worst.

(U)Thus it appears that the recording level of the duplicate is much lower than that of the original, and the equalization suppresses the high frequencies, so that system noise rather than ambient noise is measured. It is also significant to note that while the calibration levels are reasonably constant for the original, they fluctuate as much as two decibels in the duplicate, clearly indicating degradation.

(U)Table (8), taken from Reference (15), shows 50 and 200 Hz internal calibration levels at different times on the original and duplicate tape recordings. At 50 Hz there is a variation of about 1 dB for both data sets.

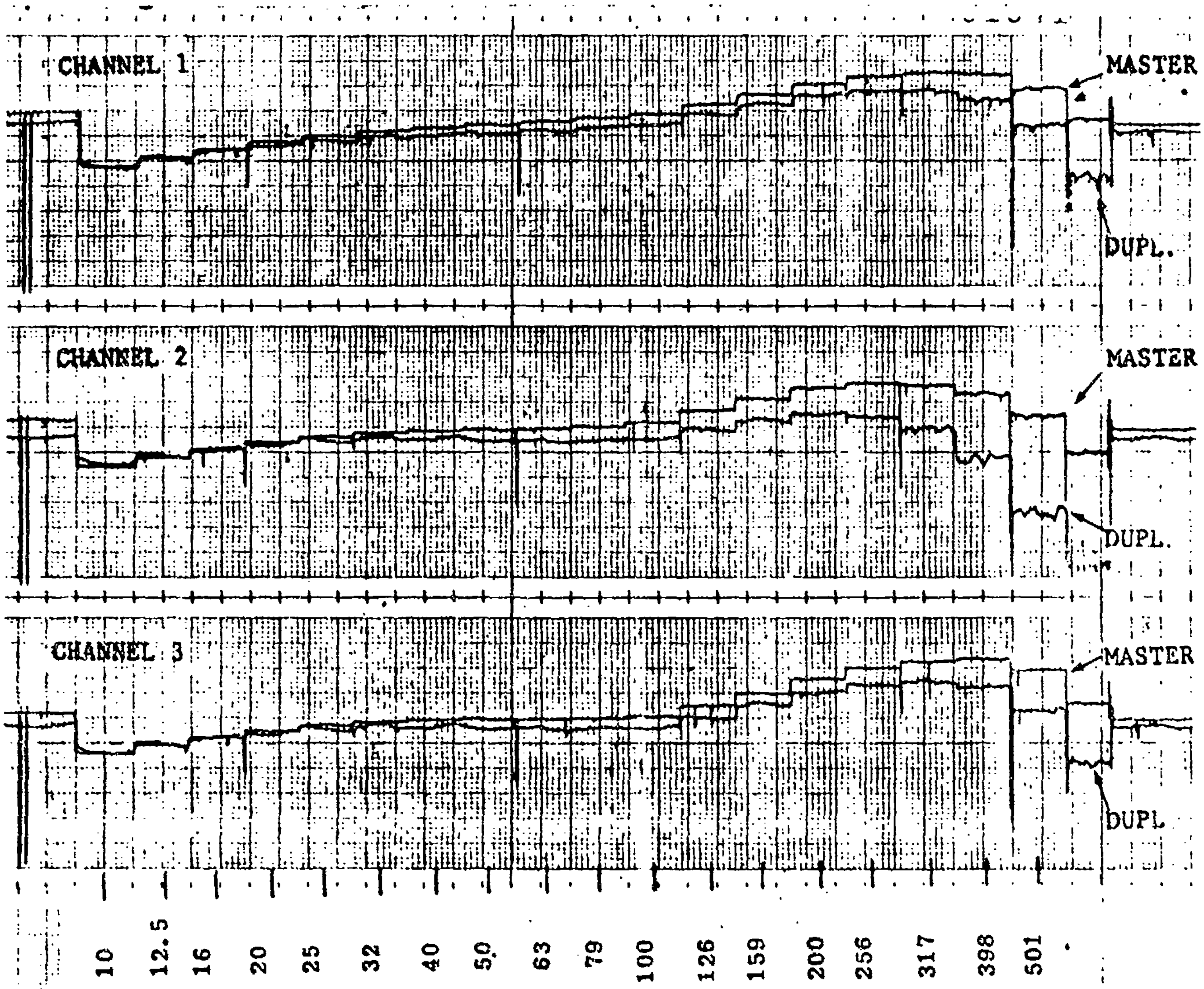


Figure (17). Initial calibrations - Channels 1-3.

2C21 db re 10 volts fs

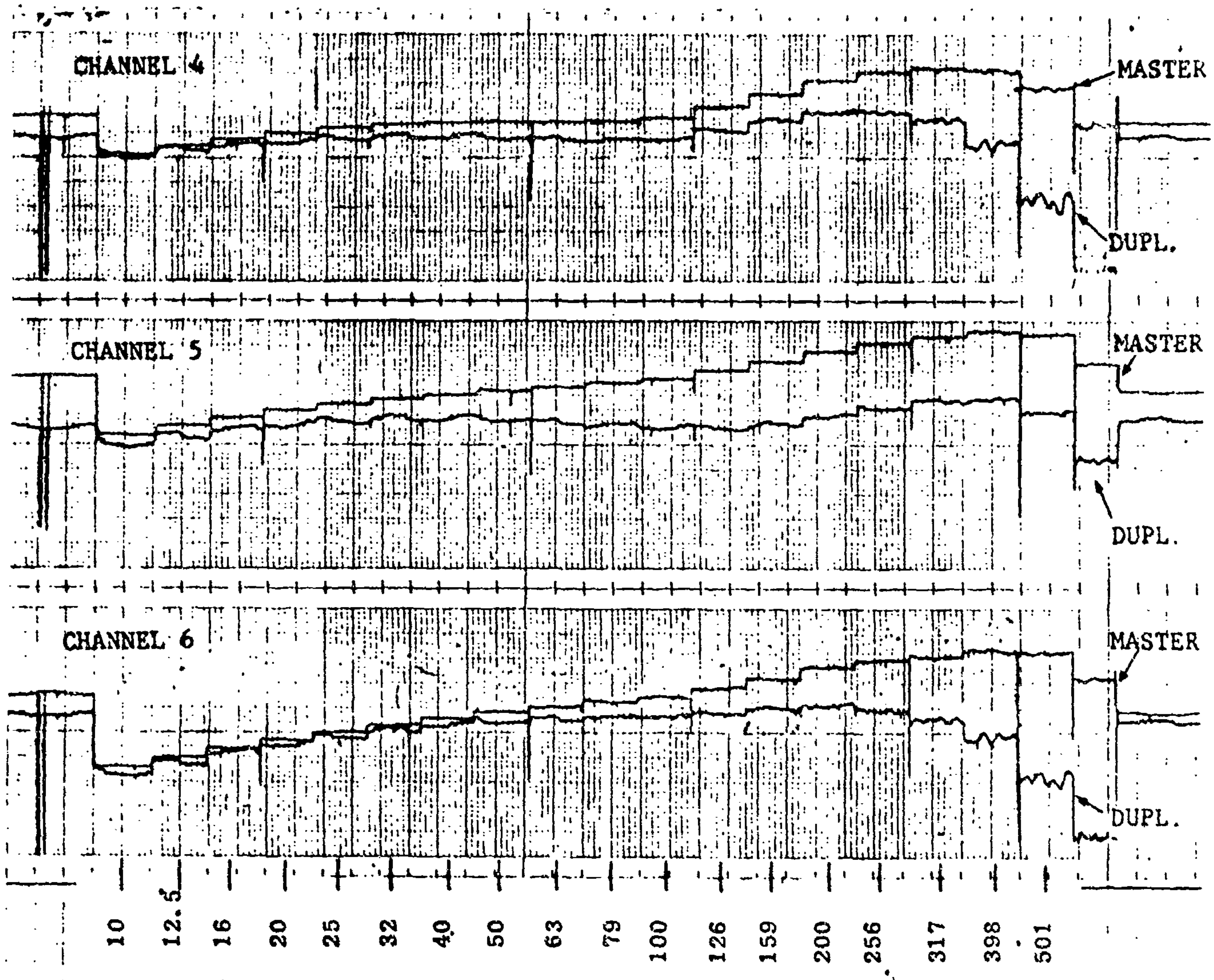


Figure (18). Initial calibrations - Channels 4-6.
2C21 db re 10 volts fs

Table (8)

Internal channel calibrations,
50 and 200 Hz

50 Hz Periodic Calibrations
(db re 1 volt)

Time	Channel 1 Mast.	Channel 1 Dub.	Channel 2 Mast.	Channel 2 Dub.	Channel 3 Mast.	Channel 3 Dub.	Channel 4 Mast.	Channel 4 Dub.	Channel 5 Mast.	Channel 5 Dub.	Channel 6 Mast.	Channel 6 Dub.
201/1700	- 9	-10	-11	-13	- 9	-12	- 9	-11	- 4	-10	-11	-13
201/2300	- 9	-10	-11	-13	- 9	-12.5	- 9	-11	- 4	-10	-11	-13
206/1100	- 9	-10	-11	-12	- 9	-12	- 9	-10.5	- 4	- 9	-11	-12.5
206/1700	-10	-10	-11	-12	-10	-12	- 9	-10.5	- 4	- 9.5	-11.5	-12.5
207/1700	- 9	-10	-11	-12	- 9	-12	- 9	-10.5	- 4	- 9.5	-11	-12.5
207/2300	- 9	-10	-11	-12	- 9	-12	- 9	-10.5	- 4	- 9.5	-11	-12.5
208/0500	- 9	-10	-11	-12	- 9	-12	- 9	-10.5	- 4	- 9	-11.5	-12.5
208/1100	- 9	-10	-11	-12	-10	-12	- 9	-10.5	- 5	- 9.5	-11.5	-12.5
208/1700	- 9	-10	-11	-12	-10	-12	- 9.5	-10.5	- 4.5	- 9.5	-11.5	-12.5
208/2300	- 9	- 9.5	-11	-12	-10	-12	- 9	-10.5	- 4.5	- 9	-11.5	-12
209/1700	- 9	- 9.5	-11	-11.5	-10	-11.5	- 9	-10	- 4	- 9	-11	-12
209/2300	- 9	-10	-10.5	-11.5	-10	-11.5	- 9	-10	- 4	- 9	-11.5	-12
210/0500	- 9	-10	-11	-11.5	-10	-11.5	- 9	-10	- 4	- 9	-11	-12

200 Hz Periodic Calibrations
(db re 1 volt)

Time	Channel 1 Mast.	Channel 1 Dub.	Channel 2 Mast.	Channel 2 Dub.	Channel 3 Mast.	Channel 3 Dub.	Channel 4 Mast.	Channel 4 Dub.	Channel 5 Mast.	Channel 5 Dub.	Channel 6 Mast.	Channel 6 Dub.
201/0500	-15	-15.5	-17	-19	-16.5	-16.5	-15	-19	-10	-21.5	-16.5	-22
205/2300	-14	-15	-17	-19.5	-16	-17	-14	-18	- 9	-20.5	-15.5	-21
210/0500	-12.5	-15	-15	-20	-15	-17.5	-13	-19	- 8	-21.5	-14	-22

At 200 Hz the variation on the original is as high as 2.5 dB. Although it does not appear to be as large in the duplicate, it must be remembered that these numbers are estimated averages of fluctuating levels. Also note that the calibration level on the original on Channel 5 is 5 dB lower than on the other channels. Somehow this was corrected in the duplicate.

(U) Short sections of all the CHURCH ANCHOR and SQUARE DEAL duplicate tapes in the WHOI library were examined for the phenomena just described. It was present on all duplicates, but generally to a lesser extent. The tape used for the preceding discussion was the worst and, as noted, Channel 5 was one of the worst channels on the tape. The discussion above therefore represents a worst case for both CHURCH ANCHOR and SQUARE DEAL duplicate tapes.

(U) In the previous comparisons of SUS levels, only 50 Hz data were considered. It is now obvious that at higher frequencies difficulties may be encountered. The dividing line appears to be about 160 Hz in the WHOI data. To determine whether similar degradation at high frequencies was present in ARL processing, previously processed data was re-examined and ARL was requested to provide comparisons at 200 and 250 Hz, 1/3 octave bandwidth. Table (9) summarizes data derived from References (12) and (13) at 25, 50 and 160 Hz, and Table (10), taken from the enclo-

Table (9)

Frequency dependence of original vs duplicate comparisons, ARL processing, data from one hydrophone each exercise. (1/3 octave analysis)

	Frequency (Hz)	CHURCH ANCHOR Original - Duplicate						SQUARE DEAL Original - Duplicate	
		S/N > 3 db		S/N > 0		All S/N		All S/N	
		μ	σ	μ	σ	μ	σ	μ	σ
PL Difference	25	0.37	0.41	0.39	0.49	0.38	1.10	1.34	1.23
	50	0.36	0.42	0.20	0.54	0.34	1.51	1.12	0.74
	160	0.44	0.92	0.42	0.81	0.12	2.13	0.47	0.62
Ambient Noise Difference	25	-0.82	0.56	-0.82	0.56	-0.78	0.54	-1.68	0.29
	50	-0.50	0.35	-0.47	0.32	-0.43	0.37	-1.75	0.32
	160	-1.09	0.61	-0.99	0.56	-0.90	0.70	-1.67	0.70
S/N Difference	25	0.37	1.06	0.31	1.10	0.29	1.46	0.49	1.00
	50	0.35	1.18	0.45	1.10	-0.02	1.92	0.76	0.75
	160	0.50	0.81	0.67	0.92	0.71	2.03	1.37	0.82

Table (10)

ARL data comparisons at 200 and 250 Hz. (1/3 octave analysis)

	200 Hz						250 Hz					
	Mean	σ	Mean	σ	Mean	σ	Mean	σ	Mean	σ	Mean	σ
Background Noise[1], Original - Dupl.												
CHURCH ANCHOR[2] Site C Hyd. 1, 5, 6	-1.5	0.4	-1.2	0.5	-1.2	0.9	-2.6	1.0	-2.4	0.8	-1.5	1.4
SQUARE DEAL 1C3 Hyd. 1, 3, 5	-1.7	0.4	-0.4	0.4	-2.1	0.6	-1.3	0.7	-0.7	0.6	-2.5	0.4
SQUARE DEAL 2D2 Hyd. 1, 2, 6	-1.5	0.4	-2.4	0.4	-2.1	0.6	-1.2	0.6	-5.2	0.6	-4.5	0.8
Propagation Loss[3], Original -Dupl.			S/N > 0									
CHURCH ANCHOR[2] Site C Hyd. 1, 5, 6	0.1	0.3	-0.3	0.5	0.6	0.9	0.7	1.1	0.5	0.8	0.2	1.4
SQUARE DEAL 1C3 Hyd. 1, 3, 5	0.4	0.3	-0.4	0.3	0.5	0.5	0.0	0.6	-0.4	0.5	1.2	0.4
SQUARE DEAL 2D2 Hyd. 1, 2, 6	0.3	0.3	0.4	0.3	-0.1	0.7	0.1	0.5	1.8	0.5	0.9	0.9

[1] Comparison of this and WHOI ambient noise data should be made with caution. They are different duplicates, and the ARL noise measurements are those corresponding to SUS signal processing so that the gains are different. The ARL levels may correspond to ACODAC system noise and not ambient, for both the original and the duplicate. The additional noise due to duplication is apparent, but not as high as for the WHOI data. Note the large variability between tapes and channels.

[2] CHURCH ANCHOR tape has no calibrations at 160 and 250 Hz. There is a calibration at 200 Hz.

[3] With increased noise on the duplicates, the PL shows a bias towards greater loss on the original; i.e. using S/N > 0, some points may be dropped out on the duplicate for which S/N > 0 on the original. Note that the variability between original and duplicates for PL is smaller than for noise. This is a natural consequence of the selection of only those shots for which S/N > 0 on both tapes.

sure to Reference (16), presents results at 200 and 250 Hz. It may be seen that the ambient noise level differences between original and duplicate tapes do get larger at the higher frequencies, but the increase does not approach in magnitude that encountered at WHOI. The actual ARL and WHOI values should not be compared, for the reason given in Note 1 of Table (10).

(U)The system noise introduced during duplication is part of the measurement noise in the shot signal. If a particular channel shows a relatively large statistical difference of background noise between duplicate and original, it might be expected that the statistical difference of the PL between the original and duplicate on the same channel would also be relatively large. However, Table (10) shows that this is not the case. This is due to the processing procedure whereby the noise estimate is subtracted from signal plus noise to determine propagation loss. It is of little account whether the noise is ambient or system generated, except, that when system generated noise dominates, the signal to noise ratio will be reduced, and the measurement accuracy for propagation loss will thereby suffer.

(U)To summarize, it is apparent that degradation has been introduced in the preparation of the duplicate tape recordings. The degree of degradation varies from one set of tapes to the next. This degradation can result in considerable error in noise measurements, particularly at frequencies above 160 Hz. To a lesser extent it also contributes to inaccuracy in the measurement of propagation loss.

6. Comparison of ACODAC Data and Survey Array Data(U)

(U)This comparison was undertaken because an initial examination of data indicated apparent differences in propagation loss between the Survey Array and ACODAC in the SQUARE DEAL Exercise. The PL measured with ACODAC was 5 to 10 dB higher than that measured by the Survey Array. It is evident from the data processing comparisons discussed in Sections (4) and (5) that processing differences cannot account for differences of this magnitude. Further investigation therefore included a comparison of ACODAC and Survey Array data with model computations performed by AESD. References (20) and (21) are the reports of this work.

(U)Figure (19), taken from the enclosure to Reference (22), shows the SUS track (Olmeda) and the ACODAC location (1C) for the data considered. Figure (20), taken from Reference (20) with some information added, shows the experimental SUS PL data compared with the PE model computations. As can be seen, the agreement is quite good. Also shown are the envelopes from a FACT computation for bottom class 5 (dotted line) and for bottom class 3 (dashed line). Bottom class 5 with FACT is in reasonable agreement with PE and the data points. By contrast, the PL predicted with bottom class 3 is much lower than the data.

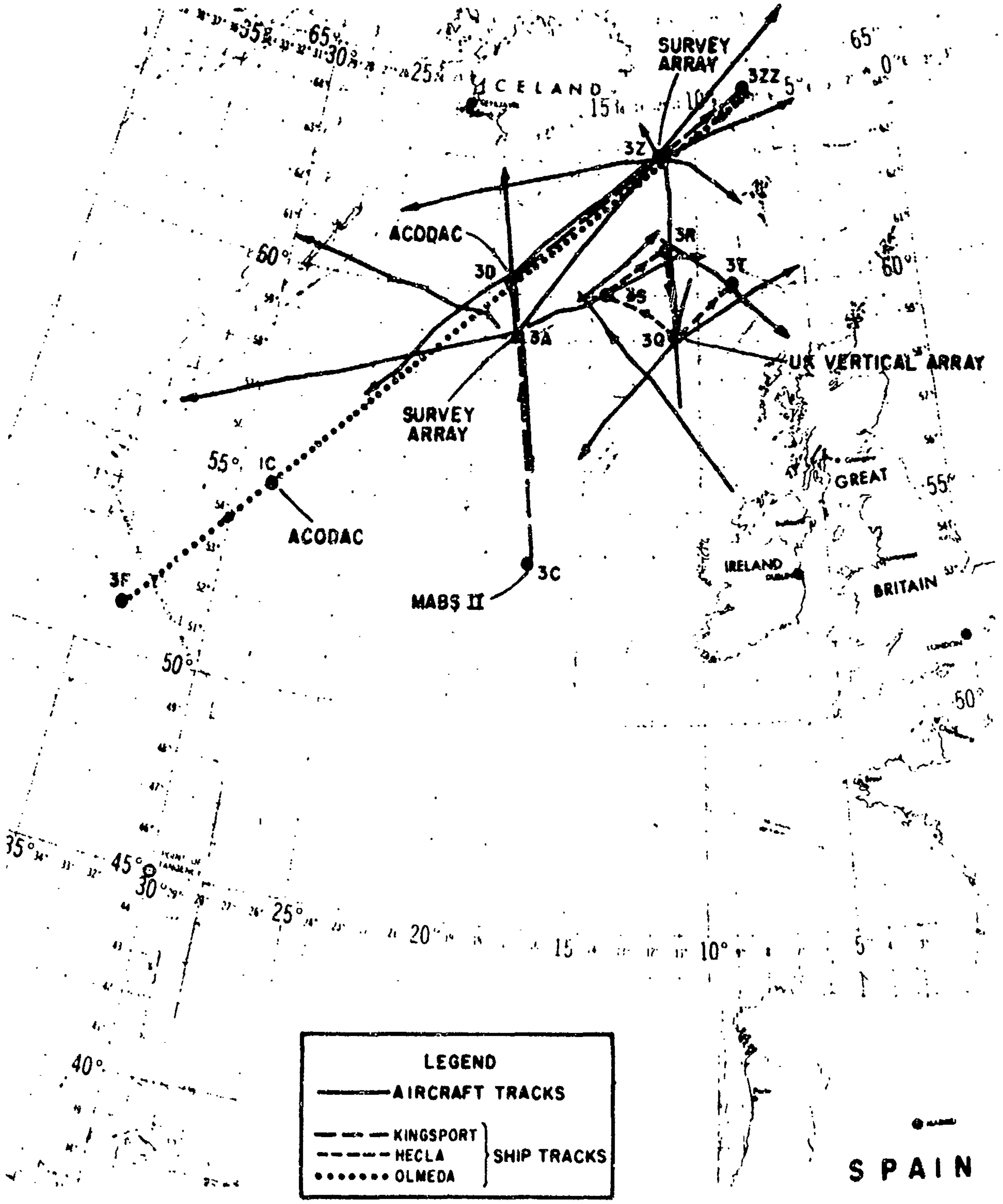


Figure (19). (C)Location of acoustic receivers and tracks of acoustic sources during Phase III(U).

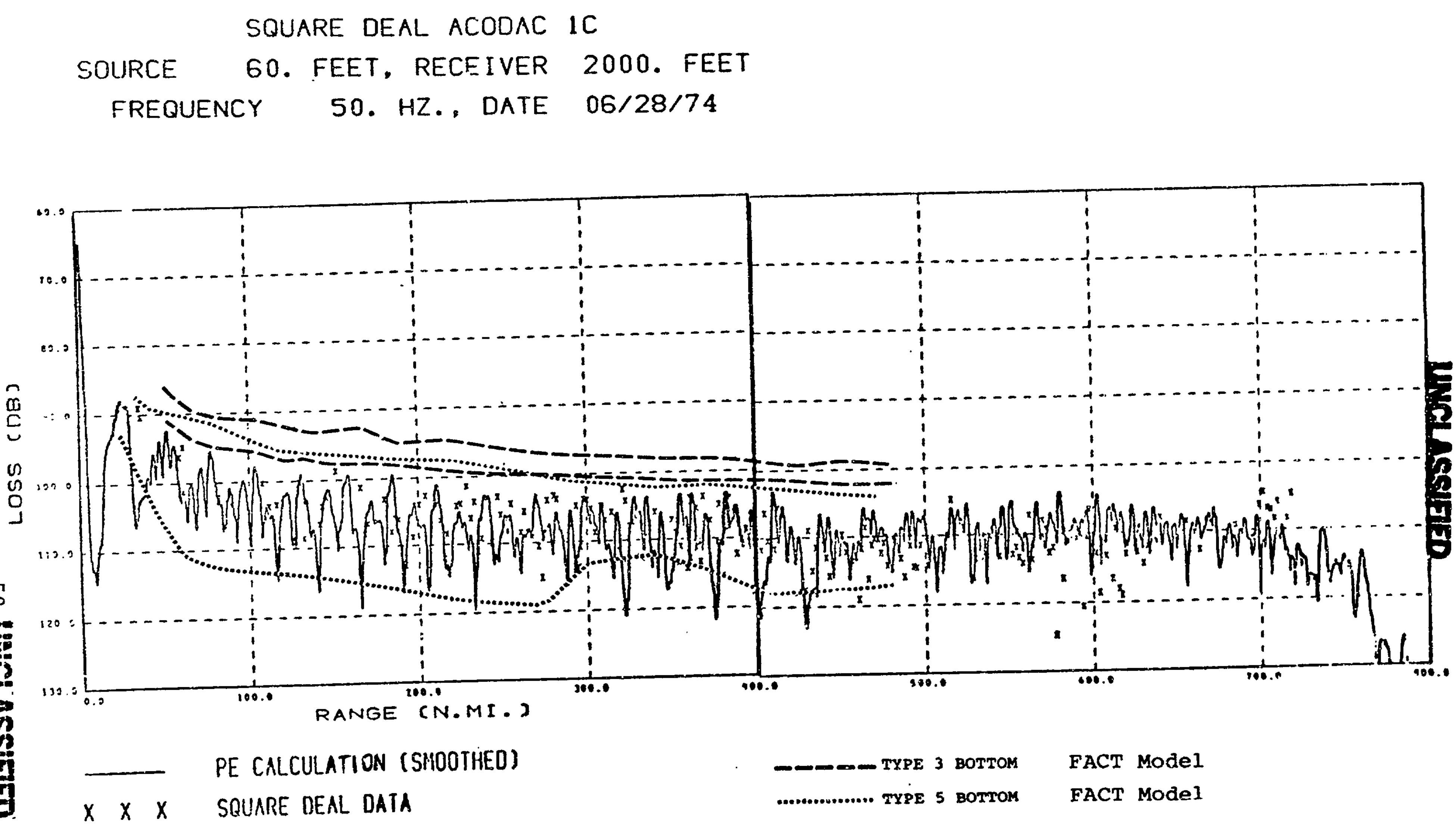


Figure (20). Model predictions compared to SQUARE DEAL data - ACODAC 2000 feet.

(U)Figure (21), also taken from Reference (20) with some information added, shows the comparison of PE and data for ACODAC for conditions closest to those for the Survey Array. Note the following:

(U)1. There is very little data in the first 300 n.m. because of overloads. Since the overloads and poor S/N points are not plotted, this data can be misinterpreted. At close range the missing overloaded data would generally correspond to low propagation loss values; at long range the missing poor S/N data would correspond to high propagation loss values. The effect of these two factors is to introduce a narrow band of propagation loss values within which the data must lie because of measurement system characteristics. Except for a few points, the bulk of the data lie between 98 and 113 dB. As in the case of the CHURCH ANCHOR data, the limitation of PL points to this interval is due to the logic employed in setting up the gain in the ACODAC recording system for SUS signals.

(U)2. In the vicinity of 100 n.m. the PL data points indicate about 100 dB of loss. These are the higher loss values, the low values having been lost due to overloads.

(U)Figure (22), taken from the enclosure to Reference (22), shows the PL data obtained with the Survey Array. The inset shows the location and track. This is a

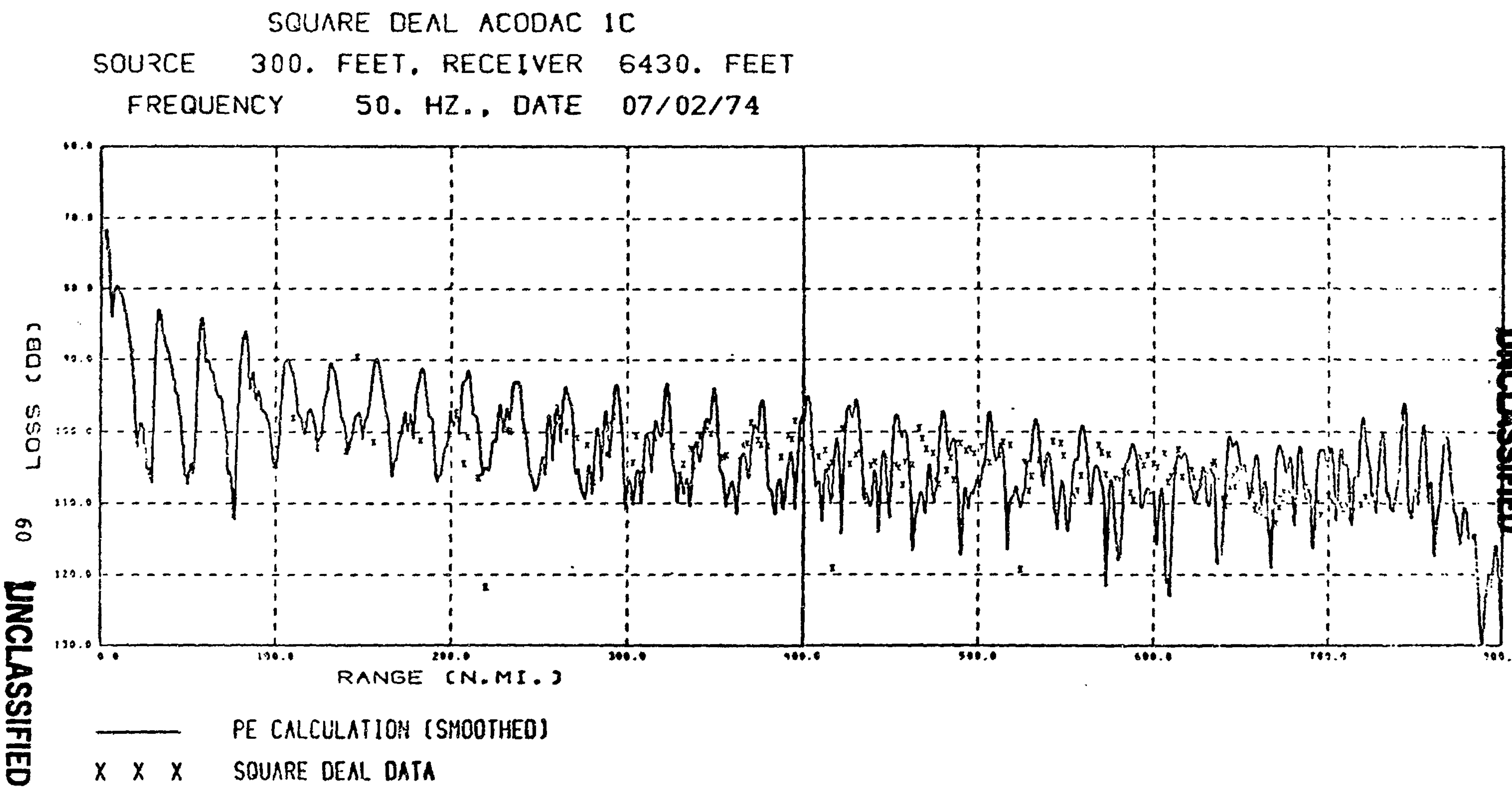


Figure (21). Model predictions compared to SQUARE DEAL data - ACODAC 6430 feet.

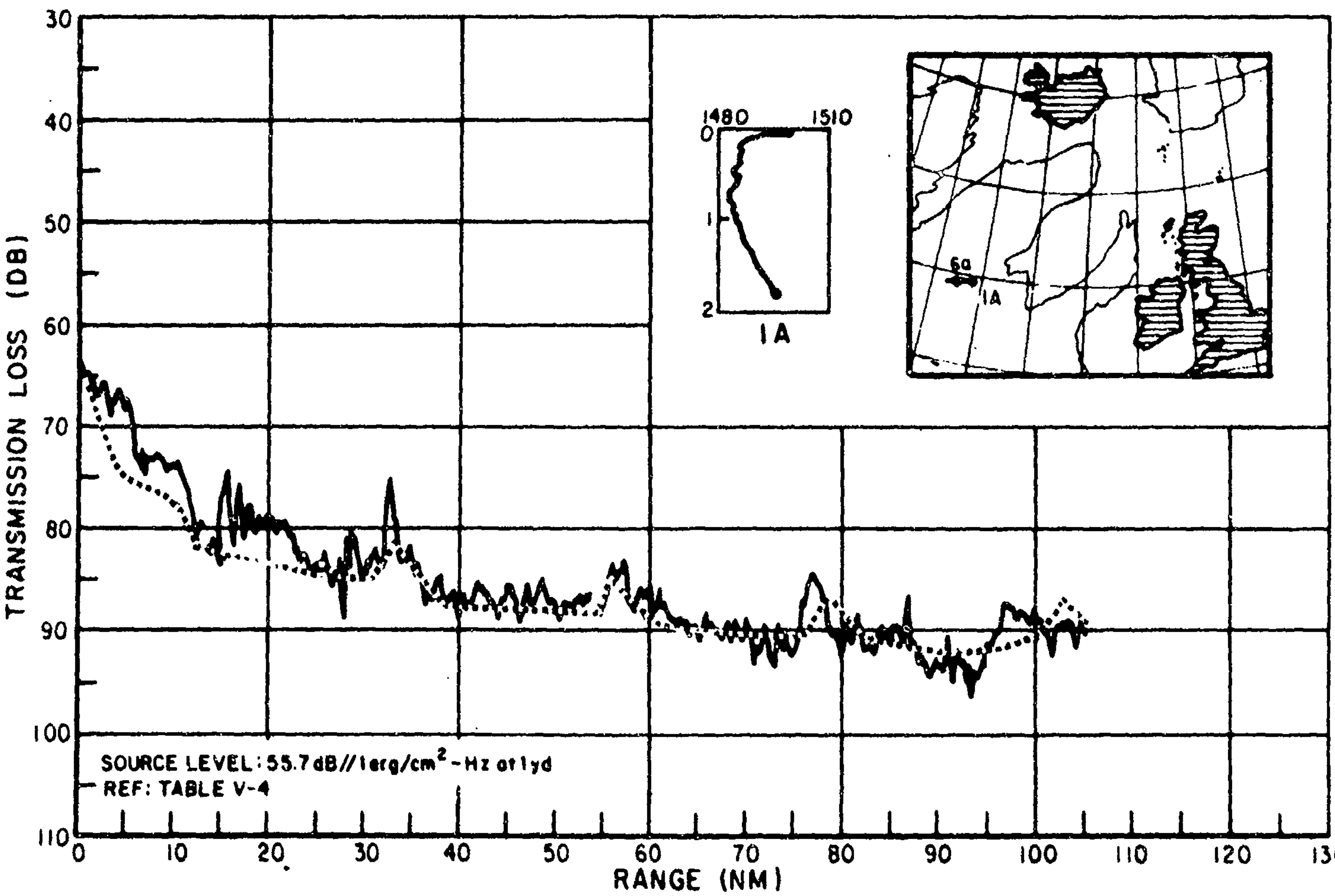


Figure (22). (C)Model predictions compared to SQUARE DEAL data - Survey Array(U).

———— Experimental ············ FACT

radically different track than for the ACODAC data. In the vicinity of 100 n.m. the propagation loss is about 90 dB, or 10 dB lower than for the ACODAC data. The dotted line is a FACT computation for bottom class 3, superimposed on the experimental data. The fit is reasonably good.

(U)A comparison of the data shown in Figures (20) and (22) suggest that both data sets, those for ACODAC and the Survey Array, may be correct, and that the differences noted stem from two factors. First, for the ACODAC data the lower PL values at the shorter ranges have been lost due to overloads. Secondly, J. Hanna of AESD suggested that the bottom loss along the track to ACODAC is high, while that along the track to the Survey Array is moderate or low.

(U)A further investigation following the recommendations of J. Hanna was undertaken to determine if there is other evidence for a difference in bottom type along the two tracks. Figure (23) shows data obtained by the Survey Array from a shot at 25 n.m. distance. The top curve displays in arbitrary units the pressure-squared vs. time data; the lower curve shows the integration of the received energy. It is apparent from the top curve that bottom bounce arrivals are present and that the major portion of the total energy received is attributable to those arrivals. The propagation loss for the direct arrival alone would be about 6 dB higher, or 85 dB.

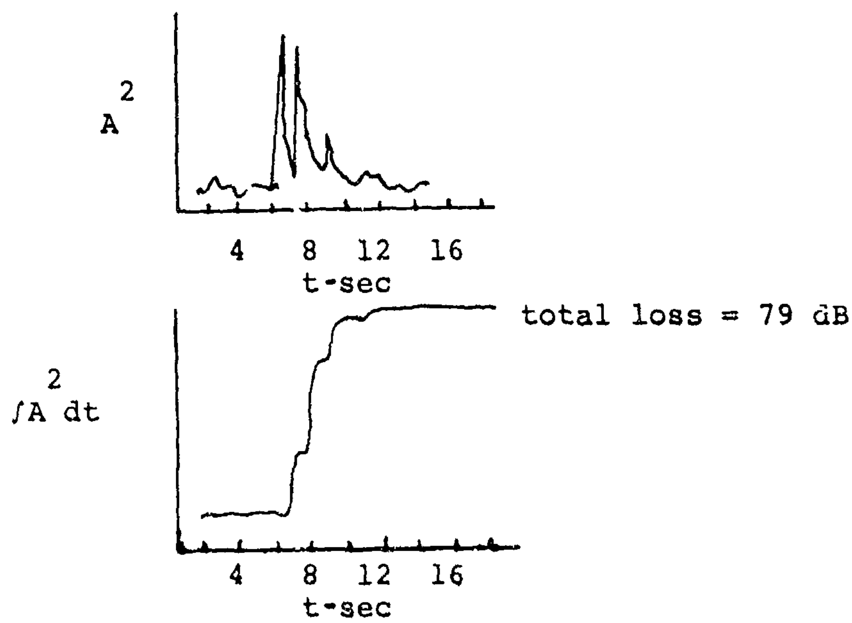
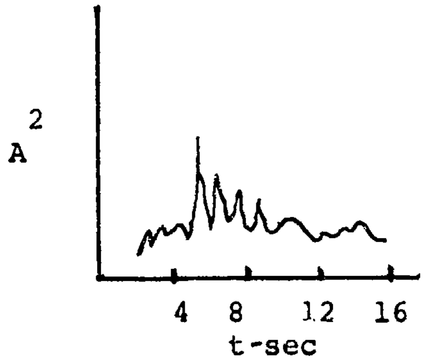


Figure (23). Shot arrival at Survey Array from 25 n.m. Event 6a, shot #458 at 300 feet, 35 Hz, 18% bandwidth, WECO processing.

Since the shortest range of suitable data received at the ACODAC site was about 200 n.m., the shot received by the Survey Array over the longest path was examined to see if bottom bounce arrivals were still clearly evident. Figure (24) shows an event at 99 n.m., in the fourth convergence zone. The bottom bounce arrivals are indeed evident in the upper plot and the energy curve shows that about half the total energy received is attributable to them. It would be expected that a shot at 200 n.m. would display similar features.

(U)Figure (25) shows the SUS arrivals on two ACODAC hydrophones with an expanded time scale. The frequency band is 10 to 300 Hz. The range is about 270 n.m. All received energy is contained within approximately 1/2 second, with the two major energy bursts corresponding to RSR arrivals separated by 300 to 400 milliseconds. As previously noted, the ACODAC overloaded for most shots at ranges less than 200 n.m. and the data could not be processed to determine propagation loss. However, ARL has found that it is possible to determine the duration of the received shot signal, even though it is overloaded. The results as received on ACODAC [illegible] for event 22a are shown in Figure (26). For ranges less than 175 n.m., the signal duration is 15 seconds or greater, suggesting a low bottom loss out to this range. The signal duration drops abruptly within 50 n.m. to three seconds, which



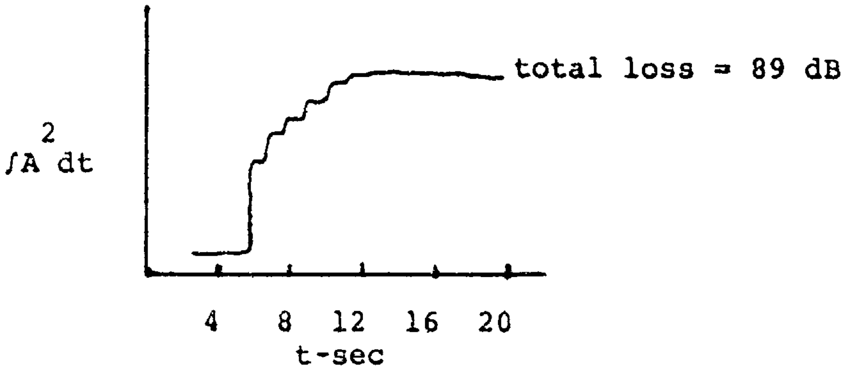


Figure (24). Shot arrival at Survey Array from 99 n.m. Event 6a, shot #100 at 300 feet, 35 Hz, 18% bandwidth, WECO processing.

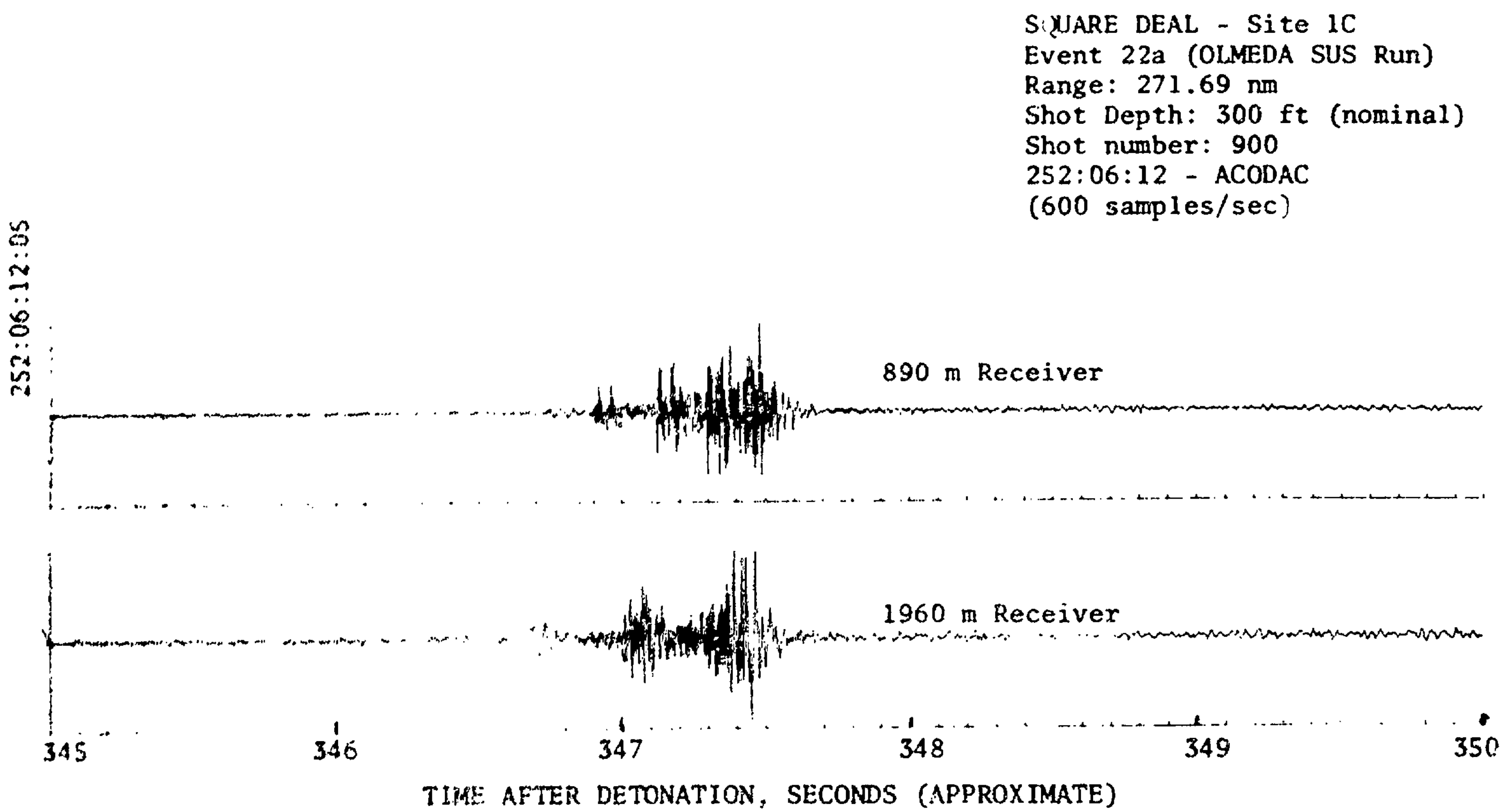


Figure (25). Shot arrival at ACODAC site A1C from 272 n.m. Event 22a, shot at 300 feet, 10-300 Hz broadband, ARL processing.

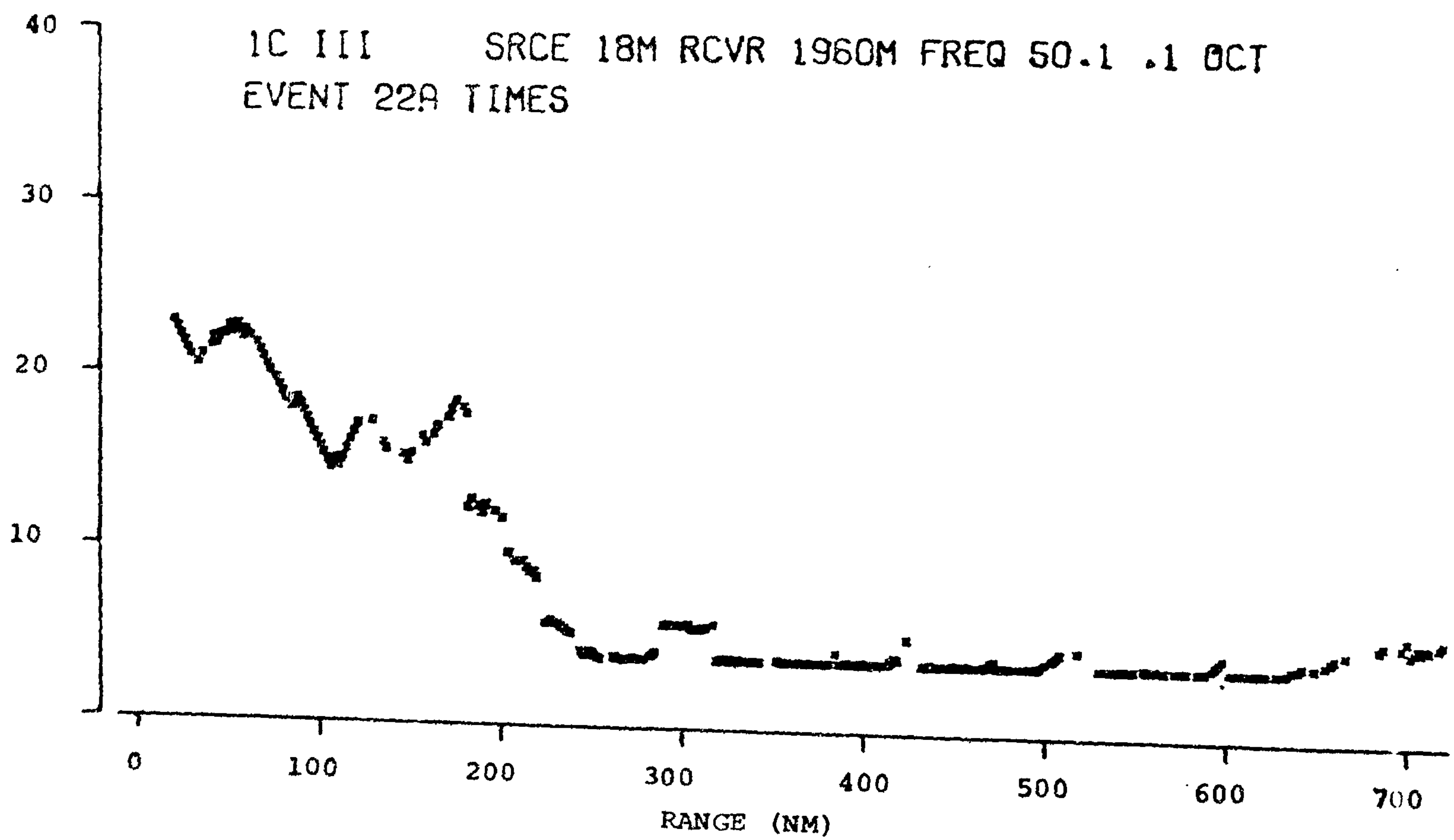


Figure (26). Shot signal duration as a function of range.

is the shortest integration time available with the ARL processor. Signal duration can be much shorter as is evidenced in Figure (25). This suggests a bottom loss transition at about 175 n.m., with high bottom loss conditions persisting for a sufficient distance to suppress bottom bounce arrivals from longer ranges. The effect of bottom-reflected paths on propagation loss is discussed in greater detail in Reference (25).

(U)It is concluded that the ACODAC and the Survey Array data are probably both valid. The low propagation loss measured with the Survey Array is due to the low bottom loss along the entire track. The high propagation loss measured with ACODAC at ranges greater than about 200 n.m. appears to be due to a transition from low to high bottom loss at about 175 n.m., with high bottom loss persisting for a sufficient distance to suppress bottom bounce propagation. Had it been possible to measure propagation loss at ranges shorter than 200 n.m. with the ACODAC, it is likely that significantly lower values would have been attained.*

*Overloading at the short ranges is due to the higher peak signal levels, and should not be interpreted to be due to or indicate the presence of low bottom loss conditions.

7. Other Considerations (U)

(U) To further investigate the validity of the ACODAC data a comparison was attempted between ACODAC and MABS, an independent system recording the same events. An event was chosen for the comparison during which the two systems were located reasonably close to each other geographically. However, the tracks to the two sites were over different paths and of different path lengths. Furthermore many of the ACODAC shot arrivals were overloaded, whereas there were no comparable indications for overloaded shot arrivals at MABS. Considering these different conditions and judging the results qualitatively, it may be said that the measurements made by the two systems agreed reasonably well. More details regarding this work may be found in Reference (19).

(U) It is apparent that in many cases information regarding bottom loss is an important factor in evaluating the applicability of various models, and that models must take bottom loss into account. It is recommended that future exercises include provisions for bottom loss measurement, or for data processing procedures designed to obtain bottom loss information.

(U)There are two ways that bottom loss measurements can be made. The first is a direct measurement in which the loss as a function of frequency and bottom angle is determined using SUS and single bottom encounters, as in the standard MGS surveys conducted by the Naval Oceanographic Office. A second method is to use the procedure discussed in this report and exemplified by Figures (23) to (25). This type of measurement can provide a more average value, in that more than one bottom encounter is involved, particularly for the longer ranges. J. Hanna of AESD views this as an inferred, rather than a direct measurement. For each track in each experiment we strongly recommend that a number of SUS signals be selected for processing in the manner described.

8. Summary and Conclusions(U)

(U)Because of puzzling discrepancies in SUS propagation loss data processed by different organizations, preliminary plots of experimental data showing confusing results, and differences in propagation loss measurements made by different systems, investigations were conducted in three general areas:

- Editing of CHURCH ANCHOR data
- Data processing comparisons and accuracy analysis
- Model computation comparisons with data from the SQUARE DEAL Exercise

(U)The CHURCH ANCHOR data was edited to a level satisfactory for use in the final report. This was accomplished by editing the PL data to eliminate data points that were shown to be suspect. Irregularities in the ambient background contaminate the PL measurements in three basic ways. First, the shot signal is masked by the presence of the noise; with very high noise levels, the shot may be totally hidden. Second, fluctuations in the noise tends to change the measured level. Third, narrowband, high amplitude noise components selectively contaminate the PL in certain bands. These problems are always present to some extent. It has been observed on multichannel recordings such as the ACODAC that high noise levels may render some channels useless, while not affecting others. The following factors should be taken into account when interpreting or editing PL data.

- Consistency and Reasonableness(U)

(U)Ideally, the PL data should trace a reasonable pattern. If the majority of the points do so, exceptional deviants should be checked for origins in recording or processing problems or eliminated out of hand.

- Background Noise(U)

(U)If the measurement signal-to-noise ratio is low (less than 3 dB, say), then a plot of the background noise should be inspected. If noise contamination is evident, then PL measurements near the noise peak are suspect. Also, correlations between the PL curves and the noise curves should prompt further investigations. However, if the noise is stable, then even PL data with low S/N may be used. Close study of the noise fluctuations may permit the establishment of estimated confidence levels for various S/N levels.

- SUS Spectra(U)

(U)If there are questions about what signals are actually being measured, then the power spectra of the shot and noise levels should be inspected. The presence of a SUS signal is confirmed by the characteristic bubble pulse spectrum. Additionally, it may be discovered that contamination of the PL data is limited to certain frequency bands.

(U)The data processing comparisons and accuracy analysis permitted an understanding of most of the discrepancies originally noted between facilities. The ACODAC and WECO Survey Array data both appear to be valid, since it was shown that the bottom conditions were different over the two sound paths. The ACODAC and MABS data agreed reasonably well. The repeatability of processing results and the agreement among results processed by different activities were reasonably good, although not yet as good as is desirable, except that WHOI processing yields propagation loss values about one or two dB too low on average. It is clear that all details must be meticulously documented. Source levels and processing bandwidths should be documented to permit data comparisons. A statement of the quality assurance procedures used, or a best estimate of data accuracy should be made. Ultimately it appears desirable to develop standardized procedures for calibrating processing systems.

(U)Although a small amount of degradation always occurs in the duplicating process, the duplicate recordings were found to be degraded by varying amounts relative to the original, sometimes by quite large amounts at the higher frequencies. The principal impact is to introduce serious artifacts in the measurement of ambient noise; i.e., measurement of system rather than ambient noise under some circumstances. This also affects propagation loss measurement accuracy, but to a lesser extent, by reducing S/N ratio. It is important to note that when processing SQUARE DEAL ambient noise data, WHOI used the original recordings, so that degradation in tape duplication would not affect those results.*

(U) Comparison of available experimental data with model computations showed reasonable agreement, when bottom loss is taken into account. It is apparent that bottom loss information is an important factor in evaluating models and that models must take bottom loss into account. It is recommended that future exercises include provisions for bottom loss measurement, or for data processing procedures designed to obtain bottom loss information.

*Since the commencement of the work discussed in this report, the Manager, LRAPP has contracted with the Martin Marietta Corporation Facility at Denver, Colorado to establish a magnetic tape repository and duplication facility, with the responsibility of insuring the quality of duplicate tapes. They are aware of the many problems involved, are developing detailed plans and procedures for their internal handling of LRAPP magnetic tapes, and are interacting with users of the duplicates.

REFERENCES

1. Underwater Systems, Inc. ltr #04277 to Manager, LRAPP, dtd June 17, 1974.

2. CHURCH ANCHOR Environmental Acoustics Summary, Draft, SECRET, June 1974.

3. CHURCH ANCHOR Environmental Acoustics Summary, Revised Draft, SECRET, June 1974.

4. Applied Research Laboratories ltr F-775 dtd 3 Oct. 1974 as corrected (encl. to ARL ltr F-780 dtd 9 Oct. 1974), Subj: Interpretation of SUS Measurement S/N and Editing of PL Data.

5. CHURCH ANCHOR Environmental Acoustics Summary, SECRET, September 1974.

6. Applied Research Laboratories ltr F-770 dtd 16 Sept. 1974, Subj: Editing of SUS Propagation Loss Figures for CHURCH ANCHOR Summary Report.

7. Applied Research Laboratories ltr F-749 dtd 11 July 1974, Subj: Comments on Propagation Loss Data for CHURCH ANCHOR, Site D.

8. Applied Research Laboratories ltr F-752 dtd 15 July 1974, Subj: Overloads in CHURCH ANCHOR Shot Propagation Data.

9. Woods Hole Oceanographic Institution ltr to M. S. Weinstein dtd June 24, 1974.

10. Private communication from R. Nowak, Woods Hole Oceanographic Institution.

11. Applied Research Laboratories ltr F-748 dtd 11 July 1974, Subj: Shot Processing Errors Introduced by Duplication of ACODAC Tapes, Playback Variability, and Processing Techniques.

12. Applied Research Laboratories ltr F-755 dtd 24 July 1974, Subj: Comparison of Shot Processing Between CHURCH ANCHOR Duplicate and Original ACODAC Tapes.

13. Applied Research Laboratories ltr F-760 dtd 8 August 1974, Subj: Comparison of SQUARE DEAL Duplicate and Original ACODAC Tapes for Site 2D.

14. Woods Hole Oceanographic Institution Memorandum, no serial, dtd August 11, 1974, Subj: WHOI Ambient Noise Comparisons of Original and Duplicate Tapes.

15. Underwater Systems, Inc. ltr #04362 to Manager, LRAPP dtd August 15, 1974, Subj: WHOI ACODAC Data Processing (report of task team visit to WHOI 9-10 August 1974).

16. Underwater Systems, Inc. ltr #04373 to Manager, LRAPP dtd August 27, 1974 (forwarding M/R "Briefing on Results and Status of Work on Diagnostic Plan").

17. Applied Research Laboratories ltr F-763 dtd 13 August 1974, Subj: Comparison of SQUARE DEAL Shots Processed at NUSC and ARL.

18. Applied Research Laboratories ltr F-785 dtd 29 Oct. 1974, Subj: ARL/UT-WECO SUS Processing Comparisons.

19. Applied Research Laboratories ltr F-776 dtd 22 Oct. 1974, Subj: MABS II and ACODAC Comparison.

20. AESD memorandum, no serial, dtd 18 July 1974, Subj: PE Comparisons with SQUARE DEAL Data for ACODAC 1C, Event 22A.

21. AESD memorandum, no serial, dtd 18 July 1974, Subj: FACT and PE Calculations for SQUARE DEAL Location 1A.

22. Underwater Systems, Inc. ltr #04375 to Manager, LRAPP dtd August 27, 1974 (forwarding copy of presentation given to the LRAPP Office on August 19, 1974).

23. Applied Research Laboratories ltr F-800 dtd 17 Dec. 1974, Subj: Comparison of SUS PL Measurements at WHOI and ARL/UT (Original ACODAC Tape).

24. Applied Research Laboratories ltr F-790 dtd 7 Nov. 1974, Subj: Comparison of SUS PL Measurements at WHOI and ARL.

25. R. C. Cavanagh, J. F. Hanna, C. W. Spofford, "SQUARE DEAL Model Evaluation Report", AESD Technical Report in preparation.

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Report Number	Personal Author	Title	Publication Source (Originator)	Pub. Date	Current Availability	Class.
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BKD2380	Unavailable	WESTLANT 74 PHASE 1 DATA SUMMARY (U)	B-K Dyanmics, Inc.	750301	NS; ND	U
TM-SA23-C44-75	Wilcox, J. D.	MOTION MODEL VALIDATION FROM LRAPP ATLANTIC TEST BED DATA	Naval Underwater Systems Center	750317	ND	U
RAFF7412; 74-482	Scheu, J. E.	SQUARE DEAL SHIPPING DENSITIES (U)	Raff Associates, Inc.	750401	ADC003198; NS; ND	U
PSI TR-004018	Barnes, A. E., et al.	ON THE ESTIMATION OF SHIPPING DENSITIES FROM OBSERVED DATA	Planning Systems Inc.	750401	ND AD 096 582	U
NUSC TD No.4937	LaPlante, R. F., et al.	THE MOORED ACOUSTIC BUOY SYSTEM (MABS)	Naval Underwater Systems Center	750404	ADB003783; ND	U
USI 460-1-75	Weinstein, M. S., et al.	SUS SIGNAL DATA PROCESSING (U) INVESTIGATIONS CONDUCTED UNDER THE DIAGNOSTIC PLAN FOR CHURCH ANCHOR AND SQUARE DEAL SHOT DATA (U)	Underwater Systems, Inc.	750414	ADC002353; ND	U
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NUC TP 419	Wagstaff, R. A., et al.	HORIZONTAL DIRECTIONALITY OF AMBIENT SEA NOISE IN THE NORTH PACIFIC OCEAN (U)	Naval Undersea Center	760501	ADC007023; NS; ND	U
NRL-MR-3316	Young, A. M., et al.	AN ACOUSTIC MONITORING SYSTEMS FOR THE VIBROSEIS LOW-FREQUENCY UNDERWATER ACOUSTIC SOURCE	Naval Research Laboratory	760601	ADA028239; ND	U
ARL-TR-75-32	Ellis, G. E.	SUMMARY OF ENVIRONMENTAL ACOUSTIC DATA PROCESSING	University of Texas, Applied Research Laboratories	760705	ADA028084; ND	U
Unavailable	Unavailable	SUMMARY OF ENVIRONMENTAL ACOUSTIC DATA PROCESSING	University of Texas, Computer Science Division	761013	ADA032562	U
TTA83676285	Unavailable	ANALYSIS PLAN FOR NARROWBAND/ NARROWBEAM AMBIENT NOISE (U)	Tetra Tech, Inc.	761112	ADC008275; NS; ND	U
USI 564-1-77	Wallace, W. E., et al.	REPORT OF CW WORKSHOP. NORDA, BAY ST. LOUIS, MISS., 28-29 SEPT 1976	Underwater Systems, Inc.	770124	ND	U