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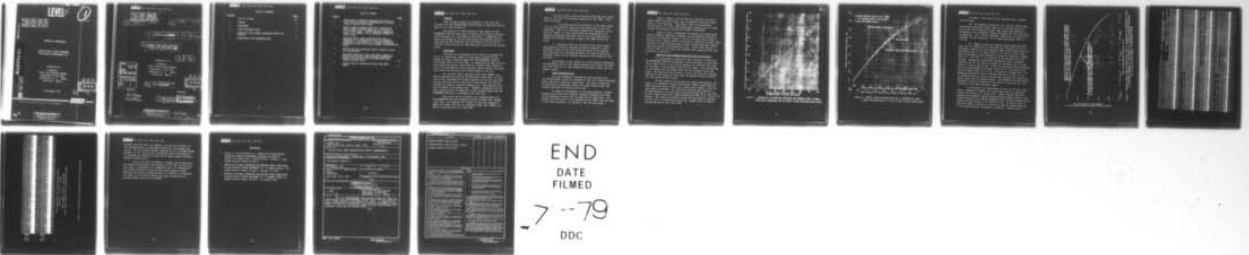
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Project Serial SS041 001
Tasks 8100, 8156, 8193
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TECHNICAL MEMORANDUM

**AN/SQS-26(BX) CODED PROCESSOR
AND DISPLAY PERFORMANCE (U)**

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Submitted to:

Commander,
Naval Ship Systems Command
Department of the Navy
Washington, D. C. 20360
Attention: PMS-87

30 November 1967

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Prepared

10 Douglas W. Duderstadt
Project Director

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1. SUMMARY

This document reports the analysis of sea test data recorded from the AN/SQS-26(BX) sonar system to check the performance of the coded processor.

The analysis of data recorded by USL aboard the USS WAINWRIGHT (DLG-28) shows that the gain of the clipped correlator coded processor is in accordance with theory. A comparison of expected performance criteria with signal detectability measurements made by USL during the sea tests shows a 2.5 dB loss in effective (S/N) between the coded processor output and the display output.

2. BACKGROUND

This work is an outgrowth of the effort to pinpoint the causes of significant losses in performance reported by USL during sea tests conducted aboard the USS WAINWRIGHT (DLG-28) from 28 May 1966 to 23 June 1966. An examination of this sea test data during the period 1 July 1966 to 4 October 1966 yielded no clear cut determination of any specific system failure that could have caused the observed loss in performance at sea [1].

On 5 October 1966 a meeting of USL, EDO, TRACOR, and PMS-87 personnel was held at the EDO plant in New York. At that time it was concluded that further analysis of the sea test data on hand would not yield a solution to the problem, and USL was directed to prepare a plan for another test. USL presented this plan to PMS-87 on 26 January 1967. TRACOR's subsequent work has been concerned with the analysis of data recorded aboard the USS WAINWRIGHT (DLG-28) in accordance with this plan.

USL carried out an extensive test program aboard the USS WAINWRIGHT (DLG-28) during the period 13 March 1967 through 1 May 1967. USL reported the results of this test program to PMS-87 on 26 May 1967 and to a meeting of EDO, USL, TRACOR, and PMS-87 representatives on 2 June 1967.



The USL results cited two factors which may have contributed to the loss in performance observed in June 1966. These were as follows:

1. A voltage controlled oscillator in the sonar system test set had drifted as much as 40 Hz during some of the test sequences. Since this oscillator controls the frequency of the test set signal, it could have caused the observation of an apparent performance loss when the test set was being used to measure the minimum detectable signal level (MDL) during the tests.

2. Excessive noise was observed in the video scanner (multiplexer) circuitry between the twelve channels of coded processor output and the scan converter prior to the display. This noise may be a contributing factor in losses between the processor output and the display observed by USL during the 1967 sea tests.

The purpose of this report is to show results validating the performance gain of the coded processor and to place an effective "dB" value on the loss between the processor output and the display output.

3. CODED PROCESSOR GAIN

The test equipment producing the data recorded from the AN/SQS-26(BX) system was designed to test the system performance under realistic conditions aboard ship. The tests, consisting of variations of synthetic signals and noise injected into the system, were made at dockside and at sea.

To check the performance of the coded processor, TRACOR compared the output of a computer simulated processor with that of the hardware processor for the same sets of input data. The signals and noise used for the simulation were taken from the input to the coded processor, as recorded on the sea test tapes.



Figure 1 shows a plot of computer simulated correlator output signal-to-noise ratio (S/N) vs hardware correlator output (S/N) for the same data. This figure shows the measurements falling about a 45° line, indicating equal average gains in (S/N) through the processor, except for random fluctuations.

Figure 2 shows a comparison of measured processing gains between computer simulated, hardware, and theoretical processors. These are in agreement within 0.5 dB for the input (S/N) range of interest here. Output (S/N) is plotted as a function of input (S/N) measured in a 500 Hz noise band in order to make numerical comparisons with similar data presented by USL. Input (S/N) relative to a 100 Hz band is also shown for reference and comparison with data presented in Section 4.

4. EFFECTIVE LOSS BETWEEN PROCESSOR OUTPUT AND DISPLAY

The measurements conducted by USL observers on board the USS WAINWRIGHT (DLG-28) established a 50% probability of detection for an input (S/N) of -11.5 dB as measured in a 500 Hz noise band at the input to the Automatic Gain Control (AGC). This corresponds to an average +15.5 dB output (S/N) for the hardware coded processor. The observers were alerted, in that they knew the expected location of the signal and knew that the signal had been injected into the system on each sweep.

The USL observers noted that the signal detectability was better on a makeshift storage oscilloscope display monitoring the coded processor output than on the A-scan sonar display, under the same signal conditions. The observers reported that signals at an input (S/N) of -11.5 dB could be detected about 90% of the time on the storage scope while being detected only 50% of the time on the display. USL reported potential causes and observations relating to this loss at the meeting between USL, TRACOR, EDO, and PMS-87 representatives at USL 2 June 1967.

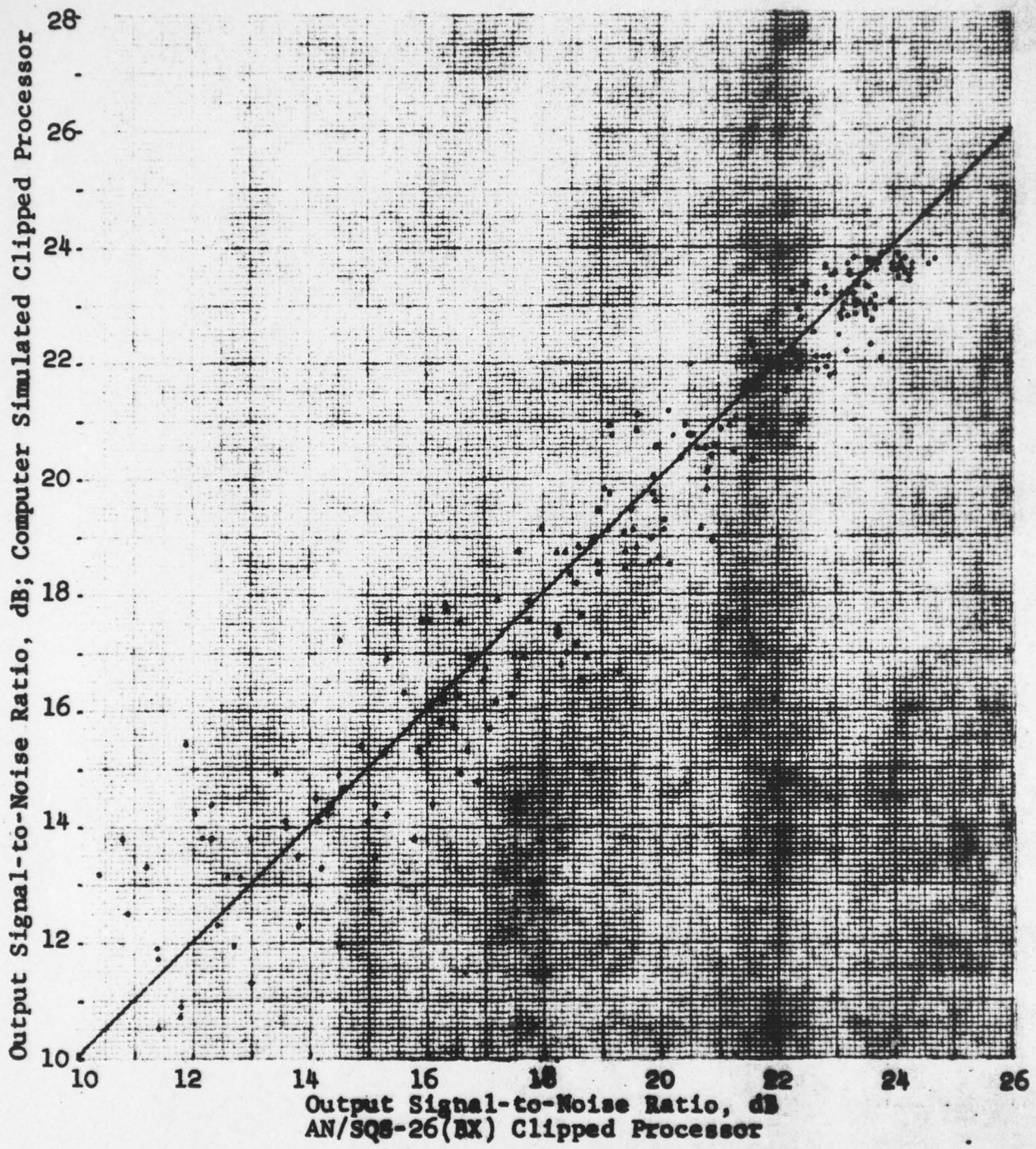


Figure 1 COMPARISON OF COMPUTER SIMULATED AND AN/SQS-26(BX) CLIPPED CORRELATOR PROCESSORS ON AN OUTPUT SIGNAL-TO-NOISE RATIO BASIS

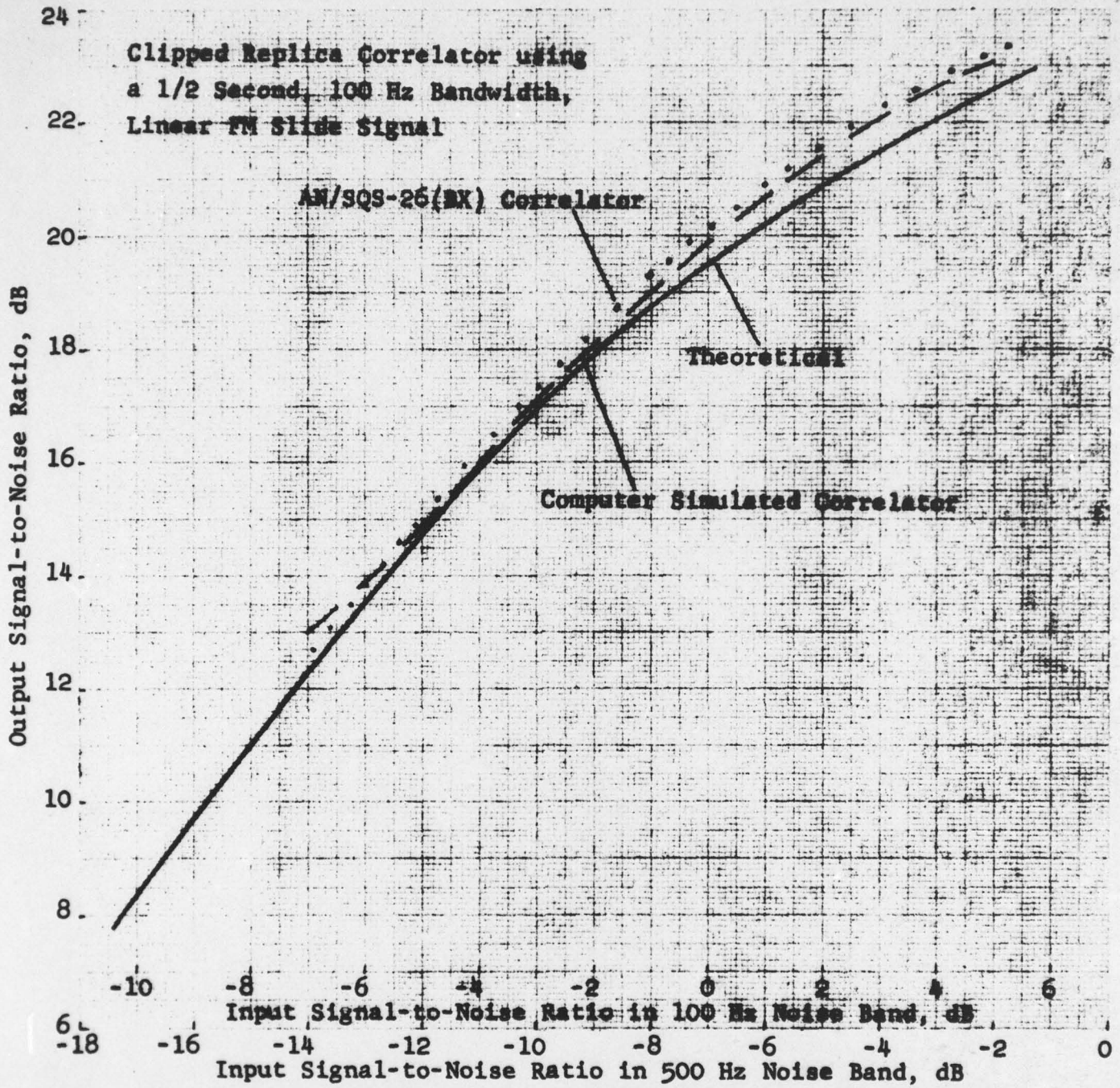


Figure 2 OUTPUT SIGNAL-TO-NOISE RATIO AS A FUNCTION OF INPUT SIGNAL-TO-NOISE RATIO IN A 100 Hz AND A 500 Hz NOISE BAND

To place a "dB" value on this reported loss, consider the following:

(a) For signals injected at -11.5 dB in a 500 Hz band, the hardware processor output (S/N) is 15.5 dB (See Figure 2). In the sea tests conducted by USL, this output was observed to correspond to the effective display threshold for 50% probability of detection. For a 100 Hz bandwidth, which will be used in the remainder of the discussion, the corresponding input (S/N) is -4.5 dB.

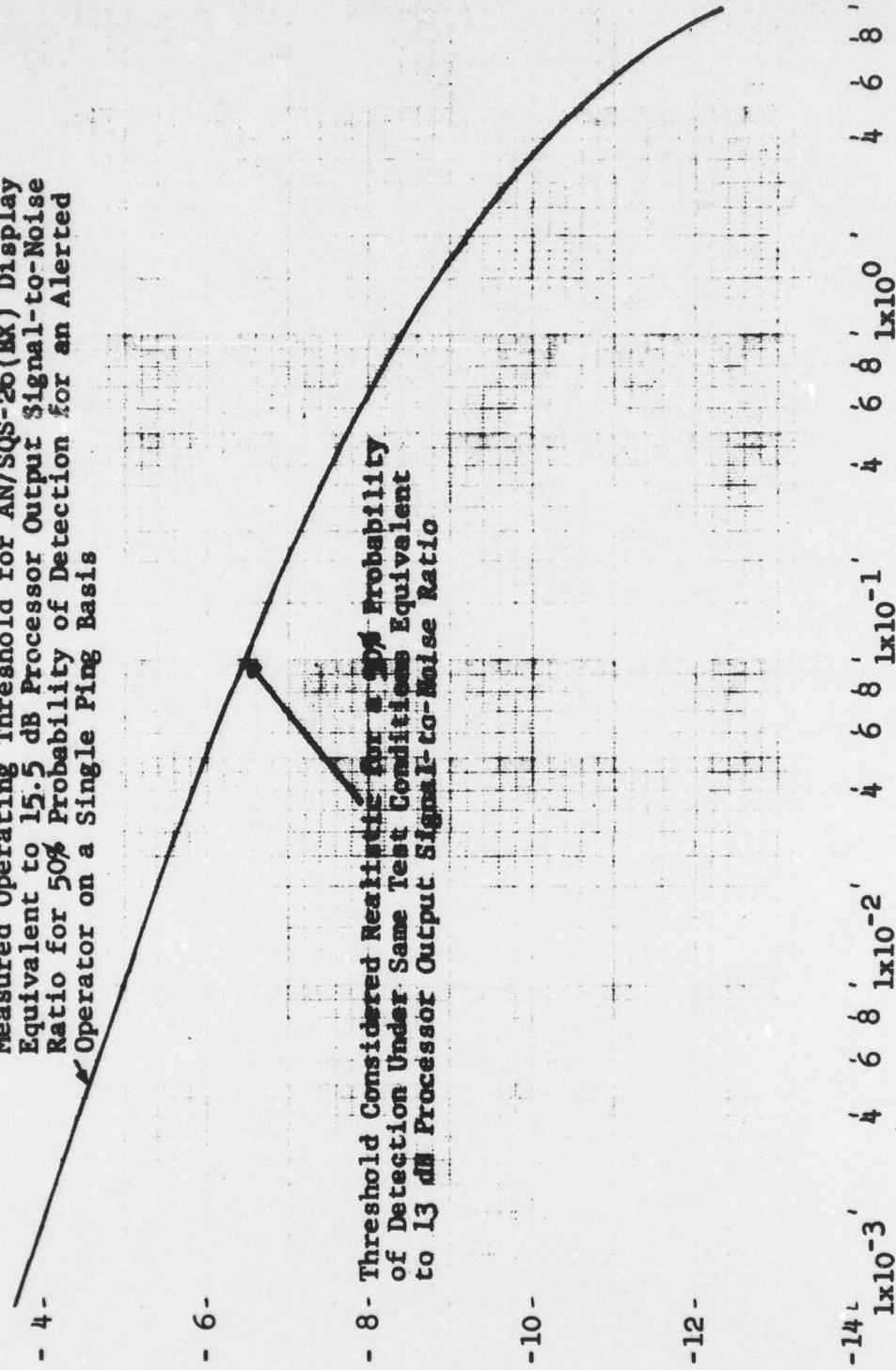
(b) Figure 3 shows the required input signal-to-noise ratio for 0.5 probability of detection as a function of rate of exceeding threshold for the processor under consideration here [2]. As shown in Fig. 3, an input (S/N) of -4.5 dB in a 100 Hz noise band corresponds to the threshold at which the threshold crossing rate is $5 \times 10^{-3} \text{sec}^{-1}$, or an average of one crossing every 200 seconds. Making the conservative assumption that a threshold crossing rate of one every 10 seconds is reasonable for a single sweep, it can be seen in Fig. 3 that the operating threshold should be that corresponding to an input (S/N) of -6.5 dB, which would give an output (S/N) of +13 dB. For greater crossing rates, the operating threshold would be lowered even more, so that it can be concluded that at least 2.5 dB are lost between the coded processor output and the display output. The AN/SQS-26 display should, therefore, be able to operate at an effective threshold of 13 dB referred to the coded processor output.

To illustrate the significance of this 2.5 dB loss, Fig. 4 shows a sequence of signals one second apart with the amplitude plotted vertically on a linear scale. These clipped correlator outputs were prepared using $\frac{1}{2}$ second FM slide signals added at one second intervals into 100 Hz bandwidth noise to yield average output signal-to-noise ratios of 15.5 dB and 13 dB. In traces A and B, note the change in ability to detect the 15.5 dB signals over the 13 dB signals without reference to threshold. Traces C and D

- 2 -

Measured Operating Threshold for AN/SQS-26(BX) Display
Equivalent to 15.5 dB Processor Output Signal-to-Noise
Ratio for 50% Probability of Detection for an Alerted
Operator on a Single Ping Basis

Required Input Signal-to-Noise Ratio for 0.5
Probability of Detection, dB



- 8 - Threshold Considered Realistic for a 30% Probability
of Detection Under Same Test Conditions Equivalent
to 13 dB Processor Output Signal-to-Noise Ratio

- 10 -

- 12 -

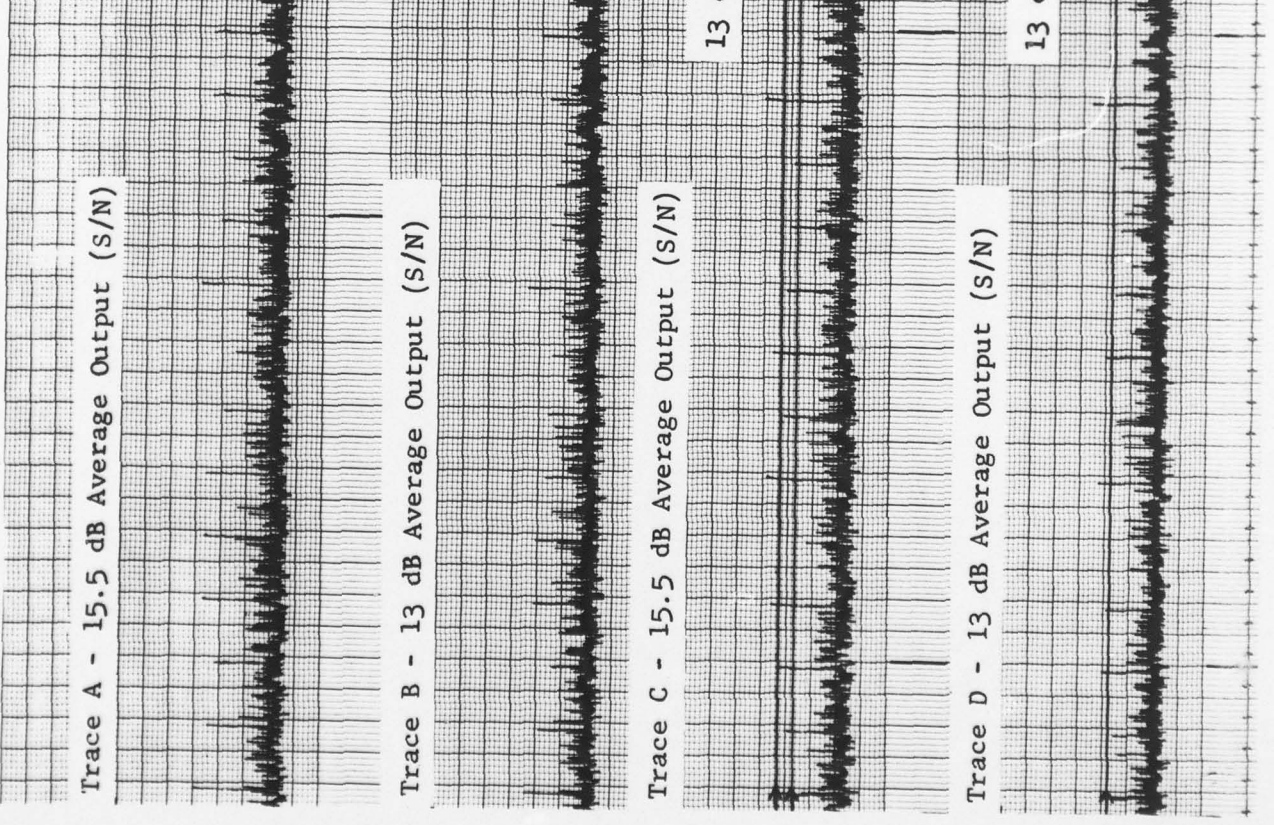
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1x10⁻³ 4 6 8 1x10⁻² 4 6 8 1x10⁻¹ 4 6 8 1x10⁰

Rate of Exceeding Threshold, sec⁻¹

Figure 3 REQUIRED INPUT SIGNAL-TO-NOISE RATIO FOR 0.5 PROBABILITY OF DETECTION vs RATE
OF EXCEEDING THRESHOLD AT THE OUTPUT OF A CLIPPED CORRELATOR OPERATING

ON 100 CPS FM SLIDE SIGNALS IN RECTANGULAR NOISE

Figure 4 CLIPPED REPLICA CORRELATOR-OUTPUT SIGNALS
SPACED 1 SECOND APART
100 Hz Bandwidth, 1/2 Second FM Slide Signals
Time Scale: 10 mm = 1 Second





from the same sequences of data have 15.5 and 13 dB thresholds marked. In trace C, significantly more signals can be detected without an excessive increase in false alarm rate by changing the threshold from 15.5 to 13 dB.

Figure 5 shows the measured probability that the clipped replica correlator output will exceed a given threshold for average input signal-to-noise ratios as shown [3]. This curve may be used to estimate the expected spread in output signal-to-noise ratio for a given input signal-to-noise ratio. For example, 90% of signals with an average input (S/N) of -3 dB will lie between 14 dB and 19 dB. The curve also may be used to determine the change in probability of detection for a given average input (S/N) as the detection threshold is changed. For the case considered in the preceding paragraph a sequence of 100 signals was added to the noise to yield 15.5 dB average output (S/N). Fifty-two of these signals exceeded a 15.5 dB threshold, 87 exceeded a 13 dB threshold. This is in close agreement with the same change indicated on the curve for -4.5 dB input (S/N).

To further support the assumption that a 13 dB operating threshold would not result in an excessive false alarm rate, consider Fig. 6. This figure shows 100 seconds of clipped correlator output using noise alone as input. The noise never crosses the 15.5 dB threshold, and it crosses the 13 dB threshold only three times. A 10 dB threshold is shown to illustrate how quickly the threshold crossing rate changes to an unacceptable value as the threshold is lowered.

5. CONCLUSIONS AND RECOMMENDATIONS

From the data presented in Sections 3 and 4 it is concluded that the coded processor is performing properly and that 2.5 dB is lost between the processor output and the display output for the AN/SQS-26(BX) system aboard the USS WAINWRIGHT. The causes of this loss, except for the excessive noise in the video scanner

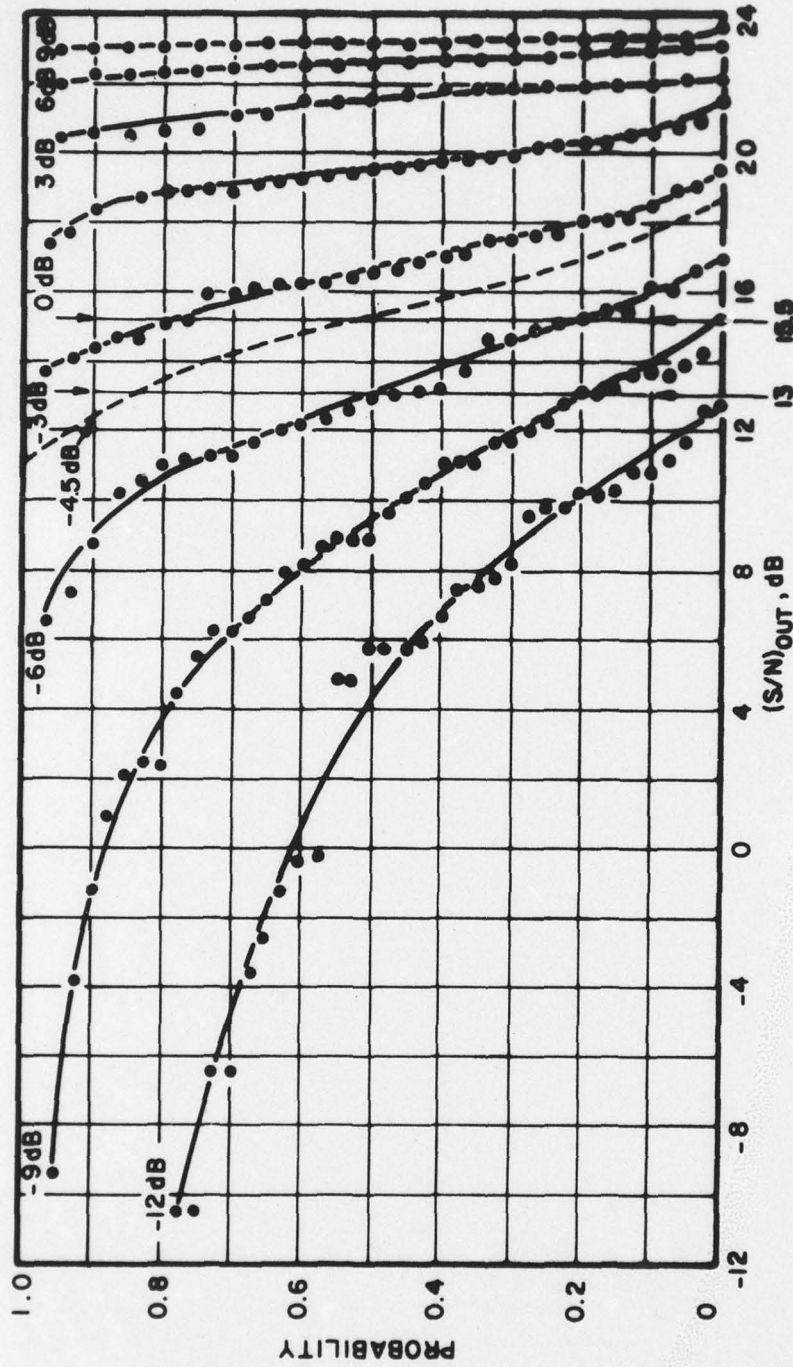
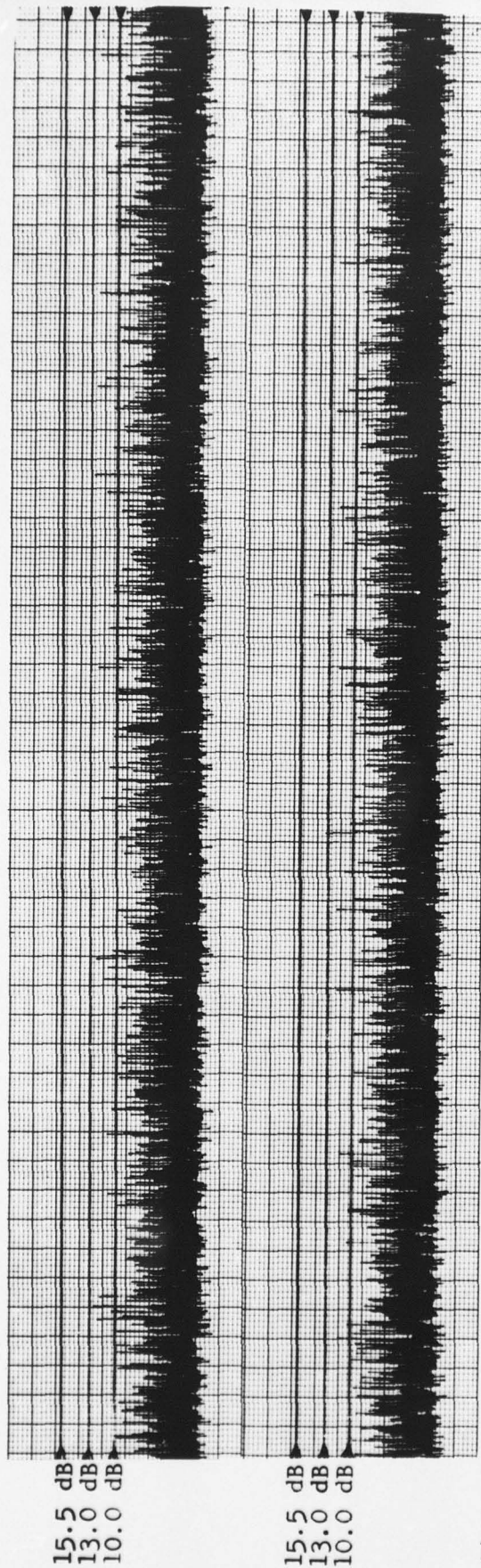


Fig. 5 - MEASURED PROBABILITY THAT THE OUTPUT SIGNAL-TO-NOISE RATIO OF THE CLIPPED CORRELATOR EXCEEDS THE ABSCISSA FOR THE INDICATED INPUT SIGNAL-TO-NOISE RATIO



11

100 Hz Bandwidth; 1/2 Second FM Slide Replica

Time Scale: 2.5 mm = 1 Second

Total Length of Trace = 100 Seconds

Output Signal-to-Noise Ratio Thresholds as Marked

Figure 6 CLIPPED REPLICA CORRELATOR OUTPUT FOR NOISE ALONE



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circuitry noted by USL, are unknown. No data are available on the recorded tapes to investigate problems in the display subsystem. If this problem appears consistently in all AN/SQS-26(BX) systems, it is a serious one, warranting further investigation to determine if corrective action can be taken without extensive hardware modifications.

Due to the lack of evidence to support any requirements for further investigation and analysis of the 1967 sea test data, this task is considered to be completed, and it is recommended that further efforts to describe and verify expected signal processor and display characteristics, if required, be continued as a part of the overall display and signal processing work programs being carried out by TRACOR.



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1. Butler, B. and Duderstadt, W. ANALYSIS OF AN/SQS-26(BX) SONAR DATA FROM USS WAINWRIGHT (DLG-28) SEA TEST OF 28 MAY to 23 JUNE, 1966 - Technical Note. October 4, 1966. TRACOR Document Number 66-477-U.
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