# U. S. NAVAL SUBMARINE MEDICAL CENTER

**Submarine Base, Groton, Conn.**

REPORT NUMBER 523

# THE CODE-COPYING CAPABILITIES OF RADIOMEN UNDER SIMULATED ATMOSPHERIC NOISE CONDITIONS

by

Alan M. Richards

Bureau of Medicine and Surgery, Navy Department

Research Work Unit MF022.01.04-9004.08

Released by:

Gerald J. Duffner, CAPT MC USN
COMMANDING OFFICER
Naval Submarine Medical Center

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Submitted by:

J. Donald Harris

J. Donald Harris, Ph.D.
Head, Auditory Research Branch

Reviewed and Approved by:

Charles F. Gell

Charles F. Gell, M.D., D.Sc. (Med.)
Scientific Director

Approved and Released by:

Gerald J. Duffner

Gerald J. Duffner, CAPT MC USN
COMMANDING OFFICER
Naval Submarine Medical Center

## SUMMARY PAGE


### THE PROBLEM

To explore the code-copying capabilities of Navy radiomen under various atmospheric noise conditions, and at various S/N radios.

### FINDINGS

It was found when using a white noise masker that code copy was not markedly affected until what would appear to be a critical S/N ratio was reached. After this point, code copy deteriorated rapidly. When simulated atmospherics were utilized, code copy did not deteriorate in any noticeable manner at any S/N ratio used. It was pointed out, however, that equivalent signal-to-noise ratios for white and atmospheric noise are not necessarily the same. Therefore, some qualifications were placed upon direct comparison between these two noise types.

### APPLICATION

The information in the present report can be used for a comparative analysis between automated code-copying machines and the performance of human transcribers.


### ADMINISTRATIVE INFORMATION


This investigation was conducted as a part of Bureau of Medicine and Surgery Research Work Unit MF022.01.04-9004 — Optimizing of Special Senses in Submarine and Diving Operations. The present report is No. 8 on this Work Unit. It was approved for publication (Clearance No. 708) on 15 May 1968 and designated as Submarine Medical Research Laboratory Report No. 523.





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# ABSTRACT

The code-copying ability of Navy radiomen at various signal-to-noise (S/N) ratios under four conditions of simulated atmospheric noise, and under white noise was tested. It was found that when a white noise was used, a critical S/N ratio where code copy deteriorated markedly was reached. Prior to this point, code copy appeared to be undisturbed. When the simulated atmospherics were used, no appreciable deterioration in code copy occurred at any of the S/N ratios sampled. It was pointed out, however, that equivalent S/N ratios for white and atmospheric noise are not necessarily the same. Therefore, qualifications must be made to a direct comparative analysis between simulated atmospherics and white noise maskers. It was further pointed out that if the S/N ratios for the atmospherics were lowered, some critical S/N might have been reached, as in the case of white noise, where code copy deteriorated rapidly. If this were the case, then a simple reduction of "X" dB would be all that was necessary to generalize the obtained performance criteria obtained under white noise to atmospherics.

# THE CODE COPYING CAPABILITIES OF RADIOMEN UNDER SIMULATED ATMOSPHERIC NOISE CONDITIONS

## INTRODUCTION

Until recently, it has been possible to evaluate noisy very low frequency (VLF) radio code reception in the laboratory setting only by using Gaussian noise. Using such a masker, Smith (1964) determined the code-copying ability of 18 Navy radiomen (RM2 and above) at various signal-to-noise (S/N) ratios between + 4.4 and + 9.4 dB (measured in a 125-Hz bandwidth at the IF of a radio receiver). Smith's test consisted of presenting 167 5-letter crypto word groups at a speed of 17-wpm for each S/N ratio tape segment. In brief, his data indicated that the code-copying ability deteriorated rapidly as the S/N ratio fell off below levels approximating 6.4 dB.

Two principal reasons have made inadvisable the use of atmospheric noise, the type found in the VLF spectrum, in the laboratory: (1) recordings of true atmospherics taken at radio receiver outputs were in constant vacillation, thereby precluding any effort to systematically evaluate the effects of any given atmospheric noise type on code reception; (2) the commercially available atmospheric noise generators proved to be "unsatisfactory for reasons of stability, repeatability, equipment size and cost" (Sicard & Foster, 1967).

Aware of the problems in atmospheric noise simulation, Sicard and Foster (1967), of the USN Underwater Sound Laboratory, designed and built the XN/ØØ noise synthesizer. This instrument proved to be reliable and stable, and to permit the repetition of a given atmospheric, a necessary condition for the comparative analysis of code-copying capabilities under different noises.

The present investigation utilized tapes recorded from the USNUSL XN/ØØ noise simulator in an effort to evaluate further the aural copying abilities of radio personnel. Specifically, the research sought to investigate the percentage of correct copy obtained by radiomen when presented with a variety of signals at various S/N ratios, and embedded in different types of atmospheric noise.

## METHOD

### Subjects

Five Navy radiomen (RM2 and above) were employed as observers. Although their listening experience differed widely (13 months to 13 years), no man reported any difficulty with the rate of code presentation. Each man had listened to code regularly prior to the initiation of the study in the course of his duty watch, which lasted up to 8 hours.

### Apparatus and Procedure

Thirty-five 1½ minute magnetic tape sections, each consisting of a given atmospheric noise type at a specific S/N ratio, were used as the test stimuli.

The various atmospheric conditions generated by the XN/ØØ simulator, and subsequently recorded on each taped segment, were derived from functions which indicated the Amplitude Probability Distribution (APD) (a plot of the percent time a noise exceeds a given threshold value versus the value of that threshold) of a given noise sample, and then by taking the ratio between the RMS voltage and the average voltage at this APD. The value derived from this procedure was designated as a Vd. Algebraically, the above operation is summarized as

$$Vd = 20 \text{ Log}_{10} \frac{\text{Voltage RMS}}{\text{Voltage AVG}}$$

where the value of Vd is expressed in decibels.

It should be noted that in the condition Vd = 1.05, the simulator was not used, but rather a white noise generator used to produce masking.

All Vd values given, including the value 1.05 (white noise), are with reference to a band of noise which is 125 cycles per second, or Hertz (Hz) wide at its 3-dB-down points, and which is centered at 1000-Hz.

The code stimuli were presented at 1000-Hz, and consisted of 5-letter crypto word groups. The code speed was 17-wpm, or twenty-six 5-letter groups per segment. Table I, columns 1 and 2, summarize the thirty-five conditions tested. It should be pointed out, however, that each segment was not delivered in the order presented in Table I, but rather in a fixed-random sequence. This procedure was followed to eliminate acclimation to any given noise type.

TABLE I

Median Percent Copy and Variability Among Subjects

| Noise Type (in Vd) | S/N Ratio (in dB) | Median Percent Copy (%) | Variability (%) |
|---|---|---|---|
| 1.05 (White Noise) | 24.12 | 100 | 99.1 - 100 |
| | 19.70 | 100 | 98.2 - 100 |
| | 17.70 | 100 | 96.0 - 100 |
| | 14.09 | 97.2 | 96.3 - 99.1 |
| | 12.40 | 98.1 | 96.2 - 99.0 |
| | 10.92 | 98.2 | 92.7 - 99.1 |
| | 8.64 | 93.3 | 91.4 - 95.2 |
| | 6.92 | 49.1 | 37.3 - 65.4 |
| 1.72 | 15.66 | 99.1 | 99.1 - 100 |
| | 14.09 | 98.1 | 95.2 - 100 |
| | 10.00 | 96.4 | 95.5 - 99.1 |
| | 7.00 | 99.1 | 99.1 - 100 |
| 2.50 | 16.44 | 99.1 | 95.4 - 99.1 |
| | 14.30 | 98.3 | 95.7 - 99.1 |
| | 13.12 | 100 | 98.2 - 100 |
| | 12.85 | 98.2 | 95.4 - 98.7 |
| | 11.52 | 99.2 | 95.4 - 100 |
| | 11.02 | 98.2 | 97.2 - 100 |
| | 9.76 | 97.7 | 94.8 - 98.3 |
| 3.25 | 13.53 | 100 | 99.1 - 100 |
| | 12.41 | 99.1 | 97.3 - 99.1 |
| | 11.52 | 100 | 99.1 - 100 |
| | 10.55 | 100 | 96.5 - 100 |
| | 9.12 | 100 | 95.8 - 100 |
| | 7.52 | 99.1 | 96.5 - 100 |
| | 5.80 | 97.3 | 94.5 - 98.2 |
| | 3.40 | 98.3 | 96.7 - 98.3 |
| 3.75 | 11.88 | 99.1 | 97.3 - 99.1 |
| | 10.64 | 99.0 | 95.2 - 100 |
| | 9.98 | 99.1 | 95.5 - 100 |
| | 9.25 | 98.3 | 98.3 - 99.1 |
| | 8.34 | 98.1 | 98.1 - 100 |
| | 7.14 | 100 | 99.1 - 100 |
| | 4.91 | 99.1 | 98.2 - 99.1 |
| | -0.04 | 95.5 | 93.8 - 99.2 |

## RESULTS AND DISCUSSION

Table I also indicates the median percent copy points for all thirty-five segments, as well as the range of scores for the 5 subjects within each condition. These data are graphed in Figures 1 and 2.

It may be noted in Fig. 1 that a very definite ceiling effect existed in that under the four noise conditions represented, the maximal code copying capabilities of the men were not reached. However, it should be noted that this study was not designed to test code speed reception, but rather the copying capabilities at a given speed (17-wpm). Therefore, no attempt to rectify this condition was deemed necessary.

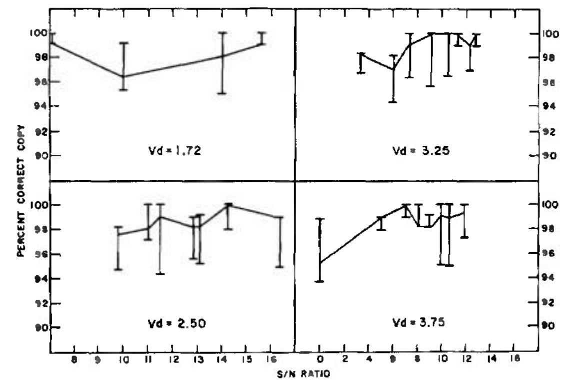


**Figure 1. Perecent correct copy and subject variability at various S/N ratios, and in four types of simulated atmospherics.**

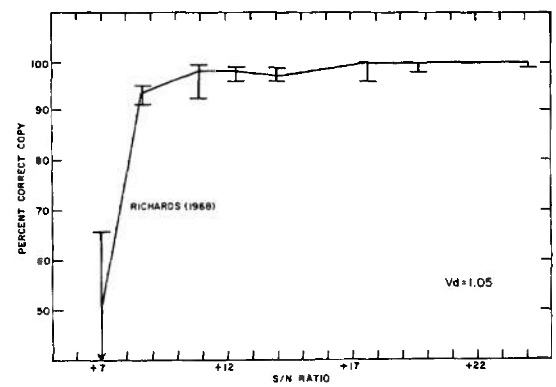


**Figure 2. Percent correct copy and subject variability at various S/N ratios in white noise.**

Further investigation of Fig. 1 reveals that the variability between the men appears to be small, and seldom exceed 5 percent. This suggests that the obtained functions lying in each quadrant of the figure, although irregular appearing, may in actuality be more linear. This view appears more tenable when one considers that the sample of men was small, and that the plotted points represent values ranging only from 90-100%.

Fig. 2 is analogous to Fig. 1 in that it indicates the percent copying performance as a function of S/N ratio, but this graph indicates values obtained in a white noise condition (Vd = 1.05). The most evident feature of the function is the rapid falloff in code copying which is exhibited at what would appear to be a critical S/N ratio. It is quite clear that a drop of 44.2% in code copy is introduced between S/N ratios of 8.64 and 6.92, which indicates that a critical value notion is tenable.

Figure 3 duplicates the function plotted in Fig. 2 (middle curve), and also includes the results obtained by Smith (1964) for a similar task (left hand curve). A 5-dB shift in Smith's function, explained later in the text, is also graphed (right hand curve).

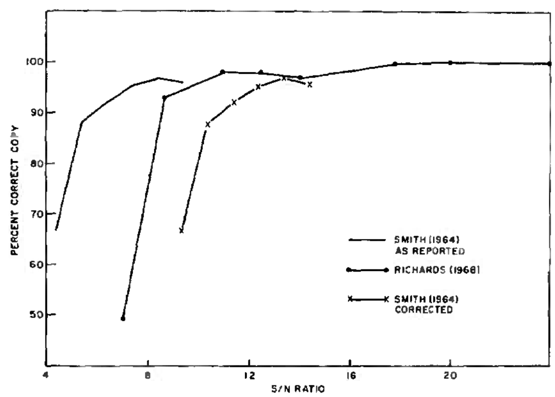


**Figure 3. Comparison of correct copy functions at various S/N ratios in white noise between the presently reported data, and those of Smith (1964).**

Smith's function indicates that a rapid drop in code copying begins at a level approximating 6.4 dB, and continues to the lower values examined. Although this falloff is less pronounced than the one in the present study, a drop of 21 percent points occurs between S/N ratios of 4.4 and 5.5. This, once again, adds to the notion that a critical masking level in code copy was reached when the dropoff occurred.

The divergence in the distance between these two analogous functions may be partially reconciled when it is realized that the place of measurement of the S/N ratios differed in both studies. Smith's study reported S/N ratios which were measured in a 125-Hz band at the IF of a radio receiver, although what the code operators heard was only 40-Hz wide, and was centered at 1000-Hz. On the other hand, the S/N ratios measured in this study were measured in a 125-Hz band at the subject's earphone. Therefore, some reconciliation between the functions may be found when Smith's ratios are referred to a 40-Hz band heard in the earphone, rather than at the receiver. This process is done by conversion, and is algebraically represented as

$$S/N_1 = 10 \text{ Log}_{10} \frac{B_1}{B_2} + S/N_2 = 10 \text{ Log}_{10} \frac{125}{40} + 9.4 = 5.0 + 9.4 = 14.4,$$

where $S/N_1$ is the new ratio to be found, $B_2$ represents the shifted bandwidth, $B_1$ is the old bandwidth, and $S/N_2$ is one of a number of old ratios. Thus the 5-dB shift in Smith's function, which is indicated on Fig. 3 (right curve), represents this transformation; it shows the S/N ratios which would have been obtained had they been measured at the subject's earphone rather than at the receiver. Using this transformed plot as a base, it can be seen that the two studies, when correctly compared, differ by no more than 2 dB along the entire continuum; differences which exist may be accounted for by the differential bandwidths (40- and 125-Hz) at the earphone, and possibly by subject variations.

Figure 4 shows all the functions obtained in this study along the same coordinates. From this figure the most important aspects regarding the code-copying capabilities of radiomen under atmospheric conditions may be gleaned. An overview of the graph indicates that while a white noise masker (Vd. = 1.05) deteriorates code copy marked-

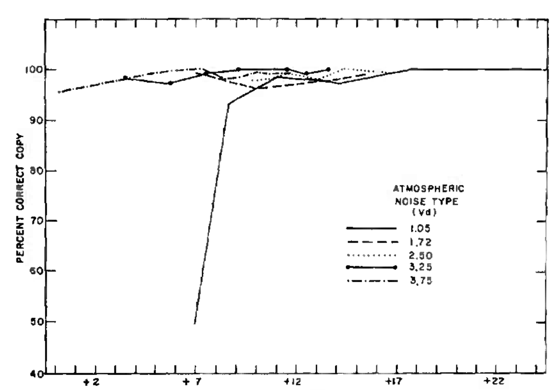


**Figure 4. Percent correct copy at various S/N ratios for all five atmospheric noise types.**

ly below a signal-to-noise ratio of approximately 8.4 dB, there is practically no deterioration of performance evidenced in the other noise conditions at any S/N ratio studied.

Although the results of the present research, as depicted in Fig. 4, seem to point to the inefficacy of white noise as a true and meaningful atmospheric noise simulator, this conclusion cannot be readily drawn. This is based upon the fact that atmospherics displaying S/N ratios equivalent to white noise may, in fact, not be equivalent at all.

It should be noted that in the calibration of any given Vd, the noise utilized is not at a set level, but varies as an amplitude probability distribution (APD). On the other hand, when white noise is measured, its levels are steady state. Thus, when S/N ratios in atmospherics are measured over a given time period, the level of the noise represents the average of greatly diverging peak levels, whereas, when measurement of the S/N ratio is made in white noise, the peak levels are relatively constant. The implication to be drawn from the foregoing is that the divergence between the atmospheric and white noise functions seen in Fig. 4 may actually be due to the inequivalence of S/N ratios, rather than to true differences between atmospheric and white noises.

It may be the case that, as the S/N of atmospheric noise becomes increasingly less, code copying performance will fall off at the same rate as occurs under white noise masking. If this is the case, white noise may be used as an atmospheric simulator, with the fact in mind that a reduction of "X" dB in S/N would convert the obtained values to any given atmospheric type.

## References


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13. ABSTRACT

The code-copying ability of Navy radiomen at various signal-to-noise (S/N) ratios under four conditions of simulated atmospheric noise, and under white noise, was tested. It was found that when a white noise was used, a critical S/N ration was reached where code copy deteriorated markedly. Prior to this point, code copy appeared to be undistrubed. When the simulated atmospherics were used, no appreciable deterioration in code copy occurred at any of the S/N ratios sampled. It was pointed out, however, that equivalent S/N ratios for white and atmospheric noise are not necessarily the same. Therefore, qualifications must be made to a direct comparative analysis between simulated atmospherics and white noise maskers. It was further pointed out that if the S/N ratios for the atmospherics were lowered, some critical S/N might have been reached, as in the case of white noise, where code copy deteriorated rapidly. If this were the case, then a simple reduction of "X" dB would be all that was necessary to generalize the obtained performance criteria obtained under white noise to atmospherics.

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