

AD A050163

JAD No.
DDC FILE COPY



DEFENSE COMMUNICATIONS ENGINEERING CENTER

AD-E 100 024

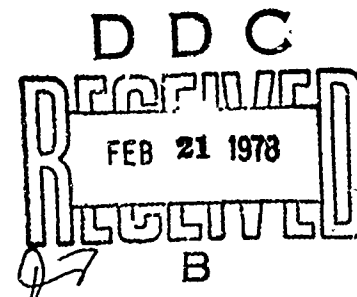
12
NW

TN 6-77

TECHNICAL NOTE NO. 6-77

PERFORMANCE MEASUREMENTS OF THE
CVSD SPEECH CODING ALGORITHM

AUGUST 1977



Approved for Public Release;
Distribution Unlimited

RE: Classified references--
DCEC TN No. 6-?/
Document should remain for unlimited
distribution per Mr. A. Trainor, DCEC

DEFENSE COMMUNICATIONS AGENCY SUMMARY SHEET

Route to	Action	Signature	Originator (Symbol)	Tel. No.	Date
R101	Concur		Code R540	437-2441	23 Sept 77
R200	Concur				
R300	Concur	<i>Robert H. Hickey (see memo on p. 3)</i>			
R400	Concur				
R700	Concur		Action		
R800	Concur		Office		
R100	Sign	<i>M. Thompson</i>	(Signature)		
			MARTIN A. THOMPSON		Typist's Initials
			Chief, Switched Networks		jmt
			Engineering Division		
			(Typed Grade and Surname)		

Subject

TN 6-77 Performance Measurements of the CVSD Speech Coding Algorithm

Summary

DDC
RECEIVED
FEB 21 1978
B

DISTRIBUTION STATEMENT A

Approved for public release;
Distribution Unlimited

TECHNICAL NOTE NO. 6-77

PERFORMANCE MEASUREMENTS OF THE
CVSD SPEECH CODING ALGORITHM

AUGUST 1977

Approved for public release; distribution unlimited.

UNCLASSIFIED R500 30 June 1977

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER TN-6-77	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) PERFORMANCE MEASUREMENTS OF THE CVSD SPEECH CODING ALGORITHM.	5. TYPE OF REPORT & PERIOD COVERED 9 Technical Report note,	
6. AUTHOR(s) 10 WILLIAM/BELFIELD	7. CONTRACT OR GRANT NUMBER(s) 14 TN-6-77	
9. PERFORMING ORGANIZATION NAME AND ADDRESS Defense Communications Engineering Center Switched Networks Engineering Division R500 1860 Wiehle Ave., Reston, VA 22090	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS N/A	
11. CONTROLLING OFFICE NAME AND ADDRESS (Same as 9)	12. REPORT DATE 11 Aug 1977	
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) N/A 18 SBIE 19 AD-E100 024	13. NUMBER OF PAGES 12 24p.	
	15. SECURITY CLASS. (of this report) UNCLASSIFIED	
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE N/A	
16. DISTRIBUTION STATEMENT (of this Report) A. Approved for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report) N/A		
18. SUPPLEMENTARY NOTES Review relevance 5 years from submission date.		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) CVSD Modulation Digital Voice Terminal Delta Modulation Digital Voice Communications Speech Coders Speech Intelligibility and Quality		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report describes a series of tests that were conducted to measure the performance of the CVSD algorithm. These tests measured the performance sensitivity of CVSD modulation with respect to the algorithm parameters. The results presented in this report show that speech intelligibility and quality of CVSD coders are most sensitive to compression ratio. As a result of these tests it is recommended that certain CVSD parameters be used for coder applications under conditions of low transmission error rates.		

TECHNICAL NOTE NO. 6-77

PERFORMANCE MEASUREMENTS OF THE CVSD
SPEECH CODING ALGORITHM

AUGUST 1977

Prepared by:

o William Belfield

Approved for Publication:

Martin A. Thompson
MARTIN A. THOMPSON
Chief, Switched Networks
Engineering Division

ACCESSION for	
NTIS	White Section ☒
DDC	Blue Section ☐
UNANNOUNCED	☐
JUSTIFICATION _____	
BY _____	
DISTRIBUTION/AVAILABILITY CODES	
Dist.	AVAIL. and/or SPECIAL
A	

FOREWORD

The Defense Communications Engineering Center (DCEC) Technical Notes (TN's) are published to inform interested members of the defense community regarding technical activities of the Center, completed and in progress. They are intended to stimulate thinking and encourage information exchange; but they do not represent an approved position or policy of DCEC, and should not be used as authoritative guidance for related planning and/or further action.

Comments or technical inquiries concerning this document are welcome, and should be directed to:

Director
Defense Communications Engineering Center
1860 Wiehle Avenue
Reston, Virginia 22090

TABLE OF CONTENTS

	<u>Page</u>
I. INTRODUCTION	1
II. BACKGROUND	2
III. TEST DESCRIPTION	5
IV. RESULTS	6
1. Compression Ratio	6
a. Intelligibility	
b. Quality	
2. Filter Bandwidth	8
a. Intelligibility	
b. Quality	
3. Time Constants	12
a. Step Size Filter	
b. Integrator	
4. Comparison of CVSD Coders	12
V. CONCLUSIONS	15
REFERENCES	17

LIST OF ILLUSTRATIONS

<u>Figure</u>	<u>Title</u>	<u>Page</u>
1.	CVSD ALGORITHM	3
2.	INTELLIGIBILITY SCORES	7
3.	QUALITY SCORES	9
4.	RELATIONSHIP OF QUALITY SCORES TO ACCEPTABILITY	10

LIST OF TABLES

<u>Table</u>	<u>Title</u>	<u>Page</u>
I.	FILTER BANDWIDTH TEST	11
II.	TIME CONSTANT TEST	11
III.	COMPARISON OF CVSD CODERS	14

I. INTRODUCTION

A set of experiments was conducted to evaluate the performance of the Continuously Variable Slope Delta (CVSD) speech coding algorithm. These experiments quantitatively measured the performance sensitivity of CVSD coding with respect to the algorithm parameters.

The parameters examined included time constants, compression ratio, and filter bandwidths. The performance of a CVSD coder in terms of speech quality and intelligibility depends on the values of these parameters. Performance also depends to some extent on the type of implementation; that is, analog or digital.

In addition to measuring the relative sensitivity of the algorithm to the basic parameters, these experiments were also used to determine an appropriate set of parameters for DCS applications.

It was found that CVSD performance is most sensitive to compression ratio. Relatively high values of compression ratio result in the best performance. In addition, the results indicate a user preference for a filter bandwidth of 3 kHz compared with a bandwidth of 4 kHz. Based on these results, certain parameters have been selected for CVSD coder operation under conditions of moderate transmission bit error rates.

1

II. BACKGROUND

Results from the Narrowband Consortium tests [1] show that the performance of CVSD coders depends on such factors as the condition of the input signal and transmission error rate. For example, it has been found that there is a degradation in speech quality when speech synthesized by a linear predictive coding (LPC) terminal is applied to a CVSD coder. Experimental evidence suggests that modifications of the CVSD parameters can result in improved performance of this LPC tandem configuration.

In a tactical communications environment, there is a requirement for CVSD coder operation under conditions of a 10% transmission error rate. However, in the Defense Communications System (DCS), error rates are expected to be less than 0.1%. These two different requirements impose different constraints on the CVSD parameter sets. One aim of the tests described here is to determine if there is any significant difference in the performance of CVSD coders whose parameters are optimized to satisfy these different requirements.

The design of the CVSD digital voice coder is illustrated by the block diagram shown in Figure 1; this diagram shows how the binary transmission data and output speech are derived. The function of the logic circuit is to generate a pulse whenever three successive transmission bits are identical. The basic parameters of the CVSD algorithm are:

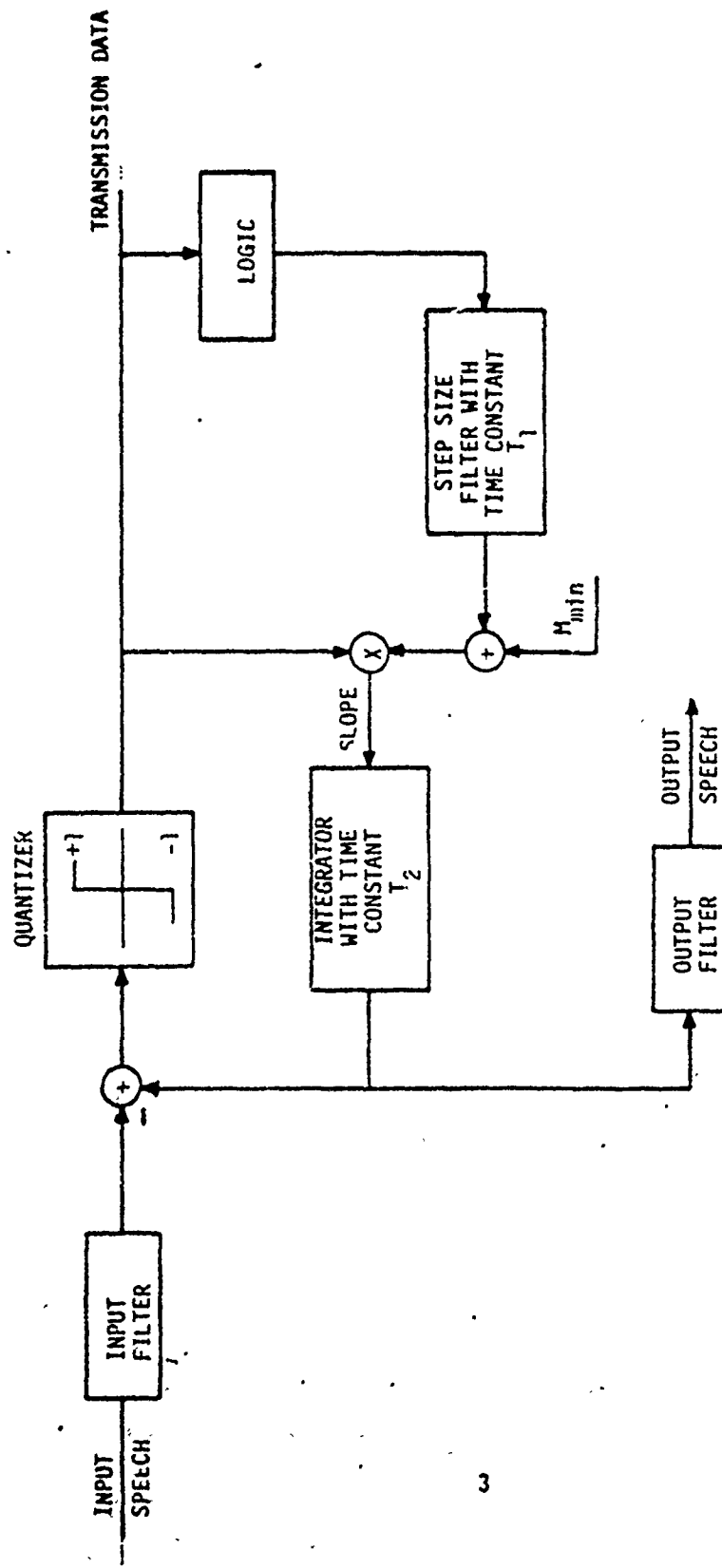


Figure 1. CVSD Algorithm

- a. Input and Output Filter Bandwidth
- b. Maximum Slope, $M_{\max}$
- c. Minimum Slope, $M_{\min}$
- d. Step-Size-Filter Time Constant, T_1
- e. Integrator Time Constant, T_2 .

The ratio of maximum slope to minimum slope is often called compression ratio. The performance of a CVSD coder in terms of speech quality and intelligibility depends on the values of these parameters. Performance also depends to some extent on the type of implementation; that is, analog or digital circuit implementation.

III. TEST DESCRIPTION

Tests were performed to measure quantitatively the performance sensitivity of the CVSD algorithm with respect to time constants, compression ratios, and filter bandwidths. The Sylvania Programmable Signal Processor (PSP) was used to simulate the CVSD coder operating in real time. The details of the simulation are described in the Sylvania final report [2]. A variety of CVSD parameter sets were selected and tested using the PSP simulation. In addition, a CVSD coder built by Codex Corporation was tested. This coder is a digital circuit implementation that was designed to optimize speech quality under conditions of moderate transmission error rates. The details of the Codex CVSD speech terminal are included in the Codex final report [3].

In these tests the speech coders were operated at a transmission rate of 16 kb/s with no transmission errors. This condition closely approximates operation in the DCS where error rates are expected to be less than 0.1%. The performance of the CVSD coders was measured in terms of both intelligibility and quality. The Diagnostic Rhyme Test (DRT) was used to measure word intelligibility [1]. The DRT employed three speakers using one-half of a full word list; the speakers consisted of two males and one female. In the set of tests described, the Quality Acceptance Rating Test (QUART) was used to measure quality [4]. It is generally accepted that a five point difference between quality test scores represents a significant difference in speech quality. All intelligibility and quality testing was accomplished by Dynastat Corp.

IV. RESULTS

1. COMPRESSION RATIO

a. Intelligibility. In order to measure the effect of compression ratio on output speech intelligibility, tests were performed using the PSP with four different compression ratios ranging from 10 to 150. The remaining parameters were fixed at the following values:

$$T_1 = 6.3 \text{ ms}$$

$$T_2 = 10 \text{ ms}$$

$$\text{Filter Bandwidth} = 3 \text{ kHz}$$

Figure 2 is a plot of DRT scores corresponding to the four different compression ratios. It should be recognized that DRT scores above 90 represent highly intelligible systems. This graph shows that intelligibility scores generally increase if the compression ratio is increased from 10 to 150. The DRT scores are maximum when corresponding to a compression ratio of 150; the scores are minimum for compression ratios in the range of 10 to 20. For male speakers the difference between maximum and minimum scores is 2.9 points; the standard error for this DRT is approximately 1.0. For female speakers the difference between maximum and minimum scores is 5.2 points with a standard error of approximately 1.0. These results indicate a measurable and statistically significant improvement in the intelligibility of speech processed by a CVSD coder if the compression ratio is increased from 10 to 150. Additional tests with a compression ratio of 200 did not indicate much improvement in performance compared with a compression ratio of 150; also with a compression ratio of 200 performance was degraded under conditions of transmission errors.

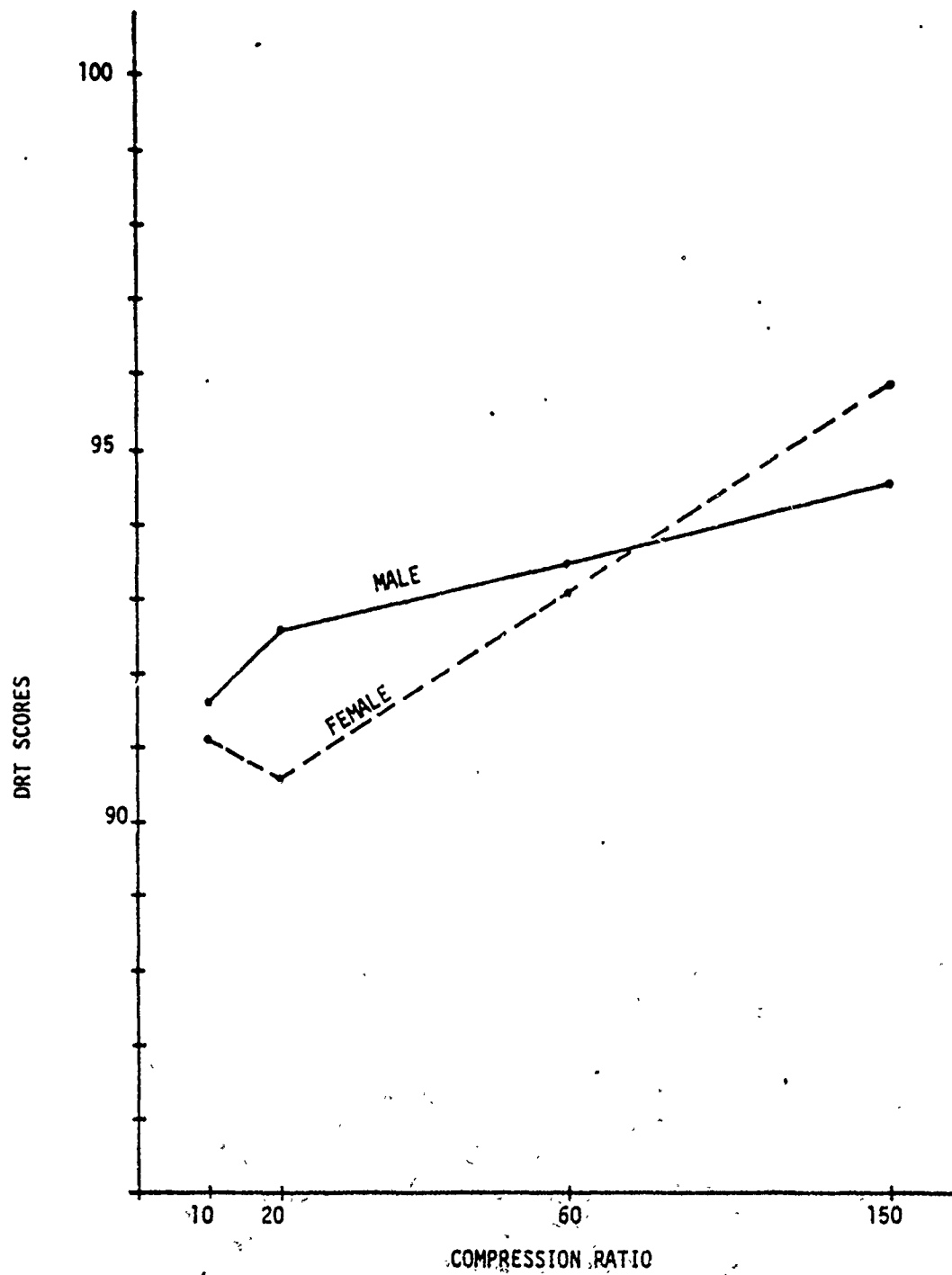


Figure 2. Intelligibility Scores

b. Quality. Quality measurements were accomplished using the QUART which assigns a numerical rating to predict user preference for communications systems. Figure 3 is a plot of QUART scores corresponding to four different compression ratios. The standard error of these quality scores is approximately 2.5. The difference between the maximum and minimum QUART scores is 10.1 points. These results indicate that quality scores increase monotonically with compression ratio and that there is a significant user preference for the highest value of compression ratio. Figure 4 shows the relation between quality scores and the percentage of people who find the communications acceptable for routine use.

2. FILTER BANDWIDTH

a. Intelligibility. The effects of changing the input and output filter bandwidths were measured. Table I lists the DRT scores corresponding to filter bandwidths of approximately 3 kHz and 4 kHz; these are the cutoff frequencies of the low pass output and input filters which are seventh order elliptic filters. The standard error of each DRT is shown to the right of the score. Although the intelligibility score for the female speaker is unchanged, the score for the male speakers is slightly higher, corresponding to the increased bandwidth. With a compression ratio of 150, the DRT scores are increased slightly for male speakers and decreased for female speakers, corresponding to the increased bandwidth. These results indicate that there is no significant overall difference in DRT scores corresponding to the two filter bandwidths.

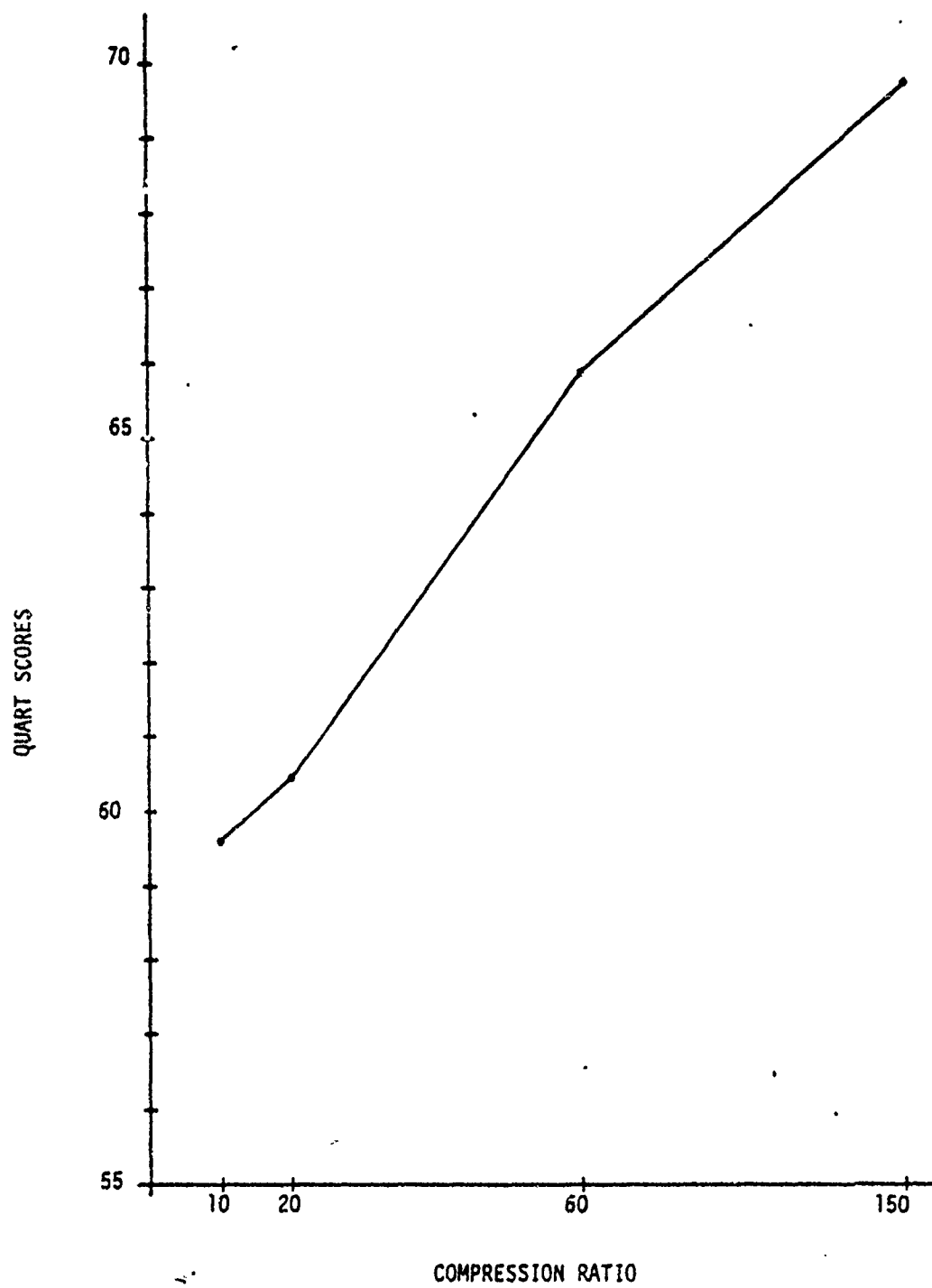


Figure 3. Quality Scores

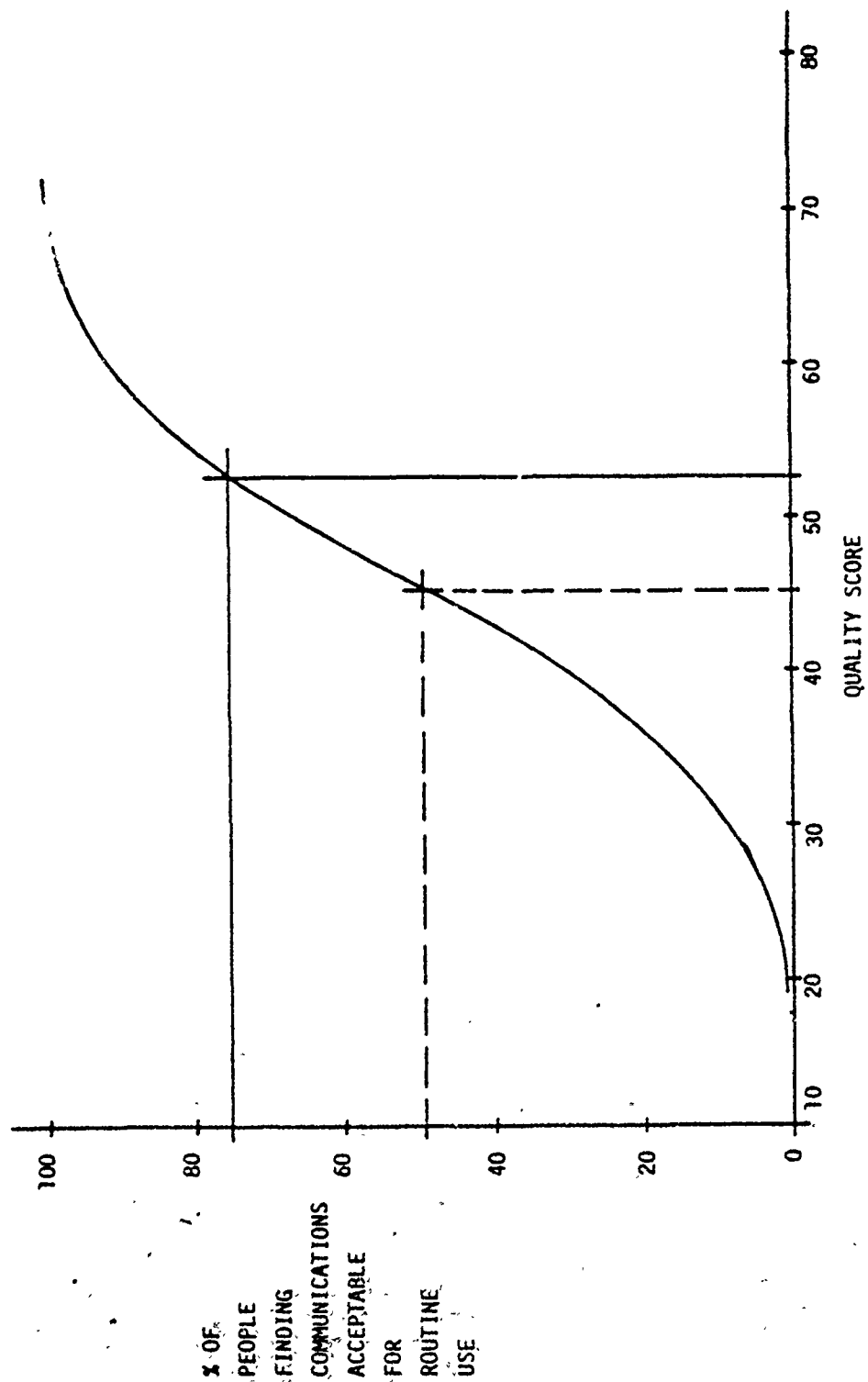


Figure 4. Relationship of Quality Scores to Acceptability

TABLE I. FILTER BANDWIDTH TEST

COMPRESSION RATIO	FILTER BANDWIDTH	DRT SCORE		QUART SCORE
		MALE	FEMALE	
10	3 kHz	91.6 $\pm$.75	91.1 $\pm$.88	59.6 $\pm$ 2.3
	4 kHz	93.1 $\pm$.81	91.1 $\pm$.94	55.2 $\pm$ 1.6
150	3 kHz	94.5 $\pm$.85	95.8 $\pm$.48	69.7 $\pm$ 3.2
	4 kHz	95.1 $\pm$.89	92.2 $\pm$.80	63.6 $\pm$ 3.2

TABLE II. TIME CONSTANT TEST

T ₁	T ₂	DRT SCORE		QUART SCORE
		MALE	FEMALE	
6.3 ms	1 ms	91.6 $\pm$.75	91.1 $\pm$.88	59.6 $\pm$ 2.3
	20 ms	91.7 $\pm$.58	90.2 $\pm$ 1.0	57.9 $\pm$ 1.6
20 ms	1 ms	91.0 $\pm$.34	87.1 $\pm$ 1.4	56.7 $\pm$ 1.3
	20 ms	90.5 $\pm$.96	88.0 $\pm$ 1.3	53.6 $\pm$ 1.0

b. Quality. The results of the quality tests are also listed in Table I. These results indicate a rather significant user preference for the 3 kHz bandwidth compared with the 4 kHz bandwidth. The improvement in the QUART score is approximately 5 points when the cutoff frequency is reduced from 4 kHz to 3 kHz.

3. TIME CONSTANTS

Tests were performed to measure the performance sensitivity of the CVSD algorithm with respect to the time constants of the integrator and step-size-filter. For these tests the following parameters were set:

Compression ratio ≈ 10

Filter Bandwidth ≈ 3 kHz.

a. Step-Size-Filter. Table II contains DRT scores corresponding to two different values of T_1 . These results show that intelligibility is generally less for the time constant of 20 ms. Also shown in Table II are the quality scores corresponding to the two different values of T_1 . The quality scores indicate a general reduction in user preference for the higher value of T_1 .

b. Integrator. Table II also lists the DRT and QUART scores corresponding to two different values of the integrator time constant, T_2 . These results suggest that if the integrator time constant is varied within the limits of 1 ms to 20 ms there is negligible change in intelligibility and user preference.

4. COMPARISON OF CVSD CODERS

The CVSD coder proposed for use in the TRI-TAC secure voice system is based on the following set of parameters:

Filter Bandwidth $\approx$ 4 kHz

Compression Ratio $\approx$ 12

$T_1 = 6.3$ ms

$T_2 = 1.0$ ms.

This particular algorithm (CVSD-A) was simulated on the PSP. The corresponding DRT and QUART scores are listed in Table III. The CVSD coder built by Codex Corporation is based on the following set of parameters (CVSD-B):

Filter Bandwidth $\approx$ 3 kHz

Compression Ratio $\approx$ 166

$T_1 = 2$ ms

$T_2 = 8$ ms.

DRT and QUART scores corresponding to the Codex terminal are listed in Table III. Also included in Table III are the scores corresponding to a PSP simulation of a version of CVSD-B. The results indicate a strong user preference for CVSD-B over CVSD-A.

TABLE III. COMPARISON OF CVSD CODERS

	DRT SCORE		QUART SCORE
	MALE	FEMALE	
CVSD-A (PSP)	93.1 $\pm$.81	91.1 $\pm$.94	55.2 $\pm$ 1.6
CVSD-B (PSP)	95.2 $\pm$.55	93.1 $\pm$.68	67.6 $\pm$ 3.2
CVSD - CODEX	94.1 $\pm$.38	91.9 $\pm$.70	71.5 $\pm$ 3.7

V. CONCLUSIONS

Speech intelligibility and quality of CVSD coders are sensitive to the values of certain algorithm parameters. In particular, it was found that CVSD performance is most sensitive to compression ratio; the highest value of compression ratio resulted in the best performance. In addition, the quality scores indicated a significant user preference for a filter bandwidth of 3 kHz.

Results have also shown that within the ranges tested, the time constants of the integrator and step-size-filter have small effects on quality and intelligibility. However, these time constants do affect performance under conditions of high transmissions error rates. Therefore the following time constants, which have been selected for such conditions, are appropriate:

$$T_1 = 6.3 \text{ ms}$$

$$T_2 = 1.0 \text{ ms}$$

Although the tests performed were by no means exhaustive, the results can be used to quantify the performance of CVSD coders corresponding to different parameter sets. The test results show that the CVSD-B parameters provide the best performance compared with the other parameter sets including the CVSD-A parameters. The quality tests indicated the greatest preference for the Codex CVSD coder. The test results also indicate that the following CVSD parameters should provide performance comparable with CVSD-B.

Filter Bandwidth = 3 kHz

Compression ratio = 150

T_1 = 6.3 ms

T_2 = 1.0 ms

REFERENCES

- [1] NSA, "Narrowband Digital Voice Processor Consortium Final Report," May 1976 (CONFIDENTIAL)
- [2] GTE Sylvania, Inc., Final Report "Adaptive Multilevel 16 kbps Speech Coder," Dr. A. Goldberg, DCA Contract DCA100-76-C-002, June 14, 1976
- [3] Codex Corporation, Final Report "Codex Speech Digitizer Advanced Development Model," S. Qureshi, DCA Contract DCA100-76-C-0026, June 30, 1976
- [4] Dynastat, Inc. Report "Methods of Predicting User Acceptance of Voice Communications Systems," Dr. W. D. Voiers, DCA Contract DCA100-74-C-0056, July 15, 1976

DISTRIBUTION LIST

STANDARD:

R100 - 2	R200 - 1
R102/R103/R103R - 1	R300 - 1
R102M - 1	R400 - 1
R102T - 9 (8 for stock)	R500 - 1
R104 - 1	R700 - 1
R110 - 1	R800 - 1
R123 - 1 (Library)	DCA 205 - 20
R124A - 1 (Archives)	931 - 1
	NCT-TS - 1

DDC

DCA-EUR - 1 (Defense Communications European Area
ATTN: Technical Director
APO New York 09131)

DCA-PAC - 1 (Defense Communications Agency Pacific Area
ATTN: Technical Director
APO San Francisco 96515)

USDCFO - 1 (Chief, USDCFO/US NATO
APO New York 09667)