THE AUDIOGRAPHIC LEARNING FACILITY: RESEARCH AND DEVELOPMENT

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Final Report

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ABSTRACT

Departing from previous project reports which described the basic hardware and software of the Audiographic Learning Facility (ALF) of the School of Information and Computer Science at the Georgia Institute of Technology, this document addresses several issues in designing audiographic learning systems for continuing science education at the graduate level, including the technological feasibility and economics of an improved version of the ALF system. This document is the final report on NSF grant GN-2628.

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I. INTRODUCTION

The work described in this report has been addressed to the problems of designing and evaluating a learning system based on audiographic technology in continuing science education at the graduate level -- the Audiographic Learning Facility (ALF). Basic hardware and software features of the system were outlined previously by Slamecka [27, 28], Slamecka and Jensen [26], Ting and Badre [29], and Ting and Jensen [30]. In the present report we consider some fundamental questions about the nature of the system's users and about the environment in which the learning is to take place; we summarize the results of a controlled learning experiment conducted to effect a partial evaluation of the system's effectiveness; we examine the problems of transmitting audiographic data over voice-grade telephone lines; and we explore the important question of ALF economics.

Section II is concerned with the special difficulties of maintaining high student motivation in the particular environment in which remotely delivered instruction takes place: i.e., the actual real-world working environment. It is concluded that management can do much to assist (or to obstruct) the learner in his task.

Section III presents the results of a controlled experiment conducted at the Georgia Institute of Technology to supplement previous evaluations of ALF's "learning effectiveness." Those results indicate (and corroborate previous findings) that there is no significant difference between the learning gains made by students using the automated learning system and those in the control group (who attended traditional classroom lectures). The importance of this conclusion is that it suggests that decisions to employ the system for a particular purpose can be made largely in terms of an economic analysis: i.e., the system may be used whenever one can demonstrate that its use is less expensive than the use of alternate modes of instruction (such as traditional classroom lectures).

The work described in Section IV was motivated by the desire to eliminate the need for one of the two voice-grade telephone channels currently needed by the Audiographic Learning Facility (and thus to make the system readily accessible to the ordinary family, which possesses a single telephone and at least one TV set). To assess the problems of using only one telephone line to transmit audiographic materials, a systematic analysis was conducted in order to determine the minimum quality of voice and graphic signals necessary for audiographic learning.

Section V concludes this report with a discussion of the future of ALF and an evaluation of the system from the perspective of its attractive economic potential.

II. CONTINUING EDUCATION IN THE WORK ENVIRONMENT: THE QUESTION OF STUDENT MOTIVATION

The evaluation of any learning system designed to deliver instruction to learners at their place of work must begin with some discussion of the realities of the work environment in which the learning is to occur. Indeed, the realities of the work environment were found to be a principal determinant of student participation in the experiment which was conducted at the Department of Administrative Services of the State of Georgia, in order to evaluate the Audiographic Learning Facility. It is therefore fitting that this project report should commence with a consideration of certain characteristics of a learning variable of paramount importance to the success of any continuing education program in a work environment: student motivation.

The saliency of the role of student motivation in a successful continuing education program is emphasized by Stadt, Bittle, Kennecke and Nystrom [29], who characterize the motivating of students as one of the "special management tasks seldom developed in preservice or inservice training of leaders in occupational education." These authors distinguish, furthermore, between the motivation of employees in their role as workers and motivation of those employees in their role as students, and conclude that relatively little financial resources have been available for studying ways of motivating employee learning as contrasted with employee job performance.

Of course, the simple rubric "employee learning" can be used to marshal quite a variety of educational experiences. This diversity is noted by Nadler [23], who finds conceptual differences between training, education, and development. According to Nadler, a learning experience which is related to a job which an individual already has is training; a learning experience designed to prepare an individual for a different job in the future -- but an identifiable job nonetheless -- is education; and those learning experiences which are designed to provide general growth for the future can be called development. However, it is not necessary to adopt Nadler's precise terminology to perceive that differences of those kinds do indeed exist, and to agree that "if an organization does not identify the distinctions in the learning activities it provides, it is not likely to achieve the objectives for the learner as well as for the organization." Instead, artificial educational barriers will be constructed, such as the barrier which Gretler [13] sees existing between what he calls vocational training, on the one hand, and general education, on the other. Implicit in Gretler's understanding of the fundamental problem is the conviction that, whereas both kinds of learning experiences are valid and necessary, particular attention must be paid to ways of motivating general education -- education not for today but for tomorrow.

Researchers who have considered the question of student motivation in a work environment typically explore one or another of the following three main themes. The first theme is that all learning experiences -- whether they are to be categorized under "training," "education," "development," or any other heading -- are ultimately motivated by a demonstration of, or a belief in, their "relevance" to the individual learner. A second theme considers the educational reward structure, and emphasizes the value of providing real and tangible payoffs for employee learning achievements. The third theme is taken by those who propose a tighter coupling between education and jobs, so that learning motivations and job motivations will be inextricably bound together, and the educational process will become part and parcel of any working activity.

Educational Relevance as a Motivational Factor

A continuous theme in the literature of motivation is that learning must be "relevant," though "relevance" is never very well defined. Relevance seems to be calculated sometimes in terms of student interests, sometimes in terms of student needs, sometimes in terms of the requirements of specific jobs. Whatever it is, it is usually thought to be both highly desirable (Charters, [6]) and extremely elusive (Burgwardt, [5]). Burgwardt finds that the problem manifests itself in a poor academic/industrial interface, which often prevents a college or university from optimizing potential profits from its educational resources. "This constraint," Burgwardt claims, "is often created by stody academic traditions which can hamper the most heroic efforts to meet industrial program requirements of timeliness, flexibility, and relevancy."

Charters shares this concern, and asserts that the "characteristic" of continuing education is the importance of making it relevant: "The relevance of education to professionals and indeed all pursuits of life has always been a matter of earnest consideration. It is desirable in each of the stages, but perhaps of most significance in the continuing education stage." The problem which Charters notes is that the future of a profession is difficult to predict and the nature of the society in which it will be practiced is quite uncertain. Nonetheless, he insists that, even though the predictions must be tentative, some assumptions about the future must indeed be made, and simply urges that, in deference to the uncertainties involved, continuing education programs be designed to be open-ended. "The current curriculum needs to be cast in this perspective," Charters argues, "or the program will be terminal." Obviously, the need for a continuing education program to be relevant under such conditions implies continuous study and revision of the curriculum, and necessitates that educators and training managers be sensitive to changing environmental conditions and to the specific needs of students in real-world work settings. This sensitivity is never easy to acquire or maintain, and it is not uncommon for evaluations or self-evaluations of continuing education programs to make an admission such as, "Our center has failed to some degree in not directing its attention to courses that are job-oriented or problem-solving" (Dada, [8]).

However, the equal valuation Dada gives to "job-oriented" courses and to "problem-solving" courses is somewhat curious, in that two entirely different kinds of relevance are equated: job-relevance is certainly a more immediate (and, as it were, a more objective) test of usefulness than is general problem-solving, and would, therefore, presumably be more relevant than general problem-solving ability. Yet some authors would deny this vehemently, and would challenge the whole notion that relevance must be immediate or even immediately apparent. For example, in examining the role of the teacher or administrator vis-a-vis the adult learner, Broudy [4] maintains that the ultimate responsibility of the instructor is precisely to provide authoritative instruction and firm guidance. According to Broudy, the implication of an educational program too concerned with the issue of relevance would be to make the fulfillment of felt wants of its diverse clientele the primary aim of adult education, and to adjust priorities so that the heart of adult educational thought would be located entirely in the problem of means, instruments and modes of organization. In rebuttal to this implication, he suggests that two considerations should make educators skeptical about obsessions with relevancy. First adults not only make procedural errors in choosing their educational fare, but frequently admit that they might have chosen differently had their value systems been as mature at the time of their choice as they later became. Second, and more basic in Broudy's view, is that the very notion of education loses its meaning if the learner retains full and literal autonomy in his choice of learning, for "to be a learner in any significant sense means to give up one's autonomy to the demands of the task being learned."

Yet learning tasks are not the only kinds of tasks which must be assessed by managers of continuing education programs. Also to be dealt with is the fact that adult learners are, at the time of their learning, engaged in work tasks and work-related responsibilities which must (and therefore will) take precedence over their learning endeavors. Thus, in a survey conducted by the University of Missouri to determine attitudes of continuing education programmers toward their job roles, Rowe [25] found that the additional job responsibilities of the programmers taking courses in the "traditional" (i.e., not job-related) extension areas constituted a definite impediment to the success of the program.

Therefore, some authors who explore the theme of relevance as a motivational factor in continuing education programs conclude that the exigencies of the world of work require that the learning process be conducted quite differently than it is conducted in traditional academic enviornments. Church [7], for example, calls attention to what he refers to as "bad assumptions" about continuing career education. The first bad assumption is that professional careers in industry are extensions of academic study; the second is that the learning process in industry after graduation is the same as it is in a school environment. To the contrary, "the environmental factors are much different, affecting the urge to learn, the subject matter learned, and how it is learned...and each engineer is different in his ability to learn, his readiness to learn, and his urge to learn." Church therefore concludes that, since two engineering jobs are seldom alike, educational programs should discard stereotyped instructional packages, and should abandon the term "continuing education" in favor of "employment related education." And so, ultimately, all the proponents of the saliency of relevance in the hierarchy of educational values stress that learning must lead to doing and that education must lead to jobs.

Motivation Through Adjustments in the Reward Structure

The second theme explored by authors who have examined the question of student motivation in a work environment is concerned with the educational reward structure, and emphasizes the value of providing real and tangible benefits for employee learning achievements. According to those who hold this view, intangible rewards, such as the pleasures of self-fulfillment, are simply not sufficient for motivating the average employee, though this generalization applies primarily to the younger and middle-years segments of the workforce, rather than to older employees. Kuhlen [18] states that, as one views the course of human life, growth-expansion motivations (such as the search for more responsibility or more prestige) seem to dominate the first half of the adult years, whereas in later years the satisfaction of growth-expansion needs is accomplished more vicariously, thereby allowing more time and personal energy for learning "for its own sake," regardless of tangible benefits.

One kind of tangible benefit used to induce employees to continue their education takes the form of employer-paid instructional programs. However, studies have shown that, whereas low-cost or no-cost instruction may be a <u>necessary</u> condition for motivating employees to keep up-to-date educationally, it is by no means a <u>sufficient</u> condition. For example, Dubin and Marlow [11] presented the results of a survey in which 79% of the engineers interviewed reported that their companies had educational assistance programs (showing the widespread availability of company payment for educational assistance courses), but that 74% of the same group also acknowledged that this availability had no effect in motivating them to undertake additional work. The conclusion of Dubin and Marlow is that the availability of financial assistance for self-improvement is "obviously not a sufficient incentive for updating in employees."

Instead, adult learners seem, on the average, to want not educational opportunities so much as educational rewards. A study by Landis [19] found that engineers seek an immediate payoff from their continuing education -- a payoff that assumes the highly specific form of recognition and salary. According to that author, most engineers are interested in performing better in the immediate, assigned job, but few are motivated to make the extraordinary effort required to keep up with the latest developments in their profession.

The Landis findings are corroborated by Johnstone and Rivera [16], whose survey of adult learners found that, other than the (vague) learning goal of "becoming a better informed person," the two other goals endorsed by sizeable numbers of participants were both directly vocational: a large percent indicated that they had enrolled to prepare for a new job, and another large percent indicated that they had done so to learn more about the job they already had. "Over and above the desire to become better informed," Johnstone and Rivera concluded, "vocational goals most frequently direct adults into continuing education, and, on the basis of the relative frequency of response to the job-connected items included in the list, it appears that slightly more adults take courses for job preparation than for job advancement."

If most continuing education students are job-motivated, but most are also preparing for jobs other than the ones they now have, it is not unreasonable to hypothesize that employers are not sufficiently motivating their own employees to participate in educational programs for which they will be rewarded within their own organizations. Research by Dubin, Alderman and Marlow [11] seems to suggest that such an hypothesis is correct, for the findings of these authors (based on a survey of middle-level management personnel) were that additional course work is not sufficiently rewarded in industry and that it is not a requirement for promotion or salary increase. (That same statement could be made about the organization of state government which served as the setting for the evaluation of the Audiographic Learning Facility; there is no program in that organization which rewards employees for successful completion of formal continuing education programs.)

Motivation and the Coupling Between Learning and Jobs

The third theme in the literature concerned with the motivation of students in a work environment subsumes the other themes by suggesting that the problem of ensuring that continuing education is relevant to the learner can both be solved by a coupling of education and jobs, a coupling which entails that the educational process become an integral, inportant, and continuous part of every job.

At the simplest level of their exposition, enthusiasts for this coupling point simply to the statistics of various manpower programs. Regan [24], for example, asserts that adult education program are most successful when they are conceived not as preparation <u>for</u> jobs, but as learning experiences concomitant <u>with</u> jobs. Noting that adult education and training programs at all levels "have contended that increased academic skills will enable the nation's poor and undereducated to compete more successfully in the job market," Regan claims, however, that labor statistics do not support this contention. The conclusions drawn from his own research are, to the contrary, that where meaningful employment is coupled with education, retention and successful course completion are significantly higher.

Though Regan's analysis of manpower statistics is intended to apply to a large range of skill-levels (including especially the relatively low skill-levels possessed by those at the lower end of the socioeconomic spectrum), the coupling of education and jobs has also been proposed at the very highest levels of professional expertise. Dubin [10] reports several interesting attempts to establish practical measures for motivating professional persons to keep up-to-date which have been established. One is that of the French Atomic Energy Commission, which initiated the practice of declaring that scientific diplomas lapse after five years, unless revalidated by attendance at refresher courses and success in passing further examinations. Another is that of the US National Advisory Commission on Health Manpower, which recommended in 1967 that professional societies and state governments should explore the possibility of periodic relicensing of physicians and other health professionals. Under this recommendation, relicensure should only be granted either upon certification of acceptable performance in continuing education programs or upon the basis of challenge examinations in a practitioner's specialty. Acting on this recommendation, the Oregon Medical Society subsequently passed a regulation requiring physicians to continue their education in order to remain in good standing in the Association.

The primary requirement for successful coupling of education and jobs is undoubtedly the attitude of an organization's management. Hughes and Wass [15] describe a company-installed management policy in which goal-oriented management behavior is rewarded "by task satisfaction, financial rewards and goal accomplishment." The system provides a means for continuous updating of employees whereby individual goal-setting is integrated with the organization's goal-setting (through the use of semi-annual goal-oriented performance reviews in which each employee participates). In these sessions, a great deal of importance is placed on identifying the individual's developmental needs, both present and future, to enable him to accomplish his specified goal.

Thus, although successful learning in a work environment may ultimately be the responsibility of the willingness and <u>self</u>-motivation of the learner, the fact is that management can do much to assist (or to obstruct) the learner in his task. If management values education, so will its employees. If it does not, its employees will either be stagnating or will be training themselves for new jobs in a different organization.

III. THE LEARNING EFFECTIVENESS OF THE AUDIOGRAPHIC LEARNING FACILITY: AN EXPERIMENT

One primary objective of the study reported in this document was to evaluate the learning effectiveness of the Audiographic Learning Facility as an educational delivery system. To accomplish this objective, an experiment was conducted at the Georgia Institute of Technology during the Winter quarter, 1974. Two groups of students were randomly selected for the experiment; one of the groups participated in the live classroom lectures and the other received instructions via the Audiographic Learning Facility. Both groups were given the same subject prepared by the same instructor during the two weeks of experimentations. Pre and post tests were administered to the subjects in both groups.

Experimental Design

A simple before-and-after experimental design was used to divide the subjects into two groups. One group took the conventional classroom lectures and the other group was scheduled in several half-hour sections for learning at an ALF terminal. The subjects were randomly selected from the School of Information and Computer Science, Georgia Institute of Technology. Twenty students participated in the live classroom lecture group and 17 in the ALF group. In order to control some of the instructor's effect, the same professor was employed in both groups to cover the same material during the controlled experimental period. The ALF instructional materials were prepared, tested and implemented on ALF before actual use. The same material was used to prepare the live classroom lectures.

A parallel test of two forms was developed (see Chart I). Form A was used for the pre-test and Form B was used for the post-test.

Control Group	Experimental Group	
		Pre-test
(Live Class)	(ALF)	
		Post-test

Procedure

Students in the ICS 3601 Computer Systems II course were used as subjects. Those who did not wish to participate in the experiment were allowed to continue within the live classroom lecture group but did not take the tests. There were 4 such students. A random selection technique was used to assign the subjects into two groups. Twenty students were selected in the classroom group (the control group) and 17 students were asked to participate in ALF (the experimental group). All students were attending the same classes in conventional classroom lecture series before the experimental period. The students in the control group continued with the live classroom and those students in the experimental group were asked to use the ALF terminal for learning during the two-week experimental period. The students in the control group were kept away from the ALF terminal during the period of the experiment. On the other hand, the students in the experimental group were not allowed to participate in the classroom lectures. They were required to discuss or conduct their further studies with the students in the same group during the experimentation.

The students in the control group were given three 50-mintue classroom lectures per week. The students in the experimental group were assigned into five 30-minute sections during the week per student for learning at the ALF terminal. All students but four were in individual sections, the remaining four students were assigned in small groups of two for interacting with the ALF terminal. The first week of the experiment was treated as a warming up period in order to familiarize the students with the ALF terminal. Only the material convered in the second week was included in the tests.

The subject matter used for the experimentation was the introduction to assemblers and loaders. The ALF learning modules were already prepared and ready to use. The same amount of the information was used to prepare live classroom lectures by the same instructor.

Data Collection and Analysis

A parallel test set was developed. The test items were generated by the instructor. The items were selected and rearranged through a validating procedure for the development of the parallel test set. One form was used as pre-test and the other was used as post-test. Both tests were administered in the classroom setting immediately before and after the experimental period.

Analysis of variance and analysis of co-variance techniques were used to test the difference in test scores between the groups. The results of both tests are presented in the following:

ANALYSIS VARIANCE (POST TEST ONLY)

Control Group

$n_1 = 20 \quad T_1 = 222$

$\bar{X}_1 = 11.1 \quad \Sigma X_1^2 = 2846$

$(\Sigma X_1)^2 = 49284$

$\frac{(\Sigma X_1)^2}{n_1} = 2464.2$

Experimental group

$n_2 = 17 \quad T_2 = 218$

$\bar{X}_2 = 12.824 \quad \Sigma X_2^2 = 2852$

$(\Sigma X_2)^2 = 47524$

$\frac{(\Sigma X_2)^2}{n_2} = 3795.53$

TOTAL

$N = 37 \quad T = 440$

$\Sigma X_t^2 = 5698$

$\bar{X}_t = 11.892$

$\sum_{j=1}^{2} (\Sigma X_j)/n_j = 5259.73$

$T^2/N = 5232.47$

$$SS_A = \sum_{j=1}^{2} \frac{T_j^2}{n_j} - \frac{T^2}{N} = 27.30$$

$$SS_T = \Sigma X^2 - \frac{T^2}{N}$$

$$= 465.57$$

$$SS_w = SS_T - SS_A$$

$$= 438.27$$

Source of Variation	df	SS	Mean Square
Treatments (A)	1	27.30	27.30
Within-Groups (W)	35	438.27	12.522
TOTAL (T)	36	465.57	

$$F = \frac{27.30}{12.522} = 2.18$$

ANALYSIS OF COVARIANCE (PRE AND POST TESTS)

Control Group		Experimental Group		TOTAL
Pre-test (X)	Post-test (Y)	Pre-test (X)	Post-test (Y)	
$\Sigma X = 145$ $\bar{X}=7.25$	$\Sigma Y = 222$ $\bar{Y}=11.1$	$X = 122$ $\bar{X}=7.176$	$Y = 218$ $\bar{Y}=12.824$	$\bar{X}=7.216$
$\Sigma X^2 = 1213$	$\Sigma Y^2 = 2846$	$\Sigma X^2 = 1008$	$\Sigma Y^2 = 2852$	$\bar{Y}=11.892$
$\frac{(\Sigma X)^2}{n} = 1051.25$	$\frac{(\Sigma Y)^2}{n} = 2464.2$	$\frac{(\Sigma X)^2}{n} = 875.53$	$\frac{(\Sigma Y)^2}{n} = 2795.53$	

TOTAL $N = 37$

Y	X
$\Sigma Y = 440$	$\Sigma X = 267$
$\Sigma Y^2 = 5698$	$\Sigma X^2 = 2221$
$\sum_{j=1}^{2} T^2 y_j/n_j = 5259.73$	$\sum_{j=1}^{2} T y_j/n_j = 1926.78$
$T_Y^2/N = 5232.43$	$T_X^2/N = 1926.73$
$SS_{YA} = 27.30$	$SS_{XA} = 0.05$
$SS_{YT} = 465.57$	$SS_{XT} = 294.27$
$SS_{YN} = 438.27$	$SS_{XW} = 294.22$

$$SP_T = \sum_{j=1}^{2} \Sigma xy = 21.139$$

$$SP_A = \sum_{j=}^{2} n_{j}\bar{x}_{j}\bar{y}_{j} = -0.825$$

$$SP_w = SP_T - SP_A = 21.964$$

$$SS_{YW} = SS_{YW} - \frac{(SP_w)^2}{SS_X} = 436.63$$

$$SS'_{YT} = SS_{YT} - \frac{(SP_w)^2}{SS_{XT}} = 463.93$$

$$SS'_A \quad SS'_{YT} - SS'_{YW} = 27.30$$

Source	df	SSx	SP	SSy	SS_y	df	MS_y
A	1	0.	-0.825	27.30	27.30	1	27.30
W	35	294.22	21.964	438.27	436.63	34	12.55
TOTAL	36	294.27	21.139	465.57	465.57	35	

$$F = \frac{MS'_{YA}}{MS'_{YW}} = 2.17$$

The results of the tests were analyzed. The analysis of variance and the analysis of covariance tests were applied, and the F ratios indicate that the differences in test scores were not significant at 0.05 level. This result leads us to conclude that the null hypothesis (i.e., that there is no difference in test scores between the students in live classroom lecture series and the students in ALF) was not rejected. However, the test scores of the ALF group may have been significantly higher than the live lecture group if greater Type I error was allowed at 0.1 level.

This general finding — i.e., that there is no significant difference between the learning gains made by students using the automated learning system and those in the control group (who attended traditional classroom lectures) — is important because it suggests that decision to employ the system for a particular purpose can be made largely in terms of an economic analysis. That is to say, the system may be used whenever one can demonstrate that its use is less expensive than the use of alternate modes of instruction (such as traditional classroom lectures).

CHART I - THE PRE & POST TESTS

FORM A

1. Taking several objects programs and putting them together into one absolute program is called "binding."
2. "Relocating" refers to moving the loaded program.
3. A "Compile-and-go" system imbeds the loader function into the compiler.
4. A "compile-and-go" system does not have to worry about relocating.
5. Using an absolute loader decreases the system's ability to have a library of user subroutines.
6. A "transfer vector" is a table of branch instructions.
7. All entry points are addresses to be branched to.
8. The relocating table causes the loader not to alter absolute addresses and data.
9. The assembler has a two-level task: translation and assembly.
10. Macro-instruction do not actually exist in the machine language.
11. Most assembly language instructions are divided into fields.
12. The location counter in an assembler tells where the assembler is located in memory.
13. The main disadvantage of one-pass assemblers is the size of the assembler.
14. The forward reference table in a one-pass assembler can be thought of as a set of linked lists.
15. A one-pass assembler can fill in forward references as the symbols referred to are defined.
16. Most of the forward reference table can actually be imbedded in the code generated by a one-pass assembler.
17. The object code of a one-pass assembler must fit in the part of central memory not used by the assembler.

FORM B

1. The purpose of a loader is to manipulate source and load it into secondary memory.
2. "Linking" refers to the connecting of references in one program to addresses in other programs.
3. When a loader transfers control it is branching to the loader program.
4. An absolute loader takes care of absolutely all loading situations.
5. An absolute object program may be executed at only one load point in the user's part of memory.
6. To facilitate linking, the creator of the object programs must produce a table of externals and a table of entry points with each program.
7. A linking loader generally searches the system library for entry points before searching the user-supplied entry point tables.
8. To relocate a program the relocating loader adds the load point address to every word in the program.
9. To facilitate loading the loader needs access to system tables relating to secondary memory (disks, etc.) if there is any secondary memory in the system.
10. Pseudo-instructions translate into several machine instructions.
11. Most asemblers output information to loaders which convert this information into viable machine-language programs.
12. The form of the operand field of an assembly language instruction is usually independent of the op-code.
13. The main problem causing the development of the two-pass assembler is the problem of backward references.
14. The symbol table is set up in the first pass of a two-pass assembler.
15. All pseudo-ops can be fully taken care of in pass one of a two-pass assembler.
16. The passes of a two-pass assembler are (1) definition and (2) generation.
17. The location counter is used only in the second pass of a two-pass assembler.

IV. AUDIOGRAPHIC DATA TRANSMISSION VIA VOICE-GRADE TELEPHONE LINES

Another primary objective of the present research was to determine the feasibility of simultaneously transmitting intelligible voice and line graphic messages via a single channel of a voice-grade telephone line. The motivation for that study was the fact that one of the limitations of the present, prototype ALF system is the requirement of two voice-grade telephone channels for the transmission of both the voice and graphic messages. This requirement has stood as an obstacle to the delivery of electronically stored learning material to ordinary homes (which are rarely outfitted with more than one such channel). To assess the problems of using only one telephone line to transmit audiographic materials, a systematic analysis was conducted in order to determine the minimum quality of voice and graphic signals necessary for audiographic learning, and a prototype system has been developed based on the results of the analysis.

The Problem of Audiographic Data Transmission Via Voice-Grade Telephone Lines

In normal telephone use, the total frequency spectrum is dedicated to sending and to receiving voice signals. However, in an audiographic application, motion line-graph signals must be sent in addition to those of voice, and so that part of the telephone line spectrum which is dedicated to carrying voice must be reduced in order to allow graphic messages to be transmitted simultaneously using just one pair of lines.

The Characteristics of Voice-Grade Telephone Lines

The characteristics of the media must be examined. These characteristics define the limitations within which the audiographic data transmission system must be designed.

a. Distortion

There are many transmission impairments which may affect data transmission. The most common of these impairments is distortion. Distortion occurs when attenuation or delay varies as a function of frequency. Attenuation refers to a loss of amplitude or power and delay refers to a time shift in the signal. These data represent attenuation distortion relative to 1000 Hz with positive values representing more loss. (see Table 1). The loss due to local loops which must be added to those data is typically less than 10 db at 1000 Hz and approximately 3 db difference between 600 and 2750 Hz.

Table 2 gives the delay distortion for end-office to end-office repsective to 1700 Hz when delay distortion is at a minimum. The local loop delay distortion is significant when compared to this data and, therefore, may be ignored. (The data in Tables 1 and 2 are taken directly from Bell System Data Communications PUB 41005, Data Communications Using the Switched Telecommunications Network.)

TABLE 1 — FREQUENCY RESPONSE IN db RELATIVE TO 1000 Hz

Frequency	Short		Medium		Long	
Hz	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
200*	11.4	5.1	13.7	4.5	12.5	5.0
250	6.4	2.7	8.0	3.7	6.8	3.1
300	4.0	1.9	4.8	2.8	4.8	2.1
400	2.2	1.4	2.8	2.2	2.0	1.4
600	0.9	0.9	1.6	1.9	1.2	0.8
800	0.4	0.5	0.7	0.5	0.5	0.4
1200	0.1	0.3	-0.3	0.4	-0.3	0.4
1400	0.0	0.6	-0.3	0.6	-0.3	0.5
1700	0.3	0.9	0.1	0.8	0.2	0.8
2000	0.8	1.1	0.8	1.1	0.7	1.0
2300	1.4	1.3	1.4	1.4	1.7	1.4
2450	1.8	1.5	2.0	1.6	2.4	1.7
2750	3.5	2.5	4.1	2.2	4.7	2.3
2850	4.4	3.0	5.4	2.6	6.1	2.7
3000	6.4	4.0	8.1	3.6	9.2	4.3
3100	9.0	5.9	10.6	4.7	11.6	5.2
3200*	12.9	8.0	14.7	6.8	15.2	7.6
3300*	17.6	10.00	20.0	8.0	19.8	7.6
3400*	21.2	9.8	24.4	6.4	25.1	6.1

*Distortion values at these frequencies are at least as great as shown.

TABLE 2 — ENVELOPE DELAY DISTORTION IN uSEC WITH RESPECT TO 1700 Hz

Frequency	Short		Medium		Long	
Hz	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
200*	4580	2461	7526	1851	7505	2422
250*	3384	1727	5866	1595	5880	1870
300	2816	1407	4884	1375	4901	1510
400	1695	930	3413	1215	3163	1144
600	656	430	1467	628	1335	592
800	290	263	737	371	649	350
1000	133	165	380	227	335	209
1200	48	103	187	130	156	128
1400	3	66	63	83	56	76
2000	50	62	36	66	80	95
2300	152	122	226	133	273	180
2450	248	159	363	153	442	230
2750	485	276	811	273	934	457
2850	616	338	1016	348	1166	573
3000	889	456	1437	468	1614	816
3100	1128	578	1903	585	2071	993
3200	1319	697	2475	750	2734	1285
3300*	1526	917	3208	1095	3333	1356
3400*	1935	1277	4040	1634	4248	2018

*A significant percentage of connections were not measurable at these frequencies.

Another impairment is that due to nonlinearities which are caused by certain transmission techniques used by the telephone company. These include suppression in amplifiers, nonlinear elements in compandors, and foldover distortion and quantizing in pulse code modulated (PCM) systems. Data systems with line speeds less than 2400 baud are usually unaffected by the nonlinearities normally encountered. If high baud rates are to be used, one must limit the power outside the 300 to 4000 Hz baud and avoid designs which generate high signal levels at certain input frequencies within this band to avoid the nonlinear distortion caused by PCM systems. Also, amplitude modulation should not be used for data transmission since the design of the compandors used in the telephone system does not allow them to follow rapid changes in signal power.

b. Echo

Due to impedence irregularities along a transmission line or at its end, a portion of the originating signal is reflected back to the originating end. This phenomenon is commonly called "echo." In fact, the echo towards the originating end may itself be reflected back to the receiving end. The first echo is not a problem for data transmission since the send-station is not trying to receive signals at the same frequency as the one it uses to transmit. The secondary echo could be a problem if the delay and amplitude of this signal is sufficiently high, but normally it is not. In fact, the real problem to data transmission is not the echo itself but the suppression of the echo by the telephone company to produce a higher quality of voice transmission. On long distance trunks when a signal in one direction is sensed, a high loss is inserted in the return line to prevent transmission in the other direction thereby eliminating the echo.

c. Noise

The general, noise is not a significant problem in data transmission over the Direct Distance Dialing (DDD) telephone system. The received signal-to-noise ratio is high enough so that the noise does not interfere with signal detection. However, impulse noise can cause unsatisfactory performance. Impluse noise is characterized by relatively short bursts of high amplitude. Most impulse noise originates in switching equipment. At this time, most switching systems are adequate for data transmission; however, there are a few switching systems which are not satisfactory for data transmission.

d. Transmission Path

Another consideration is transmission path. Due to automatic switching equipment, consecutive calls between two given stations may be connected by very different paths. The different paths may cause considerable variation in transmission characteristics. If an unsatisfactory connection is made due to this problem, the only alternative, using the switched network, is to replace the call. Other factors being satisfactory, this should correct the problem.

e. Frequency Spectrum

Examining Table 1, frequencies from 600 to 2300 Hz can be used without experiencing excessive attenuation of the signal. Table 2 shows the envelope delay distortion to be minimal in this range also. In general, envelope delay distortion is not a problem for data rates below 300 baud.

From the characteristics discussed above, it has been reasonably determined that the band from 300 Hz to 3000 Hz may be used for transmitting audiographic signals.

The Limitations of Signal Transmitting Techniques

The signals must be transmitted and are called baseband signals. In our case, we have both voice and graphic signals, and if all baseband signals were just combined and transmitted there would be no way to recover the individual signals after receiving them. Furthermore, those frequencies lying outside of the band pass range of the telphone line would be lost. These signals must be relocated into the band pass area, 300-3000 Hz, before transmission by modulation, and must be recaptured after reception by demodulation.

a. Modulation

Modulation is the technique of modifying one signal called the carrier as a function of another signal called the baseband. This modified carrier is then transmitted and, after it is received, the baseband is recovered by demodulation. There are three basic types of modulation — amplitude, frequency and phase modulation.

Amplitude Modulation

Due to the characteristics of voice-grade telephone lines, the amplitude modulation technique is impractical.

Phase Modulation

Phase modulation techniques provide higher band rates, but are more complicated and expensive. Furthermore, our objective is to send several <u>different</u> signals, not to send one signal at a high band rate.

Frequency Modulation

Frequency modulation systems are reasonably simple and inexpensive, provide good performance and versatility, and represent the most widely used technique for low-speed data transmission. Frequency modulation is the technique of changing the frequency of the carrier signal from some reference frequency, called the center frequency, as a linear function of the baseband signal. The maximum range of the carrier around the center frequency is called bandwidth. The bandwidth should be at least twice the maximum frequency of the modulating signal, and the bandwidth of the carrier divided by the center frequency should be no less than 4%.

b. Multiplexing

Since several signals are being sent at the same time, some form of multiplexing must be used. Multiplexing is combining the signals before transmission and separating these signals once they are received.

Frequency division multiplexing accomplishes this by assigning each carrier a slot on the frequency spectrum with no overlapping of signals. These signals are then summed together and transmitted. When this total is received, it is passed through bandpass filters—that is, devices which accept, as input, signals which contain many frequencies but, as output, only that portion of the total signal which falls within certain frequency limits. These bandpass filters are turned to those slots of the frequency spectrum where the carriers were assigned.

It is required that the center frequencies of adjacent slots be separated by some function of the bandwidth of the widest carrier slot. This is done to guarantee that all frequencies outside of the slot are reduced in strength by the filter to a level where they do not interfere with the desired signal. Bandpass slots must be separated two and one-half to three times their bandwidth from low-pass filter cutoff frequencies in order to relax constraints on filter rolloff specs.

c. Computer Interface

The computer interface must be considered. In our case, three different types of signals are being transmitted at the same time: the voice, the graphics, and the input control signals. Special signals are required for input to the computer for directing the Audiographic Learning Facility to work properly. A mechanism must be provided at the computer site to select these signals for computer input.

The Determination of Audio Intelligibility

A study was conducted* to record a phonetically balanced list of 50 words spoken by both male and female speakers. The term phonetically balanced implies a list chosen such that all speech sounds are presented approximately according to their frequency of occurrence in normal speech. The list of words used was obtained from "American Standard Method for Measurement of Monosyllabic Word Intelligibility."

*Requirements for a Remote Access Hybrid Computer Utilizing Common Grade Telephone Lines, Hester, William Meyers, M.S. Thesis, Florida Technological University, Orland, Fla., 1974. That document served as the foundation for much of the work summarized in this section of the report.

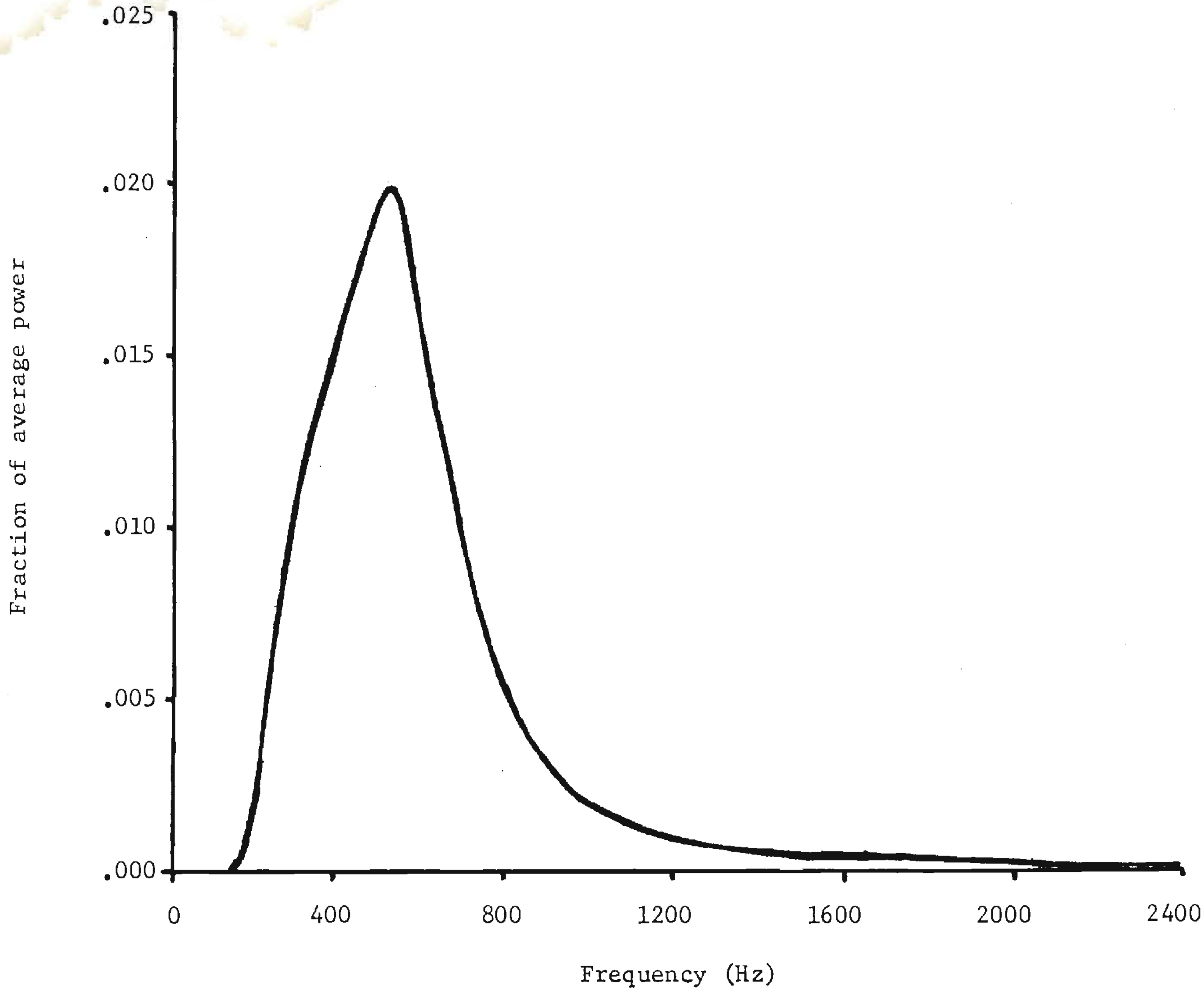

Figure 1. -- Power spectrum density of male voice

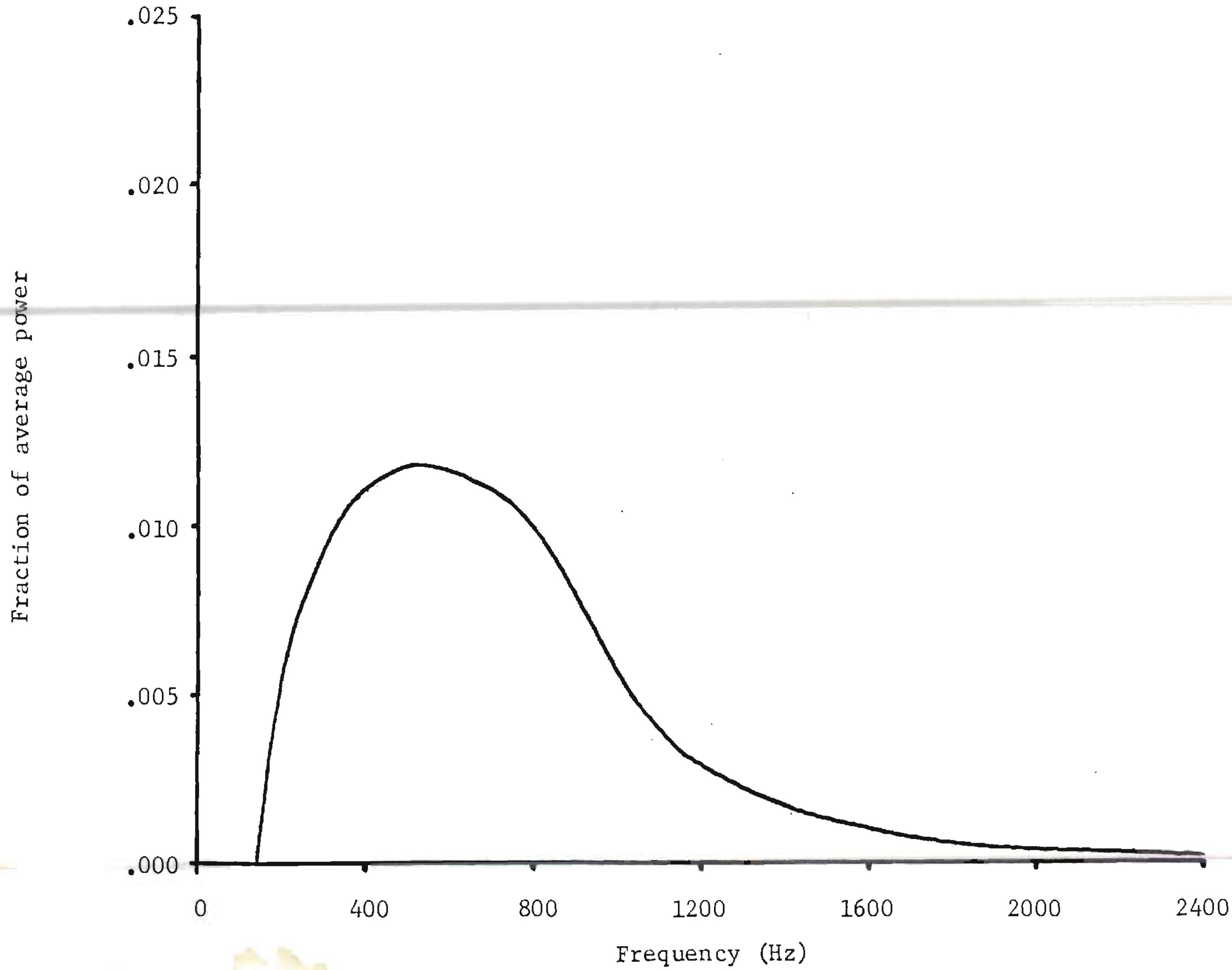

Figure 2. -- Power spectrum density of female voice

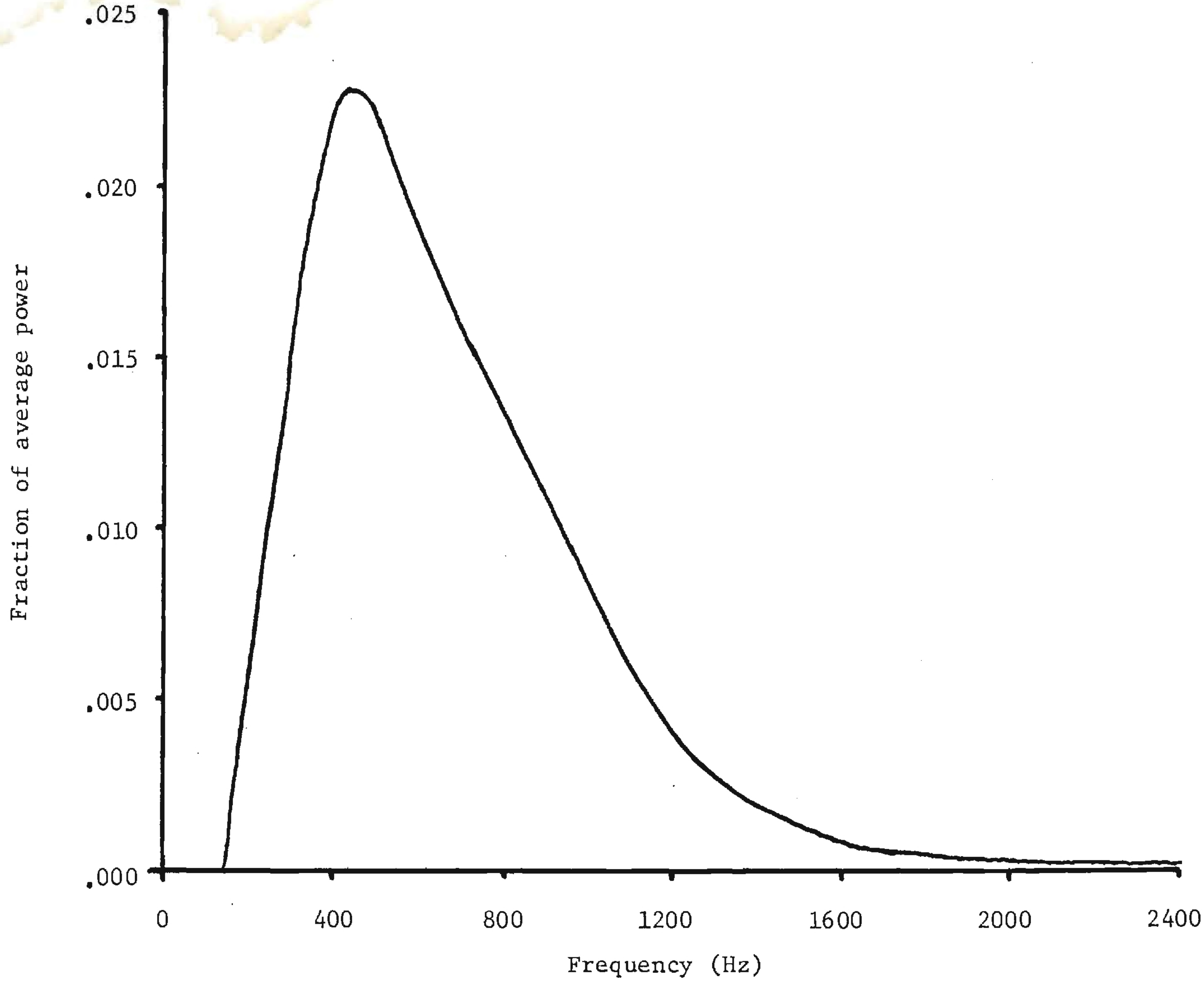

Figure 3. -- Power spectrum density of combined male and female voice

Figures 1, 2, and 3 show the resulting power spectrum density plots for the male speaker, female speaker, and the combined male and female speakers, respectively.

The plot of male voice spectrum, (Figure 1), shows that most of the power lies below 800 Hz. The plot of the female voice spectrum, (Figure 2), shows a higher range of power with the least significant band of power around 1000 to 1100 Hz. The composite plot dictates that a maximum frequency of 1000 to 1200 Hz is required to pass the major portion of the power of speech (see Figure 3).

The Determination of the Minimum Frequency Spectrum for Intelligible Voice Signals

The word intelligible is used here to mean easily understandable units of speech material which are complete and meaningful word phrases or sentences. According to the results presented in the previous sections, the normal voice range may include frequencies as low as 100 Hz and as high as 2500 Hz, but this wide range is not essential to having an intelligible signal.

A test was conducted to determine the required frequency spectrum for an intelligible voice signal. It was a simple "listening" test which consisted of having five different people listen to both male and female voices which were processed through the low pass filter with cutoff frequencies of 800, 1000, and 1200 Hz. The consensus of opinion was that: (1) there was a definite deterioration of the voice when using the 800 Hz filter; (2) the 1000 Hz filter allowed good intelligibility; and (3) an improvement in intelligibility was noticed in the 1200 Hz filter over the 1000 Hz filter, but not a significant improvement.

Based on the results of the test, a 1000 Hz low pass filter should be chosen as a minimum, and a 1200 Hz filter may be desirable.

The Transmission of Line Graphs

Motion line graphs are simultaneously transmitted along with the audio messages to learners in order to present the blackboard-like presentations in ALF-type systems. These graphic images are generated by the instructors and are electronically stored on magnetic tapes in a computer-controlled learning data base. The selected pre-stored line graphics are transmitted along with the narrative audio via regular telephone lines to the learning stations for display. The techniques used for the transmission of the motion line graphs via telephone lines are discussed in this section.

The Representation of Line Graphics for Transmission

A motion line graphic may be transmitted from an origin to a remote location via a telephone channel by sending three simultaneous signals: one represents the horizontal position; one the vertical position; and one controls the page change and other mechanical operations. Basically, the actual graphic message is represented as the change of x and y coordinates of the graphic surface in reference to the change of time. The prototype systems were developed for transmitting the graphic message. The first one uses a frequency modulation method, and it has already been implemented within the existing experimental ALF system. The second one is an improved prototype which uses a technique that may be called the period transmission technique. The latter has been tested in the laboratory and it will be implemented within the future ALF system. The first method uses a dedicated voice-grade telephone channel for transmitting the graphic message. The second uses a more narrow bandwidth which makes possible telephone link without the reduction of the quality of the graph. Both prototypes are discussed in the following.

Frequency Modulation Technique

The existing experimental ALF system uses a graphic data transmission technique which frequency modulates the x and y signals for transmission to the learning stations via a dedicated telephone channel. The change of x and y coordinates are expressed by the variations of frequencies in two separate carriers. The axes were chosen to be centered at 1400 Hz and 2200 Hz. The bandwidth of the frequency spectrum for both carriers was designed to be ± 100 cycles of the center frequency. In other words, the y coordinate varies from 1300 Hz to 1500 Hz and the x coordinate varies from 2100 Hz to 2300 Hz. Control signals were specially designed within the two carriers. A high frequency on the high side of the x carrier, 200 cycles above the center frequency, signifies the "pen-up" position. A change-page signal can be transmitted by sending two high frequency signals, 200 cycles above the center frequency, on both carriers. The frequency spectra for these messages within a single telephone line are illustrated in Figure 4.

The existing ALF system uses regular audio stereo tape for storing both the audio and graphic messages on two parallel channels. In order to compensate the distortion generated by the speed change of the tape recorder, an additional reference signal was added at 3300 Hz on the tape. During the playback, the x, y, and reference signals are sent to a compensator which inverts the modulation on the reference frequency and adds it to the x and y modulation in order to correct the distortion caused by the tape recorder. This is done in the following fashion. The corrected x and y coordinates,

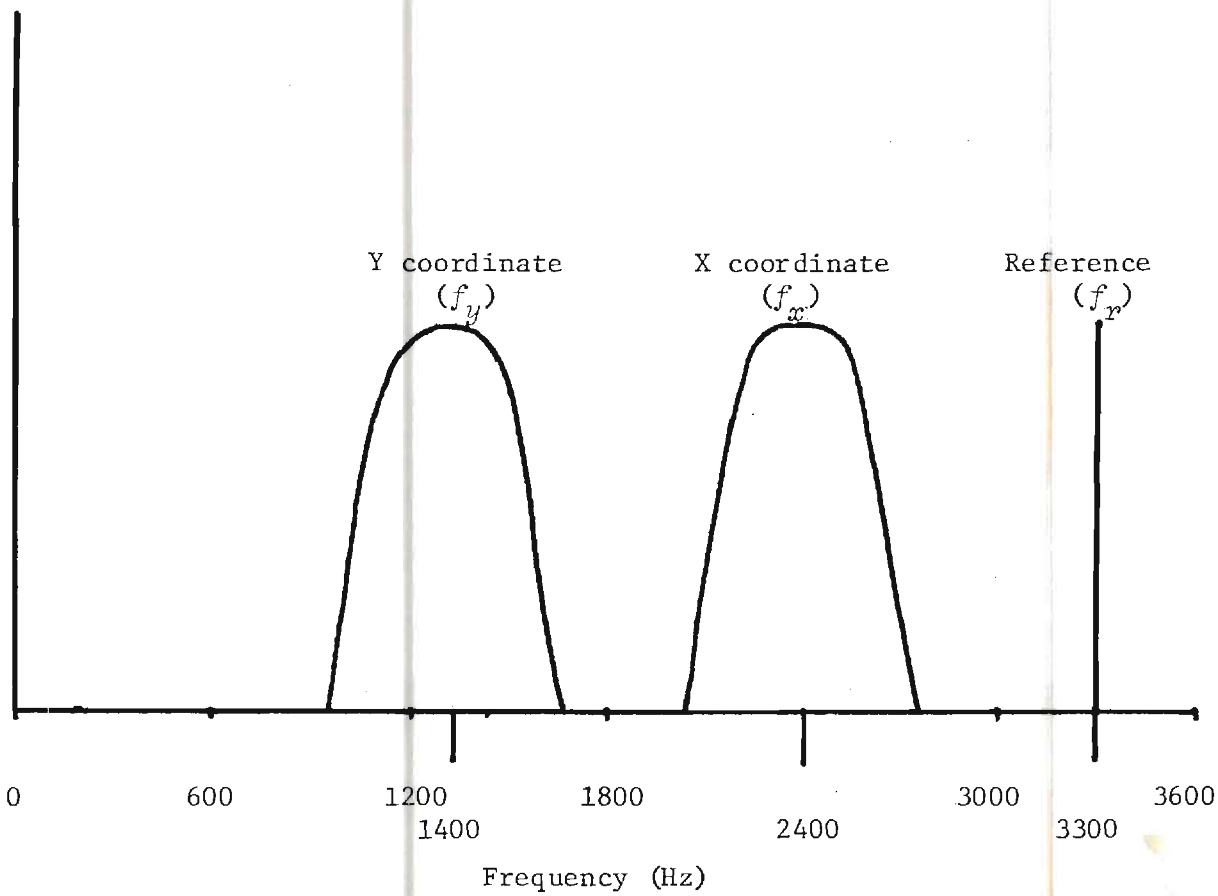

Figure 4. -- The frequency spectra for the frequency modulated graphic signals within a telephone link.

f_x and f_y, is equal to the uncorrected x and y frequency, f_x' and f_y', multiply the ratio between the reference signal, f_r, and the 3300 Hz. The compensation may be expressed as

$$f_x = \frac{f_x' \cdot f_r}{3300\ \text{Hz}}, \text{ and}$$

$$f_y = \frac{f_y' \cdot f_r}{3300\ \text{Hz}}$$

Only the corrected x and y signals, f_x and f_y, are transmitted to the learning stations for diplaying.

Digital Transmission Scheme

The present prototype graphic transmission system now under testing utilizes a new technique which codes and decodes graphic signals in digital forms during the transmission. This digital scheme codes the horizontal and vertical positions of a graphic message in x and y coordinates in digital forms which are stored in two digital words. These two numbers are updated in a fixed time interval. The prototype uses a graph pen device as the graphic input which stores the x and y coordinates in two storages of 10 bits each. These numbers are updated at a rate of 60 times per second. This allows having a picture with approximately 1000 line resolution and 60 frames per second. Since the projected ALF display system will employ regular home television sets for audiographic output, only 250 lines of resolution are required, and therefore the actual transmission requires only 8 bits information for the x and y coordinates. Therefore, in the present prototype graphic transmission subsystems, two digital signals of 8 bits each for x and y coordinates plus necessary control pulses are transmitted at a rate of 1/60 of a second. The signals equal to transmit 20 bits of information in every 1/60th of a second (or 1200 bits per second).

The digital scheme described here has several potential advantages: (1) Graphic messages generated by the input devices, a graph pen, can be stored in digital form on computer readable storage media, such as magnetic tape or disk; (2) A narrower bandwidth may be required by using a new method called period measurement technique (and, therefore, it is possible to transmit both the audio and graphic messages on a single voice-grade telephone channel); and (3) The graphic may be displayed on home television sets by using a scan converter or digital storage at the receiving stations.

Graphic Input Device

The graph pen is used as the input unit for the prototype. The pen position on the graphic surface is converted into two 10-bit binary numbers, the x and y coordinates. The graph pen is illustrated in Figure 5.

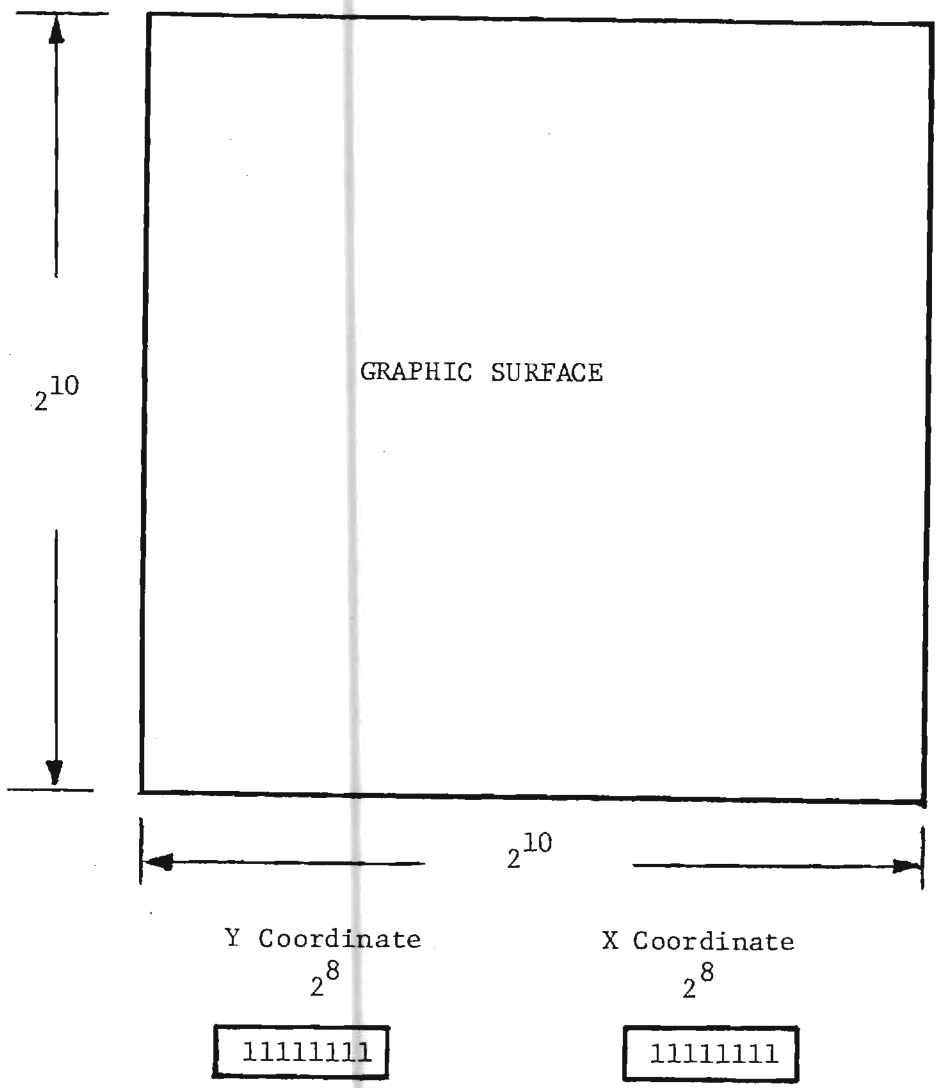

Figure 5. -- The graph pen converts the position of the graphic surface into two digital coordinates.

Period Measurement Technique

The binary coded x and y coordinates are transmitted at every 1/60th of a second. The digital storage will be updated at the receiving end by using digital counters. The traditional frequency modulation method is too insensitive to detect the difference in frequency change. For example, a frequency centered at 1000 Hz, during a period of 1/60th of a second less than 20 cycles, may be measured. The given frequency may change from 1000 Hz to 1100 Hz during the period but only two cycle difference may be found. A new technique called period measurement was developed. Instead of counting the number of cycles per every 1/60th of a second, a time period representing the value of the digital number is used to start and to stop a high-speed clock which generates 10 M Hz signals. A single cycle for a frequency of 1000 Hz takes 1 millisecond to complete, and if the period of one cycle is used to gate the high-speed clock 10,000 cycles can be detected. A new frequency of 1100 Hz takes 0.91 milliseconds to complete a cycle which can cause the digital counter to detect 9100 impulses. This slight change in frequency yields 900 points difference.

By using the new technique, the values of the x and y coordinates are used to control the time periods of the signals. At the receiving end, the length of the time period is used to set the digital counter for obtaining the values of the coordinates.

A period transmitter was designed to generate a tone and the period of the signal is varied by the value of the input. The period transmitter is illustrated in Figure 6. The value of the input data word and a present constant determine the base for a presetable counter. The base indicates how far up the presetable counter starts and the counter stops when an overflow is generated. In this way, the period of the output signal is varied by the input value in the data word which is set by the graph pen. This type of digital graphic data transmission has high accuracy because the high-speed clock is crystal controlled and has 10^{-7} stability. Another advantage is that it has a narrow bandwidth which provides the possibility of sharing a single telephone channel with the voice signal.

Graphic Display

At the receiving end a scan converter is used to drive the home television set for displaying the motion line graphics. The scan converter is basically a storage device that allows a graphics point to be written during the vertical retrace interval in a television caster scan. Every 1/60th of a second a new dot which is expressed by the x and y coordinates is written on the storage. The scan converter acts as a television transmitter and reads out the stored image that has been built up by the dots. Figure 7 shows a block diagram for the display unit. The digital signals of 8-bit binary words of x and y coordinates are converted into analog signals with D-to-A converters to drive the x and y position amplifiers in the scan converter every 1/60th of a second for writing a dot on a storage tube. The image on the storage is then read out to a television monitor.

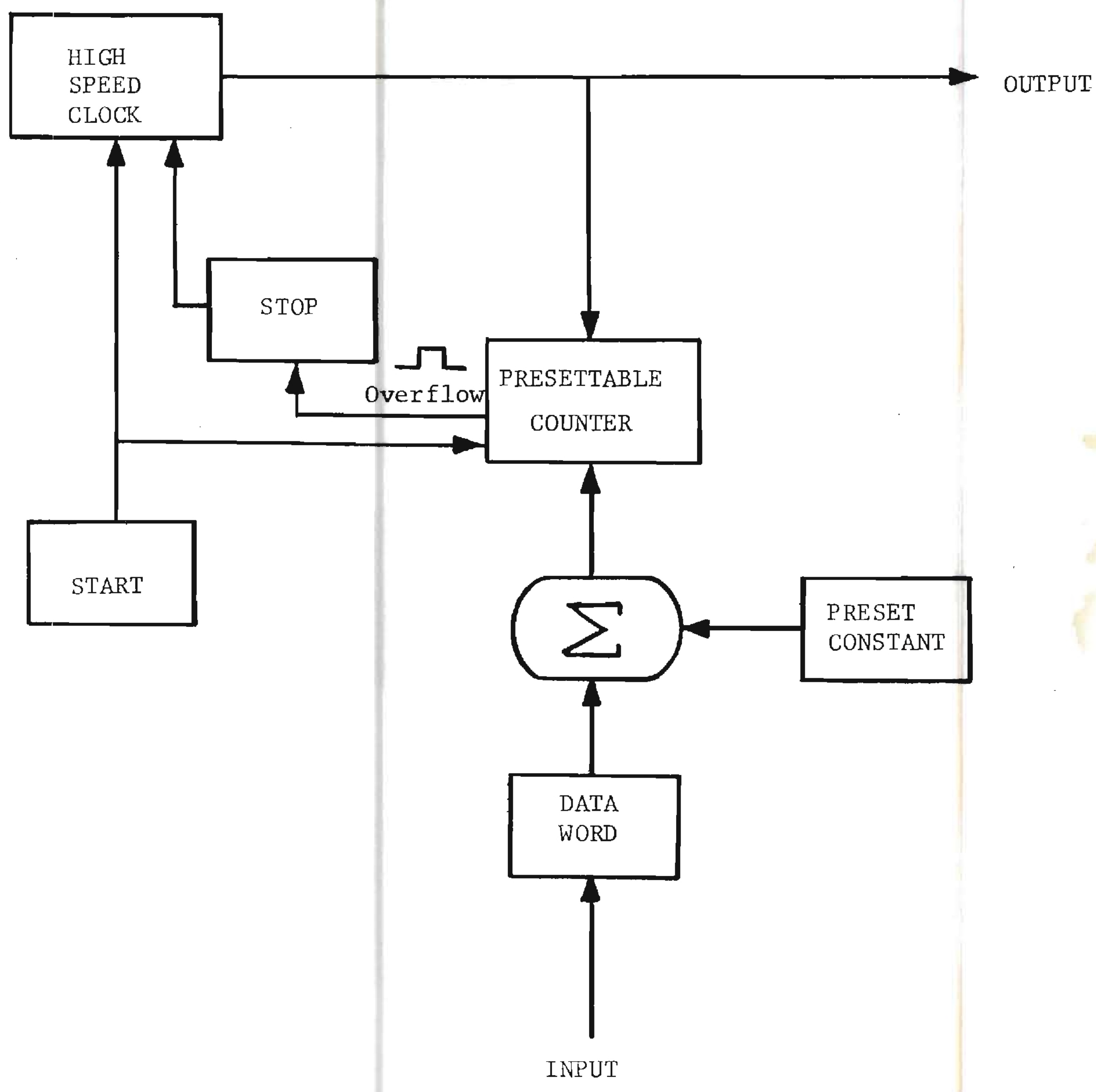

Figure 6. -- The period transmitter.

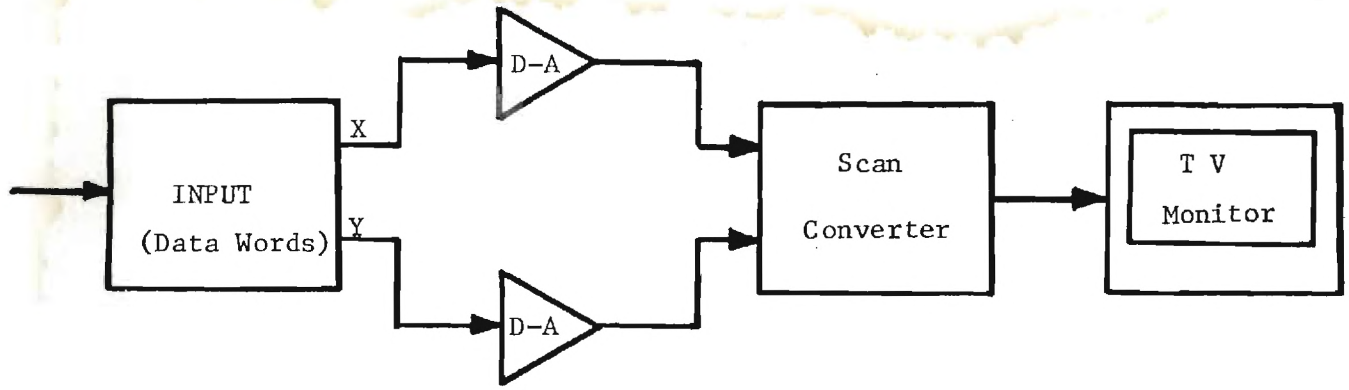

Figure 7. -- Graphic Display.

Figure 8 illustrates a timing diagram of the operation of the scan converter and the screen positions on a television monitor. Most of the time the scan converter is reading out the stored information that is written on the storage mesh of the tube. During the time of the vertical retrace of the television monitor, a new dot of graphic information from the input is written on the storage tube. The cycle repeats every 1/60th of a second.

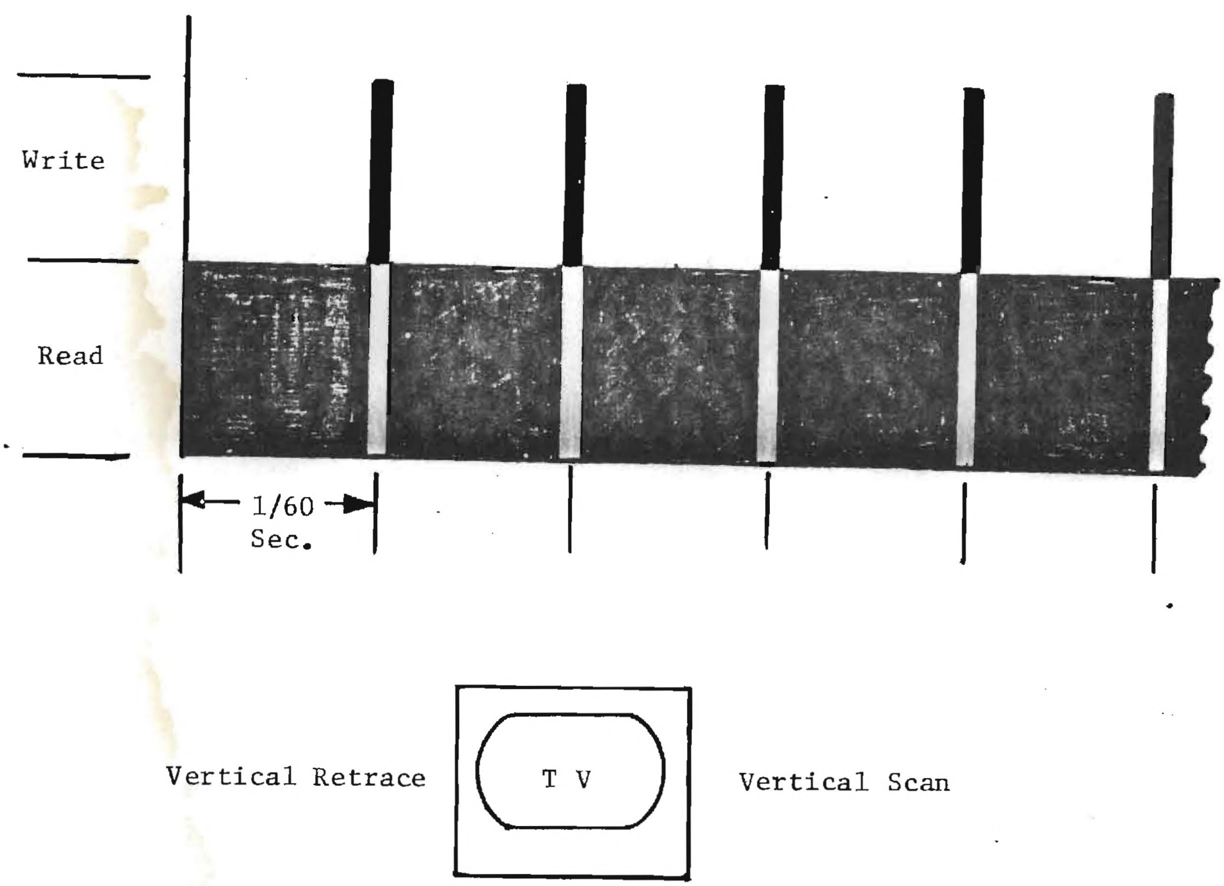

Figure 8. -- Timing of the operation of the scan converter and the screen position on the television monitor.

Vector Generator

One of the problems in the digital graphic data transmission scheme was that, if the graphs were drawn very quickly, the uniting dots failed to keep up with the handwriting and gave an unusual type of distortion that formed trains of dots rather than lines. Figure 9 illustrates this effect.

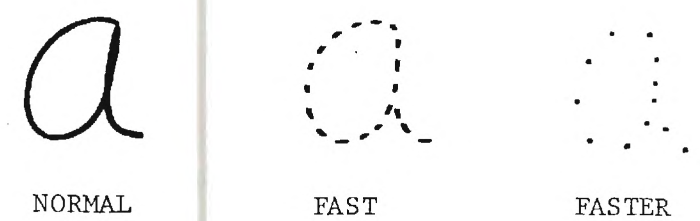

Figure 9. -- The graphic distortion caused by the fast hand writing.

A vector generator was designed to eliminate the problem. A vector generator generates a scan or a series of dots between two points.

The Multiplexing of the Audio and Graphic Signals Over a Single Voice Grade Telephone Channel

The reduced audio signal and the digitally transmitted graphic messages are sent to the receiving station via a single voice-grade telephone link. A prototype audiographic data transmission system was designed. The voice bandwidth is from 300 Hz to 800 Hz which should provide a fairly good voice quality according to the data reported earlier. Frequencies above 1800 Hz will be filtered out. The remaining part of the spectrum was designed to transmit the graphic messages. The x axis is centered at 2200 Hz with 200 cycle bandwidth for transmitting the x coordinate, and the y axis is centered at 2800 Hz with the same bandwidth for the y coordinate. Figure 10 illustrates the frequency spectrum of the audiographic signals over a voice-grade telephone link.

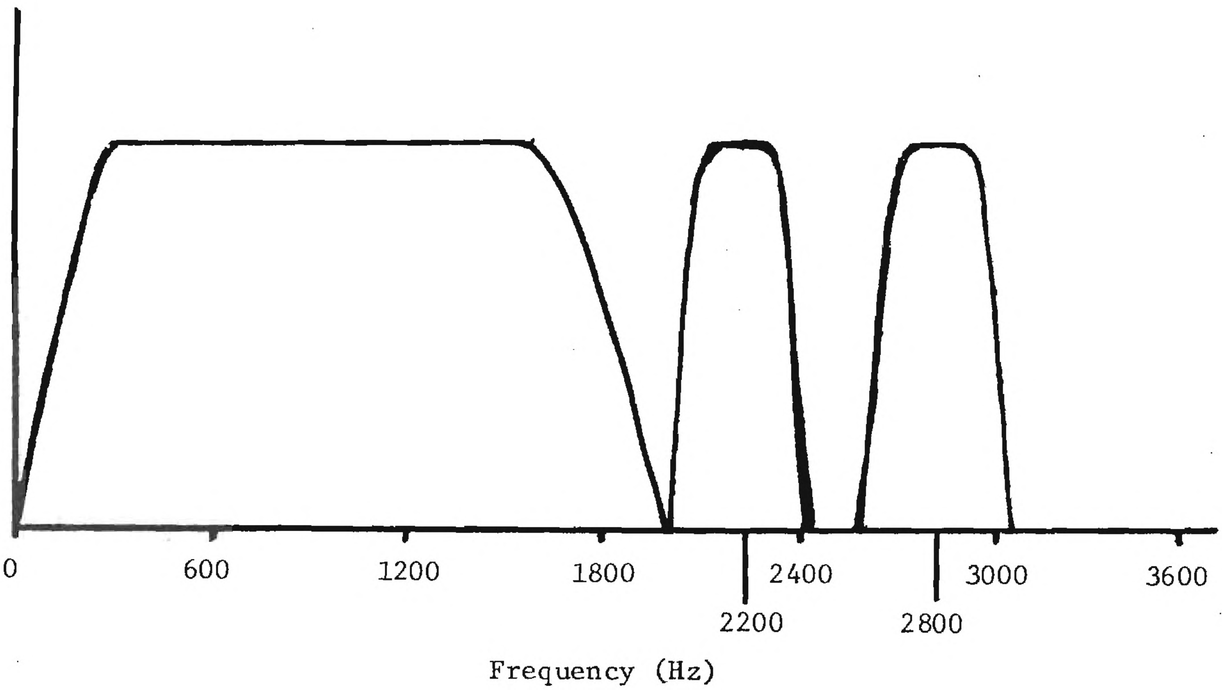

Figure 10. -- The multiplexing of audiographic data over a single voice grade telephone link.

The Prototype System

One of the most important feautres of the improved prototype audiographic data transmission system is the share of single voice-grade telephone link for simultaneously transmitting both the voice and the motion line graphics to remote learning stations. The overall system is illustrated in Figure 11.

Another feature of the system is that the graphic information is in digital form which can be stored on digital storage media for better computer control of the image. The quality of the graphic picture is also better than the original system which uses the Electrowriter as the graphic input and output device. But perhaps the most significant improvement embodied in the new system design is that it makes it possible to deliver well-tested, electronically stored instructional information via the existing telephone network to any American home that has in it a single telephone and a single TV set.

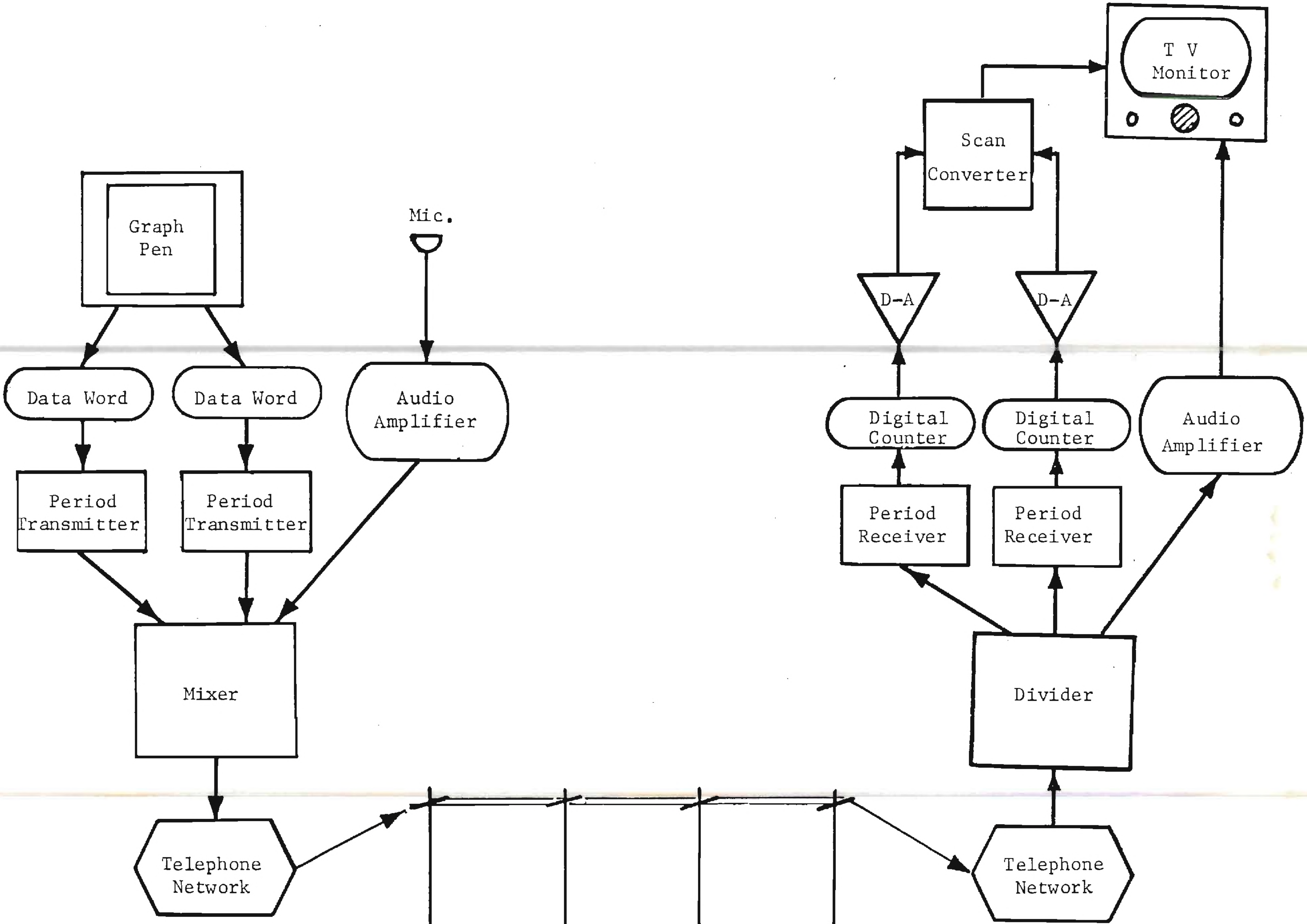

Figure 11. -- The improved prototype audiographic data transmission system.

V. ALF ECONOMICS AND THE FUTURE

In order to establish a perspective from which to consider the future of ALF-like systems, let us review the economic aspects of the Audiographic Learning Facility. The general approach by which the School of Information and Computer Science arrived at a meaning of the term 'economical' was to ask simply: What is the amount of money a customer is able and willing to pay for a learning system having specified performance and properties? The following example illustrates this 'marketing' approach to educational cost analysis:

Assume an academic department which offers, each academic quarter, 20 sections of a particular subject sequence (say calculus), where each 30-hour course section handles 25 students, for a total of 500 students per quarter (2,000 students per calendar year) or 60,000 student hours per year; assume also that an equivalent of five faculty members is assigned to this course load. Given an average faculty salary of $20,000 per 12 months (which includes the cost of support staff), the direct annual cost for offering these courses is $100,000 in Personal Services.

Assume now that the department chairman is prepared to offer the same courses via a conversational teaching system, providing this can be done without increasing his budget. Assume further than he has decided to retain two of the five faculty members to continue as full-time tutors in this subject matter, and to reassign the remaining three teachers and their support staff; this releases in his budget a sum of $60,000 which he is prepared to apply to cover the full annual cost of the teaching system — hardware, software, communications charges, operating expenses and author royalties. (We ignore certain one-time start-up expenses.)

We calculate that the total cost for the system and its operation, if amortized over a five-year period, must not exceed $300,000. Since the cost of student terminals in a conversational system can be substantial, it is of interest to determine the minimum number of terminals required to teach this student load in an individual learning mode. Assuming 2,000 working hours in a calendar year (250 eight-hour days), the minimum number of student consoles serving an annual load of 60,000 student hours is 30. (There are reasons why at times some students might prefer to learn in small groups using an appropriately designed student terminal; in such a case, fewer terminals would suffice.)

A rough cost analysis of this type is useful in that it forces recognition of the fact that there exists a pragmatic ceiling for the operating costs of realistic educational systems. For example, if "it appears both internationally and in the United States that an operating budget of approximately $250,000 to $300,000 a year is necessary merely to maintain facilities [of large-scale CAI centers] in operation" (Seidel and Kopstein, 1970), such facilities clearly do not meet our criterion of economic feasibility, and consequently may be eliminated from the range of devices which can be considered. If the learning materials were procured at a cost of, say, $500, per lecture hour (the total cost of five 30-lecture courses is $75,000, or 25% of the total budget available), the annual operating costs associated with the physical facility cannot exceed $45,000. Given the lower bound on the cost of conversational terminals to be not less than $1,500 (or $9,500 per year for 30 terminals amortized over five years), it is possible to derive rather accurately the permissible and available cost items for control hardware, memory, communications, maintenance, and operator costs. This approach, while obviously not guaranteeing a widespread acceptance of learning systems, should nonetheless be able to preempt the argument of economics which has been frustrating a more rapid application of information technology to education—provided it is possible to design educational systems within the economic constraints so determined.

Pursuant to the goals of this concept of economics, two approaches to delivering ALF materials may be compared. The two approaches are represented by a Free-Standing ALF and a Ten-Terminal ALF, both employing the concepts used throughout this project. Analysis of such systems reveals that the cost per student hour for presenting ALF materials to a class of ten students is about $0.20 per hour. The cost per student hour for a class of one student (one terminal dedicated to one student) is about $1.95.

This cost per student hour is predicated on the technology of ALF as it now exists and is <u>not</u> based on assumptions about the reduction of costs through the development of mass markets. These figures therefore do not include economic advantages to be effected through the bulk buying of equipment or other benefits of the economy-of-scale.

If ALF in its current form were expanded to a size which would support 1,000 receiving stations, the cost of those receiving stations could be reduced by at least 40 percent.* Also, the unit costs of appropriate minicomputers, switch registers, magnetic tape decks, etc., could be reduced by a similar percentage. Although the cost of editing, managing, duplicating and maintaining the ALF tapes and equipment would increase and thus offset a portion of the savings on the order of 25%, a net reduction of the cost per student hour to a figure of $0.15 might be achievable.

In spite of these favorable economics, the state of ALF technology at this time leaves much to be desired. The Electrowriter Receiver units operate well, and with few maintenance problems, in a reasonably controlled environment. However, with environmental variations experienced when room air conditioning is turned on and off, the inking pen becomes clogged and the ink reservoir takes on moisture, causing difficulties which are hard to overcome at the user station. Also, the management, editing, formatting and duplication of magnetic tapes is tedious and costly. Further, the very nature of magnetic tape as a storage medium imposes annoying delays in servicing many requests and tends to limit the amount of "browsing" a learner is

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*Based on private conversations with Stewart Wilson of Polaroid Corporation regarding bulk-buying benefits from Victor Electrowriter Corporation.

inclined to do. While such problems (even the necessity of using two telephone lines) have not significantly impaired research-related activities, it is clear that future commitments to serving large segments of the public should not be made on the basis of current facilities. Hence it is appropriate to examine alternatives for future system development and use.

One obvious alternative is a digitally stored system interfacing a receiver unit which allows exploitation of the home-quality TV set. First, let us consider the problem of digital storage. The simplest approach to accomplishing a digital ALF (DALF) would be to convert the audio and graphic signals to digital values employing an adequate sampling rate and quantization level to preserve telephone-quality sound. For these purposes, it can be shown that about 30,000 bits per second of recording would be adequate (1,200 Hz for voice, 1,800 Hz for data, guardbands and control). Therefore, each hour of DALF recordings would require about 108,000,000 bits of digital data.

Employing current-day, off-the-shelf technology of the PDP-11/45, it is possible to construct a DALF capable of maintaining, on-line, 32 hours (a complete one-quarter course) and of serving 32 simultaneous learners for a central systems hardware cost of about $500,000. (Given current trends in bulk storage costs for small computer systems, it is conceivable that this cost could be reduced by as much as 20% in the next two to three years.) For estimating purposes, let us look at the cost of supporting 32 learning stations serving 32 individual learners.

First consider the terminal unit required. As has been discussed previously, the desired terminal unit should be capable of receiving multiplexed voice and graphic digital data on a single telephone line. This unit must then separate the voice and the line graphics data, submit the voice signal to an amplifier and speaker, and present the current data point in the form of two eight-bit values to a digital-to-analog converter which generates the input to a video scan converter for the production of a signal to a home-quality black-and-white TV set.

While no such unit exists as a standard product, its logic has been designed and to some extent tested. The principal item of cost is the video scan converter. The cost of video scan converters is still high (on the order of $2,500) when purchased one at a time; however, for reasonably large orders, the unit cost drops to about $1,500, and for very large orders (1,000 or more) the unit cost drops to $750.00. Also, it has been predicted that the units cost of such "refresh units" will drop to below $500 in the next two or three years.* The implications are, therefore, that

*The Mitre Corporation, Technical and Economic Considerations of Interactive Television, February 1974, M72-200, Vol. II.

a desirable terminal unit can at this time be developed at a cost of $2,000-$2,500 per unit in small quantities and that the unit cost in production quantities might be less than $500 within a five-year period.

Thus, for estimating purposes, assume a terminal unit cost of $2,500, a central facility cost of $500,000, 32 simultaneously active terminals, 30 hours of digitized on-line ALF (DALF) type instruction, and a 2,000 hours-per-year utilization by each terminal. If we use $100 per hour as the cost of generating the course materials, allow only one user at each terminal, and amortize the capital costs over a five year period, the cost per student hour is $1.82.

If each learning station accommodates ten students per session, then the cost per student hour is about $0.18 per hour which is roughly the cost of ALF as it stands. However, these costs of digital ALF (DALF) are premised on strict data processing equipment standards today: it is reasonable to expect that in five years the cost of an equivalent central facility will be reduced to only $250,000 and the cost of terminals will drop to $500. Therefore, for the same system above, the cost per student hour would drop to $0.84 per student hour for one student per station and $0.09 per student hour for ten students per station.

These data place a DALF system in very favorable light from both the point of view of limited capital investment and the point of view of cost-per-student-hour. While this analysis has not explored the opportunity in depth, there is every reason to believe that a careful application of today's microprocessor and bulk storage technology could produce a DALF system with even greater cost advantages than those outlined above.

VI. REFERENCES

1. Acoustical Society of America. American Standard Method of Measurement of Monosyllabic Word Intelligibility. New York: American Standards Association, 1960

2. Bell System Data Communications. Data Communications Using the Switched Telecommunications Network: PUB 41005. Newark: American Telephone and Telegraph Company, 1971.

3. Bennet, William R., and Davey, James R. Data Transmission. New York: McGraw-Hill Book Company, 1965.

4. Broudy, Harry S. Aims in Adult Education: A Realist View. Notes and Essays on Education for Adults, No. 28. Center for Study of Liberal Education for adults, Chicago, Ill., 1960.

5. Burgwardt, F.C. "Continuing Education — An Industrial Commentary." Journal of Continuing Education and Training 1(1):43-48 (May 1971).

6. Charters, Alexander N. "Continuing Education for the Professional." In: Handbook of Adult Education (Robert M. Smith, F.F. Aker, J.R. Kidd, eds.). New York: MacMillan, 1970, pp. 487-498.

7. Church, C.A. "A Nonacademic View of Continuing Engineering Education." Journal of Continuing Education and Training 1(1):65-71 (May 1971).

8. Dada, Paul O.A. Evaluation of Courses and Programs Offered Under the Auspices of Wayne State University and the University of Michigan at the University Center for Adult Education, Detroit, Mich. Michigan University, Ann Arbor, Department of Community and Adult Education, 1972.

9. Davenport, William P. Modern Data Communication. New York: Hayden Book Company, Inc., 1971.

10. Dubin, Samuel S. "Motivational Factors in Professional Updating." In: Professional Obsolescence: A Symposium Held at Cambridge, Eng., June 1970 (S.S. Dubin, ed.). Lexington, Mass.: Lexington Books, 1971, pp. 35-38.

11. Dubin, Samuel S., and Marlow, H. LeRoy. A Survey of Continuing Professional Education for Engineers in Pennsylvania. University Park, Pennsylvania. Continuing Education, The Pennsylvania State University, 1965.

12. Dubin, Samuel S., Alderman, Everett, and Marlow, H. LeRoy. Managerial and Supervisory Educational Needs of Business and Industry in Pensylvania. University Park, Pennsylvania. Continuing Education, The Pennsylvania State University, 1967.

13. Gretler, Armin. The Training of Adult Middle-Level Personnel. Paris; UNESCO, 1972.

14. Hester, William Myers, Requirements for a Remote Access Hybrid Computer Terminal Utilizing Common Grade Telephone Lines, M.S. Thesis, Florida Technological University, Orlando, Florida, 1974.

15. Hughes, C.L., and Wass, D.L. "Promoting Goal Seeking Behaviour in Managers." In: Managing for Accomplishment (B.M. Bass, R. Cooper, and J.A. Hass, eds.). Lexington, Mass.: Heath, 1970, pp. 102-108.

16. Johnstone, John W.C., and Rivera, Ramon. "Why People Take Courses and What They Get Out of Them" Chapter 8 in: Volunteers for Learning (John W.C. Johnstone and Ramon Rivera, eds.). Chicago,: Aldine, 1965, pp. 142-162.

17. Kosky, T.A., et al. Polyvalent Adult Education Centre (An Integrated Approach to Adult Education for Workers). National Council of Educational Research and Training, New Delhi (India), Report No. 27, August 1971.

18. Kuhlen, Raymond G. "Motivational Changes During the Adult Years." In: Psychological Backgrounds of Adult Education (R.G. Kuhlen, ed.). Papers presented at a Syracuse University Conference, October 1962, at Sagamore, New York.

19. Landis, F. "Continuing Engineering Education — Who Really Needs It?" Paper presented at Continuing Engineering Studies, American Society of Engineering Education, Pittsburgh, Pennsylvania, Nov. 5-7, 1969.

20. Lathi, B.P. Signals, Systems and Communication. New York: John Wiley & Sons, Inc., 1965.

21. Martin, James. Teleprocessing Network Organization. Englewood Cliffs: Prentice-Hall, Inc., 1970.

22. Mitre Corporation, Technical and Economic Considerations of Interactive Television, M72-200, vol II, February 1974.

23. Nadler, Leonard. "Are you Training, Educating, or Developing?" Journal of Continuing Education and Training 1(1):49-58 (May 1971).

24. Regan, T.F. "Employment as a Motivating Force in Manpower Training Programs." Journal of Continuing Education and Training 1(1):49-58 (May 1971).

25. Rowe, George P. How Continuing Education Programmers Perceive Their Job Roles. Missouri University, Columbia Extension Division, Report SR 22, August 1971.

26. Slamecka, V. and Jensen, A.P., "The Audiographic Learning Facility: Objectives and Design." Atlanta, Georgia, Georgia Institute of Technology (School of Information and Computer Science), Research Report GITIS-70-08. 44 pp., 1970.

27. Slamecka, V., "An Audiographic System for Self-Instruction," Journal of the American Society for Information Science, November-December 1973.

28. Slamecka, V., "Use of Audiographic Technology in Continuing Graduate-Level Science Education." Atlanta, Georgia, Georgia Institute of Technology (School of Information and Computer Science), July 1973. Annual Progress Report on NSF Grant GN-2628.

29. Ting, T.C., and Badre, Albert N., "A Dynamic Model of Man-Machine Interaction: Design and Application with an Audiographic Learning Facility." To appear in International Journal of Man-Machine Studies.

30. Ting, T.C., and Jensen, A.P., "An On-Line Interactive Audiographic Learning System," ACM 1974 Annual Conference Proceedings, p. 239-244.