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ABSTRACT

The decision to employ direct rather than diffraction recording in the Lincoln Training System (LTS) is reported. This resulted from the findings that direct recording was practical at higher densities than previously thought possible and that rapid access to a number of fiche would compensate for the limited number of frames per fiche realized with direct recording. The initial stages of the educational development program for the LTS, consisting of programs in Principles of Electronics and Air Traffic Control developed at Keesler Air Force Base (AFB) are described. Finally, a report of LTS-3, a microfiche-based training system which will be field-tested at Keesler AFB, is offered. Information is given which explains how a microfiche reader provides access to audio/graphic frames and how lesson branching logic is stored photographically. Supporting author facilities for merging voice and lesson-branching logic and for recording these signals on film are described. In addition, detailed technical data are provided on terminal design, the audio recording system, the audio read system, the LTS-3 terminal/computer interface, the author's voice/data merge facility, and on diffraction-pattern recording techniques. (LB)

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ABSTRACT

A major shift in the schedules and priorities of the program took place during this quarter as a result of the decision to employ direct rather than diffraction recording in the next model of the LTS. This entails some slippage in the Keesler trial, but will permit us to test out a prototype microfiche system. This system, LTS-3, has been designed and is now under construction.

15 March 1971

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EDUCATIONAL TECHNOLOGY PROGRAM

I. INTRODUCTION

In the past quarter there have been major changes in the schedule and detailed concept of the Educational Technology Program, brought about by two developments:

(a) Laboratory experiments indicated that direct (point-by-point) recording and tracking of audio on film was practical at higher densities than our original analysis had suggested.

(b) We came to realize that rapid access to a number of fiche could compensate for the limited number of frames per fiche that we would be able to realize with direct audio recording. Furthermore, a commercially available system built by Image Systems Inc. offered this capability.

Based on these considerations, it appeared that we could develop a prototype microfiche system for the proposed field tests at Keesler AFB. This would mean a slippage of several months in the original start date, but it would also eliminate the expense of developing a simulated system, as originally proposed, and would involve us much earlier with microfiche production. This, in turn, would mean a speedup in the overall program.

II. EDUCATIONAL DEVELOPMENT PROGRAM FOR THE LTS

A. The Keesler Trial

A team of six Air Force personnel at Keesler Technical Training Center has begun preparation of educational materials. Two areas have been selected: one in Principles of Electronics, and the other in Air Traffic Control. Members of the project have visited Keesler each month to work out procedure and to assist in adapting Keesler educational techniques and goals to this new environment. We plan to have the team visit Lincoln and try out sample lessons on the LTS-1 simulated machine.

Plans have been made that permit the Keesler authors to check over their materials before they are committed to fiche. As shown in Fig. 1, an author drafts materials in notebook form. Each frame of lesson material is represented by a sketch of the visual frame – a text representing the audio script, and a table indicating the branching for each response. Each of these must be converted to final form. The pictures will be prepared at KTTC by their visual arts production facility. A typical frame is shown in Fig. 2. The audio will be recorded at Keesler on a quality tape recorder, and the logic will be expressed as a text file on-line to the Laboratory IBM 360/67 computer. The computer converts the logic to an IBM binary tape. At Lincoln, the binary logic and audio tapes are merged and converted to 10-inch spiral film images, one per frame. These images, along with a copy of the branching logic text prepared on the computer, are returned to KTTC for editorial checking. An optical phonograph is being constructed so that the authors can check the accuracy and quality of the auditory messages. When approved, the auditory images and original art work are paired and sent out for transfer to fiche.

B. Educational Techniques

A recent request by personnel of Keesler for more sophisticated branching mechanisms prompted us to increase the flexibility of numerical response processing. One of the most

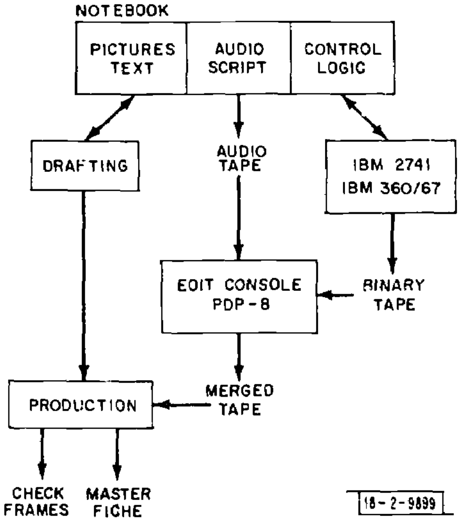

Fig. 1. Lesson preparation.

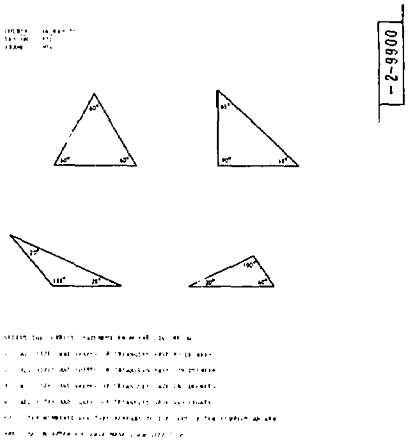

Fig. 2. Sample frame.

interesting of the associated methodological advances concerns remedial branching from quiz frames that require composite numerical responses. Consider this quiz for example:

> "After sections of P-type and N-type germanium are joined chemically, the P-type section becomes [negative (1); neutral (2); positive (3)] in its overall charge. Once the P section is joined, in other words, it has [fewer (1); more (2); the same number of (3)] impurity atoms and [fewer (1); more (2); the same number of (3)] holes."

The paragraph form of this quiz enables the author of the lesson to summarize conveniently on a single frame the interrelationships that the student is expected to learn in the respective lesson unit which comprises several instructional frames. Thus, the quiz can be used to give the student a preview of the unit's contents before he begins the unit, as well as to test and confirm his understanding of the unit after he has studied all or part of it. The chance that a student who just guesses will be transferred to the next unit is also very small.

A variety of branching paths can be made contingent on the student's composite response. A completely correct response of 131 can be programmed to branch the student to the next unit of the lesson. A response of either 231 or 331, in which the first numeral is incorrect, can be programmed to branch the student to a remedial frame that deals specifically with such matters as the cancellation that occurs between positively and negatively charged particles, after which the student might be transferred back to the quiz to try it again. In this way, remedial frames can be programmed for one or more incorrect numerals, allowing the author to provide remediation in an interesting and efficient fashion.

III. LTS-3 DEVELOPMENT

During this quarter we began to design a microfiche-based training system (LTS-3), which will be field-tested at the USAF Technical Training School, Keesler AFB, Biloxi, Mississippi, starting in the last quarter of this calendar year. We are modifying an Image Systems Inc. Model 201 microfiche reader to provide random access to audio/graphic frames, and lesson branching logic stored photographically on 4 × 6-inch microfiche cards. Supporting author facilities for merging voice and lesson-branching logic and recording these signals on film have been designed and are being constructed. The system will consist of four operating consoles and one active spare, under control of a DEC PDP-8/I digital computer, with 8192 words of memory at 12 bits per word.

A. Terminal Design

The interior arrangement of the Image Systems Inc. reader will be modified to provide separate video and audio outputs from the same 4 × 6-inch fiche. A projection system has been designed to permit locating the audio frames 3 inches above their corresponding video frames. From this location, it is possible to project the audio images past the video-system mirrors and on to the audio-tracker/reader mechanism.

The x-y positioning mechanism in the Image Systems Inc. fiche reader has been tested to see if any improvement in the x-y positioning can be made. As received from the manufacturer, the fiche reader positions the video image to within ±0.010 inch. In order to be compatible with the audio reader, it is necessary to considerably improve the film registration. Tests were made using photopots fastened to the video view screen and feeding into the existing control loop. It was demonstrated that registration could be improved to ±0.001 to 0.002 inch by this approach. A more sophisticated approach using x-y diodes may make it possible to improve on this. However, the ±0.001-inch tolerance is adequate for the proposed audio reader.

The design for the audio-image illumination system has been worked out. Final design awaits the arrival of the actual components which will be used. When these components are received, it will be possible to breadboard the actual system and make measurements for uniformity of illumination over the whole audio spiral.

B. Audio Recording System

A servo-controlled turntable has been produced for making the audio spirals. It is a transcription turntable featuring feedback speed control, modified to rotate at 60 rpm, and has been provided with a ball-bearing slide cross-feed mechanism employing a variable-speed drive through a servo-controlled lead screw. The carriage of the cross feed supports a Maurer optical recording galvanometer. By varying the controls to the lead screw, many different spiral pitches can be produced.

After verifying the design by producing several satisfactory test spirals, we fabricated a controller that provides automation sufficient for a production environment. The controller provides for automatic source-tape start/stop, programmed light for constant film exposure at all spiral radii, automatic high-frequency pre-emphasis at smaller radii, and operator convenience. We anticipate that the production rate for ortho film (which can be handled in red light) will be at least 30 frames/hour, but perhaps only 20 frames/hour for pan film (which must be handled in darkness).

A similarly modified transcription turntable has been produced to enable the reading of the audio spirals produced on the above device. This turntable, however, is equipped with a conventional phonograph tone arm which is controlled by a servo system. The end of the tone arm is equipped with a small optical system which feeds a photodiode to provide tracking and audio output. The assembly has been used to reproduce speech, but its performance has not yet been measured to determine its ability to produce an audio output to the required standards.

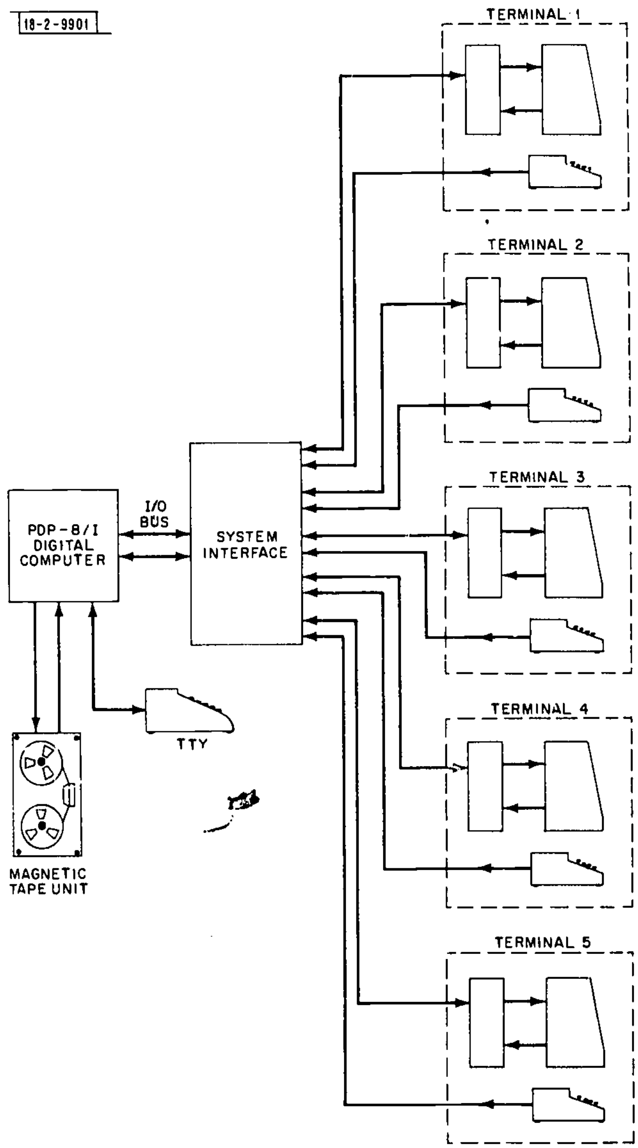

Fig. 3. LTS-3 system block diagram.

We are presently investigating variable-area and variable-density recording techniques for the audio voice/data signals. Although both techniques afford comparable recording capacity, it is the intent of this study to determine which record/reproduce system can be more easily implemented for an eventual production facility.

C. Audio Read System

An audio tracking and reading mechanism has been designed and is presently under construction. The reading mechanism rotates at 60 rpm and carries a photodiode which provides both the error signal for tracking the audio spiral and also the audio output signal. This system reproduces audio from either variable-area or variable-density film records.

D. LTS-3 – Terminal/Computer Interface

Design of the LTS-3 system computer interface is essentially complete, and hardware procurement to implement it is under way. As presently proposed, the system will consist of 5 student terminals, each containing a microfiche reader with separate keyboard. Each of the terminals will occupy 6 input/output (I/O) channels of a DEC PDP-8/I digital computer. Figure 3 is a block diagram of the proposed system, and Fig. 4 shows one of the 5 terminal interfaces included in the system. The I/O channels perform the following functions.

> Channel 1 will be used to remotely control the card-selection mechanism of the microfiche reader at the terminal.
>
> Channel 2 will carry frame-select commands to the reader, designate microfiche format to be used, and effect repeat, audio, and video on/off control at the terminal.
>
> Channel 3 will provide for computer control of external indicators and/or equipment. Three bits are reserved for this function, the first of which will control a key-push-error or unauthorized-entry indicator located at the console. The remaining two control bits of this channel are as yet unassigned.
>
> Channel 4 will be used for transferring frame branching and control information into the computer. These data will originate as part of the audio recording included with the presentation of each frame at the student terminal. The data will be outputted from the terminal in serial form, demodulated, converted to 12-bit words, and transferred across the interface.
>
> Channel 5 will be used to carry keyboard inputs to the computer. This information will be in the form of 5-bit coded characters.
>
> Channel 6 of each terminal will be used to signal the computer regarding terminal equipment status. One such signal will indicate the completion of a card-change operation, following a channel 1 command.

As indicated in Fig. 4, the computer input channels 4, 5 and 6 of each terminal have interrupt capabilities, whereby they interrupt the computer for service as their data become available for transfer.

E. Author's Voice/Data Merge Facility

The author's facility permits an author to record, play back, and modify an audio tape which contains interleaved sequences of voice and data. The computer, by means of a preprepared binary-data magnetic tape, automatically interleaves the data with the voice portions which are recorded by the author while on-line to the computer. The result is an audio magnetic tape which can be directly transferred to film without any additional formatting.

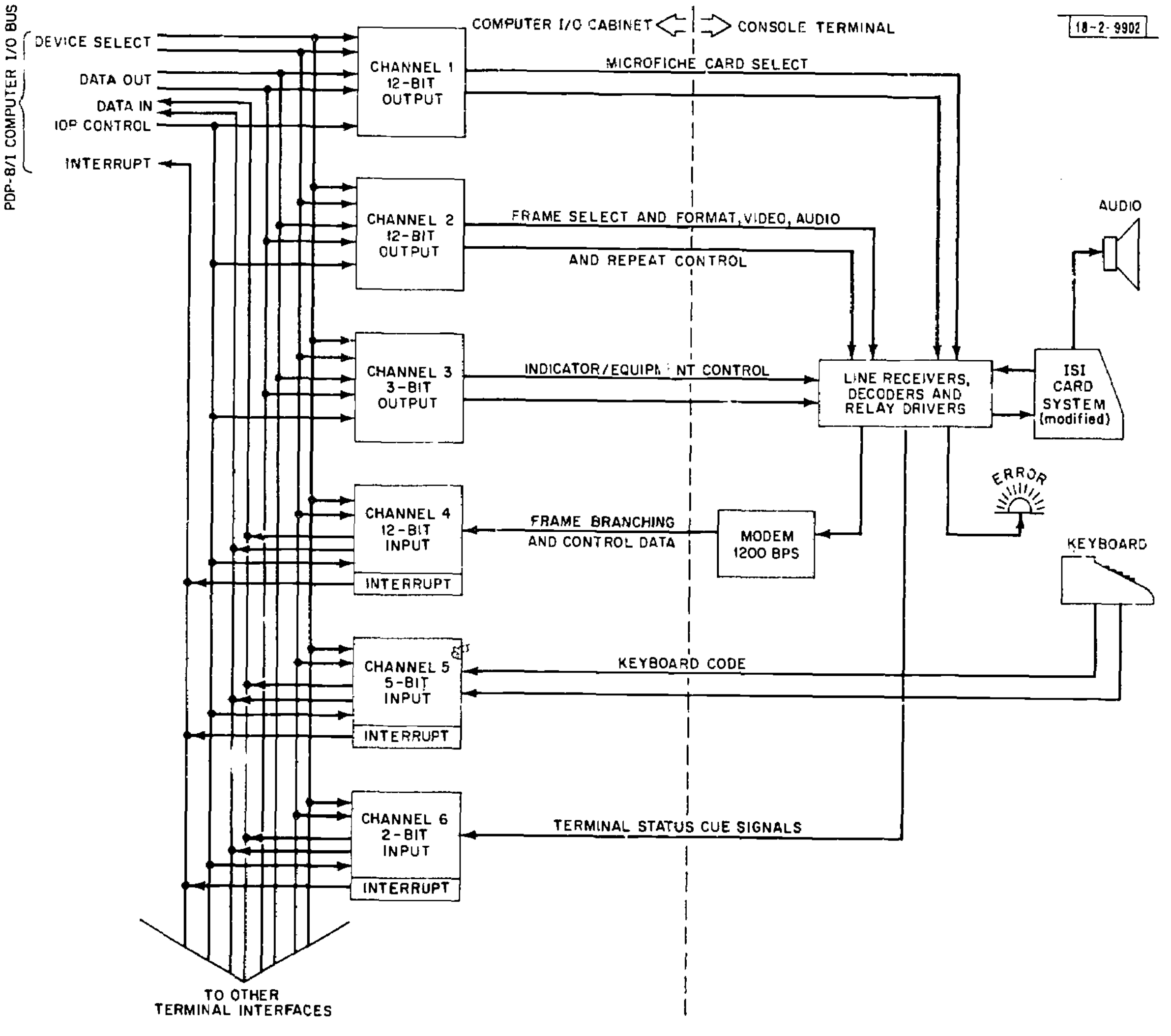

Fig. 4. LTS-3 terminal interface block diagram.

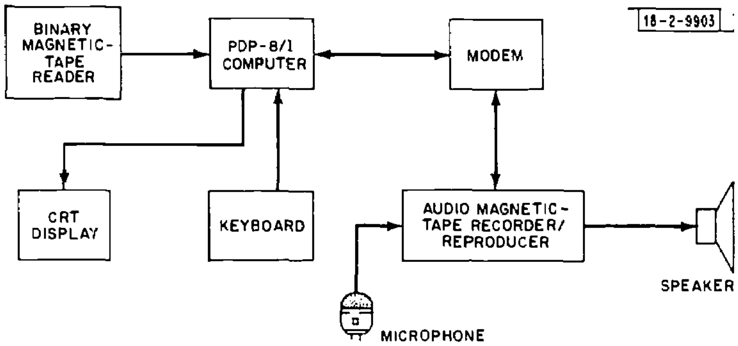

Fig. 5. Block diagram of author's facility, LTS-3.

A simplified block diagram of the author's facility is shown in Fig. 5. It consists basically of a magnetic-tape reader containing a properly formatted binary author's tape; a keyboard and CRT display terminal which are used as the author's control, communication, and display system; the computer; a data modem for converting the branching logic to audio tones and back again; an audio tape recorder which records the interleaved voice and data; and a microphone and speaker.

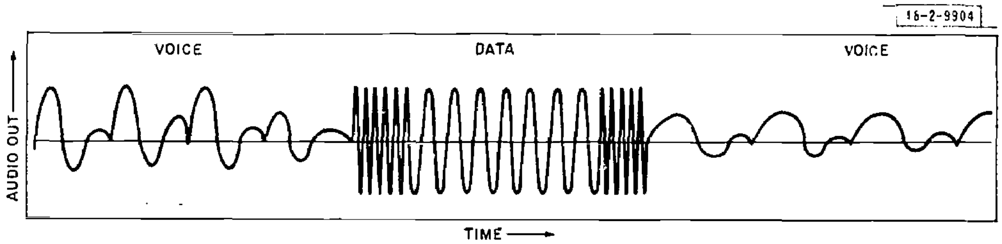

Fig. 6. Interleaved audio signals, LTS-3.

Branching information to enable the student terminal to select the next frame, based on student response and other related data, will be stored on the microfiche frames in the form of FSK audio tones interleaved with the voice on the audio sound track, as shown in Fig. 6.

IV. DIFFRACTION-PATTERN RECORDING TECHNIQUES

The concentration of effort on LTS-3 during the past quarterly period has required a sharp reduction in work on diffraction-pattern techniques for recording and reading random-access audio. This activity, designated LTS-2 in our previous quarterly technical summaries, has been redesignated LTS-4.

During the last quarter, investigations were carried out regarding the recording of clipped binary diffraction patches. Using the computer output microfilm facility, we tried several signal processing approaches to increase the attainable signal-to-noise ratio for different choices of beam positions. The writing of a program for the Group 64 Fast Digital Processor was begun; it would have performed all the computations related to the choice of dots to be intensified by the microfilm plotter in making a patch. However, in line with the decision to implement LTS-3 using direct (point-by-point) rather than diffraction-pattern recording techniques for storing audio, we decided to redirect the development of the diffraction technique toward the long-range goal, that of recording analog speech samples using only two beams to store each speech sample. This would result in a greater density of information on the film and a simpler reader mechanism, assuming that a sufficient dynamic range is available for each sample using only two beams.

In line with this goal, it appears that the diffraction patches should be generated by means of optical Fourier transforms, rather than by means of computer output microfilm. Since clipped diffraction patches are no longer envisioned, it is necessary to confront the problems of film linearity and granularity head-on. We believe that the same mechanisms which provide good linearity for volume phase holograms, chiefly Bragg-angle scattering for suppression of non-linearities, will operate to provide a wide dynamic range for our diffraction patches. Accordingly, a facility for optically producing diffraction patches is being assembled. This facility (Fig. 7) will consist of a HeNe laser and a high-speed electro-optic shutter to permit a short flash of coherent light, beam-forming optics to produce a 150-μm-wide beam with a raised-cosine (or $\sin^2$) weighting, and a two-dimensional grating pattern (M-sequence mask) to diffract the beam into a large number of beams of equal amplitude and random phase relative to one another. These beams will then be focused onto one frame of a 35-mm film which has previously been exposed with a pattern of spots such that each spot modulates the intensity of one beam. The light transmitted through this film mask will then be collected by another lens and brought to focus on a high-resolution photographic plate (Kodak 649F). A facility for processing these plates is also being planned. Essentially, the 35-mm film mask will serve as a spatial filter which modifies the spatial frequencies present in the M-sequence grating.

The 35-mm film spot pattern will be chosen so that the transmission of pairs of beams is as follows: For positive-valued speech samples, one beam will be blocked completely, and the other will be attenuated so that the transmitted amplitude is proportional to the speech sample. For

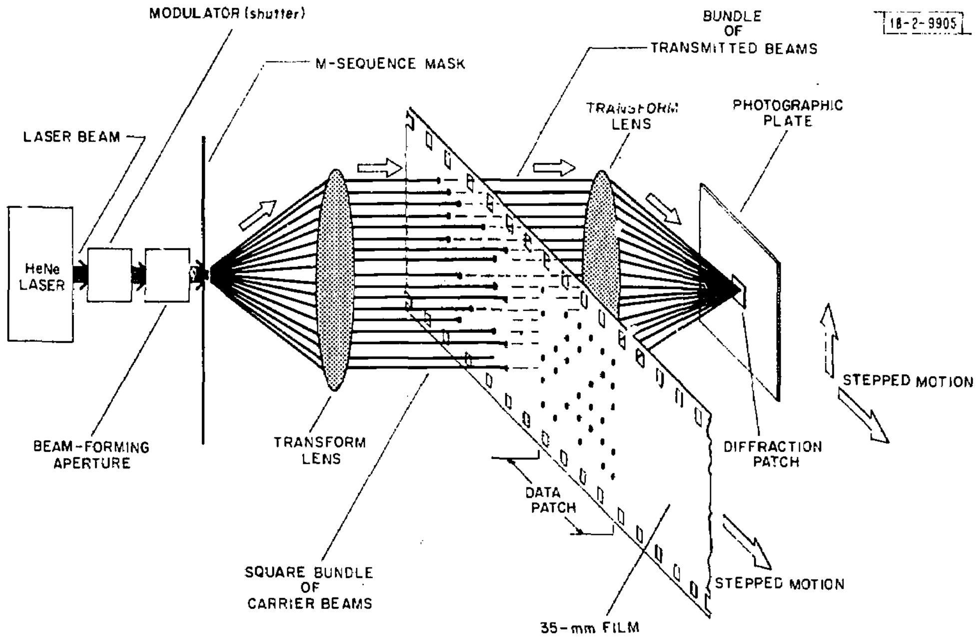

Fig. 7. Recording diffraction patches, LTS-4.

negative-valued speech samples, the other beam of the pair is blocked completely, while the first is attenuated to emerge with amplitude in proportion to the speech sample. Thus, the difference between the intensities of the two transmitted beams is equal to the signed value of the speech sample. Each patch should diffract approximately 100 pairs of beams, thus providing about 100 speech samples. To expose a new patch, the 35-mm film will be moved so that a new set of spots modulates the beams, and the high-resolution plate will be moved so that the resulting patch falls in the proper position. In a real-time recording system, it would be necessary to move the 35-mm film and the high-resolution plate about 50 times per second.

The recording method we are proposing will have several features in common with holography. As in holography, the lenses do not play any critical part. However, the various components of the recording setup must not move relative to one another by more than a fraction of a wavelength during the exposure time. To this end, the entire facility will be mounted on a granite slab, supported on springs. In addition, each exposure will be very short, of the order of 1 msec or less.

In order to produce efficient diffraction patches, we feel that the diffraction patches must employ phase delay rather than absorption as the mechanism of diffraction. The exposed emulsion will thus be developed and fixed normally, and then bleached to transparency. Variations in index of refraction within the patch, as well as reticulation of the surface of the developed emulsion, should provide the mechanism for phase delay. Phase gratings are about an order-of-magnitude more efficient than absorption gratings, and we will prepare a phase grating of the M-sequence as a first step.

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