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October 1971

INVESTIGATION OF 10.6 MICRON PROPAGATION PHENOMENA
(2880-5)

The Ohio State University

ElectroScience Laboratory

Department of Electrical Engineering
Columbus, Ohio 43212

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13. ABSTRACT

This report summarizes technical details of work performed at The Ohio State University ElectroScience Laboratory during the period 8 July 1971 to 8 October 1971.

Progress is reported on the construction and testing of apparatus and the development of computer software for experiments in imaging and image restoration at 10.6 microns. The initial experiment involves recording, in digital format, the atmospherically degraded images of a pair of point sources with subsequent computer processing for image restoration and determination of isoplanatic patch size for various atmospheric conditions.

Recent additions to the experimental equipment are described and samples of images recorded and reproduced via the Miller code digital magnetic tape recording system are presented.

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PUBLICATION REVIEW

This technical report has been reviewed and is approved.

Raymond P. Urtz Jr.

RADC Project Engineer

ABSTRACT

This report summarizes technical details of work performed at The Ohio State University ElectroScience Laboratory during the period 8 July 1971 to 8 October 1971.

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CONTENTS

I. INTRODUCTION

This is the fifth technical report on Contract No. F30602-70-C-0003 entitled "Investigation of 10.6 Micron Propagation Phenomena." This report covers the period 8 July 1971 to 8 October 1971.

This program initially provided theoretical backup information to the RADC Atmospheric Optical Propagation Studies Program and is currently centered on the study of atmospheric imaging and restoration of atmospherically degraded images at 10.6 microns. The general aim is to provide initial attempts at restoration, to determine potential problems, and to obtain initial data useful for preliminary systems design. For this purpose a system is being completed and tested which will record two 10.6 micron images simultaneously at 200 frames per second, perform image restoration via computer analysis, and display the restored images.

Primary effort during the past three months has been devoted to completing and testing the 10.6 micron imaging detector and the Miller code magnetic tape recording and playback system, and converting computer software for operation on the ElectroScience Laboratory's new DC6024 computer. Design of an interface between the serial digital (Miller code) recorder and the DC6024 computer for reduction of data pre-recorded at RADC has also been initiated.

II. IMAGING AND IMAGE RESTORATION APPARATUS

A. Description

The basic experiment to be performed following completion and testing of the infrared imaging system involves simultaneous recording of two atmospherically degraded laser beams.[1] The image received from one beam will be processed to obtain the atmospheric MTF which will then be applied to restore the degraded image received from the second beam. Preliminary tests of this process have been successfully performed using data obtained from an analog display of one channel of the scanning detector.[2] Information on isoplanatic patch size will also be obtained by varying the spacing between the two beams and noting the effects on image restoration and by studying the correlation between the two images as a function of beam separation. Later experiments involving reflected images from real objects using a point source reference, and finally, using edge effects in an image to eliminate the need for a reference beam are also planned.

A simplified block diagram of the image restoration experiment is given in Fig. 1. Two 10.6 micron sources having variable separation are obtained by splitting the output of a 10.6 micron laser into two beams which are then directed toward the receiving telescope by two movable mirrors having the desired separation. Atmospherically degraded images (degraded airy disc patterns) of these sources are

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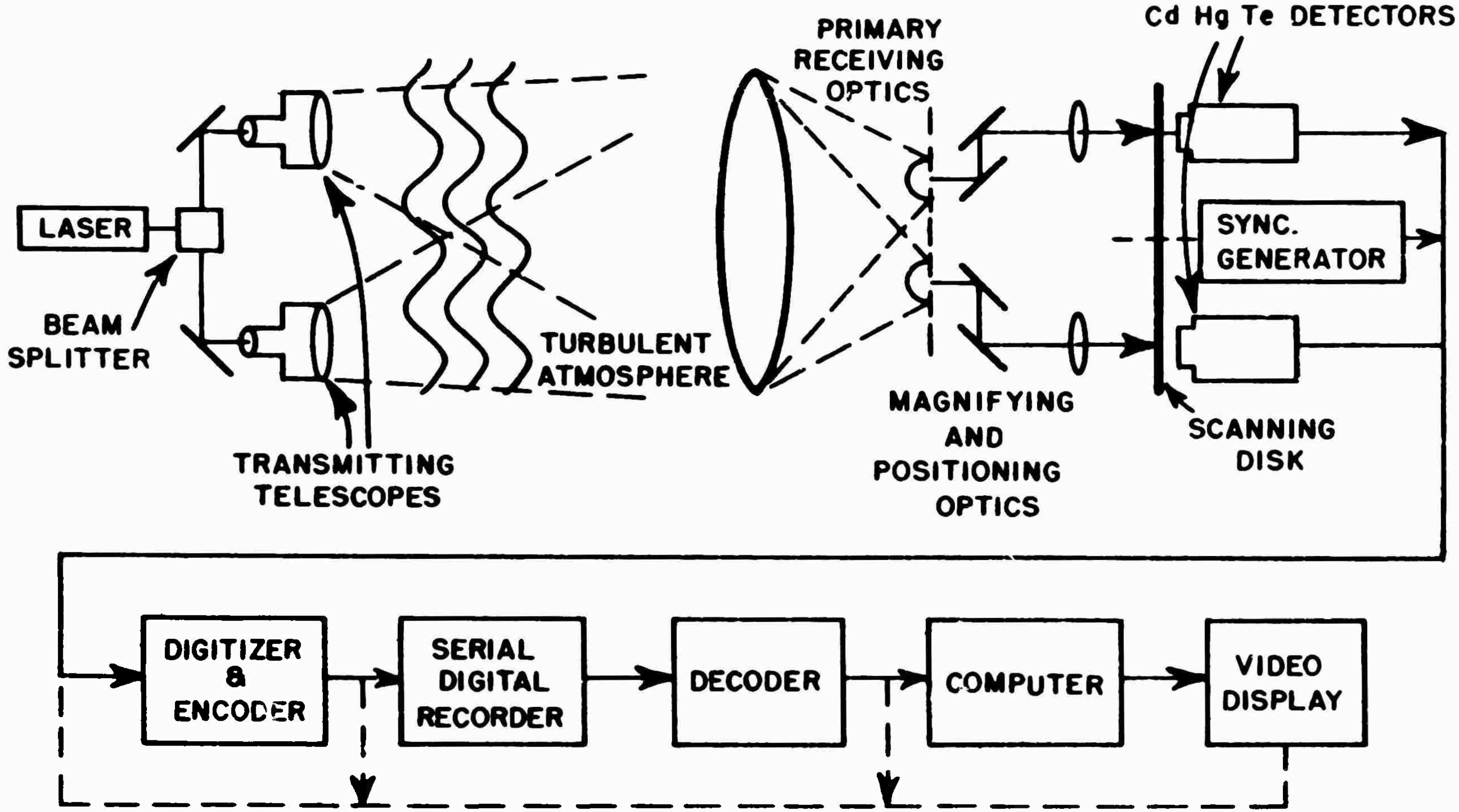


Fig. 1. Image Restoration Experiment.

formed at the primary image plane as shown. Desired portions of these images are then selected, magnified by 1, 2, or 4, as appropriate for the turbulence conditions present and are refocused onto opposite sides of the scanning disc which contains two identical sets of scanning apertures so that both images are scanned simultaneously. Infrared detectors mounted behind the scanning disc convert the infrared energy into electrical (video) signals for recording and subsequent processing. Synchronization signals are also required in order that the video data can be properly identified with respect to location within the image. These are generated as described below. Details of the optical system and of the signal processing electronics have been given in a previous report.[3]

Synchronizing signals for controlling the digitization, recording, and reconstruction of the video signals are obtained from the scanning disc as indicated in Fig. 2. Two 20 line reticles are projected onto the scanning disc using a position approximately 90° away from the IR detector. As a hole passes in front of a reticle line, a photomultiplier receives the signal and delivers a pulse to the synchronizing electronics.

The reticles are positioned with respect to successive holes in the disc such that a pulse is produced by one detector corresponding to each odd-numbered data word of the image being scanned, while the other detector produces a pulse for each even-numbered word. These pulses are then shortened and combined to form the complete A channel word sync pulse train and, via a delay, the B channel word sync pulse train. (Note that it is not possible to generate the complete word sync pulse train by means of a 40 line reticle and single detector since the scanning hole diameter is equal to the word spacing and successive pulses would overlap. Smaller holes could theoretically be used to generate the required sync pulses in this manner but would be extremely difficult and costly to drill and to position with the required accuracy.)

Two additional holes are diametrically located on the periphery of the scanning disc for generating frame sync and a third hole is located near one frame sync hole to provide disc sync (i.e., a method for determining which half of the disc scanned a particular image). A separate line source projector and photomultiplier are used for these signals. This line source and detector also operate in conjunction with the 80 scanning holes to produce line sync. The detector output is thus a combination of line, frame, and disc sync pulses which are then separated by the synchronization electronics. Coarse adjustment of the sync pulse timing is accomplished by movement of the reticle projector, while fine adjustments may be made via delay gates within the sync electronics.

Details of the digitizer and encoder, serial digital recorder, and decoder of Fig. 1 have been given previously.[3] Basically, the video signals from the A and B channel detectors are multiplexed,

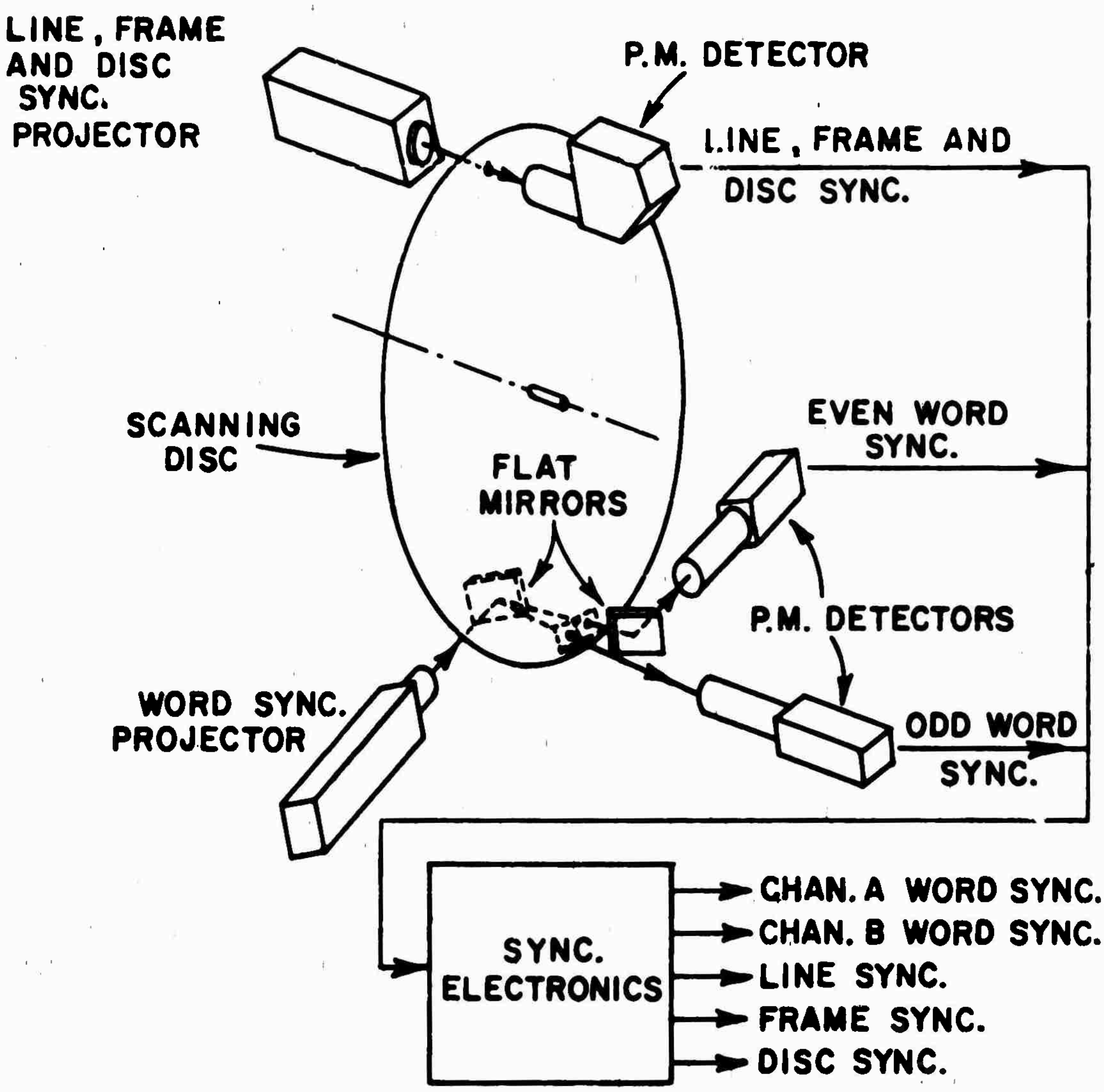


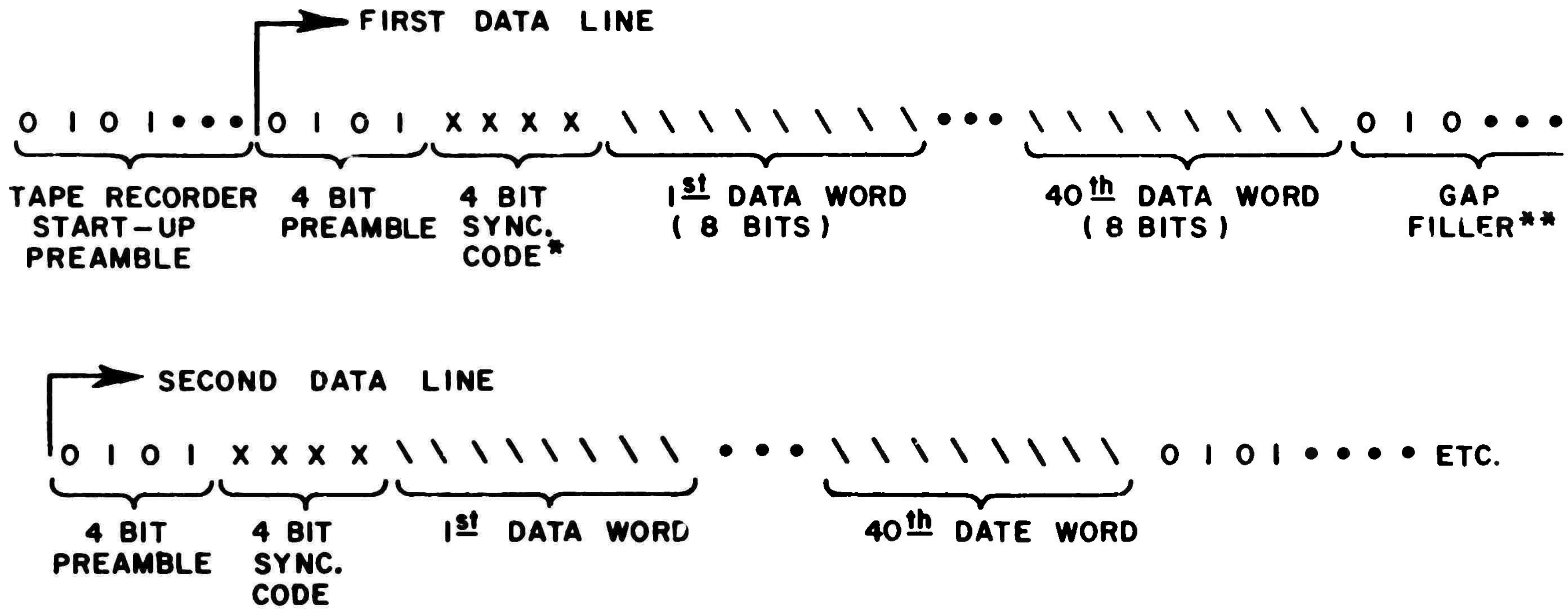
Fig. 2. Scanner Synchronization System.

digitized, demultiplexed, converted to serial form, and are then combined with the necessary sync signals so that the output from each channel may be recorded on a single track of the serial digital (Miller Code) tape recorder.

The serial coding technique used for this purpose is illustrated by Fig. 3. A preamble of 0101··· code is first recorded in order that the Miller code decoder clock can be synchronized during playback prior to arrival of the first actual data. (The 101 sequence is unique in the Miller code system and is used for clock synchronization.[4]) Each data line then begins with a 4-bit (0101) preamble to maintain clock synchronization followed by a 4-bit sync code from which line and frame sync and recording mode used are extracted during playback. Actual video data words for the corresponding image line are then recorded in succession. Following the 40th (last) data word of the line a gap filler code (0101···) is recorded until data for the following line becomes available. Output of the encoder is synchronous (as required for reliable operation of the Miller code system) at a fixed, crystal-controlled frequency of 2.716 Megabits per second, while input is asynchronous, both because of the variable word rate from line to line used to obtain equal line lengths from the scanning disc,[3] and because of possible variations in disc speed. Hence the gap filler code, which varies in length as required, is needed. Since the 0101 sequence is used for this code it also aids in clock synchronization.

The particular four bit sync codes used (see Fig. 3) can be uniquely identified and precisely located within a string of 0101's (which they always follow) hence detection of one of these by the decoder during playback signifies the beginning of a data line. Word sync pulses used to extract the data and generate a CRT raster for display are then obtained via a data bit counter. The sync code detectors are gated off during data word input so that if these 4-bit combinations are present within the data stream they will not produce false sync pulses at the decoder output. Following reception of the 40th data word plus two extra bits (to allow for possible errors in the data bit count) the sync code detectors are gated on again, and, when the next 4-bit sync code is detected, the bit counters are reset and the cycle is repeated for the next data line.

The serial encoder and decoder described above utilize standard NRZ (non return to zero) binary code. This is not suitable for direct magnetic tape recording, however, because of the DC response required, the undesirable spectral density (which peaks at dc), and the inability to extract a clock for decoding from a single channel of recorded data. Hence for the actual recording process the NRZ data is converted to Miller code which effectively eliminates these difficulties.[4] Characteristics of the Miller code are compared with the standard NRZ data format in Fig. 4. The spectral density of typical Miller coded data closely approximates that which is available on a standard direct record channel of an instrumention magnetic tape recorder, hence capabilities of the recorder are fully utilized and very high bit



* SYNC CODES

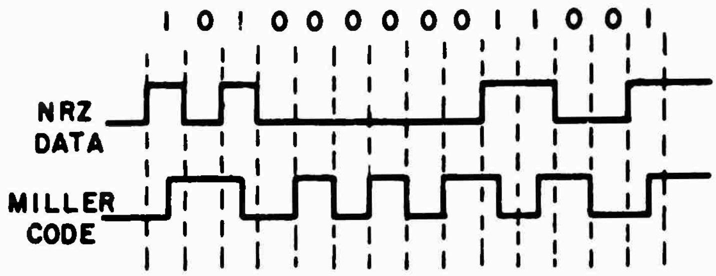
0000 = LINE SYNC

0011 = FRAME SYNC., 8 DATA BIT MODE

1100 = FRAME SYNC., 7 BIT + PARITY MODE

** GAP FILLER = AN EVEN NO. OF 0101•••BITS (NORMALLY 10 TO 12 BITS)

Fig. 3. Serial Coding Technique.



	MINIMUM BANDWIDTH	PEAK SPECTRAL DENSITY AT
NRZ DATA	DC TO 0.75 f	DC
MILLER CODE	0.1f TO 0.75f	0.375 f

MILLER CODE DEFINITION

1 = TRANSITION IN CENTER OF BIT CELL

00 = TRANSITION AT END OF 1st 0'S BIT CELL

Fig. 4. Miller Code Format.

densities (22.6 K bits/in. for the present system) can be achieved. Also, as mentioned earlier, the 101 sequence is unique in the Miller code, having a period exactly two bit cells in length, and can be used to extract the clock required for decoding from the recorded data.

B. Current Progress

The two-channel infrared scanner package and associated control and display console are nearly completed. The temporary relay lens used in the scanner for initial tests has been removed and the disc and detector mounts have been completely rebuilt to achieve a simpler, more rugged, vibration-free mount. The temporary sync projectors and detectors have also been replaced and the associated electronics have been revised as described in the previous section of this report. A rim has been added to the scanning disc to eliminate buckling of the thin disc edges and provisions for dynamically balancing the entire motor and disc assembly are now being incorporated. A control package housing scanner controls, indicators and a viewing scope has been added to the scanner package. Cross-hair alignment targets, retractable via a stepping motor, have been installed, and remote gain controlled linear video amplifiers have been designed and constructed and are now being installed. All analog-to-digital and digital-to-analog converters, multiplexer and demultiplexer, parallel to serial encoders, and serial data decoders have been installed and successfully tested. Several circuit boards are now being revised to incorporate temporary changes made during the debugging and testing phase.

Alignment and testing of the Miller code digital recording equipment is now in progress. The complete system has been successfully operated in real time (i.e., recording and playback at 120 ips.).

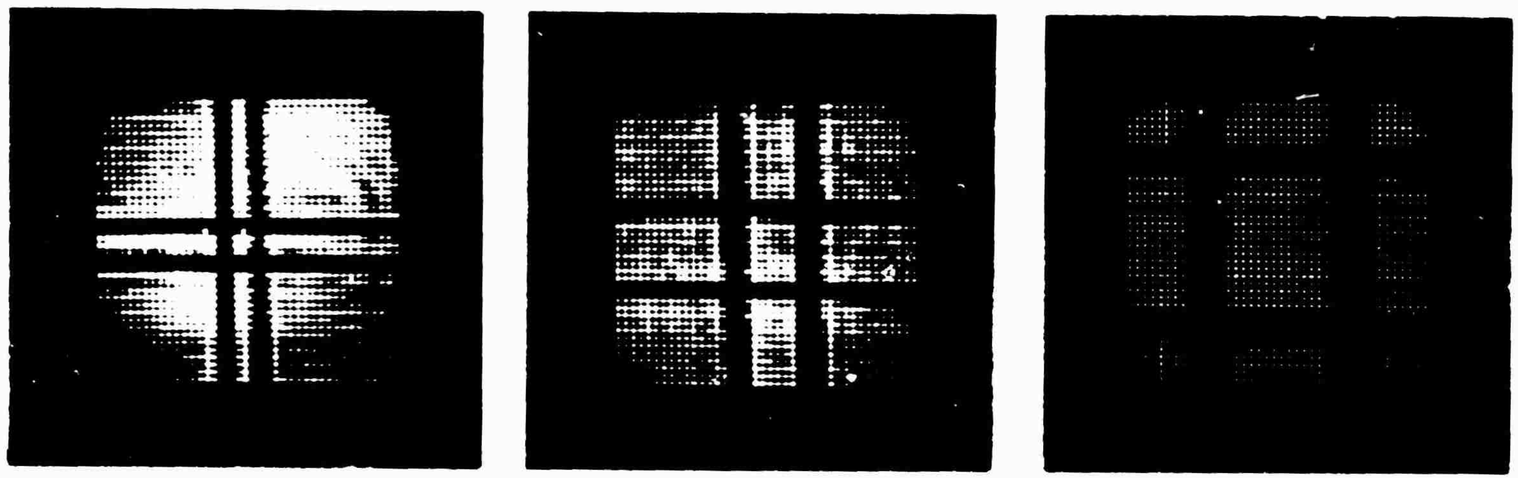
Examples of test images obtained are given in Fig. 5. These show a silhouette of the cross-hair alignment target produced by illuminating the input aperture of the scanning detector with 10.6 micron laser radiation. Images recorded using magnifications of 1, 2, and 4 are included in Fig. 5. Irregularities in illumination in these images are caused by varying mode patterns of the incident laser beam. Successful playback, decoding and display of the recorded images at reduced speed (15 ips. and 7-1/2 ips.) which will be required for subsequent computer processing of recorded data has not yet been achieved. Reasons for this difficulty are now being investigated.

Anodizing of aluminum components, final alignment, and installation of dust covers, name plates, cable markers, and hoisting rings will then be performed prior to shipment of the scanning detector control console, and recorder to RADC for data recording. The Ohio State University playback, display, and computer interface will then be completed in preparation for data analysis.

III. DATA PROCESSING

The computer software necessary to restore an atmospheric turbulence degraded 10.6 micron image has been developed and demonstrated. The program flow diagram and three dimensional intensity plots of an actual point spread function and turbulence degraded image (computer program inputs) and the subsequent restored image (program output) are all presented in a previous technical report.[2] The computer software was originally written for the Ohio State University IBM360/75 computer; however, at the present time this software package is being converted for use on the ElectroScience Laboratory's Datacraft DC6024/3 computer. In addition to the convenience of the inhouse computer facility and the direct computer interface link with the ElectroScience Laboratory's 10.6 micron data playback and decoding system, this change in computer systems will allow the analysis of a sufficient number of data runs to cover a meaningfully wide range of turbulence conditions.

Effort has recently been directed toward providing the necessary software and hardware to complete the data link previously mentioned. Once completed, this link will make it possible to decode a Miller code tape recorded at the RADC Verona PATS test site and store the data on a DC6024/3 computer compatible 9 track digital tape for further processing.



a. 1:1 Magnification b. 2:1 Magnification c. 4:1 Magnification

Fig. 5. Test images of the alignment target illuminated by a 10.6 micron laser beam.

IV. SUMMARY

This report has described work performed during the last three months in completing and testing the infrared scanning detector and Miller code recording system to be used for atmospheric image restoration experiments and in converting the present image restoration computer software for use on the ElectroScience Laboratory's DC6024 computer. Modifications of the scanner synchronization and video systems are described and serial coding techniques used for digital video recording are presented. System tests including image scanning, digitizing, serial encoding, recording, playback, decoding, and display are reported, and examples of test images obtained during these tests are given.

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2. "Investigation of 10.6 Micron Propagation Phenomena," (Semi-annual Report), Report 2880-4, October 1971, The Ohio State University ElectroScience Laboratory, Department of Electrical Engineering; prepared under Contract F30602-70-C-0003 for Rome Air Development Center.

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