TECHNICAL DEVELOPMENT REPORT NO. 218

THE STATUS OF THE EXPERIMENTAL PICTORIAL SITUATION DISPLAY PROJECT

FOR LIMITED DISTRIBUTION

by

R. E. Baker
T. H. Bottoms
W. E. Miller

Navigation Aids Evaluation Division

and

C. S. Bartholomew

Air Navigation Development Board

October 1953

Prepared for
The Air Navigation Development Board
Under
Project No. 6.2.11
by

CIVIL AERONAUTICS ADMINISTRATION
TECHNICAL DEVELOPMENT AND EVALUATION CENTER
INDIANAPOLIS, INDIANA

The Air Navigation Development Board (ANDB) was established by the Departments of Defense and Commerce in 1948 to carry out a unified development program aimed at meeting the stated operational requirements of the common military/civil air navigation and traffic control system. This project, sponsored and financed by the ANDB, is a part of that program. The ANDB is located within the administrative framework of the Civil Aeronautics Administration for housekeeping purposes only. Persons desiring to communicate with ANDB should address the Executive Secretary, Air Navigation Development Board, Civil Aeronautics Administration, W-9, Washington 25, D. C.

THE STATUS OF THE EXPERIMENTAL PICTORIAL SITUATION DISPLAY PROJECT

SUMMARY

The status of the development of the Pictorial Situation Display, an air navigation system and a traffic control aid, is described in this report. The Pictorial Situation Display was developed by the Radio Corporation of America at Camden, N. J. The equipment is a modified version of the Teleran ground-to-air pictorial communication system. The ground equipment transmits to the aircraft, in television form, aircraft position information obtained from surveillance radar, maps of the neighboring terrain, and simulated visual commands. A large number of picture channels can be transmitted over one r-f channel by use of a time multiplexing system in conjunction with a storage tube.

Recent television techniques and the Graphechon storage tube have been incorporated in the modified equipment. At present, certain characteristics are unsatisfactory. The evaluation of the equipment has been cancelled at the request of ANDB because of the lack of operational requirements and the cost of further development to rectify the troubles in the present equipment.

INTRODUCTION

In the early part of 1946, the Radio Corporation of America proposed development of a navigation and air traffic control system utilizing radar and television techniques. The proposed system would provide to each equipped aircraft its range and azimuth with respect to a selected ground station, the location of other aircraft in the same altitude layer in the area, the altitude of the aircraft, means for self identification, map and weather information, and information to enable instrument landing. On the recommendation of the Stratton Committee on Air Navigation and Traffic Control, the Department of the Air Force initiated the project for the development and evaluation of such a system under Contract W 28-099-ac-107. In April, 1948, two ground stations, one an airport station and the other an airways station, were installed at Andrews Field and Gravelly Point, respectively. Evaluation tests on these installations were performed from December 6, 1948, to February 18, 1949, and the results are set forth in an RCA report.[1] This evaluation was also reported by the

[1]RCA Statistical Report on the Performance of the Teleran Model Equipment During the Evaluation Tests Made from December 6, 1948, to February 18, 1949.

3151st Electronics Group, Watson Laboratories.[2] This latter report states that the system had not proven to be of value to the military service, was complicated and difficult to maintain, required excessive bandwidth for operation, did not provide a sufficient number of altitude separation layers, was entirely inadequate with regard to azimuth resolution, and did not provide a satisfactory landing display. In view of the above, the Watson Laboratories report recommended that no further development of this device be carried on by the Department of the Air Force.

Since the equipment did provide means for televising information from ground to air, consideration was given to using it to demonstrate the utility of an airborne pictorial display. RCA prepared a proposal, based on the Teleran experience, for an experimental system. After negotiation and modification of the proposal, Contract Cca-28672 was entered into on June 30, 1950, between ANDB and RCA for the development of a visual air-ground communication link. The purpose of this contract was "to develop a pictorial display that could be televised to an aircraft presenting the pilot with a display of the terminal area traffic situation, a map of the surrounding area, terrain features, and to provide a system for visual commands to be transmitted to the pilot." This activity was to be under the technical responsibility of the Department of the Air Force All-Weather Flying Division because of their interest and previous experience with portions of the Teleran system which would be used in this program. Later, the reorganization of the Wright Air Development Center and designation of the All-Weather Flight Section as an evaluating organization made it necessary to withdraw this project which was then in the developmental stage. The traffic control aspects of this project suggested its assignment to the CAA Technical Development and Evaluation Center, and on October 31, 1951, the technical responsibility for this project was transferred to TDEC.

At the time of the transfer, all ground components had been checked and were operative except the antenna. The airborne equipment was about 65 per cent complete, but no actual flight testing of the system had been accomplished by that date.

EQUIPMENT DESCRIPTION

The Pictorial Situation Display presents information to the pilot in visual form on a seven-inch kinescope. All necessary flight information, such as position, proximity of other aircraft, weather, and flight instructions, are collected at a ground location, converted as necessary, and transmitted as a standard television picture for visual presentation in the aircraft. Each type of information is transmitted separately and can be selected for individual display by the pilot. However, any desired group of signals can be combined in the channel normally used for test pattern

[2]Technical Report No. 46, dated November 30, 1949, 3151st Electronics Group, Watson Laboratories.

transmission. All signals are confined to a 12-megacycle channel by time-shared multiplexing techniques.

Since time-sharing involves interruptions in the transmission of a given signal and each period required the transmission of at least one full frame of a television picture, covering 1/30 of a second, it follows that with 90 time-shared periods, transmission in a given channel would occur once in three seconds. To obtain a continuous display in the aircraft, a Graphechon storage unit is employed between the receiver and display. This unit stores the intermittent signals and delivers a continuous output to the display unit.

In the present equipment facilities are provided for handling the following types of information:

RADAR DATA - A PPI display of all aircraft in the mapped area, showing azimuth and range, obtained from a suitably located search radar.

MAP DATA - A map of the terrain over which the aircraft is flying, covering an area consistent with reliable television transmission and accurate radar scan, showing airports, beacons, and salient topographical features.

ORDER DATA - Special flight instructions, weather maps or weather information.

TEST PATTERN - A bar or grating pattern intended primarily for checking system operation and making linearity adjustments.

Description of Ground Equipment.

The equipment comprising a ground installation consists of ten rack assemblies arranged in two groups. Six racks, containing data preparation circuits, are grouped to form the studio equipment. The remaining four racks contain the radio transmitter circuits and may be located at some distance from the studio racks.

A target simulator rack may be employed to provide a simulated radar input when a check of equipment operation is desired. The signals provided consist of trigger pulses, one- and ten-speed servo information, and two simulated target echoes, 180° apart, that may be adjusted to automatically traverse a radial, circular or spiral course. Variable levels of noise may also be introduced into its video output.

An over-all functional block diagram of a complete ground installation is shown in Fig. 1. For clarity and ease of description, the chassis in the studio racks are grouped according to function in the diagram and will be described under these groups.

1. Synchronizing and Multiplexing Circuits.

The pulse unit develops the timed synchronizing pulses. These timed pulses are used by the code unit to develop horizontal and vertical synchronization, and blanking pulses that are distributed to the various chassis by the distribution amplifier. These pulses provide for a 525-line interlaced television signal with a field of 60 fields or 30 frames per second. The code unit, by means of an internal units-count ring oscillator and a separate tens-count ring oscillator, develops coding for the individual intelligence signals and enabling pulses to control multiplexing of the channels. Thus, the code unit, in conjunction with the multiplex injector, causes the output of the information circuits to be gated through the multiplexer in the correct order.

The enabling pulses are timed to permit each channel to feed one complete television frame in sequence to the transmitter. Since the frame rate is 30 per second and 90 channels are provided, a given frame will be repeated every three seconds when the full 90 multiplexed channels are in use. To maintain a constant display in the airborne equipment under these conditions, a picture storage unit is used between the receiver and display unit. A Graphechon tube in the storage unit provides sufficient signal storage to assure continuous signal input to the display during the three-second intervals between signal transmissions in a given channel.

2. Radar Video Circuits.

These circuits accept video, trigger, and azimuth data signals from a suitable search radar, which is not part of the equipment or the target simulator, and develop a flickerless PPI type of display output with standard television scan.

Conversion from radial radar deflection to television scan is made in the Graphechon chassis, where the storage property of the tube also steadies the video output. The Graphechon unit includes a wide band r-f amplifier. The writing deflection and video chassis provides video amplification and radial deflection, keyed by radar trigger pulses, for the writing end of the Graphechon. The rotating yoke at the input end of the Graphechon tube is driven in synchronism with the search antenna rotation by means of the servo control in response to azimuth data derived from the radar equipment. At the reading end, television deflection is obtained from the reading video chassis which is triggered by synchronizing pulses from the pulse unit. Enabling pulses from the code unit are used to switch the reading beam on during transmission periods, and the output is fed through the video mixer to the transmitter.

3. Map and Order Circuits.

Two sets of video signals are developed in these chassis, namely, map video and order video. A dual flying spot scanner assembly is incorporated in the FSS unit. The kinescope yoke is driven by deflection currents from the deflection unit with the beam set for optimum brilliance. The moving spot on the kinescope screen is projected through an angularly-positioned, half-silvered mirror which divides the illumination, permitting one-half to pass to the map slide and reflecting the other one-half to the order slide. The slides contain the information to be transmitted in the form of clear lines on an opaque film between glass plates.

Light passing through the clear sections of the film, as the projected spot traverses the entire face of the slides, is picked up by photocells to form the elements of the video output signals. The outputs are amplified in the video amplifier to provide two outputs for each channel. One output of each channel is gated through the multiplexer to the transmitter, and the other output is fed to the monitor.

4. Test and Monitoring Circuits.

The A-scope monitor, with a five-inch screen, is used to determine video signal amplitudes and waveshapes of the signals at horizontal or vertical synchronizing sweep frequencies. In addition, the A-scope monitor can be used with a patch cord to check waveshapes at test points on the various chassis when trouble shooting. The raster monitor, with a ten-inch screen, is used to check video picture quality at the outputs of the various intelligence channels. When switched into the output of the multiplexer, it displays the signals as fed in sequence to the transmitter. The monitors can be switched into the various output circuits by means of the monitor selector panel. The grating generator provides barred or grating video signals to check the linearity of television deflection circuits in the entire system, including the airborne equipment. The generator output is fed to the multiplexer and gated into proper time-sharing sequence to be fed to the transmitter.

5. Transmitter Circuits.

The video mixer chassis was originally used in Teleran for the limiting and mixing of video signals. Video signals are not mixed or clipped in the transmitter, but the removal of the unused components was not considered economically desirable. The circuits used consist of two completely separate channels. The video channel includes an attenuator and a linear video amplifier. The synchronizing channel includes provision for clipping both the top and the base of the synchronizing pulses and is followed by a linear amplifier.

The exciter and modulator chassis contains circuits for amplifying and mixing the video and synchronizing signals, phased to cause increase of carrier level for video and decrease of carrier level for synchronizing signals. The circuits include the master oscillator, buffer amplifier, and modulated amplifier, the latter being modulated by the above-mentioned video and synchronizing amplifier output. The modulated r-f output is fed to the high level assembly. The high level assembly consists of two power amplifiers operating in cascade to raise the r-f signal level to the power level required. Circuits are included for bias control, overload protection, and for monitoring the amplified signals. A standing wave indicator is also included to facilitate power output checks and antenna matching. The monitor selector panel provides switching facilities to connect the monitors into the transmitter circuits at such points as require frequent checks during operation. It simultaneously connects the A-scope and raster monitor to a selected point and connects the proper enabling pulses to provide individual display of any of the four time-sharing picture signals. The scope monitor displays the waveform at any selected point, either with line or with frame sweep frequency. Provision is made to display vertical deflection voltages from test points on the chassis, as may be necessary for trouble shooting or for adjustment procedures. A panel meter also indicates transmitter output, as represented by the r-f voltage on the plate of the power amplifier. The monitor displays the picture signal at various points in the equipment, either each picture separately or the combined signals as desired. It provides a continuous check on video transmission at all times.

6. Target Simulator.

The purpose of this rack is to provide a readily available source of radar signals when a radar installation is not available or is inoperative. It can be used for checking and adjusting the radar video channel in the equipment or as a radar signal source for evaluation tests. The antenna chassis contains the motor-driven selsyn generators, differential generators, and potentiometers that develop azimuth and range data. The mechanism includes clutches that allow a manual change of azimuth and range data or automatic development of radial, circular, or spiral target courses. The signal simulator chassis develops the basic 1200 pps radar trigger and the target echo pulses. The circuits also include a noise generator to simulate closely conditions of actual radar reception.

Description of Airborne Equipment.

The airborne equipment consists of a receiver, storage unit, indicator, and associated power supplies. An over-all functional block diagram of a complete airborne installation is shown in Fig. 2.

1. Receiver.

Fig. 3 is a photographic view of the receiver. The 300-megacycle television signal transmitted by the ground transmitter is detected in the receiver. A keyed AGC system in the receiver tends to prevent video output signal variations due to aircraft propeller modulation of the incoming signals, aircraft attitude, aircraft range, and antenna patterns. Separation of the synchronization signals from the video signals and decoding of the picture channel identification pulses are accomplished in the receiver. Video output signals are provided for the storage unit.

2. Storage Unit.

Fig. 4 is a photographic view of the storage unit. Video and synchronization signals from the receiver operate the storage unit. The intermittent picture information is written on the target of the Grpahechon by the writing deflection and video circuits. The stored picture on the target of the Graphechon is read off the target by the reading deflection and video circuits. Due to the storage properties of the Graphechon, output video signals are obtained from each field of scanning so that the picture viewed on the indicator kinescope will be free of flicker.

3. Indicator Unit.

Fig. 5 is a photographic view of the indicator unit. Synchronization signals from the receiver and video signals from the storage unit operate the indicator unit. The scanning and video circuits of the indicator unit present the pictorial information on the face of the indicator kinescope in rectangular television coordinates. A transparent aircraft heading disc in front of the indicator kinescope shows heading of the aircraft with respect to other aircraft courses which are indicated by trails behind the target.

EQUIPMENT DEVELOPMENT

General.

In general, the original Teleran equipment was modified to incorporate recent television techniques and the Graphechon storage tube. A large portion of the features of Teleran were eliminated in the experimental Pictorial Situation Display since it was felt that the evaluation could be accomplished without the complexity of the Teleran system. The features of Teleran not incorporated in the experimental Pictorial Situation Display include the self-identification line, altitude coding, instrument landing presentation, write-in display, and number of channels available.

RCA made the following detailed modifications to components of the Teleran system that are used in the Pictorial Situation Display:

The synchronizing and multiplexing circuits have been modified to give odd-line interlacing instead of even-line interlacing. An automatic frequency control circuit has been added to synchronize the television field pulses with the power line frequency. The ring oscillator circuits have been modified for better stability. The flying spot scanner chassis has been modified to incorporate a shorter persistence cathode-ray tube, an improved video amplifier, head-on multiplier phototubes, and an improved mechanical design in the phototube mount.

The monitor circuits have been modified to operate on the odd-line interlaced television system. The scanning circuits have been improved to give better stability, and the monitor kinescopes have been replaced with kinescopes with P7 type phosphors.

The band pass characteristics of the transmitter modulator have been improved. A standing wave indicator has been added to the transmitter and an insulating material with higher dielectric strength has been used in the filament lines to the final power amplifier tube.

The Graphechon chassis is a completely new unit and it replaces the storage orthicon console. The Graphechon gives improved resolution, improved signal-to-noise ratio, less cross talk, less shading, a wide range of control of storage time, and is simpler to align. The Teleran ground antenna had been broken by a windstorm. The antenna has been completely reworked to strengthen it and to remove corrosion on the internal tapered transmission lines. An improved, keyed AGC system has been incorporated in the airborne receiver to minimize video output signal variations due to aircraft propeller modulation of the incoming signals, aircraft attitude, aircraft range and antenna patterns.

Additional synchronizing pulse output has been provided for the storage unit. The airborne storage unit is a completely new unit. The airborne indicator sweep circuits have been modified for use with an odd-line interlacing television system. The horizontal scanning circuits have been modified for more stable operation.

Progress During TDEC Supervision of Development Contract.

The airborne equipment was installed in a DC-3 aircraft, N-183, during March, 1952, at TDEC. Two representatives of TDEC attended a six-week training program on the Pictorial Situation Display equipment during the last week of April to the first week in June. Flight tests at the RCA plant started on May 14. Aircraft N-183 was flown to Camden to participate in flight tests during the periods of May 12 to 16, May 26 to 29, and June 5 to 13. The airborne receiver synchronization circuits were unstable during the tests.

Aircraft N-183 was flown to Camden for a demonstration of the equipment to ANDB and TDEC representatives on July 2. The demonstration and test flights indicated that the equipment was not ready for evaluation. The following characteristics needed improvement:

1. Airborne equipment synchronization.
2. Resolution.
3. Linearity.
4. Equipment operation reliability.
5. Signal-to-noise ratio.

A number of photographs were made of the face of the indicator kinescope in the airplane during the demonstration and preliminary test flights. Figs. 6 to 15 are photographs of the face of the airborne indicator kinescope that are representative of the conditions that prevailed during the flights.

The test flights with the equipment located on the premises of the contractor demonstrated that the system for Pictorial Situation Display was not yet ready for evaluation. The contractor estimated that considerable money and time would be required to achieve a level of performance which would be considered adequate for an operational evaluation. Furthermore, due to increased Air Force operational activity in the UHF band, the extension of the frequency authorization, 300 ± 6 Mc, for this project seemed extremely doubtful after July, 1953. Hence, any plans to continue the project would have to provide eventually for a change in the operating frequency of the air-ground channel. Therefore, the Air Navigation Development Board recommended to the Air Coordinating Committee, Air Traffic Control and Navigation Panel, in a letter dated September 9, 1952, that this project be either stopped or completely reoriented depending upon whether a firm operational requirement still existed. On October 20, 1952, the Nav Panel replied as follows:

"The Panel feels that an operational requirement continues to exist for an airborne pictorial situation display for use in the Common System. However, this requirement does not indicate that the Teleran display concept itself is desirable, but instead that some type of system is needed. In this connection the Research and Development Board guidance to ANDB on projects for Fiscal Year 1954 is cited. An operational-technical systems study should be effected to establish what the specific criteria are and what technique would best suffice for the purpose. This is to be done in lieu of actual equipment development....."

The ANDB decided to terminate the present contract for development of an airborne pictorial situation display and to postpone any further action in this field until the Air Traffic Control and Navigation Panel Special Working Group on Pictorial Display has formulated a statement for the operational requirements for this program.

A representative of TDEC visited the RCA plant during the week of January 12, 1953, to arrange for shipment of the equipment to TDEC. A conference was held between the RCA and TDEC engineers to determine the causes of improper operation of the equipment during the test and demonstration flights. It was agreed that instability in the operation of the equipment during the flight tests could be due to the unfortunate choice of the transmitted signal polarity and the receiver AGC sampling circuit. The synchronizing signal portion of the transmitted signal is at minimum modulation. Standard entertainment television transmitters transmit the synchronizing signals at maximum modulation to reduce the effects of noise on the receiver synchronization circuits. The video information in the Teleran system that makes up the bright elements of the final picture has a very low duty cycle. The bright video information is transmitted as an increase in transmitter power output so that the average power dissipated in the final amplifier of the transmitter is considerably lower than the peak power.

The AGC sample is taken from the portion of the blanking pedestal following the synchronizing pulse. The gating signal used for the AGC sampling is formed from the output of the horizontal oscillator. The airborne receiver uses a high Q oscillator that is controlled in frequency by the output of a phase discriminator. Such a system has good noise immunity but it will not respond to rapid frequency changes. When multi-path signals are received, it is possible that the occurrence of a reflected synchronizing signal during the AGC sampling time would change the AGC voltage, the amplitude of the synchronizing pulses fed to the phase discriminator, and upset the horizontal oscillator.

It is possible that reversal of the transmitted signal polarity, taking the AGC sample during the synchronizing pulse interval, and increasing the AGC time constant would improve the synchronizing stability of the airborne receiver.

The equipment was shipped to TDEC, for storage and use on other projects, during January, 1953.

CONCLUSIONS

The evaluation of the equipment has been cancelled at the request of ANDB because of the lack of detailed operational requirements and the cost of further development to rectify the trouble in the present equipment. The evaluation program for this equipment was based upon the objectives listed in Appendix A.

Components of the system are finding use in the ATC dynamic simulator at TDEC. The television synchronizing generator has been modified to provide synchronization signals at standard commercial rates to the simulator television system. The studio monitor console is being used as a control monitor. The flying spot scanner will be incorporated in the simulator television system to provide additional information for the final displays.

Should the Air Coordinating Committee determine that an operational requirement exists for an aircraft cockpit display of the type attempted in this development program, it is believed that a new development, using different techniques and some other portion of the radio frequency spectrum, will be required.

APPENDIX A

EVALUATION OBJECTIVES

During the development of the experimental Pictorial Situation Display, an evaluation program under ANDB Project 6.2.11 was prepared for this equipment to determine its operational and technical characteristics. The objectives of this program were:

1. Determine the range, accuracy, and resolution characteristics of the visual data relay equipment when installed in aircraft at various elevations and azimuths and with different headings and attitudes. Accuracy and resolution characteristics are to be measured relative to the normal ASR-PPI display indications.
2. Determine suitability of the airborne display from the brilliance, linearity, resolution, and stability standpoints.
3. Prepare recommendations for future development work as indicated by the performance of the equipments tested. In particular, determine quantitative, realistic values for resolution, accuracy, stability, display brilliance, size and weight of airborne components, extent of time multiplexing desired, methods of message insertion desired, and the degree of airborne storage desired.
4. Determine test equipment needs and maintenance features desired.
5. Determine the value of the equipment as a traffic control aid, including the feasibility of using the equipment as a ground-air communication link in terminal areas experiencing traffic rates similar to those encountered at today's major air terminals. This determination should consider the utility of the equipment when used in conjunction with standard voice communication facilities, and should include consideration of the reduction, if any, which can be achieved in the use of voice facilities as a result of visual data relay. Commands sent aloft should be in the form of control messages and also in the form of pictorial description of the path to be followed by the aircraft.
6. Determine the utility of the equipment as a terminal area navigation aid. The flyability and accuracy should be compared to that achieved on the VOR-DME system using pictorial and/or course line computers.

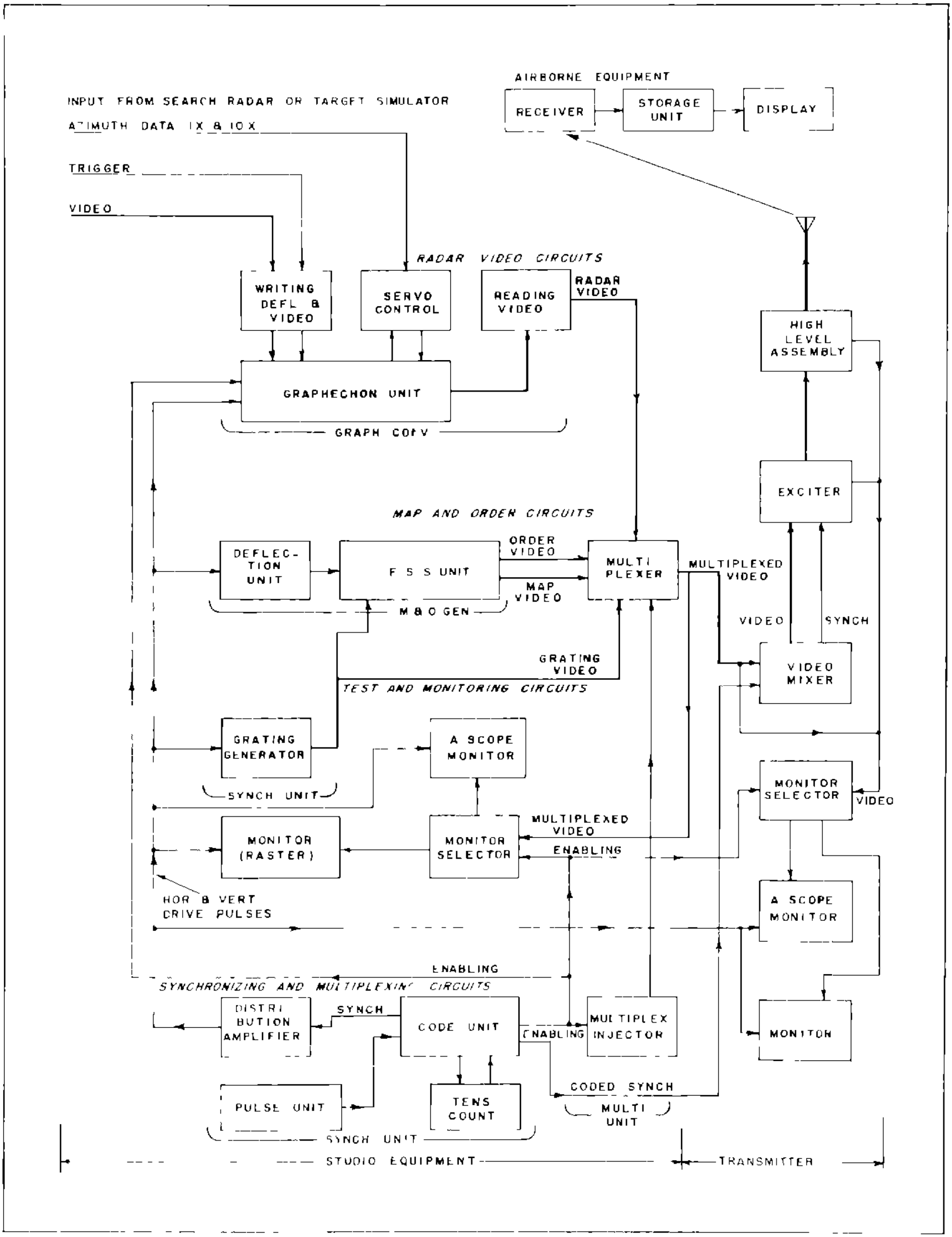

FIG I BLOCK DIAGRAM OF GROUND EQUIPMENT

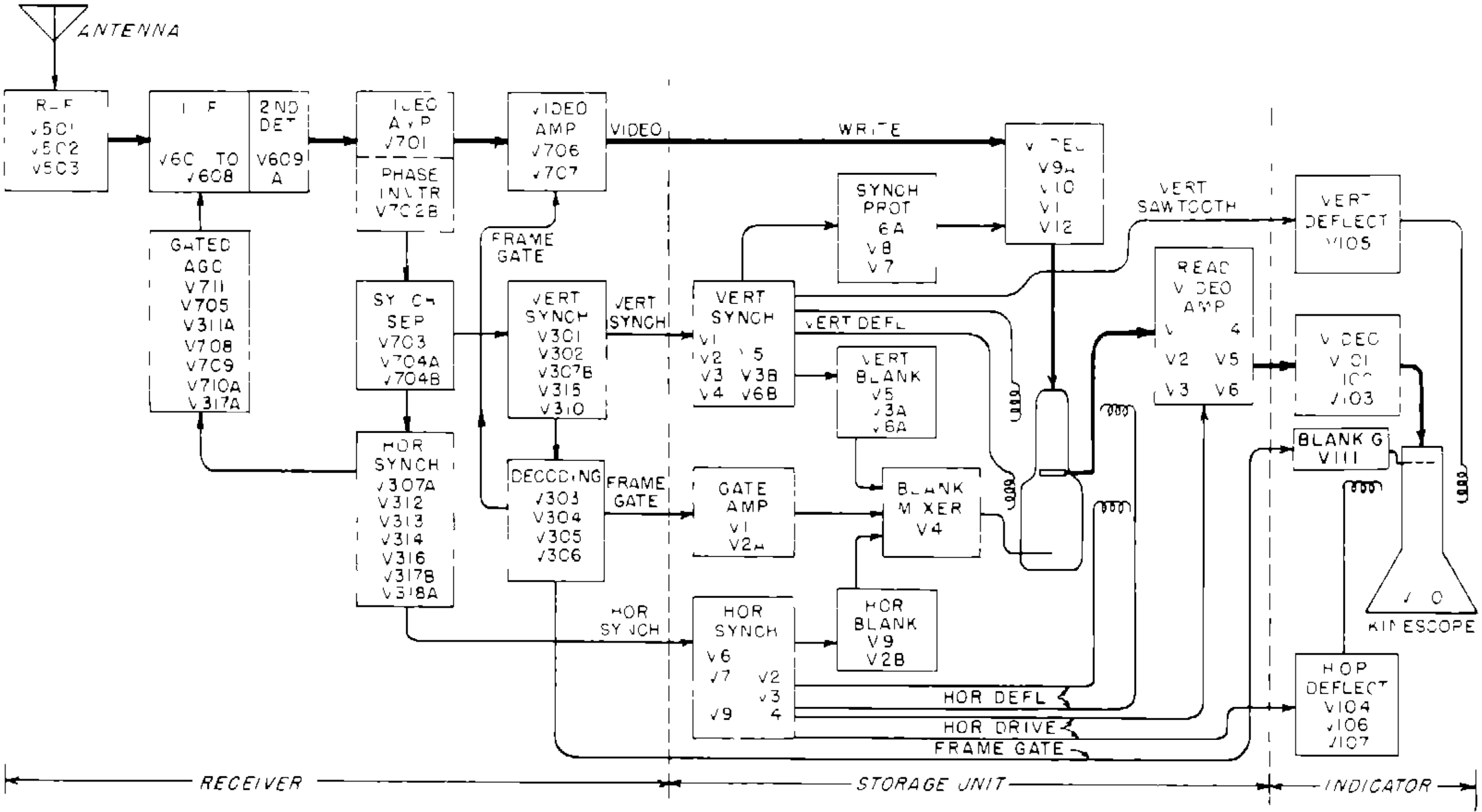

FIG. 2 BLOCK DIAGRAM OF AIRBORNE EQUIPMENT

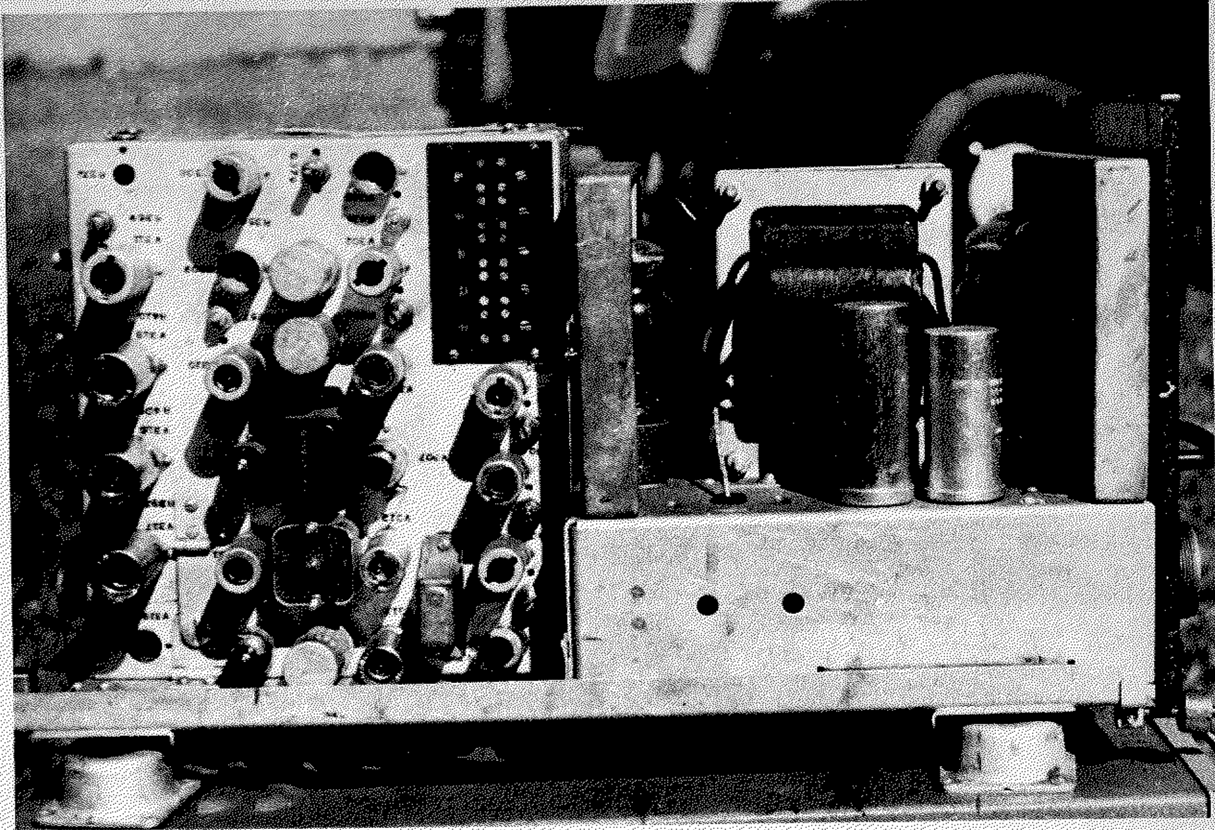

FIG. 3 SIDE VIEW OF AIRBORNE RECEIVER (DUST COVER REMOVED)

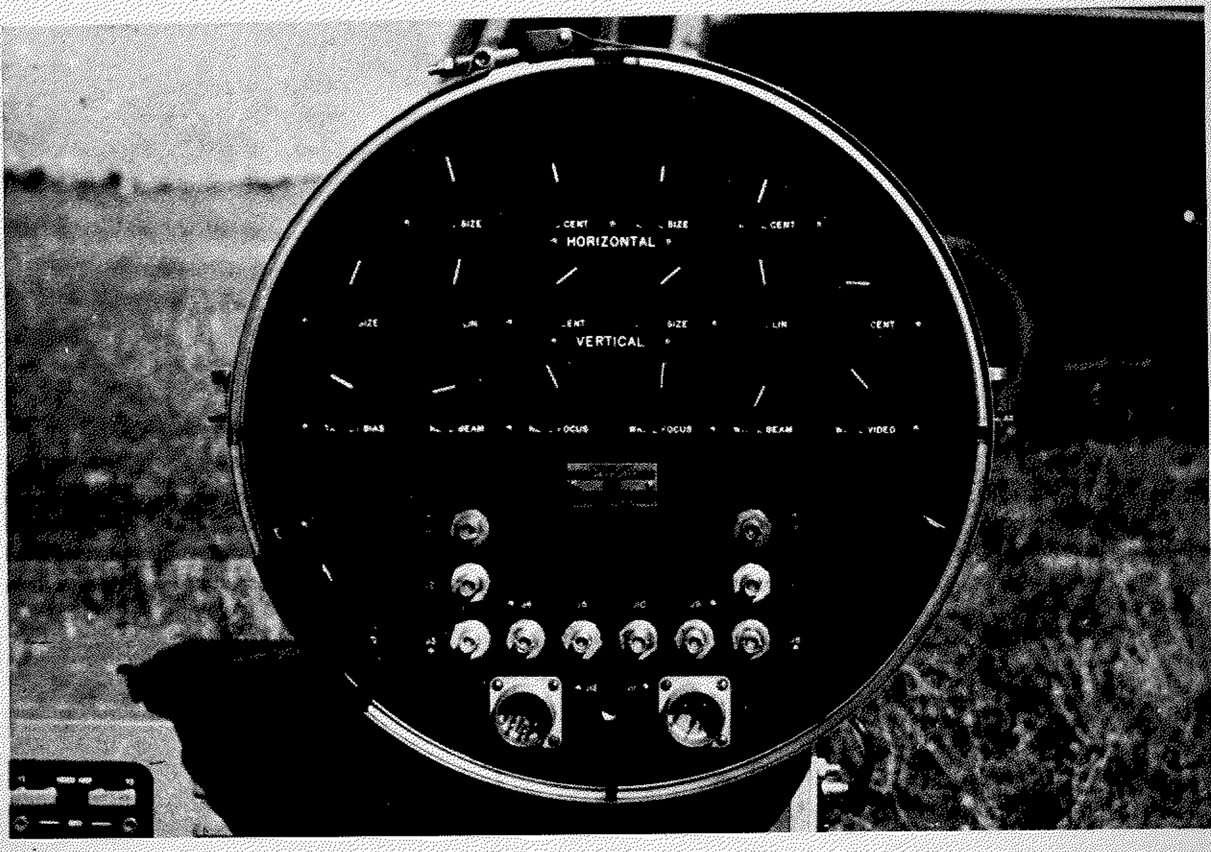

FIG. 4 FRONT VIEW OF AIRBORNE STORAGE UNIT

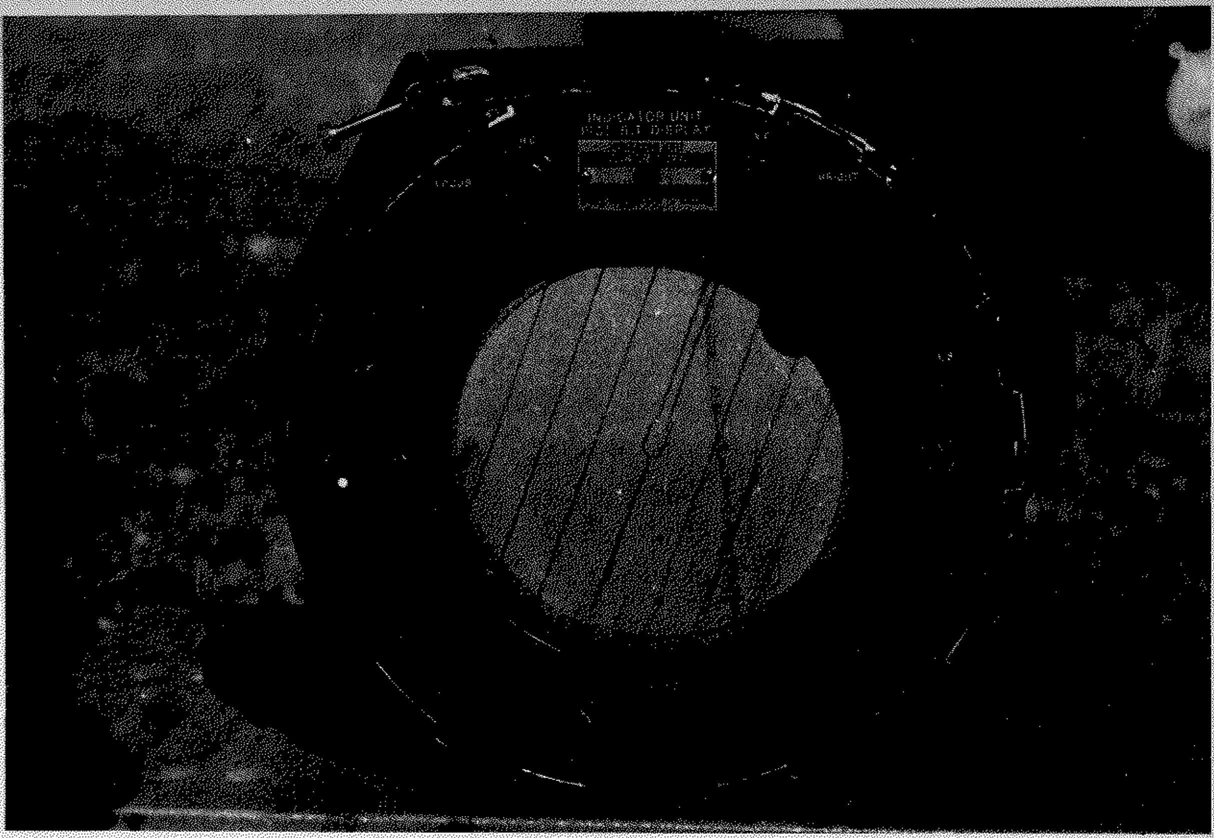

FIG. 5 FRONT VIEW OF AIRBORNE INDICATOR UNIT

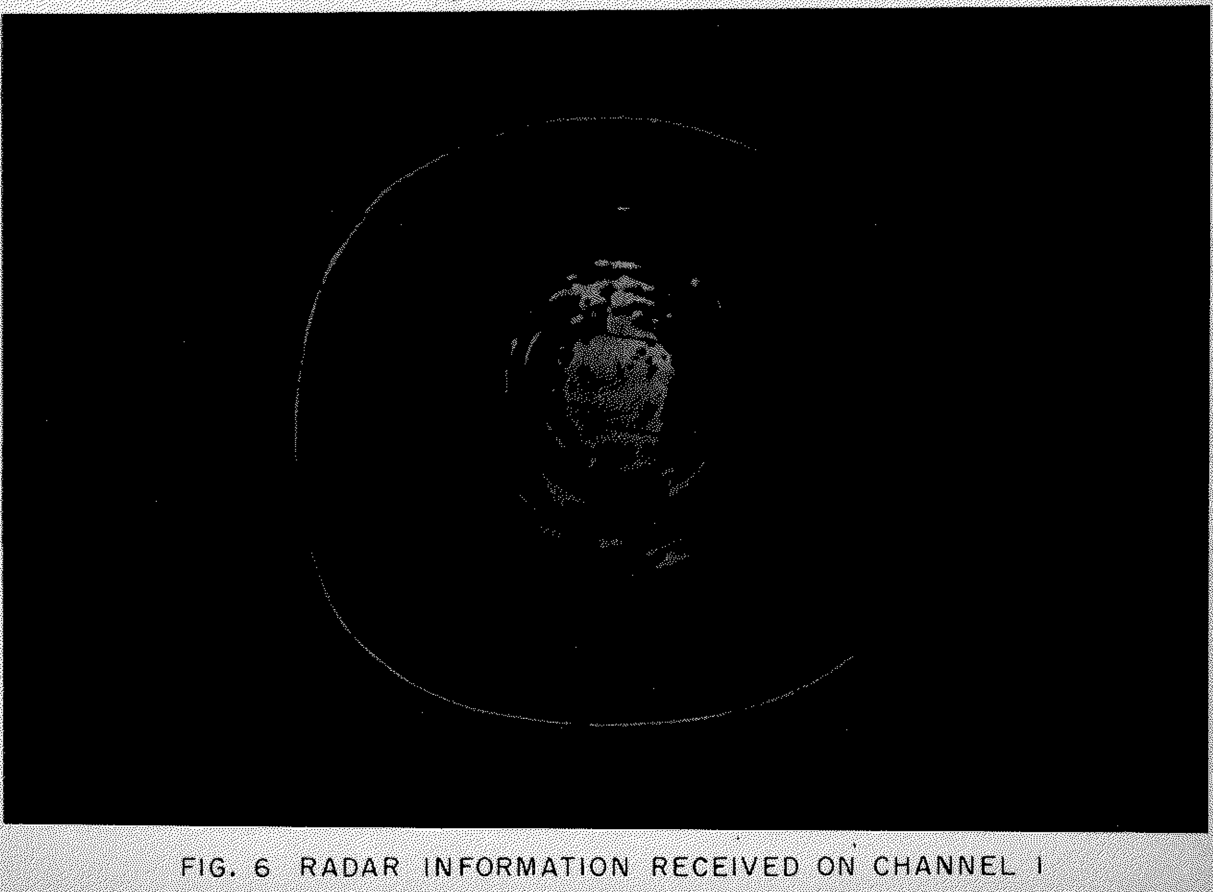

FIG. 6 RADAR INFORMATION RECEIVED ON CHANNEL I

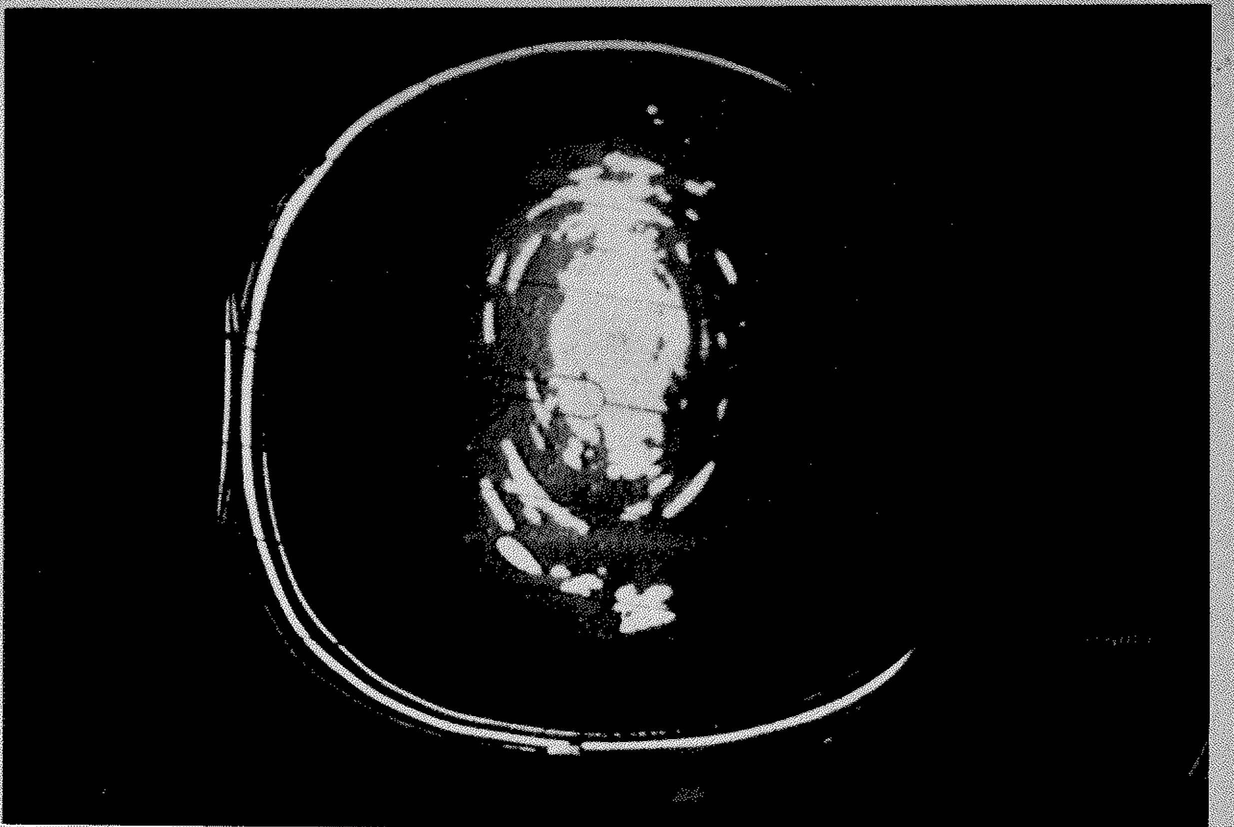

FIG. 7 PHOTOGRAPH OF RADAR INFORMATION RECEIVED ON CHANNEL I SHOWING VERTICAL SIZE DISTORTION AND EFFECT OF POOR SIGNAL-TO-NOISE RATIO

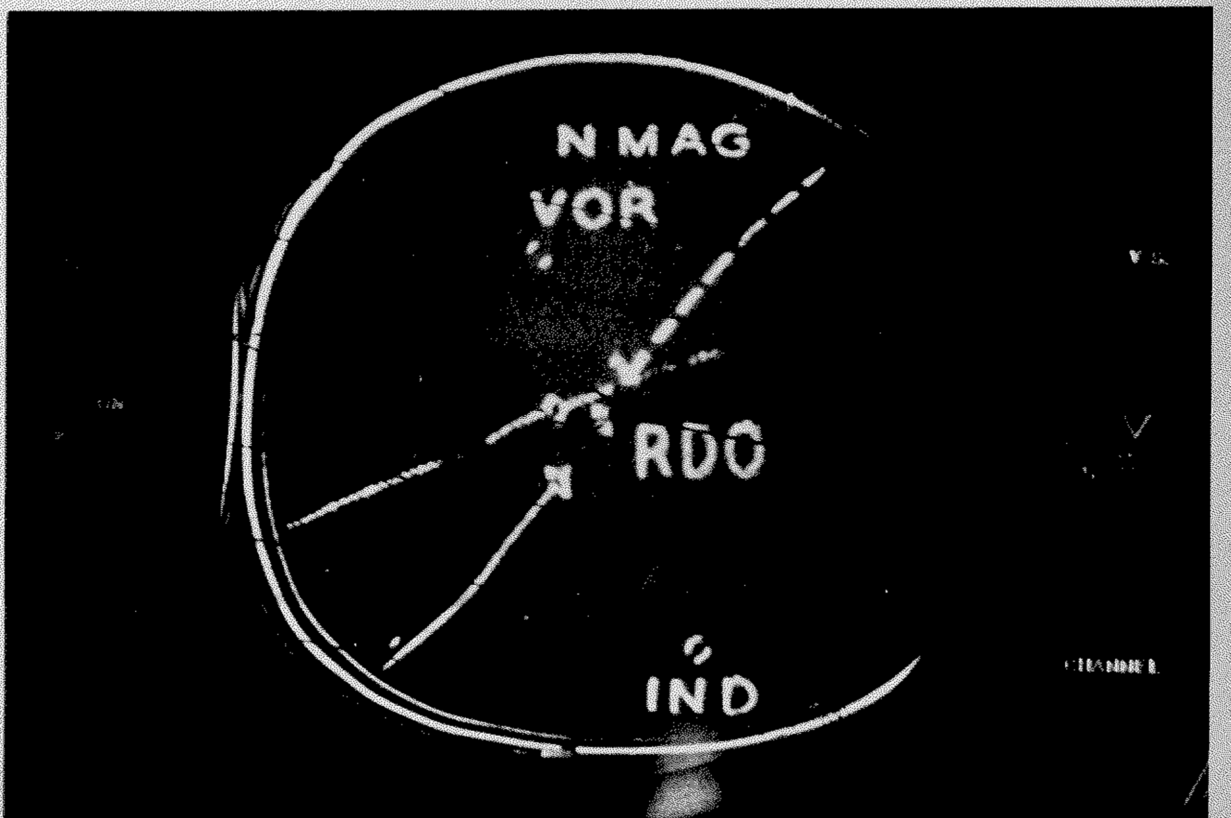

FIG. 8 MAP RECEIVED ON CHANNEL 2

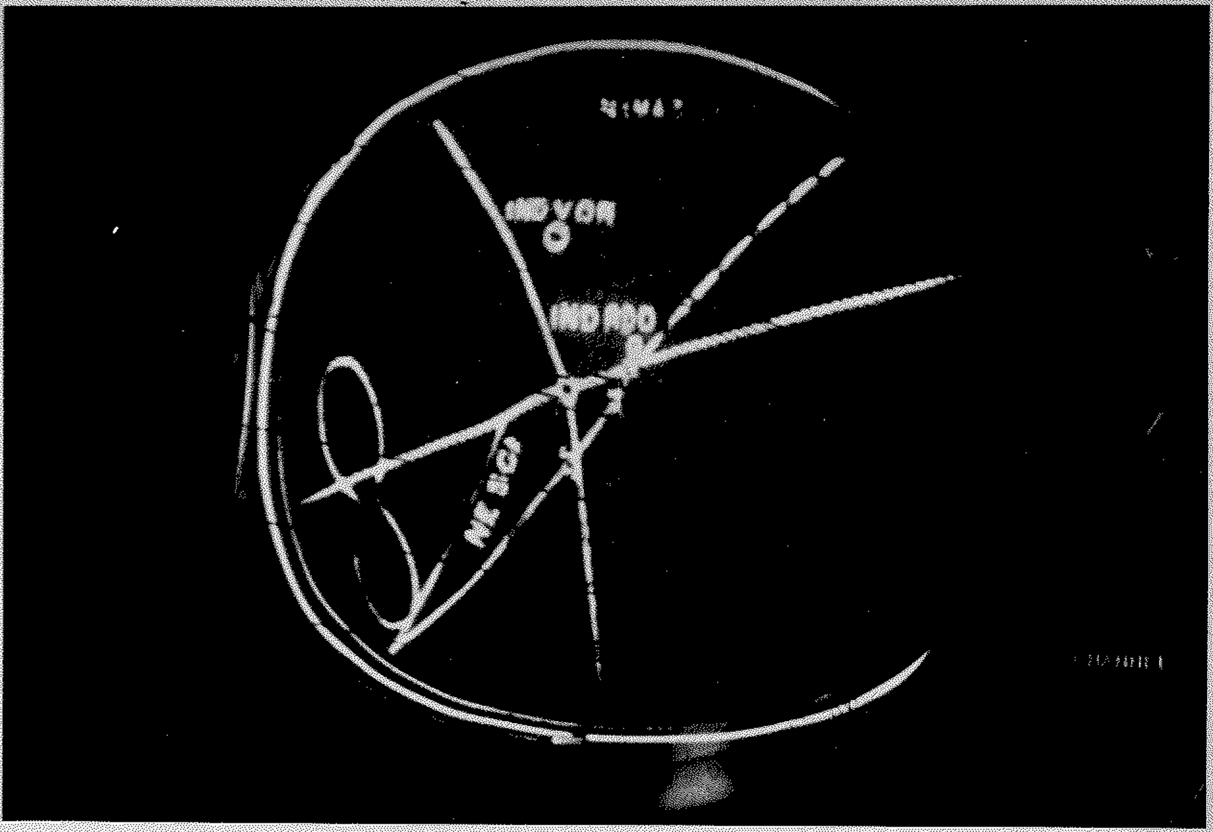

FIG. 9 MAP RECEIVED ON CHANNEL 3

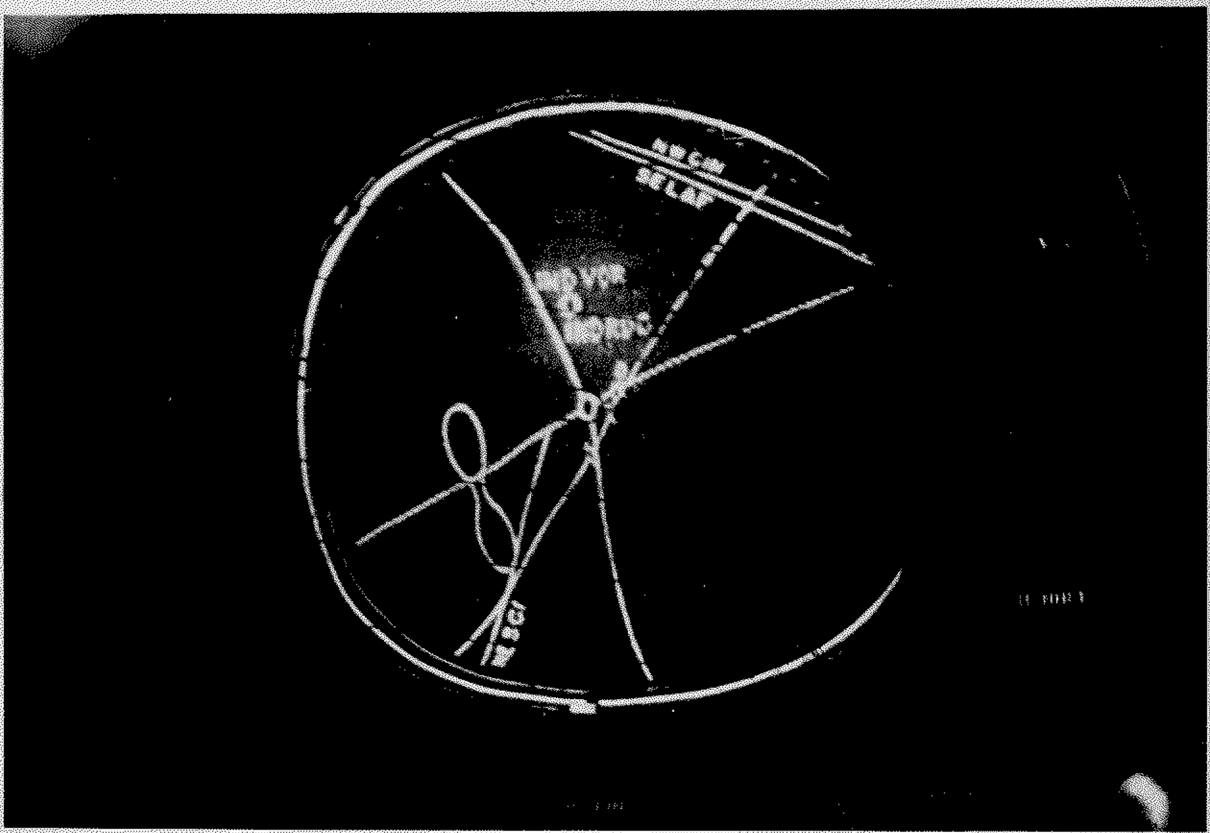

FIG. 10 MAP RECEIVED ON CHANNEL 2 SHOWING POOR LINEARITY AND IMPERFECT SYNCHRONIZATION

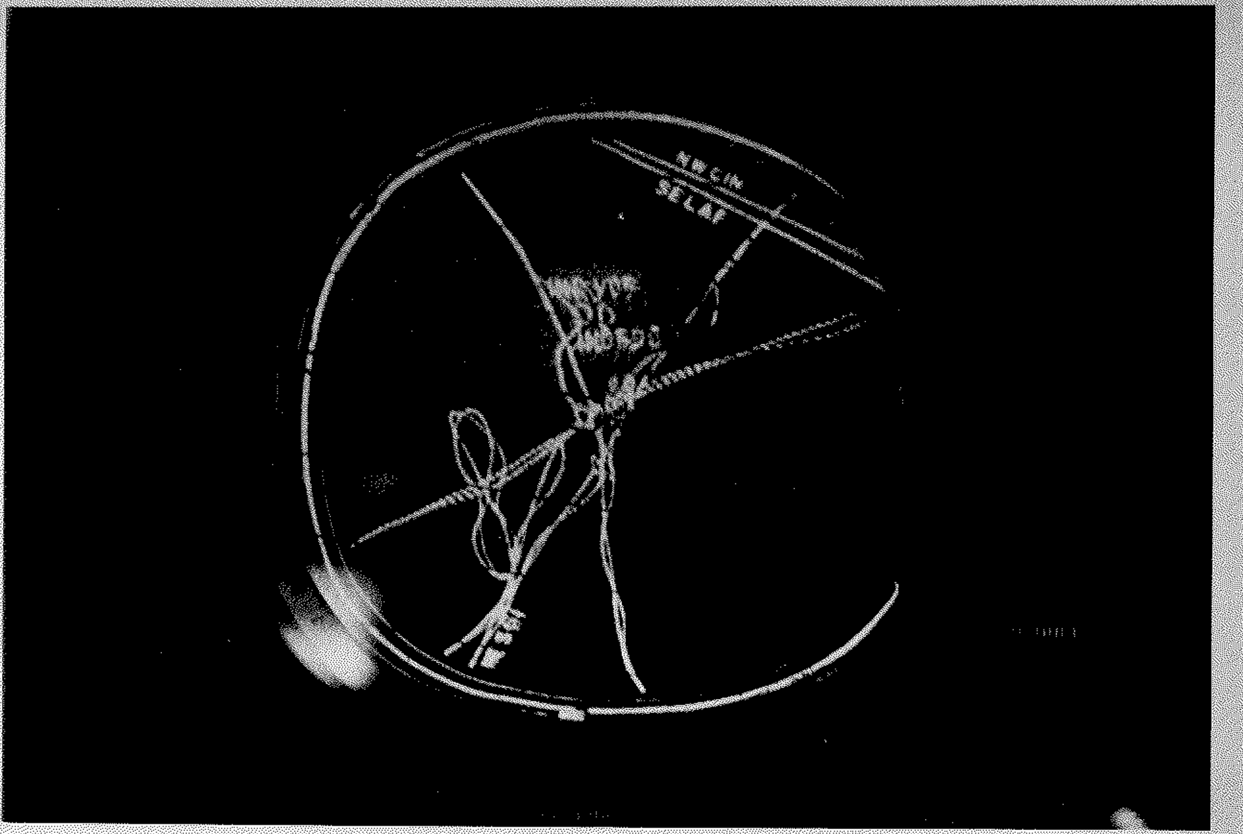

FIG. 11 MAP RECEIVED ON CHANNEL 2 SHOWING POOR LINEARITY AND SYNCHRONIZATION

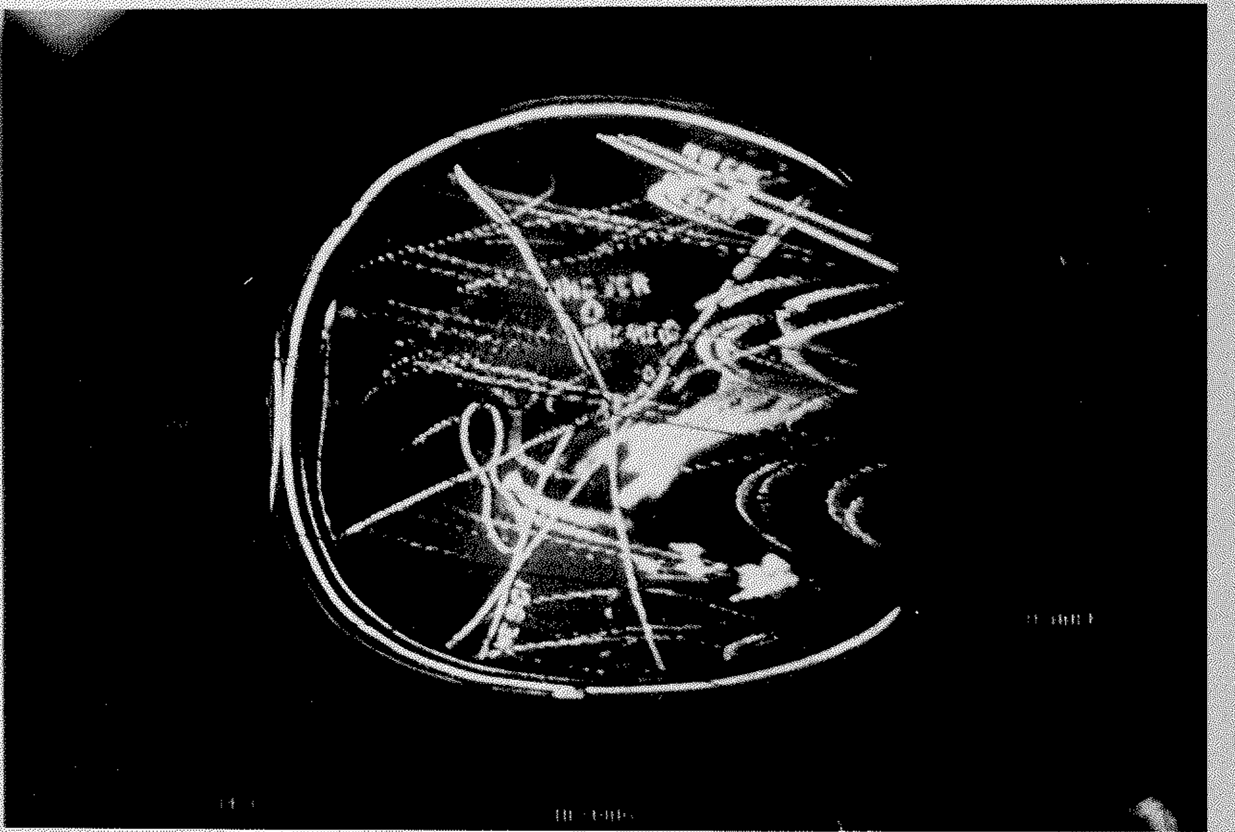

FIG. 12 PHOTOGRAPH SHOWING EFFECTS OF POOR SYNCHRONIZATION

FIG. 13 MAP RECEIVED ON CHANNEL 1
SHOWING POOR SYNCHRONIZATION

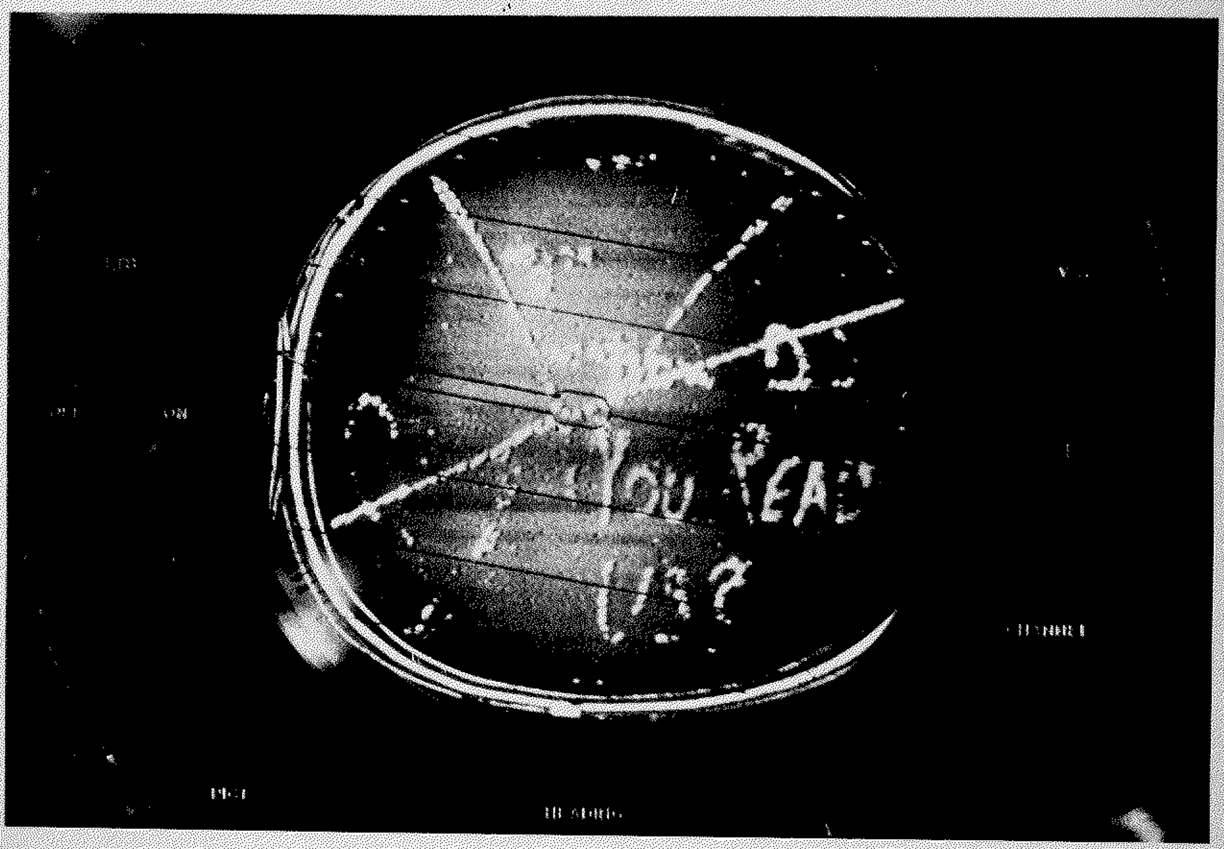

FIG. 14 AUXILIARY WRITE-IN DISPLAY RECEIVED
ON CHANNEL 4. PICTURE QUALITY POOR.

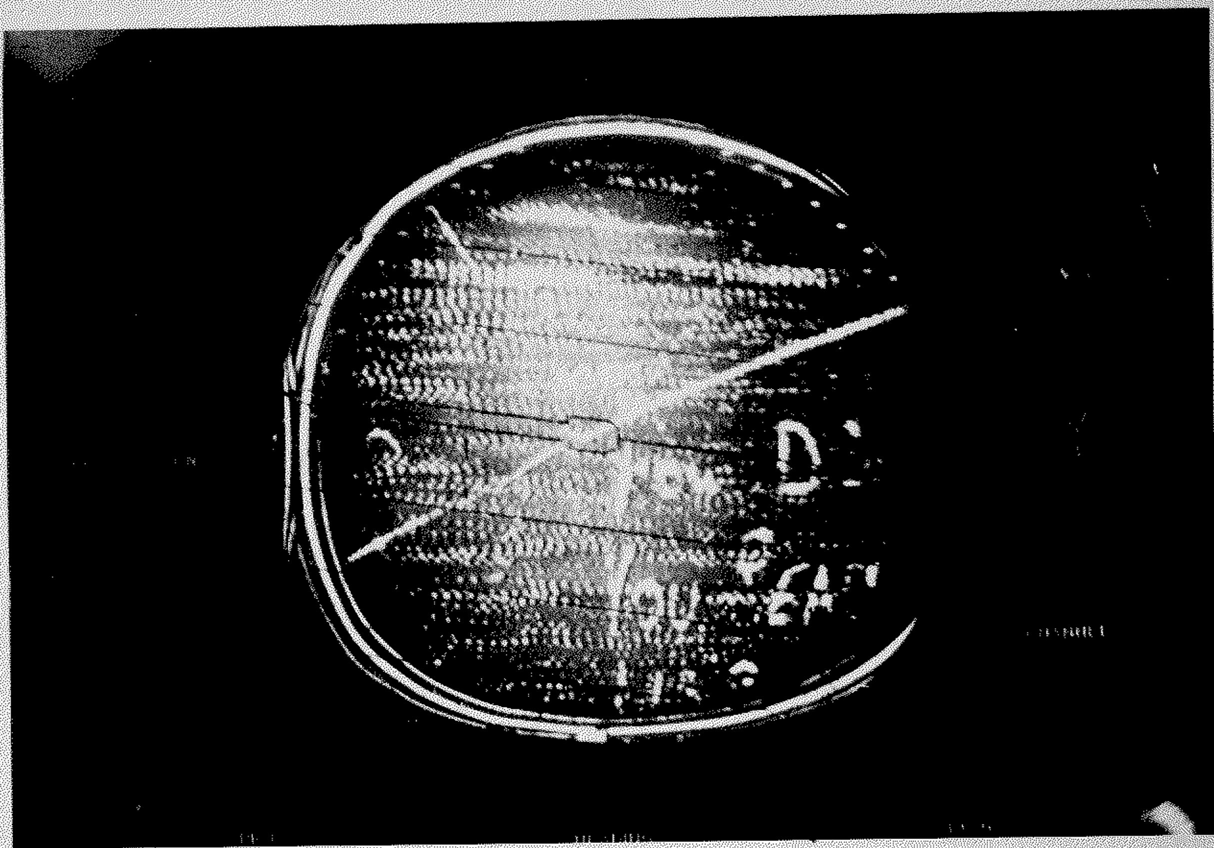

FIG. 15 AUXILIARY WRITE-IN DISPLAY. POOR PICTURE QUALITY AND SYNCHRONIZATION.