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AN EVALUATION OF IATRON PROJECTION UNITS AND RAFAX NARROW-BAND RADAR TRANSMISSION SYSTEM

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by

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AN EVALUATION OF IATRON PROJECTION UNITS AND RAFAX NARROW-BAND RADAR TRANSMISSION SYSTEM

SUMMARY

This report describes a test of the Farnsworth Iatron system for projecting radar information in the New York Air Route Traffic Control Center. During part of the test, RAFAX (radar facsimile) equipment built by Haller, Raymond, and Brown, Inc , was used to transmit radar information from a remote site via a narrow-band transmission line. The Iatron was used to project the RAFAX information on a panoramic display A subsequent test used two Iatrons, one projecting information from an FPS-8 long-range radar and the other projecting the RAFAX decoder output of an ASR-3 airport surveillance radar. Both Iatrons projected the information for a common panoramic display

The Iatron and RAFAX equipments used during this evaluation were found to be too unstable for traffic control purposes Center and linearity drift in the Iatrons and azimuth shift in the RAFAX produced such poor registration between the two projected displays that controllers could not be certain of target identity during tracking processes Targets could not be followed through precipitation or ground clutter due to the lack of gray scale or halftone characteristics of the Iatron tube Lack of trail information made it very difficult to determine direction of flight or turn information. It must be concluded that the Iatron equipment used in this test had not reached a state of development suitable for control of air traffic The RAFAX equipment problems appear rectifiable. Its operational value was not determined in this evaluation because of other system difficulties

INTRODUCTION

This report describes the tests and results of an evaluation at the New York Air Route Traffic Control (ARTC) Center of a panoramic display formed by projecting through a Farnsworth Iatron system information from an FPS-8 radar and an ASR-3 radar. The purpose of the test was to determine the feasibility of using a panoramic display to replace the VG-1 and OA-99 radar indicators as traffic control equipments

The FPS-8 long-range radar was commissioned in 1955 to serve the New York ARTC Center This long-range radar is used to control en route aircraft departing from and arriving at the New York metropolitan area Model VG-1 and OA-99 radar indicators display the radar information to the Center controllers. Although the OA-99 indicators are available, practically all radar control is accomplished on the VG-1 indicators. The VG-1 indicator is not a satisfactory control indicator from either a maintenance or an operational viewpoint. The cathode-ray tube (CRT) life is short, approximately 200 hours, and the target brightness gradually fades during the entire life of the tube. Working over a VG-1 is uncomfortable due to the heat generated by the equipment, ambient room lighting must be greatly reduced, length of target trail is not easily controlled, and most control must be performed from a standing position

In searching for an improved radar display, the Farnsworth Iatron was considered. Preliminary tests at the FAA Technical Development Center (TDC) with a prototype Iatron indicated promising results. On the basis of these results, three production model Iatrons were purchased by the FAA at Washington for tests at other locations. One of these locations was the New York ARTC Center

The coverage provided by the FPS-8 long-range radar used at the New York ARTC Center is cluttered by moving target indicator (MTI) residue within 20 to 30 miles of the radar antenna site. The ASR-3 radars at both the Idlewild and La Guardia air traffic control towers did not display as much ground clutter. It therefore was considered logical that if the FPS-8 radar coverage could be blanked out for 20 to 30 miles on a display, and the ASR-3 radar coverage inserted into the blanked-out portion, better radar coverage would result

The problems encountered in remoting and displaying radar in the ARTC Center over a period of approximately 9 months are described in this report. The report has been divided into two parts; the first part describes the technical problems and the second part describes the operational problems, controller reactions, and the conclusions reached.

TECHNICAL EVALUATION

Description of Equipment.

The Farnsworth Iatron radar projection indicator and the Haller, Raymond, and Brown RAFAX encoder-decoder were the display and radar remoting equipments evaluated.

Iatron Radar Projection Indicator

This projection indicator displays PPI range-azimuth information to provide a 4-foot display at 2 5 foot-lamberts of reflected brightness from a flat-white panoramic display table The projection head and control console are shown in Fig. 1. The 4-inch, flat-face Iatron tube is the foundation of the Iatron projection indicator. This tube consists of the following basic elements

1. A writing-beam gun having low intensity and high definition.

2 A flood-beam gun of large cross section

3. A fine-mesh metal screen supporting a thin insulator layer facing the electron guns.

4. An aluminized phosphor screen.

The writing-beam gun is offcentered approximately 16° from the axis of the tube The flood gun is mounted along the axis of the tube perpendicular to the insulator surface The writing-gun electron beam scans the insulator layer, and since the insulator has a high secondary emission ratio, the writing beam deposits effective positive charges proportional to the instantaneous beam intensity Because the insulator potential initially is negative with respect to the flood-gun cathode, the flood-gun electrons cannot penetrate the insulator. However, where the insulator has been charged positively by the writing beam, the flood-gun electrons are "bunched" through this area to the aluminized phosphor screen which has an ultor voltage of 15 kilovolts (kv). This insulator layer provides a means for storing video information, which may be erased by pulsing at discrete intervals The tube surface brightness was approximately 15,000 foot-lamberts

RAFAX Equipment.

The RAFAX equipment consists of an encoder and decoder-indicator, as shown in Fig. 2 The encoder incorporates a bandwidth compressor which accepts radar video and converts this radar video to a narrow-band signal in the audio range. The bandwidth reduction is carried out by mechanical-optical scanning of an intensity-modulated CRT at 30, 60, or 120 scans per second. The light intensity of the scanner is detected by a photomultiplier. The CRT has a J-sweep on which the radar video intensity modulates the sweep. The pulse repetition frequency (prf) of the J-sweep is the same as the radar prf of the information displayed, while the prf of the compressed RAFAX video is a function of the mechanical scan rate. The video information detected by the photomultiplier, as well as the trigger and azimuth information, modulate a carrier which is transmitted over telephone lines to the RAFAX decoder. The decoder separates the trigger, video, and azimuth and makes this information suitable for a PPI display.[1]

Equipment Evaluation.

The Iatron-RAFAX equipment was evaluated for reliability, stability, and factors of equipment design not compatible with panoramic display control. This equipment was in operation continuously 24 hours a day and for weeks at a time with controllers monitoring and working air traffic. Thus, any instability of equipment was recognized immediately. The inherent features of these equipments which the evaluation proved undesirable are outlined.

Iatron Projection Indicator.

During the evaluation at the Idlewild ARTC Center, two Iatron projection indicators were used to display FPS-8 raw radar video and RAFAX video. The first part of the evaluation was to display a usable 85 miles (offcentered one radius for westbound departures) at a scale factor of 2.5 miles per inch. The radar information presented was from the FPS-8 radar at a prf of 360 and a scan rate of 6 rpm The diameter of the projected display was 36 inches. There were many difficulties encountered with the

[1]The PPI scope must be capable of accepting 30-, 60-, and 120-prf triggers.

Iatron equipment Reports from the Region in New York indicate that the equipment instability was responsible for a large portion of the opposition by controllers to the panoramic display as a means of air traffic control. The troubles which were listed for the months of July, August, and September, 1957, include the following

1. The equipments did not meet voltage regulation requirements for input line voltage. Therefore, Sola regulators had to be installed for voltage regulation.

2. The equipment was found to be sensitive to varying room-temperature changes. Maintenance personnel reported that temperature changes necessitated frequent readjustment of the sweep and offcentering controls.

3. The front panels of the equipment had to be removed to allow for convection cooling. The components of the equipment were covered with dirt since no air filters were employed.

4. The offcentering supply should have the a-c input isolated from chassis ground for safety.

5. Arcing of plate supply tubes V101 and V102 was noticeable on energizing the power supply. A separate filament supply should be used for plate supply tubes with a plate-load time delay incorporated. The power supply was very unstable and required frequent adjustments. There was no fuse protection for the various power supply outputs.

6. In the sweep circuit the 6AQ5 tube life was very short. It also was difficult to balance out the bridge deflection circuit. The over-all plate-to-cathode voltage was 800 volts. The maximum plate voltage rating is 250 volts. The tubular condensers coupling the clamp gate and sawtooth sweep to the control grids of the 6AQ5 tube required frequent replacement

7. The range-mark generator circuitry was unstable Trouble was experienced with the gating and counting circuits.

8. The video limiting circuit did not have a smooth limiting action. The limiting principally was in the last 10 per cent of the adjustment control

9. The sweep centering varied with time. On a 36-inch display, this center shift was enough to require adjustment every hour.

10. The high-voltage connectors were unsuitable.

11. When the equipment was shut down and then energized again, within 3 minutes readjustment of all linearity circuits was required.

The lack of halftone or gray scale in the Iatron presentation made it very difficult to obtain the desired storage for indicating aircraft trail information. Aircraft "paints" on previous antenna rotations were almost as bright as current paints. This also was true for noise video, target video, or precipitation video. Another feature of the Iatron which reduced its ability to show trail is that the storage of video information for periods of about 50 seconds caused the display background to build up to full brilliance. It is theorized that this background buildup is caused by positive ions collecting on the target insulator. It was found that this background limited the useful storage of information to periods of less than 50 seconds. This varied slightly for different tubes. When a periodic cyclic erase is employed, the target insulator must be erased sufficiently negative to prevent integration of background noise from one storage cycle to the next. Should this integration occur, the useful display time becomes progressively shorter, making it necessary to apply extra erase pulses manually in addition to cyclic erase.

The primary maintenance complaint against the Iatron equipment was the number of daily adjustments required to keep the indicator aligned. The most frequent adjustments were sweep balance, circularity and linearity, video equalization, and tube collimation. These adjustments were in addition to the usual daily checks on focusing, intensity, centering, video level, and power-supply voltage adjustments. The VG or OA-99 indicator at the Center require these adjustments only when a CRT is replaced or when the monthly routine maintenance check is due, whichever comes first. Thus, a considerable amount of maintenance time was required for the Iatron projectors, resulting in frequent unavailability.

When two Iatrons were used for projecting FPS-8 raw video information and ASR-3 information, remoted from La Guardia by RAFAX, difficulty was encountered in obtaining registration between common targets to the two systems Although the traffic controllers were interested in only a limited portion of the Iatron radar display, it was impossible to obtain and maintain good registration because of the Iatron circuit instabilities and optical problems. Circularity in all quadrants was not possible under any combination of adjustments.

RAFAX Equipment.

The RAFAX equipment consists of an encoder and a decoder-indicator. The encoder was located initially at the Idlewild tower and after some tests, was transferred to the La Guardia tower. The decoder-indicator was located at the New York ARTC Center.

There was considerable azimuth trouble with the RAFAX encoder. The azimuth information would drift approximately plus or minus 10° each side of the correct azimuth position. This problem was similar to servo system troubles that had appeared during tests at TDC prior to this evaluation, and never was solved. It was due in part to the method of remoting the servo information. Alternating-current pickup in the remoting landlines seriously affected the accuracy of the azimuth information. Another problem was the

J-sweep circle size which would change over a period of time Usually this was due to poor regulation of the high-voltage power supply In all other respects, encoder circuit stability was reported good

After the evaluation from the Idlewild tower was completed, the encoder was relocated in the La Guardia tower. This permitted the evaluation of two different telephone lines, both leased from the New York Bell Telephone Co. The first line was between the Idlewild tower and ARTC Center. This telephone line was classed as a Schedule AAA (15-kc bandwidth) line. The second line was between the La Guardia tower and the ARTC Center Both of these lines performed satisfactorily Response characteristics are shown in Fig. 3. An interference problem was noted when displaying the La Guardia ASR video. This interference was picked up in the ARTC Center building and was traced to pickup from adjacent lines carrying teletype signals. The magnitude of this interference was high enough to trigger the Iatron and RAFAX display This problem was not observed when the Idlewild ASR data were remoted, although the same line within the ARTC Center building was used. Apparently this was due to the higher signal level from Idlewild as compared to La Guardia The La Guardia line, much greater in length, produced a considerably weaker signal at the ARTC Center and poorer signal/interference ratio This occurred even when the encoder output at La Guardia was at a maximum Had amplification of the La Guardia signal level taken place before connecting to the ARTC Center building line, this interference would not have been a problem.

OPERATIONAL EVALUATION

New York Operations

An information bulletin distributed by the New York ARTC Center requested that all aircraft operating on instrument flight plans fly on a preferential route provided by the Center regardless of weather conditions Exceptions to this ruling were made in the event of adverse weather, inoperative communications or navigation aids, or other disruptions. The RAFAX-Iatron tests were carried out in the area known as the westbound departure route Aircraft bound for Pittsburgh, Cleveland, Chicago, Detroit, Buffalo, Rochester, or Syracuse departed over the preferential routes. In this area, little or no inbound or crossing traffic was permitted except at very low altitudes or under VFR conditions.

Handoff Procedures.

When an aircraft is ready for departure, the tower controller calls the ARTC Center controller via interphone for a clearance. The Center departure controller, at a flight progress board, normally issues clearance to the destination airport at the requested cruising altitude. When airborne, the departure time is relayed from the tower to the Center, and flight progress strips are posted over succeeding fixes on the aircraft's route of flight. When the aircraft has reached an area outside of the airport maneuvering zone and is no longer a primary factor in the control of terminal traffic under the jurisdiction of the tower, the tower radar departure controller calls the Center radar en route controller via interphone, with a radar handoff This transfer of control is accomplished by the tower controller, describing to the Center controller in great detail the position of the aircraft in question When the Center controller acknowledges identification, transfer of control is accomplished, and the tower controller requests the aircraft to change to a predetermined radio frequency for direct communication with the Center. ANC or radar separation exists between the aircraft handed off to the Center and all other aircraft under the jurisdiction of the tower. The operational limits of the ASR necessitate accomplishing the radar handoff comparatively close in (within 30 miles). This area is heavily cluttered with MTI residue on the FPS-8 long-range radar

Communications and Personnel.

The test environment required the use of two radar/radio controllers, each controlling a segment of the one-way departure airways within radar coverage. Each had a two-way VHF discrete radio frequency.

When the aircraft had reached cruising altitude, or had reached an altitude of ANC separation with other traffic, transfer of control to the manual flight progress board section was accomplished. A coordinator between the radar sectors and the two ANC sectors into which the great majority of the radar departure traffic flowed resolved altitude or change-of-route assignments in the ANC sector for all the aircraft emanating from the radar sector. The coordinator also relayed any pertinent flight information to the ANC sectors

TESTS AND RESULTS

The Farnsworth Iatron projection equipment was set up originally to display the FPS-8 radar information in the northwest quadrant of the radar coverage area. See Fig 4 The display was offcentered to cover an area approximately 5 miles west of the FPS-8 site to approximately 100 miles west of La Guardia Airport. See Fig. 5. The projected image was displayed horizontally on a table top, with a scale factor of 2 1/2 miles per inch. Chart-pak tape was used to depict the airways on the table top. The coverage area was varied several times. The scale factor also was varied from 2 1/2 to 3 1/2 miles per inch. The operating procedures used in the New York Center for westbound departures require the transfer of radar control jurisdiction from the metropolitan area control towers to the Center within a distance of approximately 30 miles from the metropolitan area. The FPS-8 radar did not provide good coverage in this critical handoff area. Radar coverage, however, was good beyond a distance of 25 to 30 miles from the airport area. It was felt that the remoting of ASR-3 radar from either the La Guardia or the Idlewild tower would provide better close-in coverage and permit earlier identification which would greatly facilitate the handoff problem.

Displays.

In the New York Center, a table 35 by 54 inches provided a panoramic display shown in Fig. 5 Airways were depicted on this display using Chart-pak tape. The area from the metropolitan airports in a northwesterly direction covering Victor Airway 116 from Patterson over Branchville to Wilkes-Barre, and Victor Airway 153 from Caldwell over Stillwater, was depicted. The Iatron projectors were suspended from the ceiling, as shown in Fig. 8. One Iatron which projected the FPS-8 radar information had a "throw" distance of 47 1/4 inches and produced a picture approximately 60 inches in diameter. The other Iatron projected the ASR-3 radar information and produced a picture 24 inches in diameter at a 33 3/4-inch throw distance See Figs. 6 and 8. Since the radar coverage to the east and southeast of the metropolitan area was not to be used in these tests, only 7 to 8 inches (15 to 20 miles) was displayed in this direction on the panoramic table. In the original Iatron FPS-8 setup, a 100-mile radius was displayed At the request of the New York personnel, the west coverage of the FPS-8 was cut back to approximately 75 miles in order to cover more area in the northeast section beyond New Rochelle and Port Chester. The coverage and panoramic display were shifted several times during the tests. These shifts were made because operating personnel wanted to try to cover some of the departure routes when takeoffs and climb-outs were made over Riker's Island or Glen Cove.

Markers.

Several sizes and types of markers were tried on the panoramic display. Two- by 3-inch markers with altitude discs proved to be too large for the 2 1/2-inch scale. A number of markers were made up by cutting flight progress strip holders into 2-inch lengths pointed at one end. These small markers permitted identification, altitude, and a small amount of route to be marked on the paper insert Later, these markers were cut in half and 1- by 1-inch markers were tried On this size marker, only the identification could be written It appears that 1- by 2-inch markers probably were the most satisfactory, although in some congested traffic situations, these markers were too large. Controllers were divided in their opinions as to what information should be placed on the markers. It appeared that the majority felt that the identification alone was sufficient. This was especially true if flight progress strips were maintained adjacent to the panoramic display. In the Yew York Center, flight progress boards are maintained at all radar positions, consequently, in the panoramic Iatron test, a flight progress board also was maintained. The flight progress boards used at the VG displays and at the Iatron panoramic board were small three- or four-bay portable boards.

Backup During Equipment Failure.

During the Iatron-RAFAX test, a VG display always was available for quick transfer of control in case of equipment failure Flight progress strips also were maintained on a portable board that could be transferred quickly from the panoramic display table to the VG display.

Radar Coverage Overlap.

An overlap area of the two Iatrons provided at various times from 3 to 20 miles' overlap, depending upon equipment adjustment. See Fig. 7. In this area, both the ASR-3 and the FPS-8 assured good coverage. Overlap areas as wide as 20 miles were found to be unsatisfactory Confusion in the overlap area came about because the ASR-3 painted four scans for each scan of the FPS-8 radar. Also, the two radars did not always paint the same target, due to the different radar system parameters and geographic locations. Occasionally, lack of registration between common targets was a problem, due to difficulties in display alignment.

Ambient Lighting.

The ambient light in the control quarters of the New York Center was low to permit the use of VG indicators. This lighting did not interfere with the Iatrons and the brightness was sufficient to see targets clearly. Special lighting for flight progress boards was not necessary, other than small portable lights at the top of the boards at all VG and Iatron panoramic display locations. No other special lighting was required during this test.

Resolution.

Target size can be varied by adjustment of the Iatron equipment. The best size for control was found to be approximately 3/4- by 3/8-inch on the panoramic display table. This means that each target on the display was 1 1/2 to 2 miles long (azimuth) by approximately 1 mile wide (range). Targets with spacing of 2 miles or more were definitely resolved. Since both the ASR-3 and the FPS-8 radars were being displayed through the Iatron equipments, the resolution from both radars was approximately the same This was determined from the resolution of the display equipment, which was much poorer than that of the individual radar systems.

Operating Characteristics.

The green projection color of the Iatron gave targets a high contrast. Operators agreed generally that this contrast of target was less tiring on the eyes than VG targets Trail information was lacking. Radar operators in the New York Center have become accustomed to long trails on the VG indicators They felt that the lack of trail on the panoramic display hampered their operation considerably, since several sweeps of the radar were necessary to determine turn or direction of flight. It should be pointed out that because the Iatron continued to build up clutter, it was necessary to erase each rotation of the FPS-8 radar. The cyclic erase was arranged to clear the panoramic display just prior to the beginning of each antenna scan. This applied only to the Iatron displaying FPS-8 radar information. The Iatron on the ASR-3 normally was set to erase once every four scans of the radar antenna It was practically impossible to maintain registration in the overlap area As pointed out previously, the ASR painted four scans for each scan of the FPS-8 radar. When the first scan of the ASR overlapped the scan of the FPS-8, the next three scans of the ASR would show the target progressing ahead of the FPS-8 target. Although this appeared to be an ideal arrangement, controllers were not entirely satisfied with this type of display. The instability of the two Iatrons often caused the targets to appear side by side or one ahead of the other in the overlap area. The fact that targets were displayed by two radars that do not register, and the knowledge that either Iatron may have drifted, made a controller doubt the validity of the presentation. Also, the controller had no way of determining which radar system, FPS-8 or ASR-3, was presenting the correct position of the aircraft. Some examples of center shift and nonregistration are quoted below from an operations log.

> "An aircraft target Capital 135 over Patterson 0955, FPS-8 target small and approximately 1/8-inch ahead and to the right of the ASR target It looked like two targets all the way through the overlap area.
>
> "Another target American 771 over Teterboro at 1007, climbing from 5,000 to 9,000 feet, registration good through most of the overlap area then the FPS-8 target pulled ahead to show two targets
>
> "Tracking two targets approaching Caldwell, both the FPS-8 and the ASR-3 targets shifted from one edge of the one-inch marker to the other edge in azimuth.
>
> "TWA 509 over Patterson at 1028 showing good registration at Patterson. As the targets progressed, the FPS-8 target pulled ahead of the ASR-3.
>
> "TWA 401 over Patterson 1134 FPS-8 leading the ASR-3 target with a small line of demarcation between the two targets except for the third and fourth sweep of the ASR-3. This is just before the next FPS-8 sweep."

On one-way airways, trail is not as important as in areas where multidirectional traffic operates. Under VFR flying conditions, traffic moves in all directions regardless of one-way airways, and with no trail identification, this becomes a real problem.

Interference.

The RAFAX-Iatron portion of the test was originated because of the MTI clutter residue which is present on all the New York FPS-8 radar indicators. Normally, the ASR-3 radars at Idlewild and La Guardia have good MTI presentation. These radars also have circular polarization. Little or no interference was experienced on the two ASR-3 radars. Anomalous propagation was no problem in the west quadrant which was the test area; however, in the quadrants covering the coastal area, temperature-inversion effects were noticeable. Clutter caused by this anomalous propagation would require further consideration should Iatrons be used in other quadrants of the radar coverage in the New York area.

CONCLUSIONS

It is concluded that·

1. The RAFAX-Iatron projection of the ASR-3 radar was not helpful in effecting tower-to-Center handoffs. It was difficult to identify the proper target during handoff procedures because of poor registration.

2. Registration in the overlap area was not adequate due to Iatron circuit instabilities. Most controllers preferred the VG indicator to the Iatron display for handoffs.

3. The majority of the controllers indicated that the brightness and contrast of the Iatron display were adequate, but that resolution and target trail were inadequate.

4. Azimuth accuracy in the RAFAX equipment was not satisfactory although this appears rectifiable. The operational value of RAFAX was not determined in this evaluation because of other system difficulties.

5. The feasibility of using a panoramic display was not determined because of equipment difficulties.

RECOMMENDATIONS

It is recommended that

1. The development effort on better radar projection systems be continued and that additional panoramic display evaluations be made when more suitable projection equipment is available.

2. The design of future display equipment be carefully considered, particularly where this equipment may be combined with other equipment to make a composite radar display of two or more radar systems. Display accuracy, linearity, and stability are very important to the operational suitability of combined displays.

3. Future display developments include a requirement for providing sufficient gray scale and storage so that the direction of aircraft movements can be determined quickly by their trails

4. Additional evaluations be made of the RAFAX equipment.

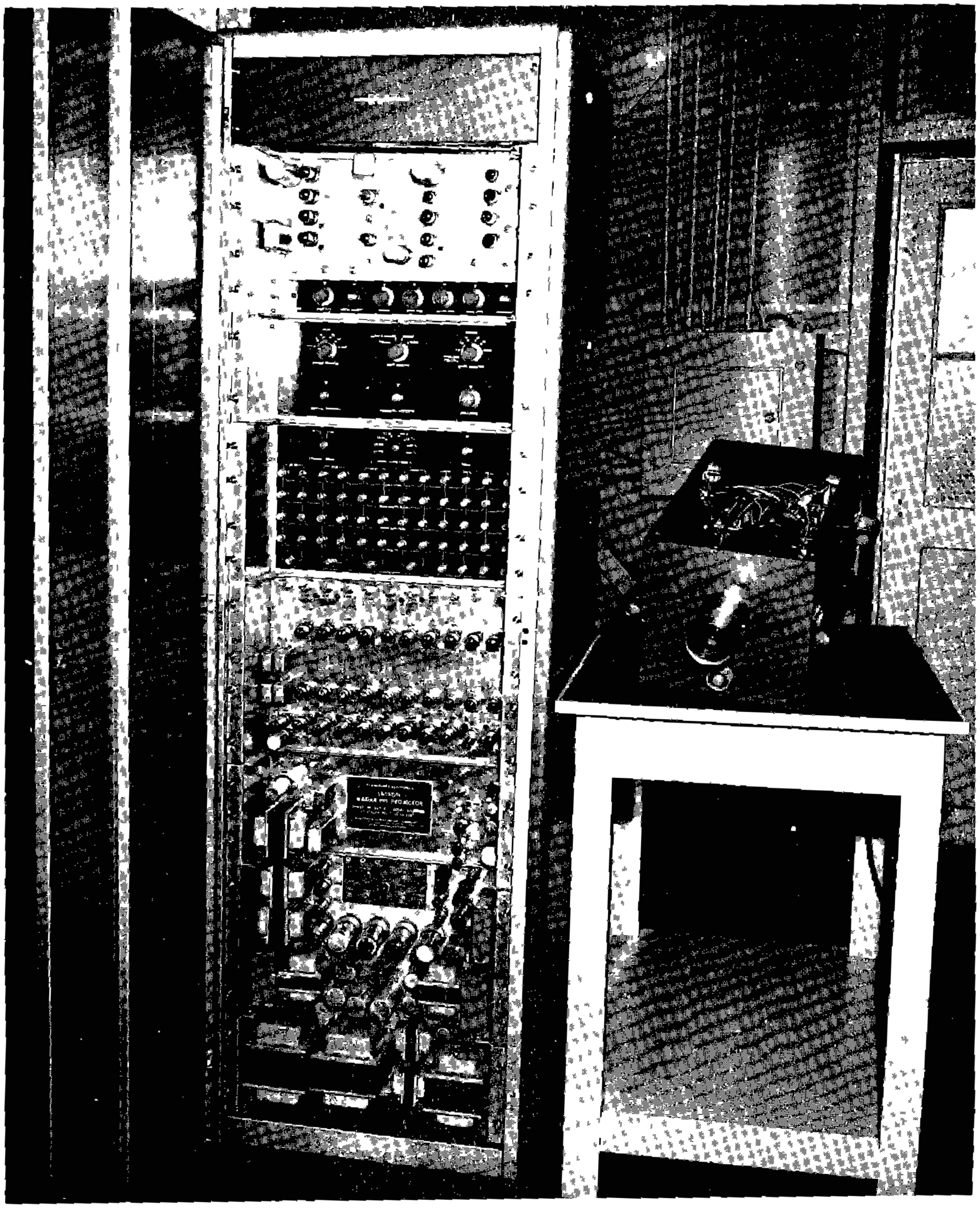

FIG 1 IATRON (PRODUCTION MODEL) RADAR PPI PROJECTOR

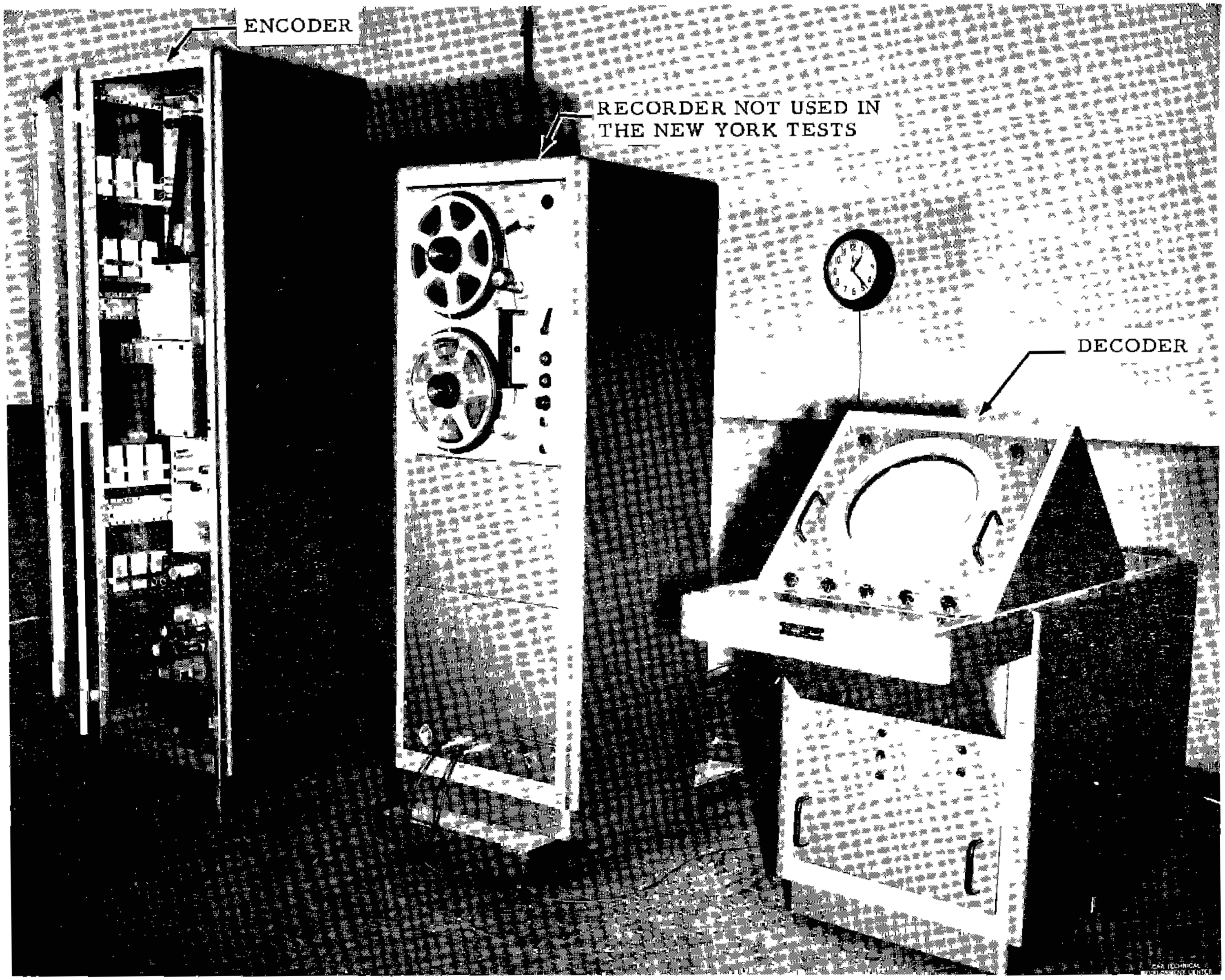

FIG. 2 RAFAX AND RECORDING EQUIPMENT

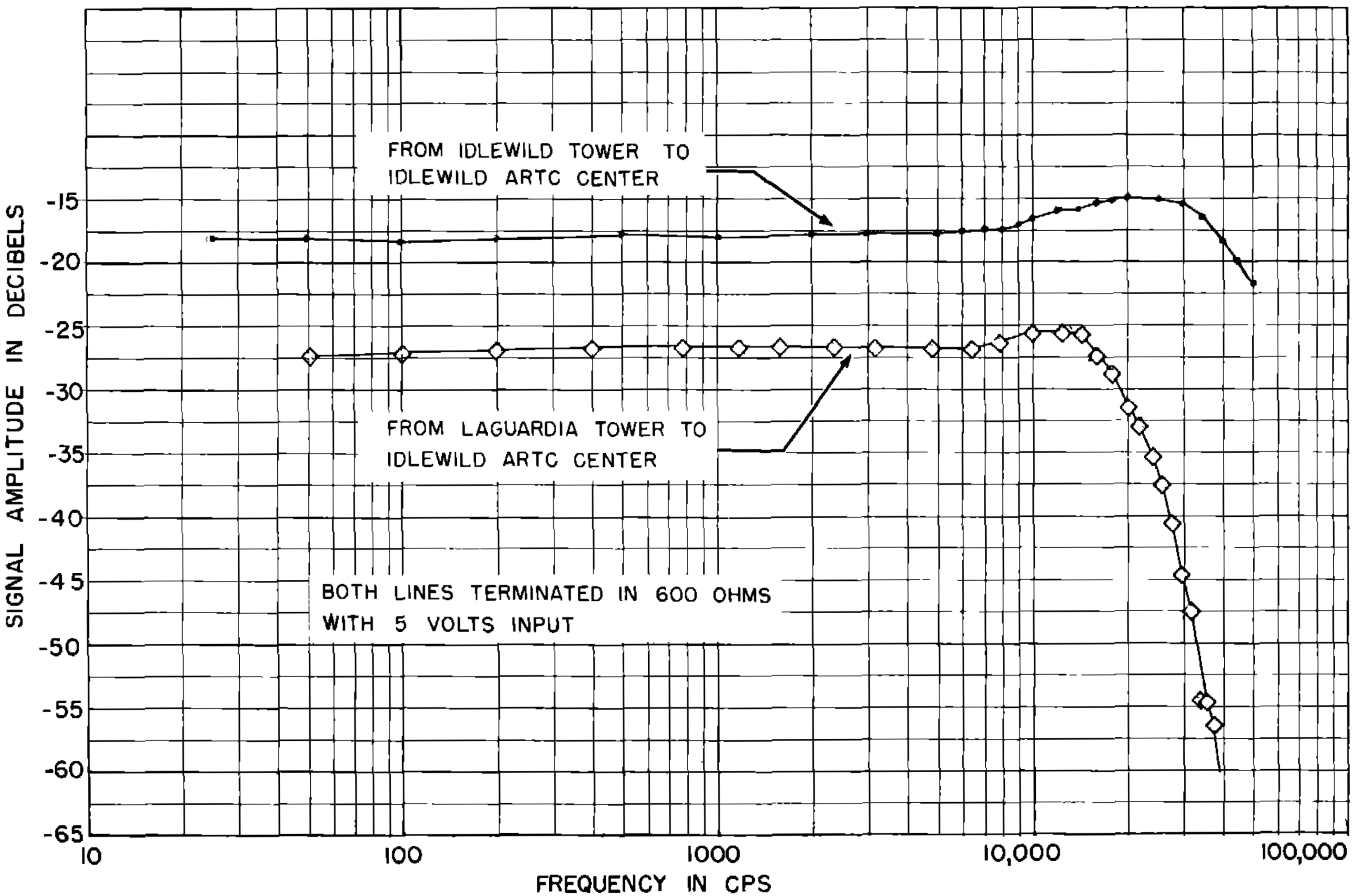

FIG 3 FREQUENCY RESPONSE OF TELEPHONE LINES TO IDLEWILD ARTC CENTER

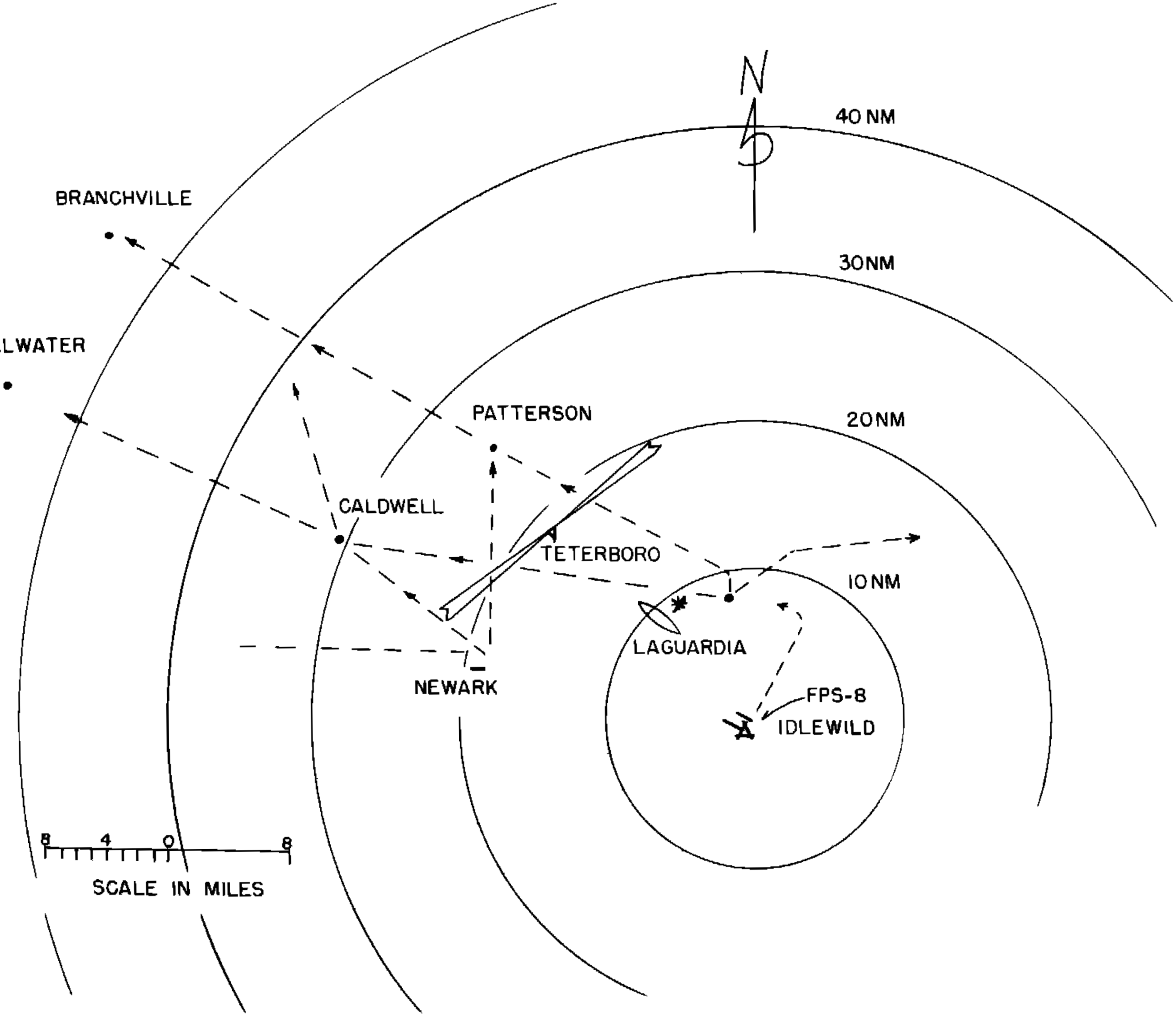

FIG 4 NEW YORK ARTC CENTER WESTBOUND DEPARTURE ROUTES

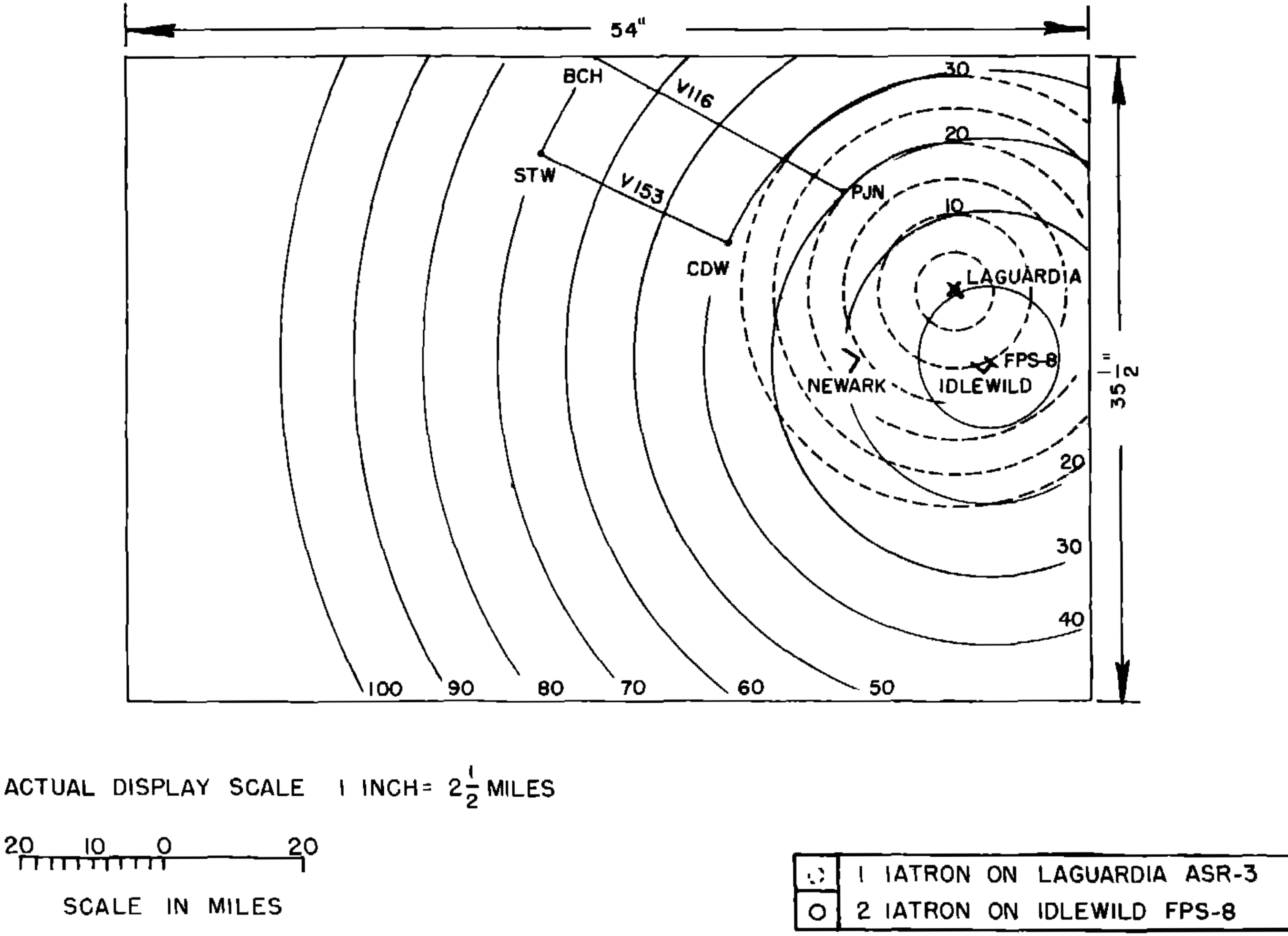

FIG 5 PANORAMIC DISPLAY TABLE SHOWING RELATIVE COVERAGE

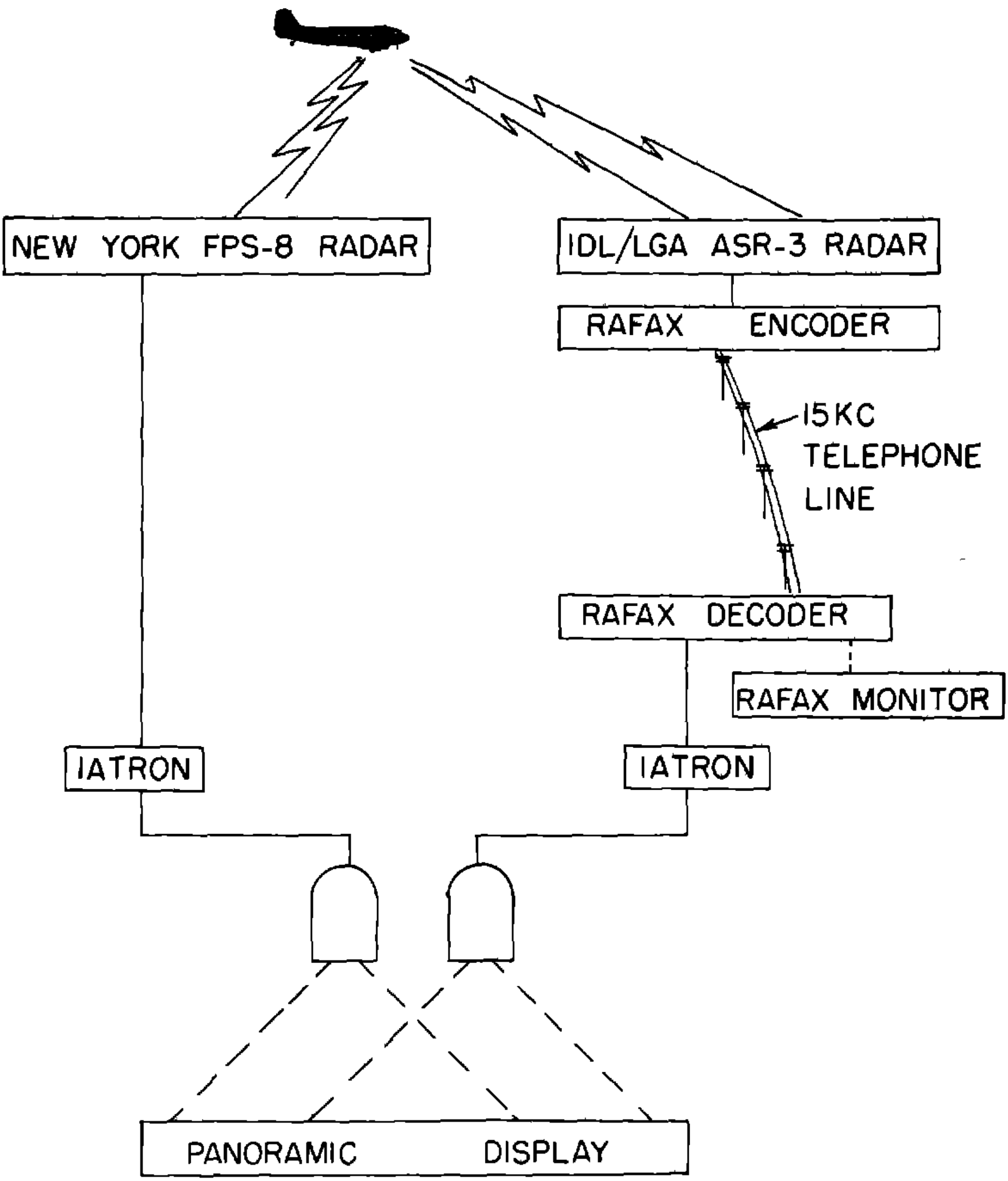

FIG 6 BLOCK DIAGRAM OF RAFAX-IATRON SYSTEM IN NEW YORK ARTC CENTER

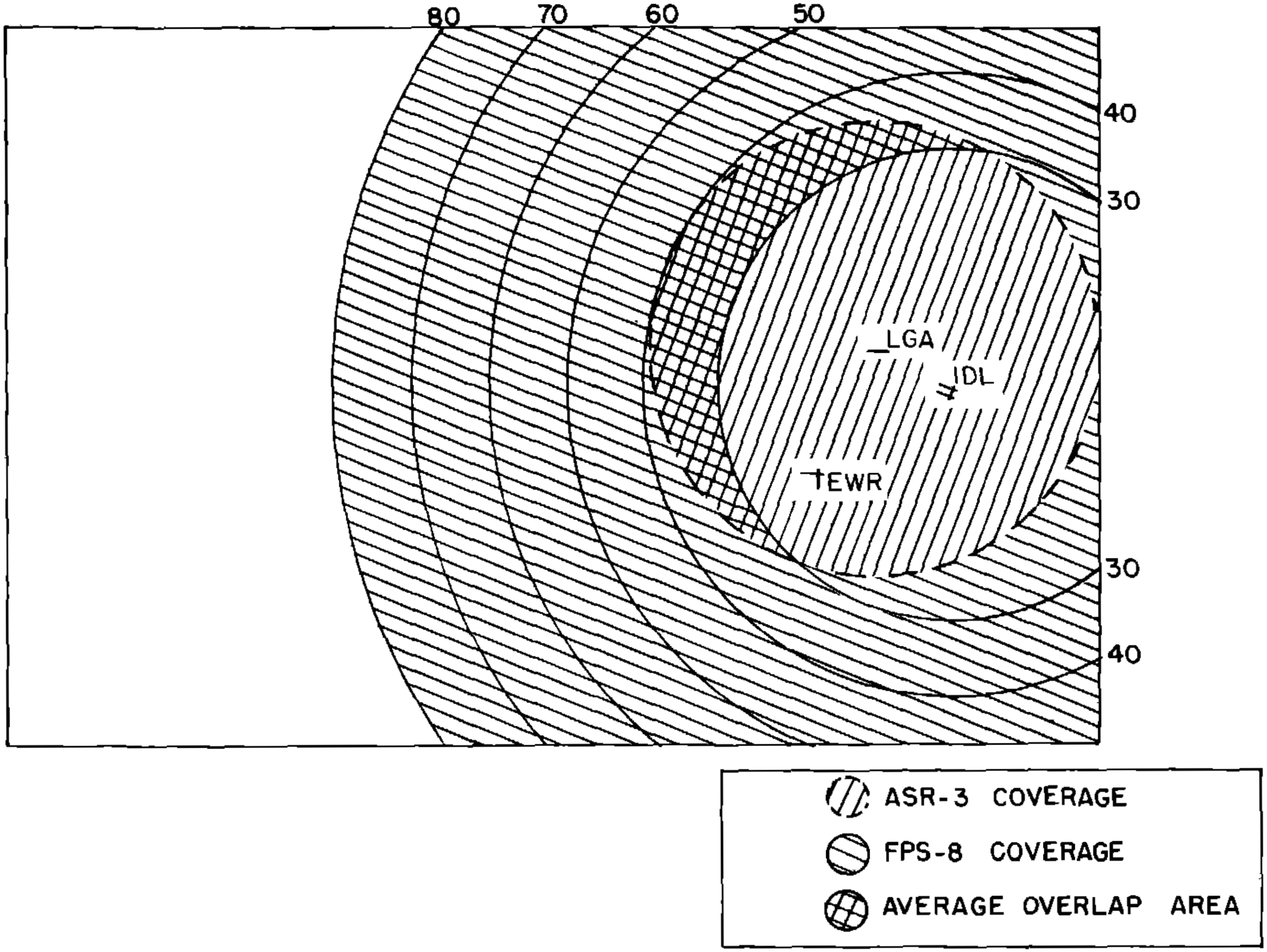

FIG. 7 PANORAMIC DISPLAY SHOWING AVERAGE OVERLAP AREA

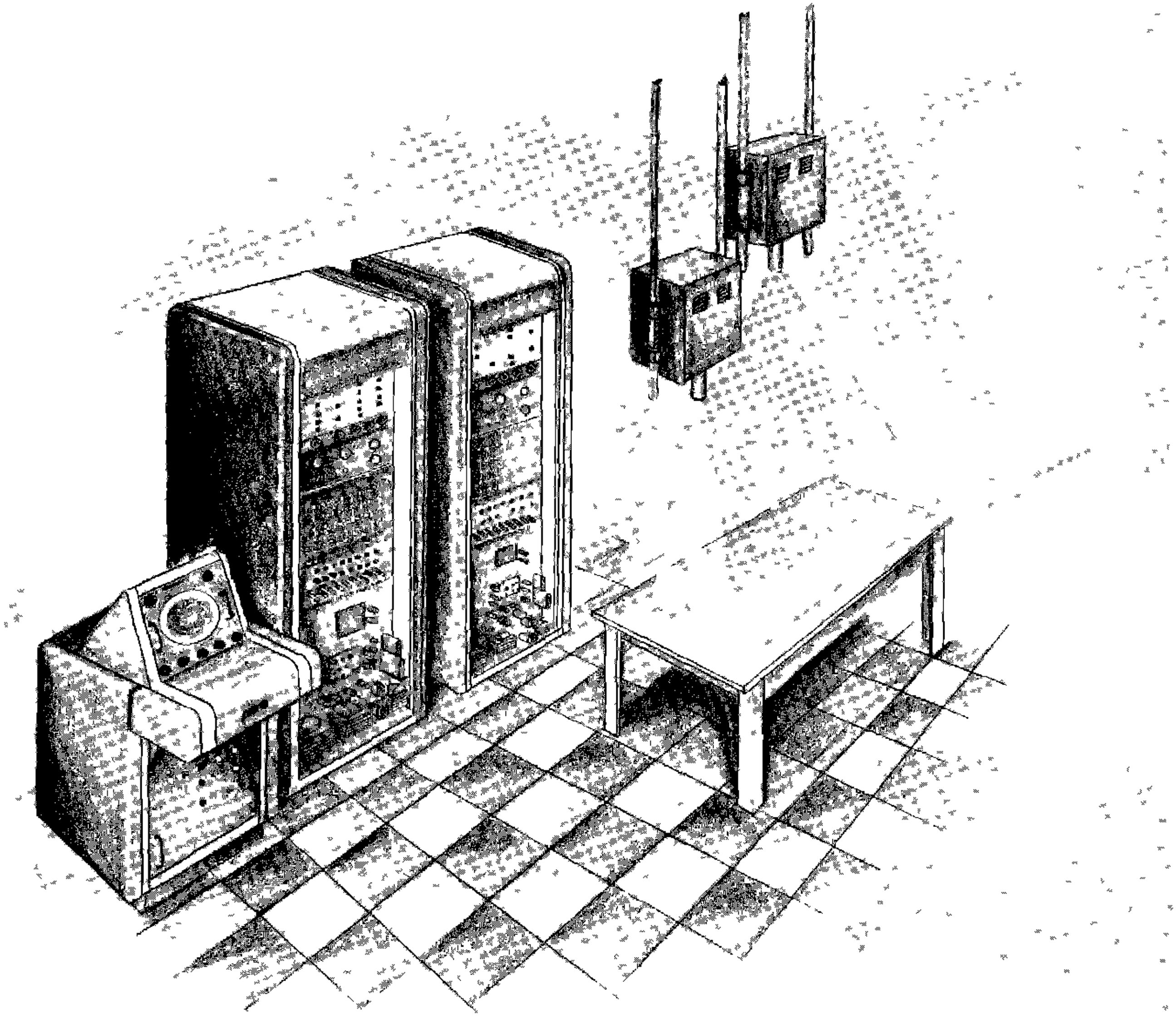

FIG 8 ARTISTS DRAWING OF EQUIPMENT ARRANGEMENT DURING NEW YORK TESTS